Tonal Priming Effects on Reaction Time Measures in Implicit Task

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Background

Studies regarding the priming effect based on Western tonal music context were previously examined by several experiments but the one we will be using in our study is the one by Tillmann, Janata Birk, and Bharucha (2008). This previous study was done over three experiments (tonic vs dominant vs baseline, dominant vs baseline, and tonic vs dominant vs subdominant vs baseline). The main question of this study was if the tonic is the sole chord leading to facilitation or if the dominant chord, which is also located between the tonic and subdominant in the harmonic hierarchy, may also improve from processing the tonal center of the harmonic context (Tillmann et al., 2008). The study evaluated if processing speed of tonic, dominant, and subdominant chords represent the correct order of the chords in the harmonic hierarchy and the cost and benefit ratios of the processing of these chords compared with baseline contexts without a tonal center.

Priming effect was first studied outside the musical context. The priming effect was heavily studied in psycholinguistics (Meyer & Meyer & Schvaneveldt, 1971; Neely, 1991; Stanovich & West, 1979). Later on, Bharucha and Stoechig (1986) presented it to the music perception area of study which resulted in developing such field of research by numerous studies since (e.g., Bigand, Madurell, Till- mann, & Pineau, 1999; Bigand, Poulin, Tillmann, & D'Adamo, 2003; Tekman & Bharucha, 1998).

Tonal hierarchy consists of tonic chord being the most important element which is the most frequently giving the sense of closure, the dominant chord is the second important chord, the subdominant chord comes third, then the other in-key chords, and out-of-key chords.

According to previous priming studies, target chords are processed faster following harmonically related settings than unrelated (Bharucha & Stoeckig 1986; Bigand & Pineau 1997) or even somewhat related contexts (Bigand et al., 1999; Bigand & Pineau, 1997; Bigand, Tillmann, Poulin, D'Adamo, & Madurell, 2001). Even when less related targets share more tones with the context than associated targets (Bigand et al., 2003; Tekman & Bharucha, 1998) and when the previous chord is acoustically the same as the target (Bigand, Tillmann, Manderlier, & Poulin, 2005), processing of strongly linked targets is facilitated. The harmonic priming data show that even those with no formal musical experience have developed innate tonal harmony awareness (Bigand & Poulin-Charronnat, 2006; Tillmann, Bha- rucha, & Bigand, 2000). Due to implicit learning activities, listeners become sensitive to musical stabilities and functions simply by being exposed to music on regular basis (Tillmann et al., 2008).

According to previous studies, listeners can distinguish between chords in the harmonic hierarchy but not at all levels (Bharucha & Krumhansl, 1983; Bigand, Parncutt, & Lerdahl, 1996; Krumhansl, 1990):

- In Bigand et al.'s (1996) study, the musical tension caused by the second chord in a triplet of chords was evaluated by participants.
- In Bharucha and Krumhansl's (1983) study, after hearing short tonal contexts, listeners were asked to rate how effectively the second chord followed the first.

The results suggested that the dominant and subdominant chords were statistically different from the tonic, but they did not specify whether the difference was significant (Tillmann et al., 2008). Observing just facilitation for the tonic and inhibition for the subdominant, despite the subdominant's significance in the harmonic hierarchy, is unexpected and shows that the tonic has a unique role in tonal processing (Tillmann et al., 2008).

Tillmann et. all's study mainly examined if the harmonic hierarchy order was able to reflect the order of the tonic, dominant, and subdominant and what are the cost and benefit patterns of interpreting chords in contrast to baseline contexts with no tonal center.

Previous studies showed that listeners can differentiate between in-key and out-of-key chords, and even between the harmonic hierarchy elements. However, no further investigation happened regarding the understanding of the listeners of what they're differentiating in the harmonic hierarchy, nor regarding the cost and benefit patterns of the processing of a tonal center including the dominant chord. Thus, Tillmann et. al's study included the dominant chord relative to the baseline context.

Their study consisted of three experiments; the first experiment had 33 psychology students with a mean of 5.91 years of experience with a musical instrument. The participants listened to 72 sequences (12 strongly related sequences ending on tonic targets, 12 related sequences ending on dominant targets, and 12 baseline sequences containing 6 matched to strongly related sequences and 6 to related sequences). Experiment 1 consisted of two phases; the first phase was a training phase where participants were getting accustomed to differentiating between consonant and dissonant chords using single chords and chord sequences. During the second phase of experiment 1, participants compared consonant and dissonant chords of sequences only. For the baseline sequence, half of the participants listened to the 6 strongly related and 6 related baseline sequences with a consonant target to the other two baseline sequences with a dissonant chord (Tillman et al., 2008). The order was reversed for the second half. The second experiment was done with 28 psychology students with a mean of 5.9 years of experience with an instrument. Each participant listened to only 48 sequences (12 related sequences ending on dominant and 12 matched baseline sequences from experiment 1). The procedure was the same as experiment 1 except for in the second phase participants all participants listened to all the 12 matched baseline sequences. For the third experiment, 30 psychology students participated with a mean of 4.97 years of musical experience. Experiment 3 used the same strongly related contexts, related contexts, and their associated baselines from experiment 1. Experiment 3 also used and modified less related contexts and their baselines from Tillmann et al. (2003; adapted from Bigand & Pineau, 1997, and Pineau & Bigand, 1997), but the last two chords remained the same. The procedure was the same as experiment 1 except in phase 2 the baseline sequences were divided into 3 sets (Tillmann et al., 2008).

Based on Fig 2, Experiment 1 showed the fastest response time for the tonic, the difference of the response times between the rest of the contexts was not as significant which proves a priming effect for the strongly related tonic targets over dominant targets (Tillmann et al., 2008). For experiment 2, Fig 3 again shows a very fast response time for tonic chords but what was interesting to find was the very slow response time for less related subdominant targets even compared to the baseline context targets. This confirmed the results from experiment 1 that having a tonal center gives no cost or benefit for dominant targets in baseline comparison contexts (Tillmann et al., 2008). Experiment 3 also showed that the listener can distinguish detailed harmonic differences. It also showed that the response time was fast for strongly related tonic, less fast for related dominant targets and the least fast for related subdominant and baseline targets. Results from all three experiments match the order of the harmonic tonal hierarchy (Tillmann et al., 2008).

According to the Tillmann et al.'s study's sensory priming result analysis (Figure 4), more repetition of tones in the target would result in prediction of these tones in the prime context which lead to faster processing/prediction. Figure 4 shows noticeable high number of shared pitch classes between targets and prime contexts for the tonic sequence (strongly related), less on the subdominant (less related), then significantly less on the dominant (related), and lastly is the baseline contexts (Tillmann et al., 2008).

Even though the study suggests that daily exposure to tonal music leads to cognitive predictions of the harmonic hierarchy, the participants did not seem accurate or consistent regarding the musical experience. There was no clear explanation of the participants' musical background. Classically trained musicians might have different perception on the tonal hierarchy than jazz or non-western musicians. Even when comparing between participants with no musical background, the type of music they are exposed to every day might differ from one subject to the other, also the frequency of music exposure might also vary (from music lovers who collect records to passive listeners who only listen to what's on the radio).

What was most significant within their findings was that neither cost nor benefit was found for the dominant when compared with baseline targets. Both experiment 1 and 2 confirmed this finding despite having the dominant second in priority in the tonal hierarchy. This was done to keep focus on the two other pitches in the chord; the tonal and the dominant (Tillmann et al., 2008). This is particularly interesting because in experiment 1 and 2, the response times for the dominant were longer than the subdominant and even slightly longer than the baseline contexts. This could show the importance of the third pitch in the chord (Tillmann et al., 2008). However, in experiment 3 the dominant targets' response times were faster than the subdominant and the baseline contexts which puts the dominant back in second place on the tonal hierarchy. Based on the sensory priming result testing the study has done afterwards, the subdominant contains more related contexts than the dominant for it shares more pitches with the tonic than the dominant, especially after the omission of the third (Tillmann et al., 2008).

Our study focuses on musician participants. The purpose of this study, similar to Tillmann et al.'s (2008), is to test the subjects' judgment of consonance and dissonance in chords. The study tests the response times speed of the participants after hearing the last chord of the sequence presented then compare the results with the harmonic tonal hierarchy of Western music theory.

Methods

Participants

The two participants (1 female JAA, 1 male CD) are music technology students in their mid-twenties (25-27). Their years of experience with musical instruments vary from classical training to more modern popular music and the number of years averages to about 10 years. Participants went through the test three times; the first trial was for the subjects to get familiar with the test and the stimuli (session 00). The second trial was done using stimuli similar to the one's used in the Tillmann et al.'s (2008) study, and was labeled session 01. The third trial used a different set of sequences stimuli created by psychoacoustics and music cognition introductory course students based on the same structure of Tillmann et al.'s (2008) sequences. Each student was assigned a key to create two sequences of 8 chords; one consonant sequence and one dissonant sequence but both end on the same last two chord (the dominant and the tonic). Thus overall, we have all the major keys covered in our sequences (12 keys). One thing to note is that the volume of each set of two sequences presented by the students varied significantly due to the use of different digital audio workstations in the process of making the audio of chord sequences.

Procedures

The participants were presented with chord sequences and they had to respond as quickly as possible upon hearing the last chord (8th chord) if it was consonant or dissonant. The test took about 10 to 15 minutes to finish. The tests were done by each participant individually using their own professional to semi-professional headphones and their own personal computers. Participants had to press the 'left' key on their computers for their consonant responses and the 'right' key for their dissonant responses. Just like in Tillmann et al.'s (2008) study, a short burst of white noise was played between sequences, and the participants had to press the 'down arrow' key to move on to the next sequence trial.

Results

The obtained error rates are illustrated in the Table 1.

Table 1. Error rate

Subject	Session	Error rate (%)			
		Tonal (tonic, dominant, subdominant)		Baseline (tonic,dominant,subdominant)	
		Consonant	Dissonant	Consonant	Dissonant
JAA	Session 1	0	0	11.11	0
	Session 2	0	0	25	0
	Total	0	0	18	0
CD	Session 1	0	0	0	0
	Session 2	3.7	0	0	0
	Total	3.7	0	0	0

We find that the total error rate of JAA is 18% for baseline consonant contexts only and 0% for tonal (consonant and dissonant) and baseline dissonant contexts, while subject CD's total error rate for the tonal consonant targets was 3.7% and 0% for the rest of the targets.

The obtained reaction time data for consonant trials are illustrated below in the Figures 1 and 2.

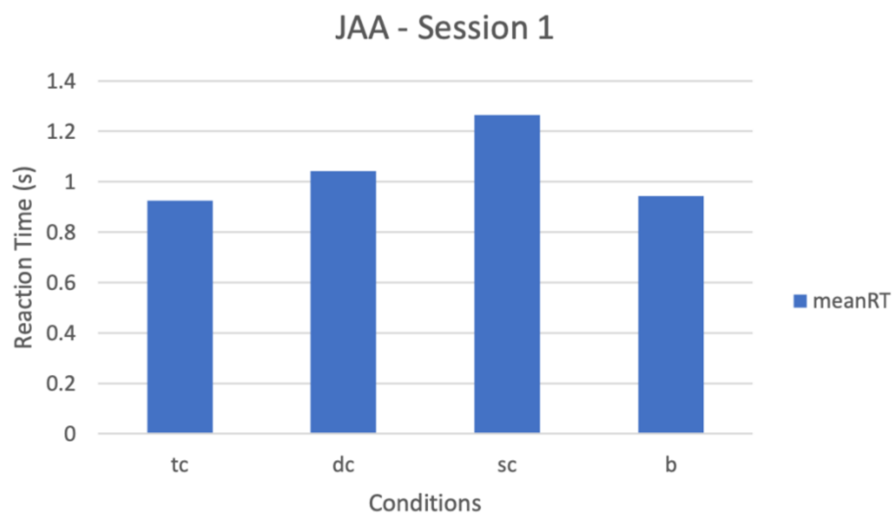

Figure 1a – JAA Reaction Times for Session 1

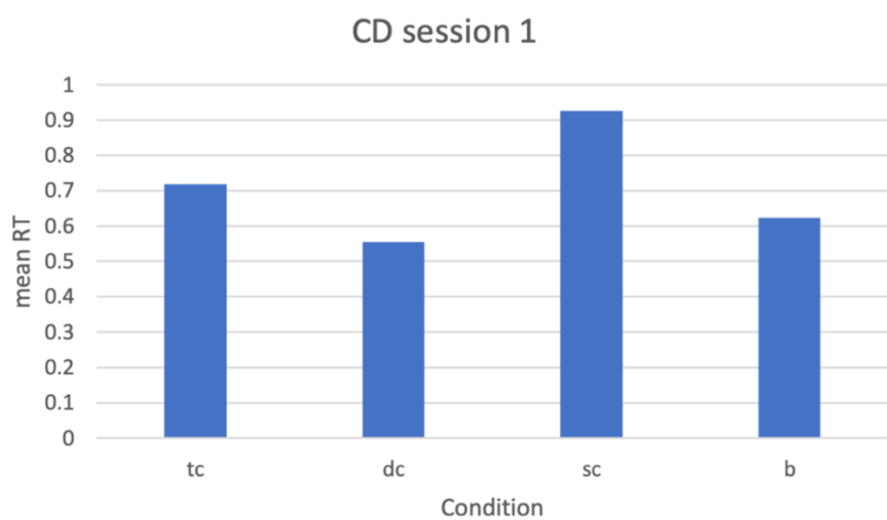

Figure 1b – CD Reaction Times for Session 1

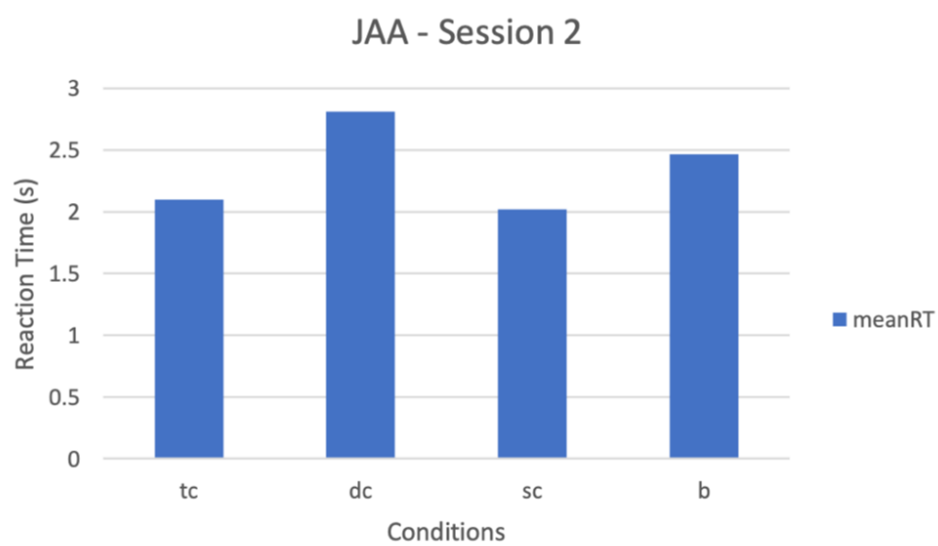

Figure 2a – JAA Reaction Times for Session 2

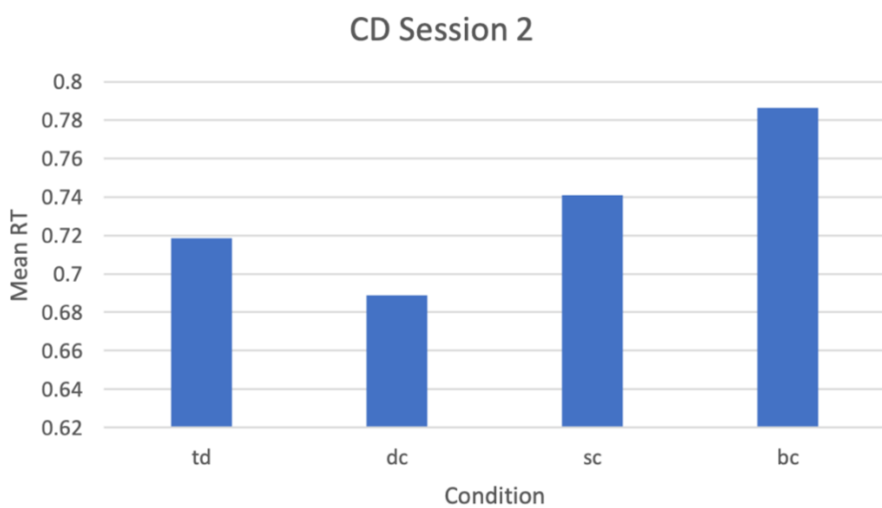

Figure 2b – CD Reaction Times for Session 2

The obtained reaction time data for consonant and dissonant correctly answered trials separately are indicated in the Table 2.

Table 2. Reaction Time for consonant and dissonant trials when answered correctly

Subject	Session	Mean RT (s)			
		Tonal (tonic, dominant, subdominant averaged)		Baseline (tonic, dominant, subdominant averaged)	
		Consonant	Dissonant	Consonant	Dissonant
JAA	Session 1	0.92495306	1.04189364	1.26457906	0.94340256
	Session 2	2.09688889	2.810000002	2.02212501	2.46649998
	Total	1.51092098	1.92594682	1.64335204	1.70495127
CD	Session 1	0.717666705	0.55399998	0.926666657	0.623000039
	Session 2	0.718444453	0.688666662	0.741111093	0.786555582
	Total	0.71805558	0.62133332	0.8338889	0.7047778

It's noticeable that the response times are longer on the second session than the first for the first subject (JAA). In session 1, subject JAA seemed to be doing better with consonant targets than the dissonant targets in the tonal contexts but the results show the opposite for the baseline contexts.

On the other hand, subject CD's response times did not significantly differ between the two sessions. They seemed to be doing better with tonal contexts (both consonant and dissonant) than with baseline contexts.

Discussion

Given the difference in circumstances of subject backgrounds, musical experience, and acoustic environment of the task between our study and the study by Tillmann et al.'s, the results still showed a priming effect for the related tonal targets over baseline targets.

We notice that the two subjects' results differ significantly from one another. For subject JAA, response times were faster for consonants in the tonal contexts than in the baseline contexts. However, the response times for dissonant targets were faster in the baseline contexts than in the tonal contexts. It's notable to mention that subject JAA had an error rate of 18% for the consonant targets in the baseline contexts.

Unlike subject CD, subject JAA had significant reaction times between session 1 and session 2. We suspect that it could be related to the varying volumes of each sequence. Thus, we looked at studies that used stimuli from realistic compositions contexts with tonal cadences. The study by Sears et al. (2019) uses three sensory–cognitive models of auditory expectation to reproduce the given findings for the most frequently used cadence patterns associated with tonal music. They took a different methodology by choosing realistic musical stimuli that ended in one of the five most popular tonal cadence types. The study consisted of two experiments; In the first experiment, participants gave expectancy evaluations before and after hearing the cadential formula's target melodic tone and chord. In the second experiment, participants were asked to report quickly if the target events were in sync with the prior context or not (Sears et al., 2019). Results showed that cadences steady melodic tones and chords received the highest and fastest ratings, therefore the most accurate (Sears et al., 2019).

Despite the error rate of 3.7% for tonal consonants, subject CD had interestingly faster response times for both consonant and dissonant targets in the tonal context than in the baseline context which corelates more with the results of Tillmann et al.'s study. This shows faster priming effect in the baseline context where the target pitch is lower than the context note. This interpretation was considered according to the study by Seror et al. (2015). This study investigated the affect of consonance and dissonance of a harmonic interval on the distinction of pitch components. The study was done through two experiments; in the first experiment the context note was higher in pitch than the target note, the opposite was presented in experiment 2 (Seror et al., 2015). The procedure consisted of playing a two-note harmonic interval played after playing a single pitch. This interval might or might not include that single pitch (would be off by a semitone) (Seror et al., 2015). The participants had to specify if they heard the singly pitch in the interval or not (Seror et al., 2015). Results in this study showed that when the context pitch was higher than the target note, pitch discrimination was faster and more accurate in consonant intervals than dissonant intervals but there was no impact of consonance when the target was higher (Seror et al., 2015).

Furthermore, we would like to see more similar research to Tillmann et al.'s (2008) but on professional musicians with more than 10 years of experience with a musical instrument. If would be more accurate to compare music professionals from different fields and genres and then compare those to non-musicians with different rates of daily exposure to tonal music.

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