KNOWLEDGE-BASED EXPECTATION EFFECTS ON PITCH PERCEPTION:

A CROSS-CULTURAL INVESTIGATION

ELİF CANSEZA KAPLAN

BOĞAZİÇİ UNIVERSITY

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KNOWLEDGE-BASED EXPECTATION EFFECTS ON PITCH PERCEPTION:
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Elif Canseza Kaplan

Boğaziçi University

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DECLARATION OF ORIGINALITY

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ABSTRACT

Knowledge-Based Expectation Effects on Pitch Perception:

A Cross-Cultural Investigation

Earlier studies have shown that harmonic (Bigand & Pineau, 1997) as well as tonal expectations (Marmel, Perrin, & Tillmann, 2011; Marmel, Tillmann, & Dowling, 2008) influence pitch processing. The ending of a melody fragment either with full or half/suspended-cadence affects the sensitivity towards pitch deviations. In the current study we investigated the influence of such knowledge-based expectations in Turkish makam music, which is a musical system that includes more minute pitch intervals than Western music. We showed that despite the narrower pitch intervals of makam music, both Western tonal (Exp. 1A) and Turkish makam (Exp. 1B) contexts influence processing of pitch in a similar fashion. In addition, a second control experiment (Exp. 2) that measured psychophysical sensitivity thresholds of pitch deviations confirmed that the effect we observed in Exp. 1 was not due to the participants' inability to hear pitch deviations.

ÖZET

Bilgiye Dayalı Beklentilerin Ses Perdesi Algısına Etkileri: Kültürler-Arası bir Araştırma

Önceki çalışmalar hem harmonik, hem de tonal beklentilerin ses perdesinin işlenmesine etkilerini göstermiştir. Bir melodi fragmanın tam ya da yarım/asma kararla bitiyor olması, ses perdesindeki deviyasyonların algılanma hassasiyetini etkilemektedir. Bu çalışmada böyle bilgiye dayalı beklentilerin, tonal Batı müziğinden daha dar ses aralıkları içeren Türk makam müziğinde nasıl etkileri olduğu incelenmiştir. Daha dar ses aralıkları olmasına rağmen ses perdesi algısının Türk makam müziği (Deney 1B) bağlamında, batı müziği (Deney 1A) bağlamına benzer etkileri olduğu gösterilmiştir. Buna ek olarak, ses perdesi deviyasyonlarına psikofizik hassasiyet eşiği ikinci bir kontrol deneyi (Deney 2) ile incelenmiş, birinci deneyde gözlemlenen etkilerin, katılımcıların ses perdesi deviyasyonlarını duyamadığından değil de bilgiye dayalı beklentilerin etkisi olduğunu desteklemiştir.

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CHAPTER 1

INTRODUCTION

Information processing is driven both by incoming sensory information and more knowledge-based information stored in our brain and mind. Our brain is a machinery that consumes a vast amount of energy such that it needs to be working in a manner that minimizes this energy consumption in encoding and processing information (Clark, 2013). The statistical regularities available in the information within the environment of an organism form the basis of this stored knowledge. It further *economizes* the utilized energy whenever new sensory information is to be processed, through activating these previously stored information (Bigand & Tillmann, 2005). Therefore, in a sense, when processing new sensory information, we form expectations as to what will come next, based on the abstraction of the regularities of a system. The role of such abstract and implicitly learnt knowledge of a musical system on a more sensory process, namely perception of musical pitch, is the main topic of this thesis.

When processing musical information, expectations driven by implicit knowledge about the musical system play an essential role and have been studied empirically in Western tonal music contexts (Bigand & Pineau, 1997; Krumhansl & Shepard, 1979; Lynch & Eilers, 1992; Marmel et al., 2011, 2008; Warrier & Zatorre, 2002). Western tonal system includes a set of equal tempered 12 semitones (C, C♯/D♭, D, D♯/E♭, E, F, F♯/G♭, G, G♯/A♭, A, A♯/B♭, B) that are organized in a systematic fashion of 7 pitch classes that constitute the keys. There exists a hierarchy in the organization of the tones that occur in the key. The hierarchy manifests itself in the statistical regularities of the musical system; certain tones within a key occur more frequently at relatively more important points within the musical event (Krumhansl, 1990). In Western tonal music *tonic* is the most frequent tone that appears within the key it specifies. Consequently, it has the highest rank in the hierarchy of Western tonal system. Tonic is followed by the dominant (fifth degree) and mediant (third degree), which are followed by the rest of the tones that exist in a scale. Melodies usually commence or end with the tonic, creating a sense of resolution when a musical phrase ends. As Krumhansl & Cuddy (2010) put it, it acts as the *cognitive reference point* (Rosch, 1975) of the key, with the other tones being constructed around this reference. In domains where perception of information is not absolute, but rather relative to the context in which it appears, such as music, the reference points have a crucial importance for economizing the cost of encoding and processing of information. The same semitones that exist in the Western tonal system can occur in different keys, but differ in the functional role they bear according to the musical context in which they appear. For instance, while C is the tonic in C-Major scale, it takes the role of the dominant in F-Major. In order for "musical meaning-making" to take place, the statistical regularities that constitute the tonal hierarchy are implicitly abstracted both by musicians and non-musicians (Bigand & Poulin-Charronnat, 2006; Krumhansl & Cuddy, 2010).

The probe-tone paradigm by Krumhansl & Shepard (1979) is one of the first studies that provided empirical evidence that Western listeners, both musician and non-musician, possess knowledge of scales and the underlying structures of Western tonal hierarchy. Participants with varying degrees of musical training were asked to give a rating from 1 to 7 of how good/bad a tone fitted a sequence of tones that made up a scale. The results were consistent with the music theory in the sense that tonics were rated as being the best fit to the heard sequence, followed by the dominant and mediant receiving the second highest ratings. The leading tone (the last note before the octave), along with the remaining tones were rated as the worst fit. The same procedure was applied to all possible scales that exist in Western tonal music and the degrees of hierarchy were reflected in the results of various contexts.

Knowledge-based musical expectations have been investigated utilizing the priming paradigm. In priming experiments, a prime and a target stimulus, which may or may not be related to the prime, are presented. Bharucha & Stoeckig (1986, 1987) asked participants to judge the target chord that was presented after a prime chord as being *in-* or *out-of-tune.* There was a harmonic relation between the target and the prime chord; the target was either harmonically *related* or *less related* to the prime. The results showed that in-tune targets that followed a related prime were judged more accurately and response times were shorter, which was not the case when the prime was less related. On the other hand, out-of-tune targets were judged more correctly and rapidly when the preceding prime was less related. These studies were one of the first to demonstrate that context affects processing accuracy and speed due to musical expectations based on the internal structure of Western tonal system.

The extent to which priming effects are due to lower-level processes or a more knowledge-based, higher-level process was further elaborated in Tekman & Bharucha (1992). They manipulated stimulus onset asynchrony (SOA) between the prime and the target chord, as well as the duration of the prime chord. There was also a mask noise added right after the prime chord in order to rule out any possible bottom-up effect. They showed that even at a SOA as long as 2500 msec, and even at a prime duration as short as 50 msec, the priming effect was still present. These findings provided further evidence for musical expectations occurring at a higher level. In a follow up study, Tekman & Bharucha (1998) showed that for shorter SOA intervals, such as 50 msec, bottom-up processes were more at work, while knowledge-based expectations effects were observed at longer SOAs. Thus, at shorter time intervals bottom-up processes seem to dominate the processing of musical information, while higher-level processes seem to take effect at longer intervals. Both Bharucha & Stoeckig (1986, 1987) and Tekman & Bharucha (1992, 1998) showed that listeners' perception of musical events is affected by prior context, even if the context is a local one.

While the former studies focused on short musical contexts, namely single chord comparisons, Bigand & Pineau (1997) explored how harmonic priming in longer melodic excerpts were affected by the global context. Their stimuli included eight chords, with the final chord being the target chord. The first six chords were varied to change the harmonic function of the target chord, either to be *tonic (strongly expected)* or *subdominant (less expected)*, while the penultimate chord was kept constant at all times to keep bottom-up processes constant across conditions. The experimental task required participants to decide whether the target chord was *consonant* or *dissonant*. Response time and accuracy were measured. Participants were faster for their consonance judgments and more accurate if the target chord was the tonic chord. This study was important because it showed that top-down influences occur over longer distances, e.g., if the first chord in a sequence of eight chords is a tonic chord, it will have a direct influence on the way the subsequent chords are perceived, including the very last one.

Cognitive psychology experiments studying how knowledge-based expectations are influencing processing of musical information mostly utilize polyphonic musical excerpts, which were accompanied by harmonic chords. Marmel, Perrin, & Tillmann (2011) and Marmel, Tillmann, & Dowling (2008) applied a different method of inquiry, testing subjects by presenting monophonic melodies. They presented participants with single line Western tonal melody pairs, which consisted of almost the same tones differing only in one or two tones in the first bar of the melody. This allowed them to keep bottom-up influences constant across conditions while manipulating top-down expectations by changing the function of the last tone. In addition, the final tone of the melodies was changed by slight *cent* (logarithmic measure of frequency dimension, with each semitone being equally 100 cents apart) deviations, to check how knowledge-based expectations would affect perceptual sensitivity to pitch deviation. Participants were asked to give a subjective judgment of in or out-of-tuneness for the target tone. The results indicated that tonal function (related vs. less-related) affected participants' perception of mistuning. This study was important for showing how knowledge-based expectations can alter lower-level processes such as perception of pitch deviations.

In the current study, I investigated how knowledge of a different system with microtonal pitch classes, namely Turkish makam music, may affect perception of pitch. The goal was (1) to see whether we can show similar evidence for the existence of knowledge-based structures regarding Turkish makam music even in Turkish participants who lack any kind of musical training, and if so, (2) whether we would find evidence for a "finer" categorical pitch representation due to the microtonal system. Before moving on to a more extensive description of the current study, Turkish makam music system will be explained in the following section.

1.1 Turkish makam music

Turkish makam music is a less standardized system and differs from Western tonal music in its pitch classes. Until recently, it was a musical system delivered through a master-apprentice type of education, like an oral language without a written counterpart. The “written” counter-part of the system that is based on Western notation, along with standardizations that are not fully integrated even today, came about in 1930s (Aydemir, 2010). There is no consensus as to how many pitch classes there are; according to some, an octave is divided into 24 while others propose 36 (Yarman & Karaosmanoglu, 2014), 53 or 79 divisions (Yarman, 2008).

The standardized 24-Note System, referred to as the “Arel-Ezgi-Uzdilek (AEU) system” is the most common form used nowadays, taught in conservatories or and utilized mostly in popular songs (Aydemir, 2010). In the current study, AEU system is taken as the basis. Unlike the Western tonal music, the intervals between the tones are not equal tempered. The interval between two whole tones is divided into 9 equal *Holdrian commas*, and the 1st (fazla), 4th(bakiye), 5th(küçük mücennep), 8th(büyük mücennep) and 9th (tanini) commas constitute the flat and sharp tones.

While the interval between two whole tones in Western tonal music is equivalent to 200 cents, in Turkish makam music it is 203.9 cents, with 1 Holdrian comma ≈ 22.6415 cents (Ederer, 2011). These intervals, which may sound bizarre to a “Western ear”, make up the pentachords and tetrachords, called *çeşni*, by being organized in a variety of combinations to create the makam scales. The organization is not arbitrary, but rather occurs in a systematic fashion as in the case of Western tonal music. However, there is another crucial difference; Turkish makam music is a horizontal musical system, meaning the melodies are monophonic, while in Western tonal music they may be accompanied by chords. Despite this difference, the hierarchy that exists in Turkish makam music can be considered homologous to the Western tonal hierarchy. There is a tonic, namely the *karar* tone, around which the makam is constructed.

A makam melody ends with a *karar* tone (full cadence), giving a sense of resolution, as its name suggests in Turkish. The *yarım karar* (half cadence) corresponds to the dominant in Western music, which still bears an important function; and the *asma karar* (suspended cadence), which may be the second, third or sixth degree in hierarchy, leaves the melody in suspension (Aydemir, 2010). One could imagine that a melody fragment ending with a karar tone is similar to a complete sentence with a full stop at the end; the one that ends with yarım karar is a phrase that ends with a comma; and the one ending with asma karar is like an incomplete sentence that requires one additional element to complete it.

The makam constructions are much more complex than that outlined above, but for the purposes of this study, the information provided should be sufficient.

1.2 Present study

The present study aimed to investigate how expectations due to implicit or explicit knowledge of a musical system may affect pitch perception. Different musical systems have different pitch representation. Pitch classes of Turkish makam music, which is a microtonal musical system, is different from that of Western tonal system. As explained above, an octave is divided into at least 24 instead of 12 intervals. So one could expect listeners encultured to the Turkish makam music to have a different categorical representation (see Goldstone & Hendrickson (2009) for a review of categorical perception) of pitch compared to Western listeners, which in turn might influence their sensitivity to minute pitch deviations.

In Experiment 1, Turkish non-musicians and Turkish makam musicians were tested with the experimental paradigm used by Marmel et al. (2008). Participants were asked to judge whether the final tone within a Western tonal (Experiment 1A) or a Turkish makam (Experiment 1B) melody was in or out-of-tune on a 4-point-scale. Each melody that ended with a tonic/karar (full cadence) had a pair melody that ended with the subdominant/asma karar (suspended cadence). For each melody, the pitch of final tone of the melody appeared either in-tune or at different degrees of deviation across trials. The main purpose of these manipulations was to detect how expectations would affect sensitivity of minute pitch deviations.

A second experiment was conducted in order to control whether the context indeed had an effect on the rating judgments of participants and whether the deviation manipulations were above the psychophysical sensitivity thresholds. A psychophysical method, 3-down 1-up staircase procedure, was utilized to measure the exact point at which the participants could hear when there was a deviation. The task required giving a same/different judgment upon hearing two consecutive sounds, which consisted of all the notes that were the to-be-judged target notes used in Experiment 1.

1.3 Research questions

1. Do people encultured or entrained in different musical systems have a different categorical representation of pitch?
2. Do knowledge-based expectations influence pitch sensitivity in Turkish makam music as well and, if so, is the influence the same as in a Western tonal context?
3. Do makam musicians have a different sensitivity to more minute pitch deviations than non-musician listeners?

CHAPTER 2

EXPERIMENT 1

2.1 Experiment 1A

2.1.1 Method

2.1.1.1 Participants

Thirty-two Turkish non-musicians from Boğaziçi University and twelve Turkish makam musicians, two from Boğaziçi University and ten from Istanbul Technical University, Turkish Music Conservatory participated in Experiment 1A. Turkish non-musician participants had an average of 0.43 years of musical training (*SD*=1.0, Median=0), and Turkish makam musicians had an average of 11.92 years of musical training (*SD*=5.30, Median=10.5).

2.1.1.2 Materials

Six pairs of tonal melodies adapted from Marmel et al. (2008), each consisting of two bars with four beats on each bar were utilized in the experiment (for the total list of melodies see 1A). The only difference between the melodies of a pair was their key, which occurred as the result of a slight manipulation in the first bar of the melody. One of the tones occurring in the first bar of the melody was either naturalized or sharpened/flattened. This slight difference within the first bar caused the tonal function of the final tone to change, without changing the melodic contour that may have given rise to a bottom-up effect. Thus, the melody pairs either ended with the tonic (full-cadence) or the subdominant (suspended-cadence). Two additional melodies, which were constructed like the experimental stimuli, were used for the practice phase.

2.1.1.3 Apparatus

The melodies were created as .wav files with Mus2 microtonal score Software[1] using its *Kanun* sample as the instrument. The main reason to choose Kanun sample was because it delivered the most natural makam music-like feel for the Turkish makam context. Inducing makam context is typically more difficult than inducing a Western tonal context within only eight beats. Also, since makam music is microtonal, extremely well-known timbres such as piano timbre, which was used by Marmel et al. (2008), produce a strange, almost 'repulsive' feeling when listening to the makam tones. The duration of each melody was 7000 msec. The pitch of the final tone of the melodies were either in-tune or shifted by +/-9, +/-17 and +/-35 cents, in line with Marmel et al. (2008). The experiment was written and run on Matlab Psychtoolbox extensions (Kleiner et al., 2007).

2.1.1.4 Procedure

Upon signing the consent form, the participants were instructed to listen to the melodies and make an in/out-of-tune judgment for the final tone of the melody on a 4-point scale. 0 referred to in-tune (*doğru*) response, and 1 to 3 corresponded to slightly out-of-tune (*az yanlış*), out-of-tune (*yanlış*) and very out-of-tune (*çok yanlış*) respectively. Before starting the practice phase, a melody sample based on Beethoven's 9th Symphony, either in-tune or with each deviation condition, was used to demonstrate concepts of in-tune and the degrees of mistuning, in order to familiarize the participants with the concepts. +/-9 cent deviation conditions were presented as being slightly out of tune*,* +/-17 cent deviations as out of tune and +/-35 deviations as very out of tune. After listening to the sample melody, participants

[1] (http://www.mus2.com.tr/)

completed the practice part, consisting of 2 melodies ending with tonic and subdominant either in-tune or one of the deviation conditions (16 trials) and moved on to the experimental part. Participants listened to a total of 96 melodies in the experimental part; six pairs of melodies ending with either the tonic or subdominant, being either in-tune or one of the 6 deviation conditions. The stimuli were presented in a pseudo-random order, where the matched tunes were never presented in consecutive order and a deviation condition did not occur more than 4 times in a row. After responding, participants heard a 250 msec long white noise mask. They did not receive feedback and had to press a key to move on to the next trial. After completing Experiment 1A, participants took a 10-minute break before moving on to Experiment 1B. The order of presentation of Experiments 1A and 1B were counterbalanced.

2.1.1.5 Data analysis

For the sake of comparison with Marmel et al. (2008), all subsequent analyses were performed on participants' 3-point ratings, false alarm rates and area under the ROC-curve (AUC). The responses were coded on a 0-3 scale, where 0 referred to in-tune target tones, 1 to slightly out of tune, 2 to out of tune and 3 to very out of tune. The mean rating scores were calculated for each participant and each condition. 2x3x2 ANOVA was used to analyze the mean ratings, with two tonal functions (tonic, subdominant), three deviation amounts (9, 17, 35) and two deviation directions (negative or positive) as within-participant factors both for musicians and non-musicians. Hit and false alarms, as well as, AUCs were calculated using Matlab *perfcurve* function, and further analyzed with 2x3x2 ANOVA with the same factors as mean ratings. Hit and false alarms were calculated based on in-tune responses; in-tune responses for no deviation condition were taken to be hit responses, while in-tune responses for all deviation amounts were false alarms. Response biases were further checked with *c* scores (Stanislaw & Todorov, 1999) based on the hit and false alarms.

2.1.2 Results

2.1.2.1 Turkish non-musicians

For the mean ratings of degree of mistuning (Figure 1), the main effect of deviation amount was significant [$F(2, 62) = 291.10$, $MSe = 46.14$, $\boldsymbol{p < .001}$, $\varepsilon = .75$ (G-G), $\eta_p^2 = .91$]. Participants' sensitivity increased as deviation amount increase from 9 to 35 cents. The main effect of tonal function was significant [$F(1, 31) = 19.37$, $MSe = .52$, $\boldsymbol{p < .001}$, $\eta_p^2 = .39$]. Melodies ending with the subdominant target tones were judged as being more out-of-tune than those ending with the tonics. The main effect of deviation direction was significant [$F(1, 31) = 159.23$, $MSe = 36.22$, $\boldsymbol{p < .001}$, $\eta_p^2 = .84$]. The interaction between tonal function and deviation direction [$F(1, 31) = 5.36$, $MSe = .26$, $\boldsymbol{p < .05}$, $\eta_p^2 = .15$], as well as the interaction between deviation amount and deviation direction [$F(2, 62) = 4.72$, $MSe = .39$, $\boldsymbol{p < .05}$, $\eta_p^2 = .13$] were also significant. All other effects were not significant ($F < 1$). These results indicate that pitch deviation sensitivity depends on both function and deviation direction. In general, participants were more sensitive to negative deviations, especially if the melody ended with a subdominant tone.

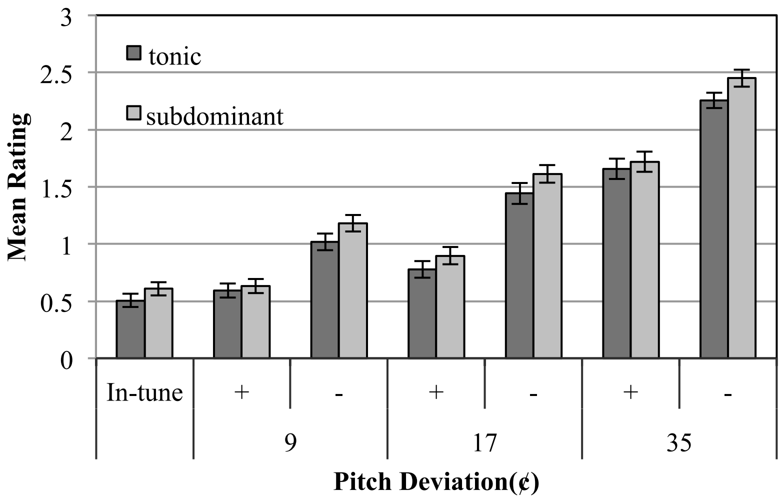

Figure 1. Mean ratings for the degree of mistuning of Turkish non-musicians for Western tonal context

For hit and false alarms (Figure 2), the main effect of deviation amount [$F(2, 62) = 90.91$, $MSe = 3.75$, $\boldsymbol{p < .001}$, $\eta_p^2 = .75$],the main effect of tonal function [$F(1, 31) = 14.15$, $MSe = .22$, $\boldsymbol{p < .01}$, $\eta_p^2 = .31$], and the main effect of deviation direction [$F(1, 31) = 51.30$, $MSe = 2.79$, $\boldsymbol{p < .001}$, $\eta_p^2 = .63$] were significant. In addition, the interaction between deviation amount and deviation direction was significant as well [$F(2, 62) = 15.31$, $MSe = .30$, $\boldsymbol{p < .001}$, $\eta_p^2 = .33$]. All other interactions were not significant ($F < 1$). As expected, there were fewer false alarms as deviation amount increased. This decrease was more pronounced for negative pitch deviations. Also, there were fewer false alarms for subdominant target tones and for negative pitch deviations.

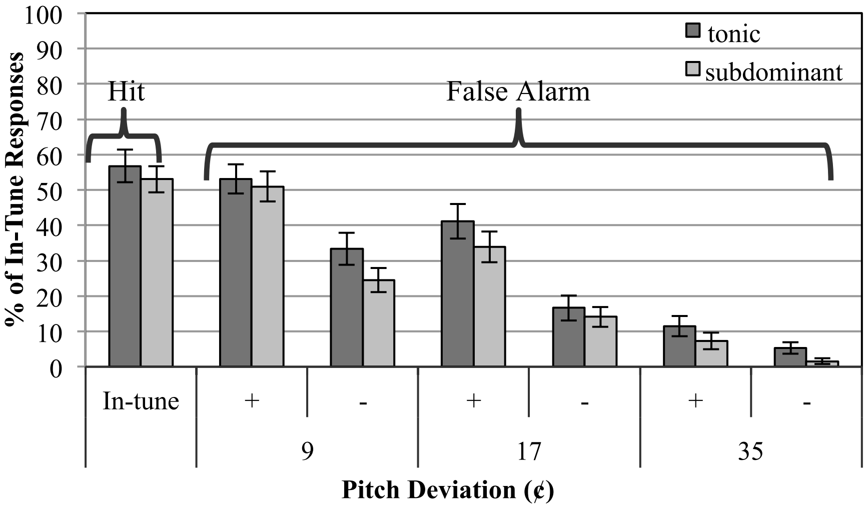

Figure 2. Hit and false alarms - represented in terms of percentage of in-tune responses at all conditions - of Turkish non-musicians in Western tonal context

For the areas under receiver-operating characteristics (ROC) curve (Figure 3), the main effect of deviation amount [$F(2, 62) = 90.11$, $MSe = .94$, $\boldsymbol{p < .001}$, $\eta_p^2 = .74$] and the main effect of tonal function was significant [$F(1, 31) = 13.84$, $MSe = .05$, $\boldsymbol{p < .01}$, $\eta_p^2 = .31$]. Deviated subdominant target tones were judged as being more out-of-tune in most deviation conditions, as opposed to deviated tonic targets. The main effect of deviation direction [$F(1, 31) = 10.93$, $MSe = 1.76$, $\boldsymbol{p < .01}$, $\eta_p^2 = .26$] and the interaction between deviation direction and deviation amount [$F(2, 62) = 14.73$, $MSe = .07$, $\boldsymbol{p < .001}$, $\eta_p^2 = .32$] were significant. The accuracy of mistuning judgments were better as the deviation amount increased, and negative deviations were better judged as being out-of-tune as opposed to the positive deviations. There was no response bias ($c_{tonic} = .38$, $c_{subdominant} = .52$)

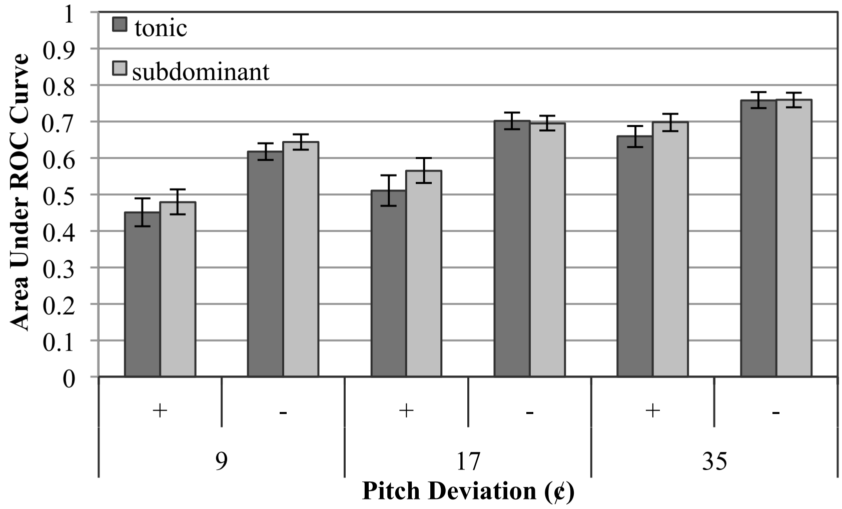

Figure 3. Area under receiver-operating characteristics (ROC) curves of Turkish non-musicians in Western tonal context

2.1.2.2 Turkish makam musicians

For the mean ratings of degree of mistuning (Figure 4), the main effect of deviation amount [$F(2, 22) = 227.23$, $MSe = 30.41$, $\boldsymbol{p < .001}$, $\eta_p^2 = .95$] and the main effect of tonal function [$F(1, 11) = 10.60$, $MSe = 1.07$, $\boldsymbol{p < .01}$, $\eta_p^2 = .49$] were significant. Makam musician participants judged deviated subdominant target tones to be more out-of-tune compared to deviated tonic targets. The mean ratings of mistuning increased as deviation amount increased. All other effects were not significant ($F < 1$). The positive/negative asymmetry observed in non-musicians was not present for makam musicians.

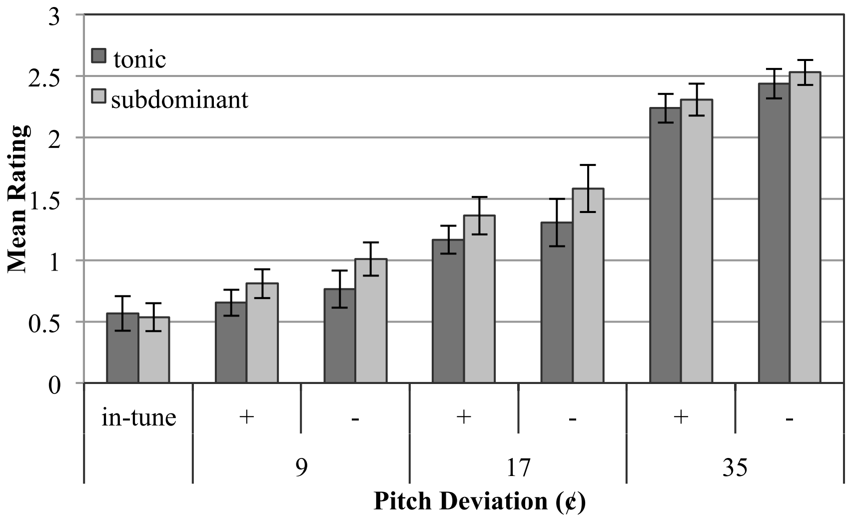

Figure 4. Mean ratings for the degree of mistuning of Turkish musicians for Western tonal context

For the hit and false alarms (Figure 5), the main effect of deviation amount [$F(2, 22) = 50.45$, $MSe = 1.77$, $\boldsymbol{p < .001}$, $\eta_p^2 = .82$] and the main effect of tonal function [$F(1, 11) = 6.18$, $MSe = .10$, $\boldsymbol{p < .001}$, $\eta_p^2 = .36$] was significant. The interaction between tonal function and deviation amount was also significant [$F(2, 22) = 3.97$, $MSe = .05$, $\boldsymbol{p < .05}$, $\eta_p^2 = .27$]. There were fewer false alarms for subdominant target tones across deviation conditions, and as the deviation amount increased, false alarms decreased. There was no significant difference between the negative and positive deviations for each of the deviation condition. For instance, the overall difference between false alarms for positive and negative of 9 cents, 17 cents or 35 cents was not significantly different. All other effects were not significant ($F < 1$).

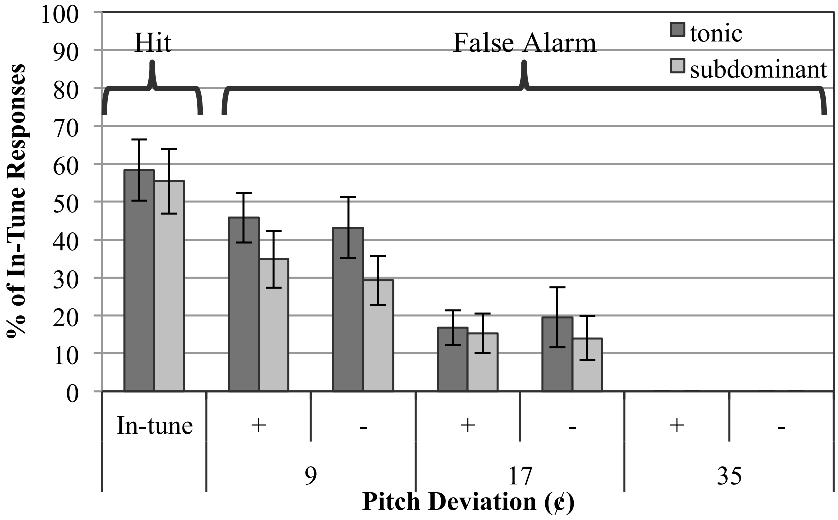

Figure 5. Hit and false alarms of Turkish makam musicians in Western tonal context

For the area under ROC curve (Figure 6), the main effect of deviation amount [*F*(2, 22) = 49.90, *MSe* = .44 , $\boldsymbol{p} < \mathbf{.05}$, ε = .65 (G-G), η_p^2 = .82], the main effect of tonal function [*F*(1, 11) = 6.24, *MSe* = .03 , $\boldsymbol{p} < \mathbf{.05}$, η_p^2 = .36] and the interaction between tonal function and deviation amount [*F*(2, 22) = 4.06, *MSe* = .01 , $\boldsymbol{p} < \mathbf{.05}$, η_p^2 = .27] were significant. Turkish makam musicians were more sensitive to deviated subdominant targets compared to deviated tonic targets. Figure 7 shows that higher pitch deviation sensitivity to subdominant as opposed to tonic ending appears to shrink with increasing cent deviations. All other effects were not significant ($F < 1$). There was a response bias to judge subdominant target tones to be more out-of-tune (c_{tonic} = .48, $c_{subdominant}$ = -.50)

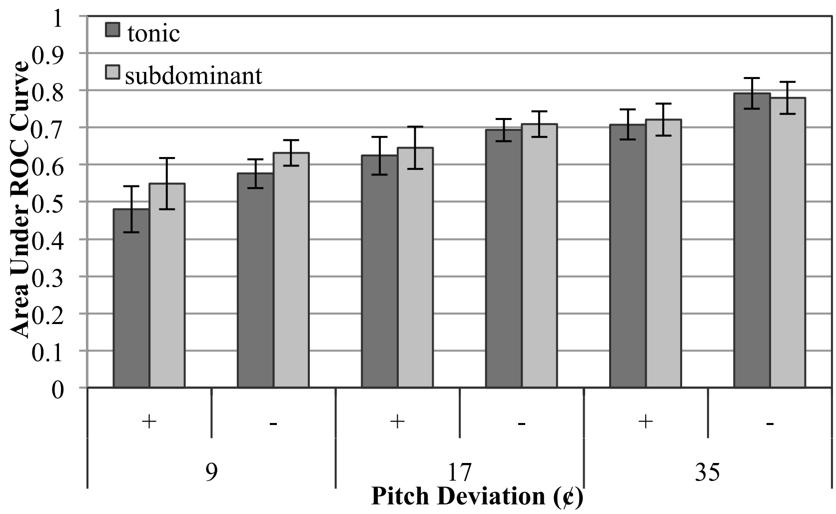

Figure 6. Area under ROC curves of Turkish makam musicians in Western tonal context

2.2 Experiment 1B

2.2.1 Method

2.2.1.1 Participants

The same thirty-two non-musicians and 12 Turkish makam musician participants that completed Experiment 1A participated in Experiment 1B. The order of presentation of Experiment 1A and 1B were counterbalanced.

2.2.1.2 Materials

Six makam melody pairs were composed in line with the tonal melodies such that, in each pair, one of the melodies ended either with a karar (full cadence) or asma karar (suspended cadence) tone (see 1B for the full list of stimuli). Three additional melodies that were written in line with the experimental stimuli were used for the training phase.

2.2.1.3 Apparatus

The melodies were created as .wav files with Mus2 microtonal score software, using the same Kanun sound sample for timbre as in Experiment 1A. The duration of each melody was 7000 msec. The pitch of the final tone of the melodies was shifted by +/-7, +/-15, +/-25 or +/-35 cents. The degrees of pitch deviations were arranged slightly differently than the tonal context, since the pitch intervals in makam music are different than those in Western tonal music. In Turkish makam music, an octave is divided into 24 intervals (according to the standard AEU system), while in Western tonal system an octave is divided into 12 intervals. The interval between two tones is divided into 9 equal intervals with one comma being equal to about 22.5 cents and some of the commas are chosen within the interval. Thus, the smallest deviation utilized is taken as one thirds of a Holderian comma (Sentürk, Gulati, & Serra, 2013). The experiment was written and run on Matlab Psychtoolbox extensions (Kleiner et al., 2007).

2.2.1.4 Procedure

The participants were instructed to listen to the melodies and make an in/out-of-tune judgment of the final tone of the melody on a 4-point scale, where 0 referred to in-tune (*doğru*) response, and 1 to 3 corresponded to slightly out-of-tune (*az yanlış*), out-of-tune (*yanlış*) and very out-of-tune (*çok yanlış*) respectively. Upon completing the practice part, the experimental part started. Participants listened to a total of 120 melodies in the experimental part; 6 pairs of melodies ending with either the karar or asma karar tone, being either in tune or one of the 8 deviation conditions. The stimuli were presented in a pseudo-random order, where the melody pairs were never presented in consecutive order and a deviation condition did not occur more than 4 times in a row. In each trial, after responding, participants heard a 250 msec long white noise. They did not receive error feedback and had to press a key to move on to the next trial.

2.2.1.5 Data analysis

The responses were coded on a 0-3 scale. A 2x4x2 all repeated measures ANOVA was used to analyze the mean ratings, for tonal functions (tonic, subdominant), deviation amounts (7, 15, 25, 35) and deviation directions (negative or positive). In addition, hit and false alarms, as well as area under receiver-operating characteristics curves were calculated using Matlab *perfcurve* function, and further analyzed with 2x4x2 ANOVA with the same factors as mean ratings. Hit and false alarms were calculated based on in-tune responses; in-tune responses for no deviation condition was taken to be hit responses, while in-tune responses for all deviation amounts were false alarms. Response biases were further checked with *c* scores (Stanislaw & Todorov, 1999) based on the hit and false alarms.

2.2.2 Results

2.2.2.1 Turkish non-musicians

For the mean ratings (Figure 7), the main effect of deviation amount [$F(3, 93) = 262.18$, $MSe = 40.68$, $\boldsymbol{p < .001}$, $\varepsilon = .78$ (G-G) , $\eta_p^2 = .89$] and the main effect of makam function were significant [$F(1, 31) = 5.30$, $MSe = .52$, $\boldsymbol{p < .05}$, $\eta_p^2 = .15$]. The main effect of deviation direction was significant as well [$F(1, 31) = 42.69$, $MSe = 11.63$, $\boldsymbol{p < .001}$, $\eta_p^2 = .58$]; negative deviations were better detected as out-of-tune in all deviation conditions. The interaction between makam function and deviation direction [$F(1, 31) = 23.82$, $MSe = 1.46$, $\boldsymbol{p < .001}$, $\eta_p^2 = .44$] was significant. These result indicate that pitch deviation sensitivity depends both on function and deviation direction. Figure 8 shows that participants were more sensitive to negative deviations which does not appear to be the case for -7 ¢. The karar/asma karar difference varied marginally across conditions. All other effects were not significant.

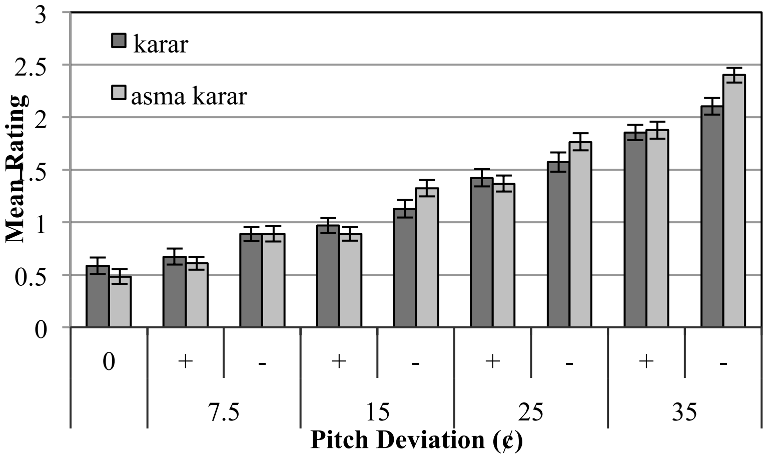

Figure 7. Mean ratings of degree of mistuning of Turkish non-musicians in Turkish makam context

For hit and false alarms (Figure 8), the main effect of deviation amount [$F(3, 93) = 86.30$, $MSe = 3.94$, $\boldsymbol{p < .001}$, $\varepsilon = .74$ (G-G) , $\eta_p^2 = .74$] and the main effect of deviation direction [$F(1, 31) = 23.56$, $MSe = .94$, $\boldsymbol{p < .001}$, $\eta_p^2 = .43$] were significant. In addition, the interaction between makam function and deviation direction [$F(1, 31) = 19.19$, $MSe = .31$, , $\boldsymbol{p < .001}$, $\eta_p^2 = .38$] and the interaction between deviation amount and deviation direction [$F(3, 93) = 4.38$, $MSe = .10$, $\boldsymbol{p < .01}$, $\varepsilon = .78$, $\eta_p^2 = .12$] were significant. All other effects were not significant. As in the tonal context, there appears to be fewer false alarms with increasing deviation – the decrease in false alarms being steeper for positive pitch deviations – and for negative pitch deviations. Karar vs. asma karar false alarms differed depending on deviation direction; for positive deviations the false alarms were higher for the suspended cadences ending with the asma karar, while the opposite was the case for negative deviations.

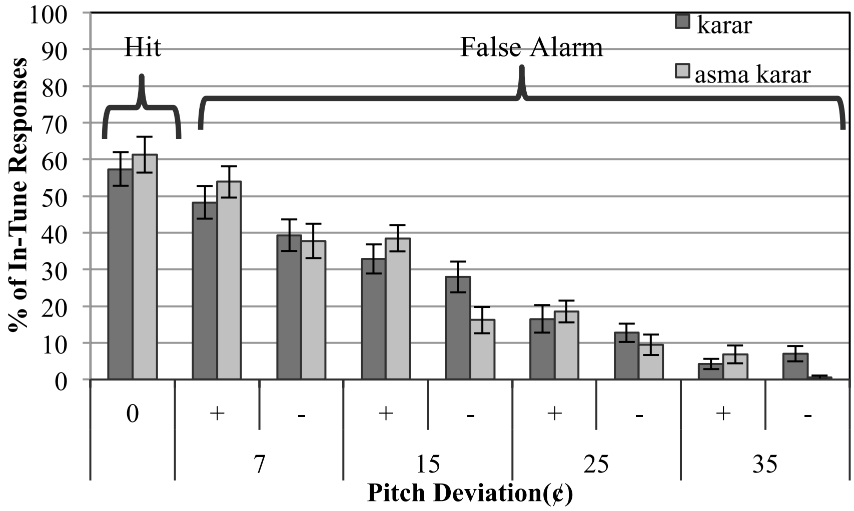

Figure 8. Hit and false alarms - represented in terms of percentage of in-tune responses at all conditions - of Turkish non-musicians in Turkish makam context

The AUC significance results were also similar to that of hit and false alarms (Figure 9). The main effect of deviation amount [$F(3, 93) = 85.77$, $MSe = .99$, $\boldsymbol{p < .001}$, $\varepsilon = .74$ (G-G) , $\eta_p^2 = .74$] and the main effect of deviation direction [$F(1, 31) = 7.90$, $MSe = 2.34$, $\boldsymbol{p < .01}$, $\eta_p^2 = .20$] were significant. Participants were more sensitive to higher deviations. The interaction between deviation amount and deviation direction was significant [$F(3, 93) = 4.43$, $MSe = .03$, $\boldsymbol{p = .006}$, $\varepsilon = .78$ (G-G), $\eta_p^2 = .13$]. Sensitivity increased as deviation amounts increased. As can be seen in Figure 10, deviated asma karar tones seemed to be better detected when the deviation direction was negative. All other effects were not significant. There was no response bias ($c_{karar} = .42$, $c_{asma\ karar} = .41$).

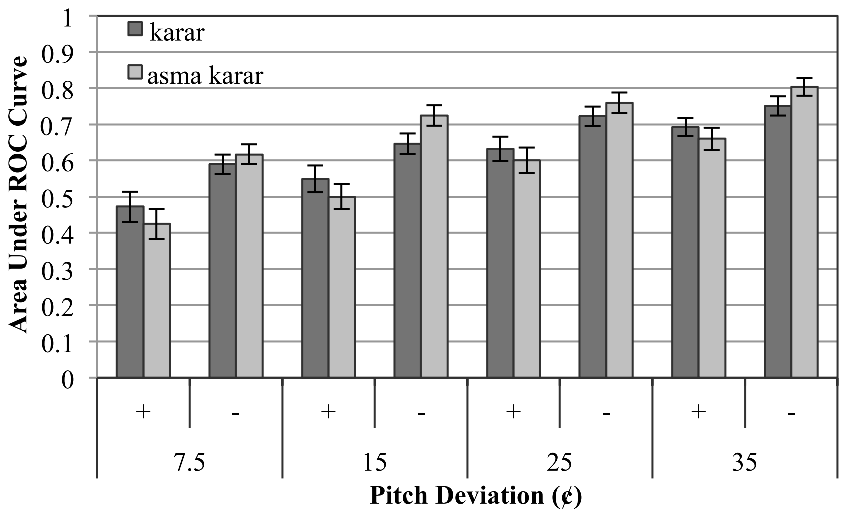

Figure 9. Area under ROC curve of Turkish non-musicians in makam music context

2.2.2.2 Turkish makam musicians

For the mean ratings of degree of mistuning (Figure 10), the main effect of deviation amount was significant [$F(3, 33) = 34.54$, $MSe = 25.01$, $\boldsymbol{p < .001}$, $\eta_p^2 = .97$]. As deviation amount increased from zero to 35 cents, sensitivity to deviations increased. The main effect of makam function was significant [$F(1, 11) = 34.54$, $MSe = 1.99$, $\boldsymbol{p < .001}$, $\eta_p^2 = .76$]. Melodies ending with the deviated asma karar tone were judged to be more out-of-tune compared to those ending with the deviated karar tone. The main effect of deviation direction was significant [$F(1, 11) = 34.54$, $MSe = 4.88$, $\boldsymbol{p < .01}$, $\eta_p^2 = .56$]. There was an asymmetry between positive and negative pitch deviations; participants were more sensitive to negative deviations among deviation conditions. The interaction between makam function and deviation direction was significant [$F(1, 11) = 23.74$, $MSe = .90$, $\boldsymbol{p < .001}$, $\eta_p^2 = .68$]. All other effects were not significant.

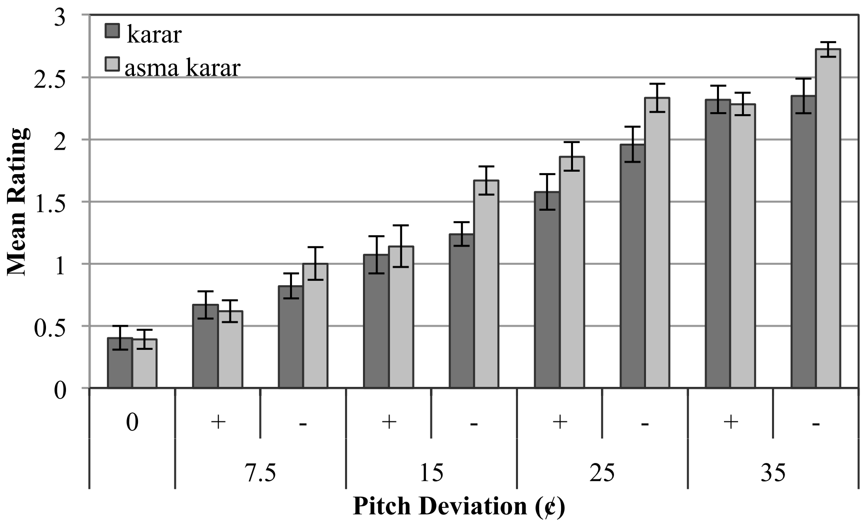

Figure 10. Mean ratings of degree of mistuning of Turkish makam musicians in Turkish makam context

For the hit and false alarms (Figure 11), the main effect of deviation amount [F(3, 33) = 45.78, MSe = 1.41 , $\boldsymbol{p < .001}$, η_p^2 = .81]). The main effect of makam function was significant [F(1, 11) = 13.71, MSe = .22 , $\boldsymbol{p < .001}$, η_p^2 = .56]. There were higher hits and false alarms for melodies ending with the karar tone. The main effect of deviation direction was significant [F(1, 11) = 8.52, MSe = .35 , $\boldsymbol{p < .05}$, η_p^2 = .44]. The interaction between makam functions, deviation amount and deviation direction is significant as well. [F(3, 33) = 3, MSe = .03 , $\boldsymbol{p < .05}$, ε = .51 (G-G), η_p^2 = .76]. Participants were more sensitive to melodies ending with the asma karar tone, especially for negative deviations.

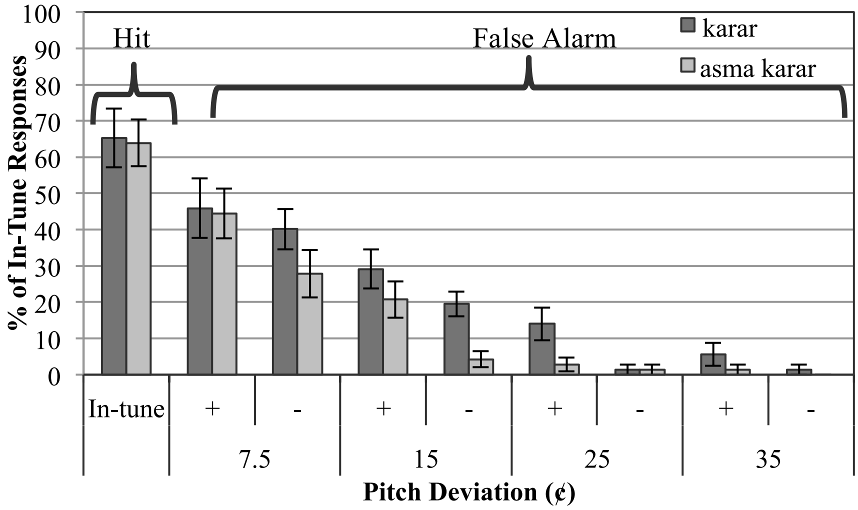

Figure 11. Hit and false alarms of Turkish makam musicians in Turkish makam context

For area under ROC curve (Figure 12), the main effect of makam function [$F(1, 11) = 13.70$, $MSe = .05$, $\boldsymbol{p < .01}$, $\eta_p^2 = .56$], the main effect of deviation amount [$F(3, 33) = 44.70$, $MSe = .35$, $\boldsymbol{p < .001}$, ε = .45 (G-G), $\eta_p^2 = .80$] and the main effect of deviation direction [$F(1, 11) = 6.01$, $MSe = 1.70$, $\boldsymbol{p < .05}$, $\eta_p^2 = .35$] were significant. The participants judged a deviated tone more accurately as the deviation amount increases and when the target tone was asma karar, in the negative direction. The increased sensitivity to asma karar target tones was not present in -25 and -35 cents deviations, possibly due to ceiling effects in these conditions. The interaction between makam function, deviation direction and deviation amount [$F(3, 33) = 3.22$, $MSe = .01$, $\boldsymbol{p = .04}$, ε = .51 (G-G), $\eta_p^2 = .23$] was significant. There was no response bias ($c_{karar} = .29$, $c_{asma\ karar} = .54$).

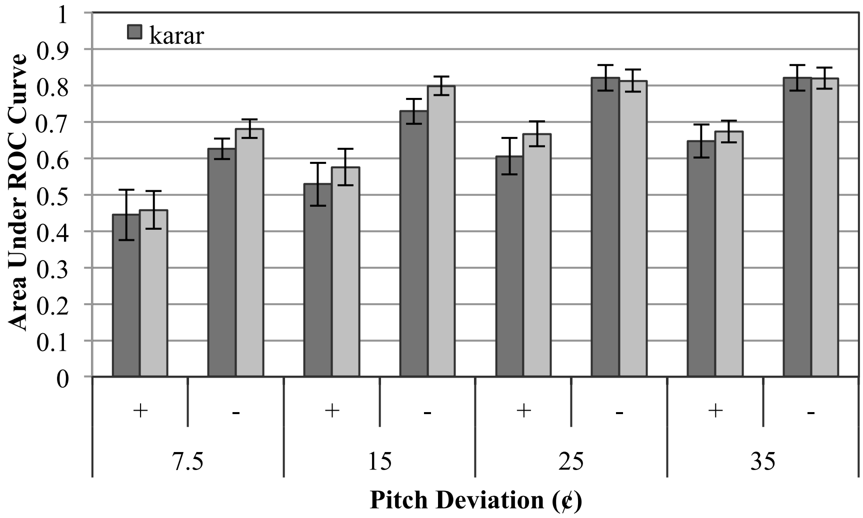

Figure 12. Area under ROC curves of Turkish makam musicians in Turkish makam context

CHAPTER 3

EXPERIMENT 2

A second experiment was conducted as control, to check what the participants' actual pitch deviation sensitivities were in a basic 2-tone discrimination paradigm without musical context.

3.1 Method

3.1.1 Participants

The same thirty-two non-musician and twelve makam musician participants completed the second experiment, as control for the first experiment.

3.1.2 Materials

8 notes sampled from the Kanun instrument in Mus2 microtonal score software were created with up to +/-20 cent deviations. The notes utilized as the final tone of the melodies from Experiment 1A & B were tested in this experiment (C, D♭, D, E, G, A, Bт, B).

3.1.3 Apparatus

Each note was created using the same Software, Mus2, as in the previous experiment. A deviation of each note was then created, which increased or decreased one by one, upto +/-20 cents. 20 cents was taken to be the final point, since it was heard clearly that there was a deviation after that point. The experiment was created and run on MATLAB, Psychtoolbox.

3.1.4 Procedure

Participants were asked to listen to two consecutive notes and make a same/different judgment. 3-up 1-down staircase procedure was implemented, where the presented stimuli changed based on the participants' response. If responded correctly, the deviation amount decreased by 1 cent (getting harder), while if the response was not correct, it went up by 3 cents (getting easier). Each note was tested on one block with positive and negative deviations of each note being tested in separate blocks. After each response on a trial, participants heard a 250 msec long white noise mask. Participants had to press a key to continue to the next trial and they did not receive error feedback.

3.1.5 Data analysis

Standard staircase method analysis is applied. The turning points are the points at which the participant reverts to correctly or incorrectly judging the given signal. The means of the turning points for each note and deviation direction was then calculated. These means estimate the participants' 75% accuracy thresholds.

3.2 Results and discussion

3.2.1 Turkish non-musicians

Average discrimination thresholds for Turkish non-musicians are presented in Table 1.

Table 1. Discrimination Thresholds of Turkish Non-Musicians in Cents

	C	**D♭**	**D**	**E**	**G**	**A**	**B𝄳**	**B**
positive	12.03	10.99	12.08	12.05	5.53	10.83	9.33	10.52
negative	1.50	7.33	2.19	1.90	1.46	2.37	9.65	2.75

3.2.2 Turkish makam musicians

Average discrimination thresholds for Turkish makam musicians are presented in the Table 2.

Table 2. Discrimination Thresholds of Turkish Makam Musicians in Cents

	C	**D♭**	**D**	**E**	**G**	**A**	**B𝄳**	**B**
positive	5.02	7.97	5.46	5.21	4.69	5.14	7.35	6.99
negative	2.91	4.09	2.55	3.83	2.98	2.48	3.44	3.14

In general, both non-musician and musician participants had smaller pitch discrimination thresholds for negative deviations. Musicians' thresholds were lower than non-musicians' for positive pitch deviations. When we compare false alarms in Exp.1A & Exp.1B for various cent deviations to psychophysical discrimination thresholds, we see that people fail to detect pitch deviations when they appear within a musical context.

CHAPTER 4

GENERAL DISCUSSION

In Experiment 1, it was observed that knowledge-based expectations influence pitch deviation sensitivity of both Turkish musicians and non-musicians, in a similar fashion in Turkish makam music as it does in Western tonal context. It has been previously shown that knowledge-based expectations influence pitch deviation sensitivity of Western non-musicians in Western tonal contexts. As in Marmel et al. (2008), negative pitch deviations received higher out-of-tune ratings than positive pitch deviations. In contrast to Marmel et al. (2008), a significant difference in response biases across conditions was not observed, except for the Turkish makam musicians' responses in Experiment 1A. Instead, our findings suggest higher pitch deviation sensitivity (rather than a response bias) for negative deviations, particularly for unresolved (subdominant, asma-karar) than resolved (tonic, karar) target notes.

The increased sensitivity for unresolved tones could be interpreted in terms of grouping. Musical events are processed in terms of groups and subgroups based on the similarity of various elements of musical information, such as timbre, rhythm, pitch, etc. (Trehub & Hannon, 2006). Listeners' sensitivity has been demonstrated to increase when a change occurs within a group rather than between groups. For instance, in a musical sequence such as XXXOOO, the Xs and Os are grouped into two separate subunits. Participants were more sensitive to a change that occurred within a group, such as a delay inserted between the Xs, rather than one that occurs between Xs and Os (Thorpe, Trehub, Morrongiello, & Bull, 1988). The increased sensitivity of change detection was further demonstrated in longer musical excerpts in Repp (1992). Participants with varying degrees of musical training were asked to detect a pause within an eight bar long melodic excerpt. The detection accuracy depended on whether the pause occurred within a phrase or between phrases; those that occurred within a phrase were detected better. Thus, when a phrase ends as expected, namely it sounds completed, listeners missed to detect the change. The increased sensitivity for pitch deviations of unresolved final tones compared to resolved ones observed in both Experiment 1A & Experiment 1B may be suggesting a similar mechanisms such that more attentional resources may be allocated when a phrase remains incomplete. The verbal reports upon completing the experiment of the Turkish makam musicians also confirm that they attended more to incomplete phrases. Especially, three of the Turkish makam musicians explicitly pointed out that melodies that ended with asma-karar sounded more out-of-tune as opposed to the full cadence melodies. The extent to which sensitivity is affected by grouping could be further tested by adding another condition where participants are asked to judge the degree of mistuning of the penultimate tone in a melody that ends with a resolved tone. I should be interesting to see whether the subsequent resolution might nonetheless dampen sensitivity to pitch deviation in the just preceding tone.

In addition, despite its much more narrow pitch intervals (the current study utilizes AEU system that divides an octave into 24 intervals), makam context did not trigger enhanced sensitivity to pitch deviations. Pitch sensitivity judgments were comparable for Western and makam contexts. Similarly, top-down expectations played an almost identical role in both musical contexts. One possible change in the design of Experiment 1 could be to give a 2-choice task instead of a rating scale from which to pick the correct final tone to eliminate potential effects.

Experiment 2 measured the psychophysical discrimination thresholds of Turkish non-musician and makam musicians. The results showed that the pitch deviations utilized in both Experiment 1A and 1B, when presented without a context, could have been detected. In general, Turkish makam musicians had a lower discrimination threshold than non-musicians. The positive/negative asymmetry that was observed in Experiment 1 was even more visible in Experiment 2. Overall, the pitch discrimination thresholds for negative pitch deviations were lower than that of positive pitch deviations. The asymmetry observed is quite interesting and was observed by Marmel et al. (2008) in the Western tonal context with piano excerpts, too. This may be due to the tonotopic organization of hair cells in the cochlear, but it may also be influenced by the complexity of the sound stimulus. When we look at Stevens' Power Law, we do notice that it contains a minute asymmetry. For instance, while we need to add say 10 mg to a 100 mg base rate for a just noticeable difference, we would need less than 10 mg to create a just noticeable difference in the negative direction. Thus, it may be the case that a minimal asymmetry that is suggested by Stevens' Power Law applies for every component within the sound stimulus. Hence, a complex sound such as a piano or kanun sound would be expected to create a larger asymmetry than a simple sine tone. It would be interesting to run Experiment 2 with sine tones to see whether this asymmetry remains as is or is indeed minimized.

While Experiments 1 and 2 have answered the second and third research questions respectively, the first question remains unanswered due to lack of Western participants. Thus, a possible future direction of the study would be to test Western musicians and non-musicians. For Western participants, who lack any representation of the Turkish makam scale and system, all final tones within the makam context may indiscriminately sound as out-of-tune, regardless of whether they are indeed out of tune or not and regardless of their tonal function.

APPENDIX A

WESTERN TONAL MELODY PAIRS

Figure A1. Western tonal melody pairs

APPENDIX B

TURKISH MAKAM MELODY PAIRS

Figure B1. Turkish makam melody pairs

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