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Comparison of Tonal Knowledge between Chinese and German Listeners

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Comparison of Tonal Knowledge between Chinese and German Listeners

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Abstract

Implicit tonal knowledge is obtained in long exposure to a musical environment, which is held by both musicians and non-musicians. According to former studies, implicit tonal knowledge is organized in different schemata in different musical cultures; and one's tonal schemata influence tonal perception and expectancy when he or she listens to either "native" or "foreign" music; however, there are also common features among different musical cultures.

In this dissertation, tonal schemata were regarded as a kind of tonal knowledge. The tonal schema of Chinese listeners was investigated, as well as the differences between the tonal schemata of Chinese and German listeners, because there are significant practical and theoretical differences between Chinese and Western musical cultures. It was hypothesized that Chinese listeners have a different implicit tonal knowledge from that of Western listeners; they are with internalized Chinese pentatonic tonal knowledge. The hypotheses were developed to investigate whether the tonal profiles of Chinese listeners are similar with K-K profiles (Krumhansl & Keil, 1982), when they listen to Western music; and whether Chinese tonal profiles are characterized by harmonic relationship or melodic relationship, etc. Based on former studies, the primacy effect (opening tone) and recency effect (or cadence effect) were also taken into account. Two experiment series with priming paradigms were carried out.

In the first experiment series, a "scale-completion" task was used, and only Chinese music students were involved. The speed and accuracy of responses were analyzed. It was found that the major profile of Chinese listeners was similar to that of Western listeners, but that their minor profile was quite different from Western listeners' minor profile. This result was further investigated through an implicit task in the second experiment series, in which participants were asked to judge whether there was a target tone in trumpet timbre in a context in piano sound or not. The speed and accuracy of responses were analyzed. Both Chinese and German musicians and non-musicians were involved. It was found that there were significant main effects of test tone position and tonal indication: listeners made faster responses to the contexts with the test tone at the end and with more tonal indications. Again, tonal profiles of response time of Chinese listeners were dissimilar to the profiles of German listeners, and there was no significant difference between Chinese musicians and non-musicians. Chinese listeners' profiles presented some flexible "fourth-frame" (including a minor third and a major second) features, but no triadic harmonic relationship.

Generally, the results suggest that Chinese tonal profile is not the same as Western tonal profile, but supports the description in Chinese music theory. It may be caused by musical culture differences, but it less depends on music education. Chinese tonal profile is based on the melodic "fourth-frame", which may be the middle level between tone level and mode level. This can be studied in further experiments.

Keywords: schemata, tonal hierarchy, tonal profile, pentatonic, harmony, fourth frame, priming effect, response time, multidimensional scaling

Zusammenfassung

Das implizite tonale Wissen von Musikern und Nicht-Musikern wird durch langjährigen Kontakt mit einer spezifischen musikalischen Umgebung erworben. Nach bisherigen Studien zeigt sich tonales Wissen in Wahrnehmungsschemata, die Erwartungshaltungen erzeugen und somit die Wahrnehmung beeinflussen, wenn der Hörer/die Hörerin „heimische“ oder auch „fremde“ Musik hört.

In dieser Dissertation werden die schemageleitete Wahrnehmung chinesischer Hörer und deutscher Hörer im Hinblick auf Tonalität untersucht und verglichen. Vermutet wird, dass sich das implizite tonale Wissen beider Hörergruppen deutlich voneinander unterscheidet. Da es einen erheblichen Unterschied zwischen chinesischer und westlicher Musik gibt, werden zunächst die musiktheoretischen Unterschiede zwischen den beiden Musikkulturen analysiert. Es wird die Hypothese abgeleitet, dass chinesische Hörer das pentatonische Tonsystem chinesischer Musik internalisiert haben. So stellen sich die Fragen, wie chinesische Hörer westliche Musik unter tonalem Aspekt wahrnehmen, ob sich auch bei ihnen in diesem Fall Profile von tonalen „Gewichten“ zeigen, wie sie Krumhansl und Keil für westliche Hörer ermittelten (Krumhansl & Keil, 1982) und ob die Profile eine melodische oder harmonische Basis haben.

Bei den Experimenten wurden Primat-Effekt und Rezenzeffekt berücksichtigt. Es wurden zwei Reihen von Experimenten durchgeführt, die dem „Priming“-Paradigma folgten. In der ersten Reihe wurde eine „Skalen-Ergänzung“-Aufgabe (scale completion task) verwendet und es waren nur chinesische Musikstudenten als Probanden beteiligt. Geschwindigkeit und Genauigkeit der Antworten wurden analysiert. Es zeigte sich, dass die tonalen Profile für Dur bei den chinesischen Hörern den aus bisherigen Untersuchungen vorliegenden Profilen westlicher Hörer ähnlich waren, sich aber die Profile für Moll deutlich unterschieden. Dieses Phänomen wurde in der zweiten Versuchsreihe näher untersucht. Hier sollten die Probanden beurteilen, ob ein bestimmter Ton (target tone) in der Klangfarbe eines Trompetentones erklang oder nicht. Wiederum wurden Geschwindigkeit und Genauigkeit der Antworten analysiert. Chinesische und deutsche Musiker und Nicht-Musiker waren Probanden. Als Ergebnis wurde festgestellt, dass es einen deutlichen Effekt der Position des zu beurteilenden Tones und „tonaler Hinweise“ im Kontext gab: die Hörer antworteten schneller auf die Stimuli mit dem Testton am Schluss und mit mehr tonalen

Hinweisen. Die aus den Antwortzeiten ermittelten tonalen Profile der chinesischen und deutschen Probanden unterschieden sich, innerhalb der chinesischen Probanden gab es hingegen keinen Unterschied zwischen Musikern und Nicht-Musikern. Die chinesischen Profile waren nicht durch Hervorhebung von Dreiklangsstrukturen geprägt, sondern durch einen flexiblen „Quart-Rahmen".

Insgesamt weisen die Ergebnisse darauf hin, dass die tonalen Antwort-Profile chinesischer Hörer sich von Profilen westlicher Hörer unterscheiden, und die chinesische Musiktheorie unterstützen. Die chinesischen Profile basieren auf einem melodischen „Quart-Rahmen", der als mittlere Ebene zwischen den Ebenen der einzelnen Töne/Tonhöhen und der Modus-Ebene angesehen werden kann. Die beobachteten Unterschiede in den Antworten der Probanden beruhen offensichtlich auf Unterschieden zwischen beiden Musikkulturen, sind dabei weniger von Musikerziehung abhängig.

Schlagworte: schemata, tonale Hierarchie, tonale Profile, pentatonisch, Harmonie, Quarte Frame, Priming Effekt, Antwortzeit, mulidimensional scaling

For my parents

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Introduction

Tonality, in the broad sense of the term, exists along with music since the earliest of times and accompanies the development of music itself. It covers nearly all forms of music, from the perspective of Western music history, including music of the Middle Ages: From the Renaissance, Baroque, Classical, Romantic; as well as Impressionistic forms, to music of the twentieth century. From the perspective of ethnomusicology, it covers Western, Russian, Chinese, Japanese, Arabic and Indian culture, to name a few. From the perspective of the genre of music, it contains several types of spiritual music (Church mode music), as well as secular forms (such as jazz and today's popular music). Among these various types, tonality is the implicit and latent character that emits the flavor of melody and harmony attracts appreciation to the ear. It is also a type of tacit to a musical grammar that rules the structure of compositions.

Tonality, in a narrower sense and as a musical theoretical term, compared to the history of music itself, has a younger life, which is only about two hundred years old. Until now, there is still no consistent definition of tonality by music theorists, who uphold ideas from different perspectives. Some of these definitions tend to be too general to cover all kinds of music; while the others tend to be too specific to refer to the major and minor scale system in the music which is only limited to the period from late 17th century to early 20th century. For its abstract and various features, music theorists or musicologists usually describe the "tonality" as complex and elusive (Cross, West, & Howell, 1991), and most curious (Huovinen, 2002), venerable (Huron, 2007), profound and enigmatic (Brown, 2005) term than any other component in music theory. Whether from a generalized understanding or a narrow understanding, these definitions share some ideas in common - that is "the relationship of pitches". Such "relationship" is the mystery in music which keeps musicologists busy with analyses of thousands of works and keeps psychologists interested in the process of tonality perception.

Tonality can evoke a set of pitches surrounding a certain tone - the tonic. The relationship in the sets of pitches gives us the possibility of feeling a cadence, modulation, thematic key areas, long-term key closure (Huron, 2007, p.143), and so on. Furthermore, with the above information, we could form or create group structures, which are as small as motive and phrase, and as large as period, movement, coda, and the like. Besides that, we could also have expectancy on harmony and melodies. In this study, the influences of the starting single tone or interval on forming tonality perception are investigated.

1. Studies on tonality perception (a general view)

In the last three decades, tonality perception became a research topic for psychologists and musicologists. They worked together to verify the tonal theory in human's cognitive and perceptive level; and also to explore the process of tonality perception while seeking factors of impact.

1.1 From the viewpoint of study fields

From the point of view of study fields, the research can be divided into two groups.

One group investigates tonal perception in psychoacoustics, which follows the academic tradition from Helmholtz (e.g. Terhardt, 1974, 1979; Parncutt, 1989). They consider that the frequency spectra play an important role in tonal perception. The psychoacoustic models include the model of pitch perception (Terhardt, 1982), the theory of pitch commonality (Parncutt, 1986), and self-organization map, based on physiological acoustics that construct the tonal center recognition model (Leman, 1995), etc.

The other group studies tonal perception in cognitive processing, which is strongly influenced by the results from different studies. Researchers set up various models to explain the tonal perception and representation. For instance, Lerdahl and Jackendorf (1983) proposed generative theory of tonal music (GTTM) which borrowed the generative grammar theory from linguistics by Chomsky; Krumhansl (1990) used topologic method to set up the tonal hierarchy; Bharucha (1987) built up a connectionist framework MUSCAT, etc.

1.2 From the viewpoint of tonality definitions

Although there is still no agreement on tonality definitions, a few ideas in modern music theories are widely accepted, such as that of Schenker and Schoenberg. The main discrepancy is between the harmonic aspect and the temporal aspect of tonality, which leads to two trends in tonal perception studies.

The pioneer of harmonic aspect is Schenker (1906) who stresses the harmonic function in Western music. In his view, nearly all harmonic progressions can be condensed into the "dominant (V) - tonic (I)" (*Urlinie*) relationship, even melodic lines also imply such chord function. The formal rule system (Deutsch & Feroe, 1981) – a "sequence-structural" hierarchy based on gestalt theory, the tonal hierarchy (Krumhansl, 1990) – the stability of pitches in the pitch-class presented by fitness to a certain musical context, the MUSACT model (Bharucha & Stoeckig, 1986) – the stability presented by conventional relatedness priming, are all based on Schenker's harmonic theory. These models focus on spatial aspect and present the psycho-tonal hierarchy in various ways which agree in that tonic, dominant and subdominant are more stable than other tones in tonal hierarchy. However, it does not mean that they totally ignore the temporal aspect; actually they do notice the influence of the temporal aspect on tonal perception, like order and metric (Deutsch, 1984).

The pioneer of temporal aspect is Schoenberg (1954). He emphasizes the temporal order, for instance, the upward and downward leading tones. He argued that "*die Töne in solchen Reihenfolgen und solchen Zusammenklängen und Folgen von Zusammenklängen miteinander zu verbinden, daß die Beziehung aller Vorkommnisse auf einen Grundton dadurch ermöglicht wird... Alle Akkorde, die sich irgendwie zur Tonart wenden lassen, und seien sie noch so dissonant, fallen noch ins Gebiet der alten Harmonie und beeinträchtigen die Tonalität nicht*" (Schoenberg, 1927/1976, p.225, p.230). In his view, tonality is not limited to chords, but stressed by the harmonic and melodic direction and orders. Besides, he considered tones or chords, which sound even dissonant but within a certain scale, would not influence the tonality. That is, the acoustic properties of consonance and dissonance cannot take the place of the structural functions of tones or chords relating to the tonic, which determine the tonality. Browne's (1981) theory of rarity and ubiquity – depending on interval frequency and relationship, Auhagen's (1994) temporal arrangements – reflecting melodic cultural convention, and Huovinen's (2002) pitch-class constellation – emphasizing the perfect fifth in Western music, for example, are originally influenced by Schoenberg's theory. These models stress tone sequences (e.g. rare and common intervals in major), different ordering and metrics; even dynamics would elicit different tonal perception, although they use the same cluster of tones.

Besides, tonality in different music cultures may have different meanings, although they all emphasize the relationship between tonic and other in-key tones or even out-of-key tones. In Chinese music, there is no concept which is similar to harmony in Western theory, and it expands melodic possibilities, especially the perfect fourth and perfect fifth tonal relationships in pitch level and key level. In the key level, the concept of mode is more stressed (there are five modes in Chinese music), which is not quite the same as the major and minor key in Western theory.

Thus, harmonic and melodic aspects of tonality seem to be controversial, but these two aspects interact in the tonal perception; and the common relationship of perfect fourth and perfect fifth in both Chinese and Western music theory makes them similar to each other.

1.3 From the viewpoint of development studies

Tonal knowledge is learned and acquired from childhood. Though there are only a few studies on the development of tonal perception acquisition, which are based on Western music, the results present that children possess tonal knowledge as early as 6 years old. Through an explicit task of harmonic function judgment, 10-year-old children can tell the harmonic differences (Imberty, 1981); with an implicit task of judging timbre, or sounded quality, or vowel in singing text, the performances of 6-year-old children from three Western countries (Australia, Canada and France) reflect the ability of distinguishing harmonic functions (Schellenberg, Bigand, Poulin-Charronnat, Garnier & Stevens, 2005). As early as 5 years old, children can tell differences between in-key and out-of-key tones (Trainor & Trehub, 1994), but they may be unable to tell tonal functions within a key.

From these developmental psychological studies, we can see that tonal knowledge is gradually formed by acquiring syntactic rules of native language in childhood. The tonal knowledge acquiring process has little to do with musical training, but it does have something to do with exposure to the musical environment. It refers to one's musical culture convention, at least for Western music (e.g. Schellenberg, et al. 2005), and also in other musical cultures – Indian music (e.g. Curtis & Bharucha, 2009), Sami yoiks (e.g. Krumhansl, Louhivuori, Toiviainen, Järvinen & Eerola, 1999; Krumhansl, Toivanen, Eerola, Toiviainen, Järvinen & Louhivuori, 2000). When tonal knowledge is automatically learned, it can work implicitly on processing musical information at a lower perceptual level, and may also function at a cognitive level with experts (Kopiez & Platz, 2009).

1.4 From the viewpoint of neuro-scientific studies

The two main points about tonal perception in neuro-scientific studies are anatomical structures and functions when tonal processing occurs.

The studies with mental patients, such as on split-brain syndrome (Tramo & Bharucha, 1991), amusia patients with bilateral cerebral damage (Tillmann, 2005), and cerebellar damaged patients (Lebrun-Guillaud & Tillmann, 2008), present that tonal information or harmonic progression is processed implicitly and laterally within the right hemisphere, but it has little to do with the cerebellum.

The studies with normal listeners, including musicians and non-musicians, demonstrate that musical syntactic information is processed not only alone by right frontal regions, but also with the activation of Broca's area on the left hemisphere, which also takes charge of processing syntactic information of language (e.g. Koelsch, Gunter, Friederici & Schröger, 2000; Maess, Koelsch, Gunter & Friedrici, 2001; Koelsch, Gunter, von Craman, Zysset, Lohmann & Friedrici, 2002; Patel, Gibson, Ratner, Besson & Holcomb, 1998; Tillmann, Janata & Bharucha, 2003). The bilateral inferior frontal regions include inferior frontal gyrus, frontal operculum and insula. The activation of these regions in musical processing appears in various neuro-physiological measurements (ERP, MEG and fMRI) with priming tasks and other explicit tasks. It shows evidence that musical information is indeed syntactically processed in either implicit or explicit tasks – mostly with harmonies as experimental stimuli.

As studies in developmental psychology and neuro-physiology verified, tonal knowledge is acquired not only by musicians, but also by non-musicians, whether they are aware of it or not; tonal knowledge can be investigated by implicit and explicit tasks; moreover, it can be efficiently tested by implicit tasks with various participants regardless of musical training or age.

1.5 From the methodological point of view

1.5.1 Direct vs. indirect methods

As Auhagen and Vos (2000) summarized the studies on tonality induction, the experimental methods can be divided into two categories: "direct" and "indirect" methods.

The "direct" methods include singing or humming the tonic (e.g. Brown & Butler, 1981; Cohen, 1991; Huovinen, 2002), pointing out the tonic on a keyboard, a "telephone key set" (Auhagen, 1994), rating the suitability of a tone as a tonic (e.g. West & Fryer, 1990), or rating the prominence of the tonal structure of tone sequences (e.g. Cuddy, 1982), after hearing a musical context (artificial melodic sequence or music excerpt, or incremental unfolding presentations).

The "indirect" method refers to evaluation task, for instance, evaluation of "fit" of a probe tone for a given context (e.g. Krumhansl, 1990; Janata & Reisberg, 1988), evaluation of "completion" for monophonic sequences (e.g. Abe & Hoshino, 1990; Cuddy & Badertscher, 1987), and evaluation of "closure" for chord progressions (e.g. Rosner & Narnour, 1992), etc.

1.5.2 Explicit vs. implicit methods

Among these methods, whether direct or indirect instructed for tasks, the methods may more or less evoke the music-theoretical knowledge. Direct methods may be "knowledge-driven" (Auhagen & Vos 2000), but the criteria for listeners' decision are not clear; while indirect methods set the criteria for the decision, yet the criteria show more aesthetic meaning of tonal knowledge rather than perception itself and may cause confusion in the judgment: e.g. evaluation of "fit", which may be blurred with "closure" (Aarden, 2003). Thus, the results from indirect methods reflect an aesthetic level of tonal hierarchy, driven by musical knowledge. In this sense, non-direct and indirect methods are more or less on a conscious level or an explicit knowledge-driven level.

Different from the methods mentioned above, the chord priming paradigms (e.g. Bharucha & Stoeckig, 1986,1987; Tekman & Bharucha, 1992, 1998; Bigand, Toulin, Tillmann, et al. 2005; Schellenberg, Bigand, Poulin, et al., 2005) are used to investigate the tonal implicit knowledge. With this method, it is possible to test listeners with no musical training in order to uncover the general musical principles. The results from these studies yield similar "tonal hierarchies" from the results of explicit tasks across age groups, musical training, or even the normal listener to the amusia patient.

It seems that explicit task is more useful to measure the cognitive level of musicians; while implicit task is more effective to evaluate the cognitive level of general listeners.

2. Problem statements

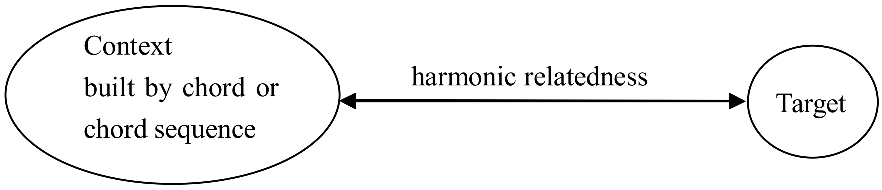
2.1 Practical problem

Tonal perception studies mainly face two practical issues: how do people listen to music, and how can listeners build up the tonal perception? According to our experience, before listening to a piece of music – whether the music is familiar or not, and without knowing the name of the piece − there is no knowledge of the work in the subjects' memory, except for the musical experiences from the past. As the music unfolds along with the time, tones and chord sequences come into awareness and the listeners gradually build up the representation (or context) of the music with the assistance of prior musical knowledge. The studies of tonality perception actually focus on such progress of how listeners infer or induct the key of a piece of music.

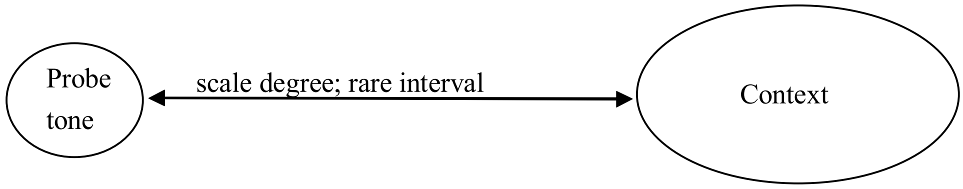
Among the above mentioned direct and indirect methods, most of them presented a musical context first followed by a probe tone producing or a judgment task (Figure 1a). It is the reverse process of the practical listening process, because the probe tone – presented after the context – can only be a tool for evaluating the static-state that is formed by a prior context. In other words, the probe tone is fixed in a given context, and the evaluation of probe tones reflects the relationship relative to a certain static context, but it does not reflect the dynamic perceptual processing. A solution to eliminate this disadvantage is to trace the unfolding context and to test the probe tone in each incremental context (e.g. Krumhansl, 1982; Abe & Hoshino, 1990; Vos, 2000).

However, few studies present the probe tones before the context stimuli (Figure 1b). In this circumstance, the prior probe tone may have two functions. One is to "inspire" a tonal context to facilitate or to interfere with the latter target's perception, and the harmonic relationship is the key for the judgment. The chord priming (e.g. Bharucha & Stoeckig, 1986,1987; Tekman & Bharucha, 1992,1998; Bigand, Toulin, Tillmann, et al. 2005; Schellenberg, Bigand, Poulin, et al., 2005) is of this kind.

The other function of prior probe tone is to facilitate its perception in the latter context. The prior probe tone is more flexible when facing the following context. That is, a probe tone could appear in several keys, and the response to detection of probe tone in the context can be one of the possibilities. The speed and accuracy of responses may depend on the tonal function of scale degrees. According to the tonal hierarchy (Krumhansl, 1990), for instance, if the probe tone can be interpreted as tonic in the following context, or a perfect fifth interval serves as starting interval with tonic in the context, the response would be faster and more accurate compared to other scale degrees; according to the theory of interval rivalry, the response to a tritone would be faster and more accurate. In this way, experiments could trace the tonality forming process using stimuli with starting single tones or intervals. This study will use this method.



a. By harmonic relatedness



b. By scale degree or rare interval

Figure 1 Function of the prior probe tone

2.2 Cognitive problem

There are four issues which should be considered when using sequentially musical materials in the experiments. Firstly, the musical sequences cause recency effects (Baddeley, 1986; Janata & Reisberg, 1988); secondly, the recency effect may influence musical sequence memories (Greene & Samuel, 1986; Auhagen & Vos, 2000); thirdly, the recency effect may be helpful to shape musical expectation (e.g. Bharucha & Stoeckig, 1986; Janata & Reisberg, 1988); fourthly, the sequence cannot avoid "cadence effect" which means reference to the cadence schema (Parncutt, 1995; Aarden, 2003).

Listeners organize musical information as it is sequentially presented, and they build the tonality perception gradually. The tone or chord at the very beginning of a musical sequence may elicit several tonal probabilities. The shrinkage of the tonal probabilities or the clarity of the tonal idea depends on the coming musical event. The coming musical event can either develop the musical idea and make it easy for modulation, or lead into the resolution to end a phrase and consolidate the formed tonal perception (Janata & Reisberg, 1988). In experimental conditions, a common procedure is to ask listeners to evaluate the probe tone after a context, and the tone would be evaluated with the limitation of mnemonic constraints, expectation constraints, and semantic meaning. The tone presented just before the probe tone is easily evaluated (Janata & Reisberg, 1988); the probe tone at the end of the context might be evaluated as an expected cadence. In other words, the evaluation of the probe tone is substituted by the evaluation of the cadence tone (Aarden, 2003). Thus, such complex “recency effect” shakes the efficient value of the results.

From another point of view, the prior tones of a preceding context also contribute to forming tonal perception. According to a connectionist model - MUSACT (Teckman & Bharucha, 1998), activations can spread through the layers of tones, chords and keys. The context tones or chords can activate several keys with different weights, which depend on near or remote relatedness. A single tone can activate more tonal probabilities than two or more tones. In other words, the probable tonalities would be limited along with more tones or chords presented. Depending on weighted relatedness, the activated tonal probabilities would influence the processing of the following tones. The closer related tonal probabilities may facilitate the processing. That is, when the coming musical event is in closer relations to the prior musical sequence, then the coming musical event would be easily processed; otherwise, it would take a longer time to process the coming musical event in the case of remote relatedness. The focus on the spreading activation of a tone makes it possible to deal with prior elements in a context, which is a good way to eliminate the recency effect. The priming paradigm is such a good solution.

Although many researchers dealt with the issue of priming paradigm, most of them stressed the harmonic expectation, because harmony and tonality are considered as special features of Western music; while tone or interval level is less studied. Therefore, this study is going to explore the activation from tone and interval levels to verify the connectionist model, and to investigate the discrepancy between tonal hierarchy and rare interval theory.

2.3 Implicit knowledge vs. explicit knowledge

Music theory is like grammar in language; it exists implicitly in every musical culture and is explicitly summarized by musicologists. Tonality is an important concept in music theory, presenting the syntactic rules of music (Schellenberg, Bigand, Poulin-Charronnat, Garnier & Stevens, 2005). It is unconsciously available to non-musicians but consciously grasped by musicians. However, the perception of tonality is still puzzling and as complex as language itself, because tones or chords in music are acoustically and semantically related (Bharucha & Stoeckig, 1987).

Knowledge can work unconsciously or implicitly. People can speak their mother tongue without learning proper grammar, and listeners can appreciate music without knowing music theory. Musical knowledge is implicitly grasped by non-musicians and is explicitly used by musicians, but musicians do not always use explicit knowledge while listening to music. The performance of some implicit tasks by a non-musician can do as well as a musician, although musicians may process musical information more deeply (e.g. Kopiez & Platz, 2009). Through implicit tasks, like judging in-tune or out-of-tune (e.g. Bharucha & Stoekig, 1986, 1987; Tekman & Bharucha, 1992, 1998), or distinguishing timbre (e.g. Lebrun-Guillaud, Tillmann, & Justus, 2008), etc. It was shown that non-musicians, involving children (Schellenberg, et al. 2005) and even amusia patients (Tillmann, 2005), possess musical "grammar" knowledge implicitly (e.g. Bigand & Poulin-Charronnat, 2006) and learn it through exposure to a certain musical environment (e.g. Curtis & Bharucha, 2009).

Thus, musical knowledge is similar to any other implicit knowledge, characterized by abstract and non-verbal features which are generally processed, automatically learned and kept for a longer period, and these features are independent from perceptual quality, with less individual difference but more cultural features, etc. (e.g. Schacter, 1992; French & Cleeremans, 2002; Reber,1993). Musical knowledge should be treated separately according to its implicit and explicit features.

3. Research objectives

The primary aim of this study is to investigate the musicians' and non-musicians' tonal schemata from the tone level and interval level, based on the idea of connectionist model - MUSACT (Bharucha, 1991).

Although harmony is the core of Western tonal music, tones and intervals are the more fundamental musical elements. On the one hand, they are commonly shared by different keys; on the other hand, they do have specific scale degree functions and present uniqueness of different keys. According to the tonal hierarchy theory (Krumhansl, 1990), the tonic is on the top of the hierarchy; according to the theory of intervallic rivalry (Butler, 1989), the tritone elicits major mode. Then, to which degree can the tonic or the tritone activate the key level? In other words, whether tonal function has advantage over interval uniqueness requires further exploration. Is there any interaction between scale degree and interval? This study is going to deal with these questions.

Besides, the differences between musical culture backgrounds (Western vs. Chinese) are also focused on, because tonal hierarchy of Chinese listeners is still unknown. Musical training (musicians vs. non-musicians) and measurement (implicit vs. explicit) are also considered.

4. Research method

An inversion probe tone technique with an explicit task and an implicit task is used in order to avoid recency effect.

The probe tone, which can be either a single tone or a successive interval, is given prior to the context. The context follows the probe tone. The context can be an associated key, a virtual musical excerpt, or an artificial melody. The relationship between the probe tone and the following context is manipulated as in-key or out-of-key.

For the explicit task, participants are asked to make a recall judgment whether the probe tone belongs to the coming context; while for the implicit task, listeners are asked to make a timbre judgment in a single tone or a melodic interval priming paradigm.

The accuracy and errors of responses will be recorded and analyzed.

5. Thesis structure

The dissertation includes six chapters, and their outline is as follows:

Part I, reviews and compares the concepts of tonality in Western and Chinese music theory.

Part II, reviews the theoretical and empirical background of tonality perception research, including the two important aspects in the tonality concept - harmonic and temporal, the tonal hierarchy, the theory of intervallic rivalry, the connectionist model, etc. Moreover, tonal schemata as musical implicit knowledge are discussed.

In part III, based on the former discussion, the aim and hypothesis for this study is proposed.

Part IV, refers to the experiment series 1, consisting of three experiments. Each description of the experiment consists of experimental design, participants, materials, procedures, data analysis; and discusses the experiment series 1 at the end.

Part V, introduces the experiment series 2, and discusses the results of the experiment series.

Part VI, is a general discussion and the summary of the findings of this study, which refers to the theoretical, methodological and practical implications, and suggestions for further research.

Part I Tonality in Music Theory

This study primarily aims to review the concept of tonality. The following questions will be taken into consideration: Which music history background defined the concept of tonality? And did the concept change along with music history? What do denotation and connotation of "tonality" refer to? What are the differences among the concepts defined by various musicologists? Whether or not the concept of tonality indicates the same thing in different cultures? And so on. The answers to these questions indicate the development of how people understand tonality in the dimensions of history and culture, as well as different theoretical foundations of the concepts which influence modern psychological studies.

6. Concept of "tonality"

6.1 Concept of "tonality"

The word "tonality" appeared for the first time in French as "tonalité". In German, "Tonalität" can be the short form of the word "Tonikalität" (Réti, 1958)[1]. Since the eighteenth century, musicologists have made great efforts in recognizing and explaining the concept of "tonality".

The theory of tonality dates from Jean-Philippe Rameau's (1722) book *Traité de l'harmonie* (Treatise on Harmony). In this book, he described how to write good music with chord progressions, cadences and structure, which were later considered as features relating to tonality – mainly the modern major and minor keys. Friedrich Wilhelm Marpurg (1757), who was greatly influenced by Rameau, also described the relationship between tones and tonic, and tried to analyze Bach's works stressing this relationship. However, an explicit term on the relationship among tones was not given by both of the two music theorists in the eighteenth century.

In the early nineteenth century, there was a further and clearer development of the concept. The term "tonalité" was first used by Alexandre-Étienne Choron in his "*Sommaire de l'histoire de la musique*" (Introduction of Music History, 1810). He

[1] Auhagen, W. (1994). *Experimentelle Untersuchungen zur auditiven Tonalitätsbestimmung in Melodien*. Kassel: Gustav Bosse Verlag. p.8.

used this term to differentiate the "*tonalité antique*" from the "*tonalité moderne*" of the later works from the seventeenth to nineteenth century, namely that "music in which notes are related functionally to a particular tonic, the tonic triad" (Brown, 2005). Besides the tonic, Choron stressed the tonal function of tonic triad, but he still did not give a clear definition for the term.

Castil-Blaze (1821) also used the term "tonalité". He divided tones into two groups: "cordes tonales" (tonal tones) and "cordes melodiques" (melodic tones). The so-called "cordes tonales" (tonal tones) included the tonic, the fourth (subdominant), and the fifth (dominant); and other in-key tones were called "cordes melodiques" (melodic tones). He argued that "tonal tones" were the important tones for showing the tonality, and "melodic tones" assisted "tonal tones" to form a major or a minor structure and feature. Although Blaze did not make any clear definition of the term "tonalité" either, he had a clearer idea of tonality which was different from Choron's. Instead of the tonic and the tonic triad, Castil-Blaze did not stress the tone center of the tonality but the hierarchical structure of tones in a scale. These two ideas of tonality would be developed by later musicologists.

As many books mentioned, François-Joseph Fétis (1844), a collaborator of Castil-Blaze, is considered the first one who put forward a clear definition of "tonalité". In his book "*Traité complet de la théorie et de la pratique de l'harmonie*" (1844, p.22), he raised the question:

> "*Qu'est-ce que la tonalité? ...La tonalité se forme de la collection des rapports nécessaires, succcessifs ou simultanés, des sons de la gamme*"
> (What is tonality?... or "*the sum total 'collection of necessary relations, both successive and simultaneous, between the notes of the scale.* " (Hyer, 2002, pp.728-729))

It is clear that Fétis stressed the relationship among tones either in melodic or in harmonic relations, and this new definition was not similar to previous ideas. He extracted the common things that were held by former musicologists. In addition, he also mentioned the "repose" of the I and III degrees strived by the VII and IV degrees; he argued that each degree had attributes in "attraction" or "repose" in a certain tonality. Although he pointed out the tonal function of tones, he still distinguished "tonalité moderne" and "tonalité ancienne" like Choron. With this historical caution, his definition is too general and abstract to understand what tonality actually is. However, it refers to the most common essence of the tonality, namely the relationship among tones. Such a relationship can be found in the music of various epochs and cultures. So this definition characterizes the broadest sense of the term "tonality".

Another important musicologist in nineteenth century who discussed the concept of tonality was Hugo Riemann. He defined "Tonalität" (1894, p.1080) as

> "*die eigentümliche Bedeutung, welche die Akkorde erhalten durch ihre Bezogenheit auf einen Hauptklang, die Tonika.*"

Compared to the concept of Fétis, Riemann's concept (1872) was relatively narrower, clearer and more concrete. He considered that the tonality is closely related to harmonic relations; that is, the tonality is generated and presented by chord functions (Akkordfunktionen) which have a tendency to gravitate towards the tonic triad. Besides the tonic triad, he would also stress the dominant and subdominant triad and their parallel degrees in tonal functions. This definition was similar to Choron's thought, but different from the idea of Castil-Blaze. However, it is not applicable to all kinds of music-making in historical-cultural perspective, but only in Western music from the seventeenth century to the beginning of the twentieth century.

The definition of tonality at its early development in the eighteenth and nineteenth century can be divided into two branches. One stressed the chord progression moving towards the tonic or tonic triad, which dated from Rameau and can still be found with Choron and Riemann; the other emphasized the hierarchical relation within the scale, which was held by Castil-Blaze and Fétis. Nevertheless, the difference between the two branches was not only in the statement of the term, but also in the theoretical foundations. Dahlhaus (1988) discussed different concepts between Fétis and Riemann, and he considered that there were four distinctions:

a) The explanatory statements for the category "Tonality" (die Begründung der Kategorie 'Tonalität') were different. Fétis stood on a historical and ethnological perspective so that his definition was broad enough to cover all kinds of music; while Rieman relied on the physical attributes of tones – the relation between overtones and the fundamental tone.

b) The determination of constitutive features (die Bestimmung der konstitutiven Merkmale) was different. Fétis, similar to Castil-Blaze, separated the I, IV, V and also VI degrees from the II, III, VII degrees, which produce tension and solution in the tonality; Riemann stressed the relations (Tonverwandtschaften) among the tonic triad, dominant and its parallel chord, subdominant and its parallel chord.

c) The conceptualization of relations between chord system and scale (die Auffassung des Verhältnisses zwischen Akkordsystem und Skala) was different. Fétis emphasized the melodic and harmonic relations, which are a little bit metaphysical; while Riemann stressed the chord system in the tonality more practically, and he argued that tonality underlies the chord progression, but scale has nearly nothing to do with tonality.

d) The assessment of the validity realms of theory (die Festsetzung des Geltungsbereichs der Theorie) was different. Fétis was cautious with certain types of musical genres when defining "tonality"; Riemann laid stress on the functional theory (Funktionstheorie) bearing in mind that music was based on harmonic foundations, regardless if it is solo or multipart music.

Either from a broader view in the historical and ethnological perspective or through a narrower concentration on the Western art music from the seventeenth century to nineteenth century, either stressing chordal function or hierarchical structure, the two branches have been further developed in the twentieth century and have also influenced the empirical studies.

6.2 Development of "tonality" definitions

The understanding of tonality did not come as a result of isolated observations but was associated with the development of art music. Introducing chromaticism destroyed the hegemony of tonality and this drastic change of art music in a short span of time, between the late nineteenth century and early twentieth century (the most rapid change in music history) led musicologists to rethink tonality itself in a new era.

In his analysis of Wagner's music drama "Tristan and Isolde", a landmark advancing on chromaticism, Kurth mentioned that tonality "*bedeutet die einheitliche Beziehung der Klänge auf eine zentrale Tonika und enthält daher zweierlei Voraussetzungen; einmal das Vorhandensein zusammenschließender Momente, zweitens das Vorhandensein oder zumindest die ideelle Rekonstruierbarkeit eines tonartlichen Zentrums.*" (1920, p.273) Like Riemann, he emphasized the central role of tonic to establish and re-construct the tonality.

Schoenberg (1927/1976), who also inherited Riemann's idea, argued that "*die Töne in solchen Reihenfolgen und solchen Zusammenklängen und Folgen von Zusammenklängen miteinander zu verbinden, daß die Beziehung aller Vorkommnisse auf einen Grundton dadurch ermöglicht wird... Alle akkorde, die sich irgendwie zur Tonart wenden lassen, und seien sie noch so dissonant, fallen noch ins Gebiet der alten Harmonie und beeinträchtigen die Tonlität nicht*"[2]. Schoenberg's concept was not limited to in-key tones and chords. He argued that the tones or chords – either in-key or out-of-key, either consonant or dissonant, chord progressions or roving harmony – could strengthen or corrode tonality through "*establishment, modulation, transition, contrast, or reaffirmation*" (1954/1969, p.1).

Schenker evolved a theory which is effective in the analysis of musical works between the seventeenth century and nineteenth century. Although there was no explicit explanation of tonality by Schenker, the feature of tonality or tonal music was completely presented in his idea of fundamental structure (*Ursatz*) with a descending fundamental line 3-2-1 and bass arpeggios between the I-V-I degrees. Such a simple cadence in the fundamentals is realized in the two upper levels of middleground and foreground through transformations, prolongations and elaborations of neighbour

[2] Auhagen, W. (1994). Experimentelle Untersuchungen zur auditiven Tonalitätsbestimmung in Melodien. Kassel: Gustav Bosse Verlag. p.9.

notes and arpeggiations. Thus, the tendency to the tonic was emphasized in an expansion of horizontal relationships.

Steinbauer and Bimberg followed the idea of Fétis. Steinbauer (1928, p.3) considered tonality as "*Gesetzmäßigkeit, in der sich die verschiedenen Töne einer Reihe auf einen gemeinsamen Grundton beziehen*"; and Bimberg (1965) mentioned it as "*jeweilig spezifische Strukturiertheit einer Bezugsreihe der Intonation*"[3]. In their opinions, functional features are not mentioned, but the tonality signifies the relationship between tones and the tonic within a scale or a structured tone series. The coverage of the concept is still broad.

Réti, like Choron, had a historical perspective, and made precise descriptions of "tonality" for certain kinds of music. He categorized tonality into two sub-types: the "melodic tonality" and the "harmonic tonality"[4]. The "melodic tonality" referred to Medieval and Renaissance music, and was described in the following way: "the whole line is to be understood as a musical unit mainly through its relationship to this basic note", and the "basic note" is not necessarily the tonic as defined in the harmonic tonality. The "harmonic tonality", quite similar to the rules stated by Schenker, stressed the chord progression I-V-I; besides, V-I was considered as the most effective way of producing tonality. Such definitions freed from the historical confusion and separated "classical music" from "early music".

The concept of tonality became much clearer in a historical sense and more tolerated in the sense of tonal function. The concept "tonality" was separated from melodic formulae of early music, but it would specifically point to the music between the seventeenth and nineteenth century. In some sense, tonality is a synonym for harmony, or harmonic tonality (Réti; Dahlhaus) since Rameau's time. The tonality is "made of" chord progression; and conversely, chord progression is restricted by a certain tonality. The concept "tonality" was no longer in the frame of in-key tones or triad in the time of Riemann who stressed tonal function, but also include out-of-key

[3] Auhagen, W. (1994). Experimentelle Untersuchungen zur auditiven Tonalitätsbestimmung in Melodien. Kassel: Gustav Bosse Verlag. p.9.

[4] Dahlhaus,C.,"Tonality" . (1980). The New Grove Dictonary of Music and Musicians. Vol. 19. London: Macmillan Publishers Limited. p.51-55; "Tonality" in wikipedia.

tones or chord which are used in succession (Schoeberg) or for prolongation (Schenker), while the most important chord progression V-I for establishment of tonality should be retained. It has not only developed the functional theory, but also the scale-degree theory (*Stufentheorien*), or the theory of "*tonräumliche Organisation*" (Auhagen, 1994, p.7). The order and position of tones within a scale were stressed since Fétis. Thus, both structural properties and temporal aspects were stressed in the tonality (Balzano, 1982).

The two theoretical branches of the tonality still continued in the twentieth century, and they would arouse tremendous discussion and empirical studies. Structural and functional factors were the two main streams to be focused on. The perceptual studies and corresponding theories were grouped into structural and functional approaches, but they became more and more integrated with each other. This aspect will be discussed in later sessions.

7. Tonality in Western and Chinese music

7.1 A look at Western tonal music history

Western music developed on the basis of the eight church modes of the Gregorian chant, which were summarized by e.g. Guido d'Arezzo and his followers for centuries. In the beginning, the eight church modes might have not been used for theoretical elaboration, but just for classification of the chants; while for the later theorists they are the "theoretical tutor" that enlightened them in early music. The eight church modes are viewed as "*tonalité antiqué*" (Choron), "*tonalité ancienne*" (Fétis), "melodic tonality" or "melodic formulae" (Réti), etc. They are grouped into four pairs, and each pair consists of one authentic mode and plagal mode. Each mode is made of a fifth and a fourth: the authentic mode is organized by the fourth over the fifth, and the plagal mode is organized by the fourth below the fifth. Each mode has a final tone and a dominant tone or a reciting tone: the dominant tone is usually five degrees above the final tone in the authentic mode, and three or four degrees above the final tone in the plagal mode. The main factors for determining the mode of a piece are the final tone, the dominant tone and ambitus.

However, not all the chants can fit to the model system. There are two ways to solve the problem: transposition and adding accidentals. This was the "beginning of the breakdown of the eight-mode system", which led to four new modes (Ionian and Hypoionian ending on C, Aeolian and Hypoaeolian ending on A) in the sixteenth century; besides, tritus and protus modes are quite like major and minor scale (Hoppin, 1978). These elements indicate the transition from church modal system to major-minor system.

The precise period when tonal music emerged into Western music history is still a controversial topic. Some music historians were confident to speculate that tonal music began as early as in the fourteenth or fifteenth century (Machabey, Besseler), while others were conservative to conjecture that tonal music started from the sixteenth or seventeenth century (Lowinsky, Bukofzer, Hyer). We will not discuss the historical issue, but will refer to the tonal music as an important phenomenon in the development of Western music. Like many changes in the course of history, the transition from Renaissance polyphony to Baroque harmonic tonality could not take place in one step, but the two kinds of music coexisted for a long period. From the perspective of musical practice, Monteverdi's madrigals *Stracciami pur il core* (1592) and *Cruda Amarilli* (1605) (Fétis, 1844), in which the dominant seventh is used, landmarks consideration for the "birth" of "*tonalité moderne*" (Choron; Fétis) [5]. In music theory, Mattheson's work *Das neu-eröffnete Orchestre* (1713), in which major and minor are listed on twelve semitones in an octave, is viewed a landmark of completed transition. The succession of harmonic triads, constituted by three tones, gradually takes the place of the intervallic collection, and melodic formulae turn into the dominant-tonic cadence. The tonic or tonic triad as cadential goal and the solution from dissonance to consonance are significant features in Classical Western music.

The tonal relations extend and harmony becomes more colorful in Romantic music. The emersion of chromaticism, with little distinction between dissonance and

[5] Hyer, B. (2002). Article: Tonality. The Cambridge history of Western music theory (Ed.: Christensen, T.S.). Cambridge: Cambridge Univ. Press, p.729.

consonance, indicates the destabilization of the major-minor system. Wagner's music drama *Tristan und Isolde* is considered as the beginning of chromaticism, leading into atonal and twelve-tone music. This decline of tonality is foreseen by Choron and Fétis with a special conception of history. Choron (1825) regarded the development of tonality in progressive stages "formation, development, progress toward perfection, permanence, and decline" (Hyer, 2002, p.747). Fétis named the stages of Western music from the perspective of tonality: the *ordre unitonique* – corresponding to *tonalité ancienne*, the *ordre transitonique* – corresponding to *tonalité moderne*, the *ordre pluritonique* – specified for transition to chromaticism, and the *ordre omnitonique* – as a prediction of tonality decline.

Furthermore, some scholars used a series of tonality terms to describe the development of "*tonalité moderne*". Ballif and LaRue studied the difference between features of tonal and atonal music. Ballif (1956) viewed tonality and atonality as two poles between harmonic stability and melodic flexibility. In a tonal context, the tone centre can be stressed and consolidated in some way, e.g. a cadence; while in atonal music circumstance each tone has the same importance. LaRue (1970) showed a more precise time-map of tonality development in Western music[6] between the two poles:

Tonality
Harmonic stability –linear tonality → migrant tonality → bifocal tonality

→ unified tonality → expanded tonality → atonality – Atonality
Melodic flexibility

Figure 2 Tonality-Atonality poles

Dahlhaus (1980) has already defined the three main stages of Western music history: (a) the stage of melodic tonality, characterized by "a congruence of structures and functions"[7] in melodic modes and formulae in Medieval and Renaissance; (b) the stage of harmonic tonality, characterized by chordal relationships of major-minor systems in instrumental and vocal works from the seventeenth to nineteenth century; and (c) the stage of decline of tonal harmony with chromaticism, as it is displayed in

[6] Huovinen, E. (2002). *Pitch-Class Constellations*. Turku: Suomen Musiikkitieteellinen Seura. p.v.

[7] Dahlhaus,C., "Tonality". (1980). The New Grove Dictonary of Music and Musicians. Vol. 19. London: Macmillan Publishers Limited. p.51-55.

the works of B. Bartók, C. Debussy, A. Scriabin, P. Hindemith, I. Stravinsky, A. Schoenberg, etc. The developments in Western music history have also brought about the changes in the perception of tonality.

7.2 Tonality in Chinese music

As it was mentioned above, the definition of tonality by Fétis projects a historical and anthropological perspective of Western music (Dahlhaus, Hyer). But he did take the non-Western music into consideration, which is also determined by mental capacities of a certain human society, and his argument was but parochial and not objective. He (1844) merely commented that the music of Chinese, Japanese, Koreans, Manchus and Mongols was "grave and monotonous", and the music of Arab, Persian and Indian was "langoureuse et sensuelle" (Hyer, 2002, p.749). So the topic of this part will be the precise meaning, structure and feature of tonality in Chinese music.

Chinese music is generally characterized by an anhemitonic pentatonic scale. The names of five notes: *Gong, Shang, Jue, Zhi, Yu*, were first recorded in the ancient book *Zhouli: Chunguan*[8] (about BC 6th-3rd century): "all the music used five tones *Gong, Shang, Jue, Zhi, Yu*" ("皆文之以五声， 宫商角徵羽"). However, the five notes were charged with other symbolic meanings in the frame of Wuxing theory (five-element theory), for instance, in the ancient book *Six Secret Teachings*[9]*: the Dragon Strategy - Five notes* (Zhou Dynasty, between 475-221 BC): "Now there are twelve pipes, with five major notes: *Gong, Shang, Jue, Zhi* and *Yu.* These are basic, orthodox sounds, unchanged for over thousands of generations. "[10] ("夫律管十二，其要有五音：宫、商、角、征、羽，此其正声也，万代不易"), five notes were used for judging enemy's situation and making strategy with their relations with timber and color. But in a musical sense, the five notes are important for a music master as it is recorded in *Mengzi: Lilou I*[11] (BC 4th century): "The acute ear of the

[8] Zhouli: *Rites of Zhou* (appeared in 2nd century BC), a Confucian ritual text. Chunguan: *Offices of Spring*, a section about social and religious institutions.
[9] Six Secret Teachings (between 475-221 BC): the writer is unknown. The book collected the conversations of King Wen, King Wu of Zhou, mainly about treatise of military strategy.
[10] http://www.chinese-wiki.com/Tai_Gong_Six_Teachings-Dragon_Teaching_Chapter_11
[11] Mengzi(372-289BC): a Confucian philosopher. The book collected his anecdotes and conversations. Lilou I: *Offices of Spring*, a section about social and religious institutions.

music-master Kuang, without the pitch-tubes, could not determine correctly the five notes" (translated by James Legge)[12] ("师旷之聪，不以六律，不能正五音").

The five tones (*Gong, Shang, Jue, Zhi* and *Yu*) of the Chinese pentatonics correspond to C, D, E, G, A (for instance) in the Western scale system; that is, in the Chinese case, the pitches of the five tones are not fixed, but only the relation among five tones is fixed. The pentatonic scale can be easily heard on black keys on the keyboard, though the tunings in the two systems are not the same. It can be seen that there is no semitone interval between two successive degrees, but only major second and minor third (between *Jue* and *Zhi*, between *Yu* and *Gong*). The five tones form five modes. Each tone can be the tonic and the mode is named after itself. For example, when *Gong* is the tonic and then *Gong* mode is *Gong, Shang, Jue, Zhi* and *Yu* (e.g. C, D, E, G, A), and when *Zhi* is the tonic and *Zhi* mode is *Zhi, Yu*, *Gong, Shang and Jue* (e.g. G-*Zhi*, A, C, D, E,), etc. The following table shows five modes with D as the tonic (starting from D).

Table 1 Five Chinese modes (D as the tonic, for instance)

Modes	Scale	Tonic
Gong mode	D-E-#F-A-B	D- *Gong*
Shang mode	D-E-G-A-C	D- *Shang*
Jue mode	D-F-G-bB-C	D- *Jue*
Zhi mode	D-E-G-A-B	D- *Zhi*
Yu mode	D-F-G-A-C	D- *Yu*

Besides the five "orthodox" tones, there are also secondary tones, known as "pien tones" (变声). With the attendance of secondary tones, the pentatonic scale extends to hexatonic scale, heptatonic scale and octatonic scale, etc. There are two kinds of "pien tones", one is "bian" – a semitone lower, and the other is "qing" – a semitone higher. The hexatonic scale is formed with one pien tone in the pentatonic scale, such as, *Yu*, *bien Gong, Gong, Shang, Jue* and *Zhi* (e.g. A, B, C, D, E, G). As for heptatonic scales, they are not imported or borrowed from Western major-minor systems, but are derived from Chinese pentatonic scale and appeared as early as the Western Zhou period[13] (Miao, 1996, p.140). There are three types of heptatonic scales: "old scale", "new

[12] http://ctext.org/mengzi/li-lou-i
[13] Western Zhou period: 1046-771 BC.

scale" and "qing shang scale" (see Table 2).

Table 2 Three Chinese heptatonic scales with same *Gong* (C as the tonic, for instance)

	Scale	Tonic
Old scale	C-D-E-#F (*bian Zhi*)-G-A-B (*bian Gong*)	C- *Gong*
New scale	C-D-E-F (*qing Jue*)-G-A-B (*bian Gong*)	C- *Gong*
Qing shang scale	C-D-E-F (*qing Jue*)-G-A-bB (*qing Yu*)	C- *Gong*

The "old scale" is also called "zhengsheng (orthodox) scale" ("正声音阶") or "yayue (elegant music) scale" ("雅乐音阶"), including *bian Zhi* and *bian Gong* with pentatonic scale; it is usually used in the ceremonial and ritual music for the imperial court. The "new scale" is also called "qingyue scale" ("清乐音阶") or "xiazhi scale" ("下徵音阶"), including *qing Jue* and *bian Gong* with pentatonic scale, exists in the Han[14] music during Southern and Northen Dynasties[15]. The third one "qingshang scale" is also called "yanyue scale" ("燕乐音阶") or "qingyu scale" ("清羽音阶"), including *qing Jue* and *qing Yu* with pentatonic scale, exists in the mixture music between Han and other minorities in the northwest China during Sui and Tang Dynasty[16] (e.g. Miao, 1996; Li, 2004). The heptatonic scale can be built on five modes on five orthodox tones, but not on the two secondary tones. It is seen that the three heptatonic scales with the same tonic (*Gong*) have different interval sequences, and different "pien tones" in the scales, so they are not identical. The importance of five orthodox tones in the heptatonic scale is the main difference from the Western major-minor system.

There is another classification of the modes called "*Jun*", in which scales share the same pitch classes but with different tonic (see Table 3). For instance, the old scale with the *Gong* (the tonic) C, the new scale with the tonic G and the qingshang scale with the tonic D have the same pitches in the scale which share more structural similarity. The modulation can take place either in the system with the same tonic, or in the system with the same *Jun.*

[14] Han: Han Chinese, the majority people in China.
[15] Southern and Northern Dynasties: AD 420-589.
[16] Sui Dynasty: AD 589-618; Tang Dynasty: AD 618-907.

Table 3 Three Chinese heptatonic scales in the same *Jun* (D, for instance)

	Scale	Tonic
Old scale	D-E-#F-G-A-B-C	C- *Gong*
New scale	D-E-#F-G-A-B-C	G- *Gong*
Qing shang scale	D-E-#F-G-A-B-C	D- *Gong*

Each pentatonic mode can extend to three heptatonic modes, so five pentatonic modes can extend to the fifteen heptatonic modes; each pentatonic mode and each heptatonic mode can start from any of twelve chromatic pitches – each of which has a Chinese name[17]. But the pitch height was not always identical in different times. It is said that the first tone of the scale Huangzhong was set differently in different times, between nowadays $c\#^1$ and a^1 (Yang, 1952). Thus in total, there are principally or theoretically 60 pentatonic scales and 180 heptatonic scales. That is, each chromatic tone can be the tonic of five pentatonic modes or fifteen heptatonic modes. However, in practice it is not that complicated; for example, the traditional qingshang scale is only set on four orthodox (*Gong, Shang, Jue, Yu*) in *Gong* mode.

The modes in traditional Chinese music (including Chinese folk songs) are various; pentatonic and heptatonic modes, are dominant. And the influence of Western and Islamic music also plays an important role in the music of minorities. The mixture of music cultures creates various kinds of Chinese music in different regions and different nations. Generally speaking, modes in *Zhi, Yu, Gong, Shang* are popular (the order is according to statistic result) in Chinese folk songs, but *Jue* mode is rare (Li, 1950; Zhou, 2009). Some scholars divide the Chinese region into two or three main parts according to mode distribution and nation distribution: in the north the *Zhi* mode is usually used with half cadence on *Gong*, but in the south the *Zhi* mode is usually used with half cadence on *Shang*; the cadence on *Zhi* is popular in Han, while cadence on *Yu* is popular in other minorities (Zhang, 2002(1980), p.283-284; Liu, 2002; Zhou, 2009).

Similar to Western tonal hierarchy, the five tones in the pentatonic scale are not equally important. The importance of pitch classes is influenced by the Chinese

[17] Names of twelve pitches: Huangzhong, Dalü, Taizu, Jiazhong, Guxi, Zhonglü, Ruibin, LinZhong, Yize, Nanlü, Wuyi, Yingzhong, Qinghuangzhong.

traditional tuning system, which is the same as the pythagorean tuning system. Pitches in perfect fifth or perfect fourth relationship were seen as being closer than pitches in major second, minor third or major third relationship (see Figure 3). Take C for example: five tones (C, G, D, A, E) of a pentatonic scale are generated at first. Among them, G is the first tone generated from C. So it is considered as the closest tone to C; while E is generated at last, so it is considered as the most distant tone to C; the other two "pien tones" are generated after E, and they are far from C in the tonal relationship.

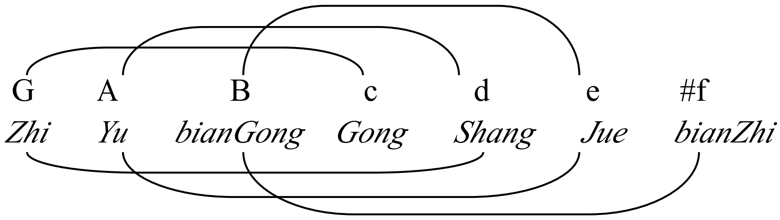


Figure 3 Chinese traditional tuning system[18]

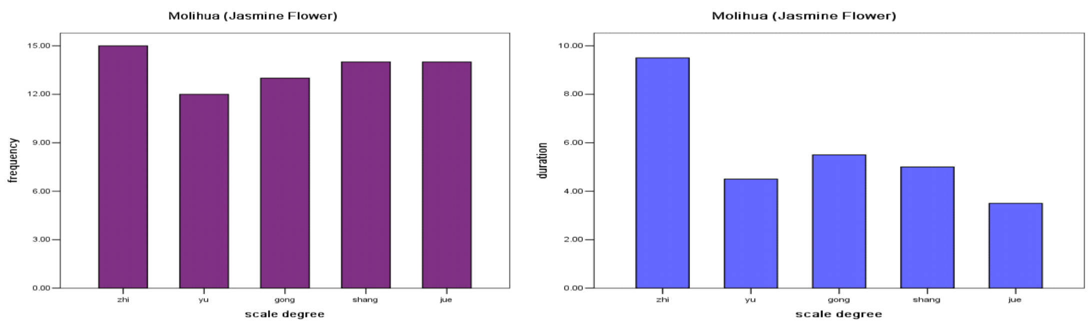
Although there are only a few statistical studies of the distribution of pitch classes in either frequency or duration, it is generally discussed and acknowledged that the tonic, and the tones around the tonic in perfect fourth or perfect fifth relationship have an important tonal function; while the other tones or "pien tones" share a dominant or subdominant "colour" that can strengthen the tonal features, usually as passing tones and at offbeats. Besides, major third and minor third are considered as dissonance for their remote tonal relation and complex ratios (81:64 for major third, 96:81 for minor third), so they are not stable and need to be solved in Chinese music (Zhao, 1964). Here 2 pieces of Chinese music are statistically analyzed, just as Nam (1998) did with three pieces of Korean court music played by piri. One is Molihua (Jasmine Flower), which is a folk song composed in Qianlong period of Qing Dynasty; the other is Yangguan Sandie (the Song of Yangguan), which is a Guqin (a kind of zither) music composed for a poem by Wangwei in the Tang Dynasty. These two pieces are chosen for two reasons: one is that they have few modulations; the other reason is that they

[18] Chinese traditional tuning system is based Sanfensunyi method (三分损益法) : take a string of a given tone (pitch C for example), adds 1/3 long of its length on it, the tone G that perfect fourth below it can be obtained; then take 2/3 length of G string, the tone D that perfect fifith above G can be obtained; in the same way, the tone A that perfect fourth below D, and the tone E that perfect fifth above A can be obtained. The reversed way (Yibansunke 益半损刻法) can also produce these tones: either add half of the certain length or cut quarter of the certain length.

share the features of local folk songs or ancient music, and were transmitted through hundreds of years. Here the distribution of frequency and duration of scale degrees is calculated.

Molihua is a household folk song, and actually it is a kind of Qupai (a titled tune or a labeled melody). Several provinces in China have their own local versions of this song. They are all in *Zhi* mode but with different scales (pentatonic scale or heptatonic scale), melodic progression and rhythm, etc. (Qian, 1997)[19]. Here the folk song from Jiangsu province is chosen, because it is the most widely accepted version. This melody is in *Zhi* mode on B flat in which *Zhi* can be viewed as the tonic of the pentatonic scale. The melody is fluent with small intervals progression or melodic progression; the rhythm is relatively faster than the versions in other areas (see notes in Appendix 1).

The following figures show the distribution of frequency and duration of five scale degrees. The x axis is the name of five scale degrees. The y axis in figure a, is the frequency of appearance; the y axis in figure b, is the collection of the number of beats. It seems that there is little difference among the five scale degrees in the frequency. The "tonic" *Zhi* appears slightly more often than other scale degrees. However, the duration of the five scale degrees is different. Zhi is much longer than other scale degrees, then follow *Gong, Shang, Yu*, while *Jue* has the shortest duration. The correlation between frequency and duration is 0.569 (p>0.05).



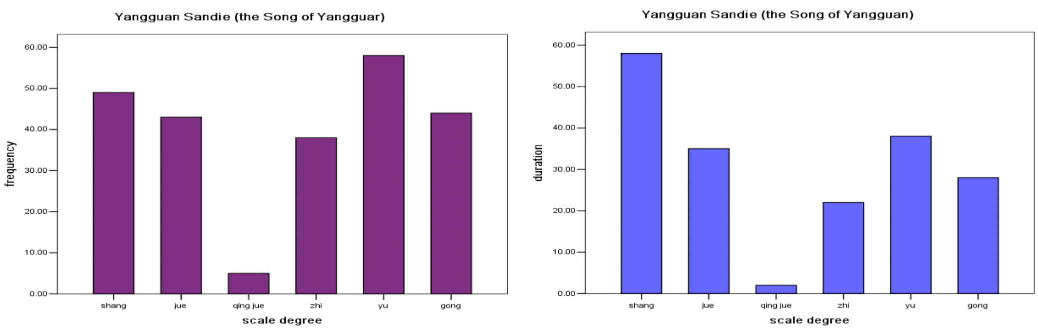
a frequency   b duration

Figure 4 Distribution of frequency and duration of five scale degrees in Molihua

19 Qian, Y.p. (1997). Anthology of Qian Renkang. Shanghai: Shanghai Music Publishing House.
Bai, Jie. (2008). The evolution of the folk music genre "Molihua" in China. *Ludong University Journal (Philosophy and Social Sciences Edition)*, 5.

Another example is Yangguan Sandie (the Song of Yangguan). The music was composed for the poem by Wangwei, which depicted a scene of farewell. The composer and the time of composition cannot be traced back, but it was well-known in Tang Dynasty (according to literature by poet Sushi in Song Dynasty), and it might relate to Daqu in Tang Dynasty (a combination of music and dance) (Yang, 1956)[20]. The melody is dominated in *Shang* mode on C (modulated once into its dominate key *Yu* mode, and then back to *Shang* mode) with hexatonic scale, which includes *qing jue* (*jue* sharp) in the scale (See notes in Appendix 2).

The following figures show the distribution of six scale degrees' frequency and duration. The x axis is the name of five scale degrees. The y axis in figure a, is the frequency of appearance; the y axis in figure b, is the collection of the number of beats. The "dominant" *Yu* appears the most, and even more frequent than the "tonic" *Shang*, because there is a modulation in the middle; while the frequencies of other three degrees *Jue, Zhi, Gong* are quite similar; *qing jue* appears most rarely, which indicates that *qing jue* is not so important as other pentatonic degrees in hexatonic scale, and it functions mostly as a passing note. As for the duration, the duration of the "tonic" *Shang* is the longest that presents its central function in the music; then follow *Yu, Jue, Gong* and *Zhi.* The high duration of *Jue* may be due to the fact, that it is the dominant of the dominant key *Yu* mode; *qing jue* has the shortest duration. There is high correlation between frequency and duration is 0.910 ($p<0.05$).



a frequency b duration

Figure 5 Distribution of frequency and duration of six scale degrees in Yangguansandie

[20] Yang ,Yinliu. (1956). Preliminary study on the old piece "Yangguan Sandie". *People's Music*,6, 21-23.

From the two examples, it can be seen that there is a tonal hierarchy of Chinese music, which is similar to the tonal hierarchy of Korean Court Music (Nam, 1998) which is strongly influenced by Chinese music. Compared with Western tonal hierarchy, the "tonic" is also more prevalent than other scale degrees. Then follow the scale degrees which are in one-step of the circle of fifths away from the tonic, then the other scale degrees follow. It should be also noted that the subdominant is as important as the dominant, or even more important than the dominant, either in original key (e.g. *Gong* in Molihua, *Zhi* in Yangguansandie) or in the modulated key (e.g. *Shang* in Yangguansandie). Therefore, it seems that perfect fourth is more important than perfect fifth, and the modulation is based on the relationship of the circle of fifths.

In Chinese music, melodies are developed mainly with "three-tone sequences" or "fourth frame" (Zhang, 2002) – including a major second and a minor third in a perfect fourth (Li, 2004; Liu, 2007), which is considered as the "pentatonic-meme" (Tong, 2004). *Shang*, *Zhi*, *Yu* are in such three-tone sequences (*Shang-Jue-Zhi*, *Jue-Zhi-Yu*, *Zhi-Yu-Gong*, *Yu-Gong-Shang*); another reason for their importance is that they have either a perfect fifth or a perfect fourth above and below themselves, but *Gong* and *Jue* do not have such an advantage. So in some sense, the Chinese pentatonic system is mainly the *Zhi Yu* modes system (Zhao, 1964; Liu, 2007); and *Shang* is the "core" tone in the system (Zhao, 1964; Tong, 2004).

Such a "three-tone sequence" is not only important in Chinese melodies, but also in cadences. In Chinese music analysis, the judgment of the mode of a music piece does not only depend on the final tone, but also depends on the "three-tone sequence" as the cadence (Liu, 2007). Besides, sometimes a melody can be sung in two modes (see the notation below, Liu, 1982, p.32). This phrase is selected from Beijing opera. Only five tones (D, A, C, G, F) are involved. The five tones can be sung in movable-do system in C major, F major, or in B flat major. Although the pitches are identical in the three keys, the melody sung in F major is only accepted by the Beijing opera players. So it should be sung starting from "*la*", and ending on "*do*". In this case, the mode that fits better to the tones used in the melody would be a more "proper" mode, and the singing system (solfège) reflects the sense of Chinese modes. The analysis method of Chinese melodies may be similar to the analysis of chant melodies in the Middle Ages.

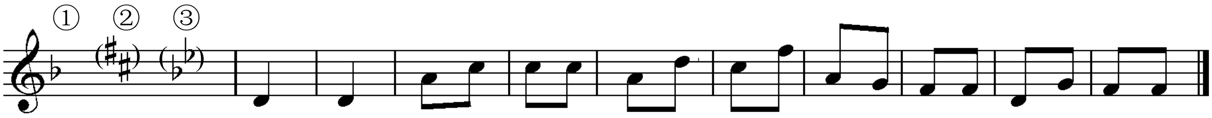


Figure 6 Musical phrase from Beijing opera (Liu, 1982, p.32)

In Chinese music theory, "tonality" is seen as a combination of "mode" and "pitch" of the tonic (e.g. Tong, 2001; Miao, 2002); and "mode" is similar to "scale" (Zhang, 2002), but superior to "scale". "Mode" is a set of scales with different tonics (Miao, 1996), and the tonic is a stable center tone, around which other tones are arranged in a system with some interval relations (Tong, 2001). "Pitch" of the tonic shows the "key" of a mode. For example, a "G *Shang* mode" means that the mode is *Shang* mode, the pitch G is the *Shang* as the tonic, and the scale of this mode is correspondingly G, A, C, D, F.

7.3 Comparison of tonality concepts between Western and Chinese music theory

The common aspect of tonality in both Western and Chinese music theory is the relation among tones. Both of them include two aspects: "mode" and "pitch" of the tonic, which are used to name a tonality. However, the two music theories are quite different from each other in details. The distinctions between the two theories are as follows:

a) Major-minor system vs. modes-system. Western music theory involves two modes: major mode and minor mode, each of them can be built on any pitch (as the tonic) of twelve pitches in an octave. Chinese music theory includes basically five modes, either pentatonic or heptatonic mode, and any of them can be built on any pitch of twelve pitches in an octave.

In Western music theory, major mode and minor mode are either in “relative” or in “parallel” relationship; remote or close relationship between two keys is based on the relations in the circle of fifths.

In Chinese music theory, besides relations in the circle of fifths, modes are also related to each other which share the same *Gong* tone, or share the same *Jun* (different modes with the same pitch-classes).

b) Differences among “scale, key and mode” in Western music theory and Chinese music theory. In Western music theory, the three concepts are relatively the same. But in Chinese music theory, the three concepts are not identical with each other. For instance, the key of C major means the tonic is C, the mode is major, and the pitch classes in the scale are C, D, E, F, G, A, B. In other words, this set of pitch classes can be also called C major scale, or C major mode. However, in Chinese music theory, this set of seven pitch classes is a *Jun* involving three modes with different tonics: the old scale with F *Gong*, the new scale with C *Gong*, and the Qingshang scale with G *Gong*.

c) Harmonic theory vs. melodic theory. Western music theory (in its narrow sense) is based on harmonic functions; while Chinese music theory stresses interval relations: “three-tone sequences” with a major second and a minor third in a perfect fourth (Tong, 2004).

In Western music, tones in tonic triad I, III, V are more important than others in the scale, and the intervals perfect fourth and perfect fifth can be built on six degrees (only except VII); while in Chinese music theory, although pentatonic scale only misses two tones compared to heptatonic scale, only *Shang, Zhi* and *Yu* have both dominant and subdominant upwards and downwards (Liu, 2007), so the “three-tone sequences” float on these three “fundamental tones” (Zhao, 1964; Tong, 2004; Liu, 2007); because of this reason, Chinese music is characterized with *Zhi* and *Yu* modes, and *Shang* mode has concurrently both *Zhi* and *Yu* features;

d) Different meanings of “scale degree” in Western and Chinese music theory. In Western music theory, scale degree refers to two aspects: one is the location in the scale, e.g. "I, II, III, IV…", and the other is the tonal function or the relation between a certain note and the tonic, e.g. "supertonic, mediant, subdominant…". While in Chinese music theory, scale degree refers to neither tonal functions nor pitch classes, but means the interval relationship with each other (Zhang, 2002). For instance, *fa* and *si* (or *ti*) are less important in Chinese modes; *fa* does not have a tendency to *mi* – the mediant in Western major mode, but usually goes up to *la* – *Yu* tone; and *si* does not tend to *do* – the tonic in Western major mode, but usually goes down to *sol* – *Zhi* tone (Zhang, 2002, p. 282).

e) Different consonances in Western and Chinese music theory. Western music theory (from the 18th century on) is based on equal temperament, in which unison, octave, perfect fourth and perfect fifth are considered as perfect consonances, major and minor third and major and minor sixths are considered as imperfect consonances, but minor second, major seventh and tritone are considered as dissonances. Chinese music theory is based on Pythagorean tuning, in which major and minor thirds are less consonant than major second in string length ratios, so tones in major third are remote in the tonal relation (Zhao, 1964);

f) In music analysis, the tonality of Western music can be judged by its cadence referring to the opening tone; the tonality of Chinese music should be weighed with the "melodic formulae" but not only depends on the "final tone", because sometimes melodies end on a different tonic of a mode in the same *Jun*, or on the same tonic of a mode in another *Jun*, or even on different tonic of a mode in another *Jun*.

8. Tonality concept in this study

8.1 Confusing terms with "tonality"

As mentioned in the broad sense of tonality, "tonality" can be a generic term for "mode" and can substitute the term "mode" (Dahlhaus, 1980). In addition, there is also confusion with other terms: "scale" and "key". So, one may ask why here only the perception of tonality is mentioned, but not the perception of scale or key. Here a short explanation of the terms is given.

According to the definitions by the Associated Board of the Royal Schools of Music (1958), a scale is "an alphabetic succession of sounds ascending or descending from a starting note"; and a key is "the set of notes on which a piece of music is built, each note having a definite relation to a note known as the key-note or tonic" [21]. The scale is just a pitch sequence, but the number of tones in a scale and the interval relationships in scale sequence are not stipulated. A scale can have five, six, seven, eight or more tones; and the interval between each successive pitch can be a semitone or minor second, a whole tone or major second, or three semitones or augmented second, which forms the diatonic scale, the chromatic scale and whole tone scale. However, there is no tone function stressed in the scale arrangement, or say, the scale has little musical sense.

The main point in the definition of "key" is the pitch of tonic. When the pitch of tonic is settled, the pitches of other tones in a pitch set or a scale are also established. For instance, the key of G major means that G is the tonal center or the tonic, a major scale starts from G, and the diatonic tones in the G scale constitute the pitch set of G major. So key is a concrete pitch set, related to a tonic. Thus, sometimes the "key" can substitute "tonality" (Hyer, 2002).

Whether "tonality" can be substituted by the term "mode" or "key" is not so important, it is only an issue of conceptual description. However, the important thing is how the relationships in a pitch set are presented in musical textures, how the musical textures lead us to be aware of the relationships. The two questions seem to be paradoxical, but they reflect two cognitive processes: one is composition; the other is perception either with implicit knowledge or with music-theoretical knowledge. The latter cognitive process is the focus of the present study: whether the implicit knowledge of listeners who are from different music cultural backgrounds is different, and how the implicit knowledge is activated.

[21] Cross, I., West, R., & Howell, P. (1991). Cognitive Correlates of Tonality. *Representing Musical Structure*. Howell, P. (Ed.). London: Academic Pr. p.202.

8.2 Common sense of tonality

Whether the definitions of tonality in a broad sense or a narrow sense, in Western music theory or in Chinese music theory, there are two keywords involved in the definitions of tonality: tonic or tone center, and relationship among tones. Tonic or tone center is viewed as the most important tone in tonal music. It is usually the first tone of a scale. In Western music, it works also as the root of tonic triad, as final resolution tone. In Chinese music, tonic usually appears at the end of the melody, but not always. Relationship among tones usually refers to the relationship between tonic and other tones. In Western music, it has temporal and spatial aspects and also includes chord succession and progression, and tonic is usually anchored with dominant harmonically and with leading tone melodically; in Chinese music, it relates to interval relations.

Although there are many specific differences in Chinese and Western music cultures and music theories, which influence the formation of implicit and explicit musical knowledge, the spatial aspect of tonality is stressed in both theories and the perception processing may be also similar. Even Fétis viewed tonality as a metaphysical principle and believed that musical material is imposed by a certain cognitive organization which is universal for all people (Hyer, 2002).

In this study, the perception of tonality is tested using German listeners and Chinese listeners. As they have different music cultural backgrounds, it is assumed that they possess different implicit music knowledge which is drawn from their own repertoires and functions as "cerebral conformation" (Fétis)[22]. Thus, the same music information may activate different implicit knowledge of two groups of listeners; and the more familiar the music is, the more accurate or faster the implicit knowledge can be activated.

[22] Shellhous, R. (1991). "Fétis's Tonality as a Metaphysical Principle: Hypothesis for a New Science", *MTS*, 13, pp. 234-236. See Hyer (2002, p.748).

8.3 From theory to perception

Although the theoretical descriptions of tonality are clear enough, they are not based on the perception of tonality, so there are some conflicts between the theory and the perception of tonality; or at least, it is not so easy to examine the theoretical conclusions in empirical ways.

Take the tonic or center tone as an example, it is nearly always used as final tone and shows a high degree of stability. The final position of a tonic can be easily detected; however, listeners can tell which tone the tonic is before the cadence appears. The “stability” of tonic is not that easy to explain and to control in the empirical study. The most direct description of “stability” is the frequency and duration of tonic, but listeners can also “find” the tonic without harmonic or melodic accumulation in a musical excerpt. The relationship among tones can be perceived in physical harmonics and in intervals and harmonies. The relationship in either functional or structural domain and in either temporal or spatial domain contributes to tonality perception.

These aspects are investigated in empirical studies on tonality perception, and will be discussed in the next section in details.

9. Summary

This chapter reviews the development of definitions of tonality. Fétis (1844) is the first one who defined the term in a broad sense, considering historical and ethnological aspects. Riemann’s concept (1872) shows the tonality features of Western classical music. Both of their ideas influenced the further development of music theory and empirical studies. Tonalities in Western music and Chinese music are compared. The common points – spatial aspects of tonality – and the different implicit musical knowledge acquired by German and Chinese listeners are the points of focus in this study.

Part II Tonality in Music Perception

As it was pointed out in Part I, there is a "gap" between definition of tonality and perception of tonality. Research on tonality perception tries to build a bridge between music theory and the cognitive world. Many results have shown that tonality plays an important role in musical perception. It influences or interacts with the perception of intervals (e.g. Wapnick, Bourassa & Sampson, 1982), melody (e.g. Dowling, 1984b; Tunks, 1986; Cuddy & Lyons, 1981), and harmony (e.g. Crowder, 1984,1985; Gibson, 1993), etc.

Tonality perception has been mainly researched in five areas: music theory, psychoacoustics, cognitive psychology, neurophysiology and artificial intelligence of music. Although musicologists, psychologists, neuro-scientists and the scholars from other academic fields have different conceptions, their goals are similar, that is, they wish to uncover the mystery of the processing of tonality perception through a complex relationship of pitches. Perception of tonality is complex and osculates within various musical contexts (harmony and rhythm), and may also depend on other non-musical factors, such as musical training and age difference. The figure 7 presents the probable factors which relate to the processing of tonality.

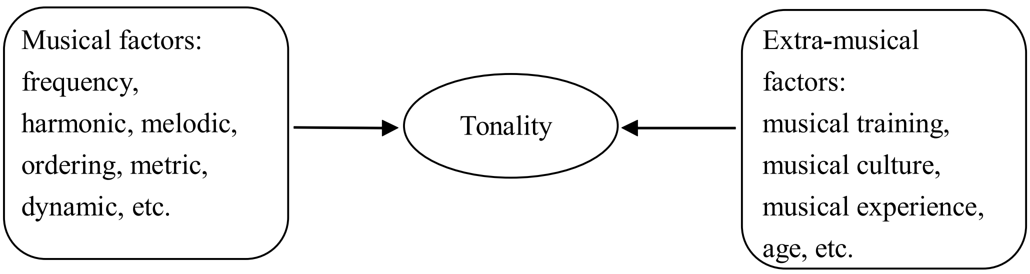


Figure 7 Probable factors of tonality perception

This part will re-evaluate the studies of tonality perception, which are based on music theory issues and will focus on the perceptual progress – a bottom-up process depending on specific stimuli (pitches, chords or cadence), or a top-down process based on implicit knowledge or schemata, or an interweaving of both. The psychological theories and studies of priming effect in relation to cultural or knowledge background will be also taken into consideration.

10. Theoretical background

10.1 Broad and narrow senses

The concept of tonality, as it is defined by several musicologists, has its broad and narrow senses, which mostly cover or represent their specific historical and cultural contexts. Generally speaking, tonality "refers to systematic arrangements of pitch phenomena and relations between them" (Hyer, 2002, p.726), and this postulate is valid for Western tonal and atonal music, Arabic and Indian microtonal music and so on; but in a narrow context of Western music, it "refers to the orientation of melodies and harmonies toward a referential (or tonic) pitch class" (ibid.); or it refers only to the music in common practice era (1600-1910), when tonality relates to harmonic organization (Hyer, 2002). The majority of researchers borrowed the narrow sense of tonality in their empirical studies. The materials used in the experiments were mostly in the frame of major-minor system, either tonal scales, artificial short melodies and musical excerpts from the repertoire of Western common practice era, or even atonal music (see also Auhagen, 2000). Music in other historical periods of Western tradition, however, was seldom used and the same was valid to the music from non-European cultures. Only music in Indian culture (e.g. Castellano, Bharuha, & Krumhansl, 1984; Krumhansl, 1990) and in Sami culture (Toiviainen, & Krumhansl, 2003) was occasionally involved.

There is also another aspect of tonality concerning with the organization of tonal hierarchy. As it has been already said, tonality signifies the relationship among tones, especially that between the tonic and other tones. This relationship among tones implies two kinds of organization: the first one is unfolded along the horizontal axis of time, named "zeitlichen Organisation"; the other one is unfolded along the vertical axis of sonorous space, named "tonräumliche Organisation" (Auhagen, 1994). The former changes the ordering of tones or chords, and the latter varies the function of harmonies, so experimental materials can be harmonic progressions or an unaccompanied melody. Although both kinds of organizations were investigated separately – e.g. Butler (1988, 1994) for tone order and Krumhansl (1982, 1984, 1990) for harmonic function, they contribute to tonality perception. In other words, they interact to influence the tonality perception.

10.2 Physical and hierarchical basis

According to Dahlhaus (1988), Riemann stressed the physical attributes of tones when he defined tonality. The first few overtones of a fundamental tone have a closer harmonic relationship with the fundamental tone than the other overtones. While Fétis stressed the I, IV, V degrees in the tonal system, which were more like a tonal schema. Besides, Schenker's fundamental structure (*Ursatz*) was regarded as a tonal schema in the background; Schoenberg (1954/1969) formed a "rectangular matrix" for key relationships (see Figure 8, the schema emphasizes a monotonality consisting of closely or remotely related regions to the cross frame). Both ideas are theoretically acceptable.

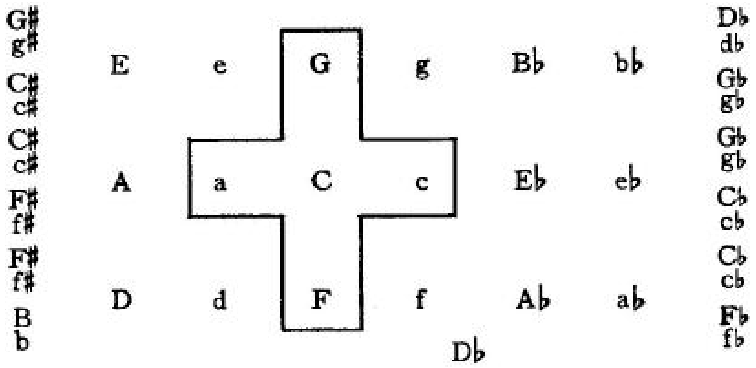


Figure 8 An example of C major regions (Arnold Schoenberg's *Structural Functions of Harmony*, 1954/1969, p.20)

For a long time, however, empirical studies have tried to explain which factors affect more efficiently the perception of tonality: the physical attributes or tonal schema. Terhardt (1982) and Parncutt (1988, 1989) argued for physical reasons based on psychoacoustics; moreover, Parncutt offered a cognitive explanation for tonality perception that pitch proximity and pitch commonality in harmonics influence chord perception. While Longuet-Higgins and Steedman (1971), Browne (1981), Krumhansl and her colleagues (1982, 1984, 1990), Bharucha (1984), Brown (1988), Butler (1989) supposed that tonal schema was learned from exposure to certain music environments through statistical learning, and they used different schemata to present tone relationship and key relationship.

10.3 Implicit and explicit knowledge

Music theory is just like grammar in language, it is deduced from the practice of music and language and is developed further into theory. But there is an exception: the music theory of the twelve-tone system proposed by Schoenberg was developed before its compositional popularity. However, both music theory of the major-minor system and music theory of the twelve-tone system are based on the historical understandings of tonality development. Seen from a psychological perspective, the understanding of tonality to musicians and musicologists was a process going from unconsciousness to consciousness, from implicit knowledge to explicit knowledge. The principles in music theory are unconsciously or consciously used in composition and analysis, in the same way as linguistic grammar permeates speech and literature. While non-musicians learn such musical grammar quite unconsciously in daily exposure to music and they do not reflect on this implicit musical grammar in the same way as with their mother tongue.

Music, like language, differs from country to country, from nation to nation. Music in different cultures varies in timbre, tempo, and also in organization of tones – tonality, so the musical grammar is also specific and different. The implicit musical knowledge and the explicit music theory have their cultural characters, just as the introduced differences between music theory of Western music and Chinese music in Part I. Although many experiments of tonality perception have been done with Western listeners and with Western music or other national music, few studies have been done with Chinese listeners and Chinese music. It is yet to be known how Chinese listeners – musicians and non-musicians – perceive Chinese music and Western music; whether their implicit musical knowledge differs from Western listeners', and whether Western listeners use their implicit knowledge to "appreciate" Chinese music. These are the research objectives of the present study.

11. Implicit knowledge & schemata

As mentioned in the last section, in this study tonality is viewed as a kind of knowledge, especially as implicit knowledge that is stored in the long-term memory. It is not disorderly and unsystematic in the mind, but unconsciously organized in some structures, as schemata, according to music features in different aspects. In this section, we will discuss more studies dealing with the formation of schemata and how they work on listeners from different cultural backgrounds.

11.1 A short review of schema theory

The concept of “schema” is proposed by Kant in his *Kritik der reinen Vernunft,* (1781) and it was further developed in cognitive psychology by Frederic Barlett (*Rememering: A Study in Experimental and Social Psychology,* 1932), Jean Piaget (*Die Entwicklung des Erkennens,* 1972) and Ulric Neisser (*Cognitive Psychology,* 1967). In cognitive psychology, schema is considered as a mental structure or unit consisting of organized elements. Different fields have different schemata. In Piaget's theory of cognitive developmental psychology, the schemata are formed at an early stage, and they still develop in further stages through assimilation and accommodation. Assimilation refers to a process that individuals absorb things into their own mental structure, and these things can be repeated in a similar way to their own schemata. Accommodation is a process by which individuals actively modify their mental structure to meet the needs in the environment. Assimilation extends the schemata while accommodation modifies them. In the frame of these basic divisions of adaptation, the schemata will develop from simple to complex, from lower level to higher level: they keep changing between imbalance and balance status, especially in childhood (through sensorimotor stage, preoperational stage, concrete operational stage and formal operational stage); but they are more stable in adulthood.

The development of schemata is a progress of “the construction of knowledge”, which occurs in the interaction between individual and environment. The schemata are developed through assimilation and accommodation of the external information; conversely, individuals rely on their schemata when they have to think, organize and understand the information, which changes along with the development of schemata. A schema reflects one's preference and tendency, which are influenced by one's experiences and cultural environment.

The concept of schemata in music is applied in separated categories: the tonal schemata, rhythm schemata, form schemata, etc., and each category might have a different or specific schema. Let's take a tonal schema as an example: this schema is refined in the course of life from discrimination of scale- and non-scale tones at about 5 years old, to discrimination of tonic triad- and other in-key tones at about 7 years old with Western children (e.g. Krumhansl, & Keil, 1982; Trainor & Trehub, 1994). The tonal schema is relatively stable in adulthood and not sensible to acoustic features; it reflects the native musical culture background of listeners, and influences their tonal perception in "native" and "foreign" music (e.g. Trainor, & Trehub, 1994; Schellenberg, & Trehub, 1999; Trehub, Schellenberg, & Kamenetsky, 1999). In their "native" music, listeners can use their tonal schema effectively, and there is little difference between musically trained and non-musically trained listeners, because their tonal schema is already constructed through assimilation and accommodation since their childhood, as early as 7 years old (e.g. Krumhansl & Keil, 1982; Schellenberg, Bigand, Poulin-Charronnat, Carnier, & Stevens, 2005). In reference to "foreign" music, which listeners may have no or only a little experience, they would prefer to organize the musical materials according to their own schema; their tonal schema cannot accommodate the "foreign" elements in a short time, but can only absorb similar things that fit to the existed schema (on further cross-culture studies see section 12). That is why native listeners are more sensitive than foreign listeners in their native music culture, as it is verified in some studies (e.g. Castellano, Bharucha, & Krumhansl, 1984; Curtis, & Bharucha, 2009). And it is reasonable to assume in this study that Western listeners and Chinese listeners would have different tonal perception in each other's musical culture.

11.2 Schema as implicit/tacit knowledge

According to Kant's thought, a schema functions in a rational and sensible way for the system of logical knowledge and the objective material understanding; it is the bridge between the abstract knowledge and concrete world. The cognitive psychology inherits Kantian concept of schema and combines it with more developmental views. Scholars pay more attention to how a schema is formed and developed, as well as to the important connection between the real world and mental structure; there are, however, fewer precise descriptions illustrating how a schema works in the sensory perception of the world. As it was mentioned, the schemata influence the way we understand the world. It can be asserted that schemata work implicitly in perception and cognition, and affect explicitly the understanding of the coming events. The explicit function of schemata depends on the knowledge or trained skills that afford clear explanation of understanding or expectations. While in the case of implicit function of schemata, the stimuli are organized with "intuition" and the rules of the organization (as in gestalt theory) have not become aware or do not need to be illustrated explicitly.

The implicit function of schemata may be more easily understood through "implicit knowledge" or "tacit knowledge", although schemata are not conceptually identical with knowledge. "Tacit knowledge", originated from "tacit knowing" proposed by Polanyi in 1950s. He believed that "*we can know more than we can tell*" (1966a, p.4), which means that the possessed knowledge of people is beyond what they are aware of or can tell. Polanyi took a face recognition task as an example: one could recognize a familiar face from thousands of faces, but it would be difficult to describe precisely how the familiar face was picked out. In gestalt theory, the perception of the face is as an integrated image by "the spontaneous equilibration in the brain". While Polanyi viewed gestalt "as the outcome of an active shaping of experience performed in the pursuit of knowledge", "the shaping or integrating" was thought "to be the great and indispensable tacit power by which all knowledge is discovered and, once discovered, is held to be true" (1966a, p.6) and "we comprehend the entity by replying to our awareness of its particulars for attending to their joint meaning" (p.13). As for perception, he argued that it "appears as the most impoverished form of tacit knowing" (1966a, p.7). That is, what people recognize is not simply what they perceive, but an integration of perception interpreted with tacit knowledge. Although people may not be aware of tacit knowledge, it does not mean that knowledge does not exist; instead, this kind of knowledge is widely available and may be organized as schemata or other forms stored in the long-term memory. They are helpful for guiding "knowing-what" (wissen) and "knowing-how" (können) (Gilbert Ryle) of the world.

Therefore, listeners know more than they "hear" with music. Listeners with less musical training can discriminate music styles, music rhythmic patterns, melodic contours, modes, etc, which have corresponding schemata. They integrate sound stimuli following gestalt rules. It does not mean that they do not attend to elements – as a foreground, but they are well aware of appeared elements in an integrated image (music style, rhythm pattern, melody contour, etc.) – as background. Schemata connect elements and integrate images tacitly with the understanding of the comprehensive entity which the foreground and background terms jointly constitute (Polanyi, 1966b). The musical images are perceived with joint meaning and comprehended by relying on the awareness of musical elements and their changes for attending to the joint meaning. Concerning tonal perception, tonality can be viewed as appearance and joint meaning of tones in a certain pitch-class. The tacit function of tonal schemata or tonal implicit knowledge is to comprehend tonality depending on the awareness of melodic and harmonic progression of tones in the pitch-class; and tones are perceived by attending to the joint meaning known as tonality. That is why listeners – regardless of their musical experience – can either recognize the tonic (ability of absolute pitch possessors) or hum the tonic, and in this case there is little difference between musicians and non-musicians. Nevertheless, there are indeed differences between musicians and non-musicians: the former can explicitly tell and explain their musical thought based on knowledge of music theory, while non-musicians do not have such an advantage (Krumhansl, 2000).

11.3 Schema & statistical learning

Although Kant did not directly mention how a schema works between the rational and perceptual world, he stressed how schema connects concept with intuition through time, because he thought time is the "purest schema" or "concept" that is shared by all things－pure concepts, categories, phenomenal objects in his philosophy. Pure concepts or categories and phenomenal objects interact in time. Time in Piaget's cognitive developmental theory is divided into four macroscopic stages reflecting developmental process of schemata; while in microscopic perspectives, schemata are developed by assimilation and accommodation. Assimilation means to absorb a new knowledge into an existed knowledge structure but without changing it; and accommodation means to integrate information into the existed knowledge structure and to change it in order to be adapted to the external world. What exactly happens in the two procedures can be observed under the scrutiny of statistical learning or implicit learning.

Learning a language is a good example to illustrate implicit learning. Children learn their first language unconsciously in a critical learning period. Their learning starts by hearing and imitating sounds and words that their parents repeat to them hundreds of times. They learn to speak without grammar and with little literal material. The syntactic part of language is implicitly acquired in a bottom-up process through conversations. Besides, implicit learning does also happen across the process of socialization, cultural adaptation, aesthetic development and formation, arts (art, music, and literature) appreciation, scientific hypothesis proposal, and complex game playing, etc. (Reber, 2002).

Implicit learning was primarily studied by Reber (1967), who focused on acquisition of artificial grammar with non-word letter strings. Reber used a series of word-strings consisting only of consonant letters with some artificial rules and a series of word-strings with randomly arranged letters as the control group; the participants were asked to remember some artificial strings without knowing the rules of the strings, and then to perform a classicification-string-task. It was observed that when the strings were organized according to the same rules, they could be categorized in a common group from others. In comparison to the participants who were asked to find out the rules of strings before the classification-string-task, those ones who were asked to do memory tasks, performed better in the classification of strings. The results showed that implicit learning did happen in the memory tasks and worked more efficient than explicit learning. However, the participants could not report the strategies of their classification; and when they were told the rules of the strings, they were aware and could agree with the concept. Although it is difficult to state that the rules of string in the paradigm of artificial grammar learning are internalized, as schema or as tacit knowledge; indeed the rules are a "tacit knowing" as a joint meaning and work tacitly in further tasks.

The artificial grammar learning exists in music as well (Saffran, Johnson, Aslin, & Newport, 1999). Six three-tone "words" were used and composed randomly into a seven-minute long tone sequence, with no repetition of any "word" unless all six "words" appeared in succession. Six three-tone "words" were without unique tonality, but the constructed sequence may more relate to the key of D major because of four repetitions of D in four of the six three-tone "words" (Huron, 2007). Listeners, both adults and 8-month-old infants, did not know any three-tone "words" and how they formed the melodies, and they were asked to listen to the tone sequences four times continuously, and 21 minutes in total. After that, participants were asked to compare 36 pairs of three-tone "words" – one was from the six "words" and the other was a new "word" – and to point out which "words" were more familiar. The authors found that listeners were familiar with the six preset "words". This reflected that listeners were able to segment "words" in the tone sequences and were aware of the words in the joint sequence. Artificial grammars are also encoded through timbres (Bigand, Perruchet, & Boyer, 1998). Participants were asked to listen to timbre-sequences. Like in Reber's study, even here participants were instructed with different learning strategies: some were informed of the rules in the timbre-sequence, but others were not informed of the rules. The task was to judge the grammaticality of timbre-sequence. It was found that the effect of implicit learning was also better than explicit learning. The artificial grammar of timbre was further studied in reference to the influence of statistical regularities and acoustical similarities (Tillmann, & McAdams, 2004). It was found that although acoustical characters affected the grouping of nonverbal auditory materials, statistical regularities could still be grasped and judgments on timbre-sequence were applied according to statistical regularities. That is, listeners were more sensitive to statistical regularities than to acoustical similarities. Dienes & Longuet-Higgins (2004), Kuhn and Dienes (2005) used atonal music in their studies. It was found that listeners could learn more than the rules of a unit or a "chunk" in tonal music, they could also learn "a context-free grammar" (e.g. retrograde or inverse retrograde in 12-tone music) in implicit learning. These results illustrate that implicit rules can be caught in listening, so it can infer that tonal rules or even atonal rules can also be grasped implicitly or unconsciously; people learn syntax rules implicitly without limitation of age; such a learning process is based on given materials, and it shows how people organize new information into a more abstract level, which possibly forms schemata or becomes implicit knowledge.

As noticed, implicit learning closely relates to statistical learning, either as successive steps or as mutual result of each other, though they are not quite the same (Perruchet, & Pacton, 2006). Statistical learning research starts also with language studies, and it is considered as one of possible ways for language learning in human's early stage. It is thought that acquisition of first language by young children is an environment-dependent mechanism (Saffran, Aslin, & Newport, 1996). Infants collect their language experience through listening; the more frequently words do appear; the more easily they are recognized. Therefore, statistical regularities in speech are an important factor for language learning. Studies show that even 8-month-old infants can figure out statistical properties in only 2-minute-long orthographic string (Saffran, Aslin, & Newport, 1996).

Statistical learning also happens with music material. In a review of Saffran et al. (1999), Huron also stressed statistical learning in the listening procedure, because their participants were only familiar with the tone sequences in artificial rules what they had learned, but unfamiliar with other unheard tone sequences as components, although such explanations were a little bit "sophisticated" (Huron, 2007). For tonal perception, although there are few studies related directly to statistical learning, some statistical results are given for indirect explanations in tonal perception. Huron and his colleagues did a great deal of statistical analysis on Western music and non-Western music with Humdrum Toolkit software (Huron, 2007). In Western major music, they found that

a) dominant (*sol*) as the initial note of major melodies appears most frequently, followed by tonic (*do*), and mediant (*mi*); then come supertonic (*re*), leading tone (*si*) and submediant (*la*) follow; while subdominant (*fa*) is "the least likely scale tone" as an opening tone;

b) tonic (*do*) as the final tone of major melodies is most frequently, followed by dominant (*sol*), mediant (*mi*);

c) in general distribution or "event frequencies" (p.148), dominant (*sol*) appears most frequently, followed by mediant (*mi*) and tonic (*do*); then subdominant (*fa*), supertonic (*re*); while submediant (*la*), and leading tone (*si*) are less common.

And the characters in minor melodies are as follows:

a) there is no difference from the major one. It is argued that mode is unknown at the opening pitch (Huron, 2007);

b) tonic (*la*) as the final tone of minor melodies appears most frequently, followed by mediant (*do*), dominant (*mi*);

c) in general distribution or "event frequencies" (p.148), dominant (*mi*) appears most frequently, followed by tonic (*la*) and mediant (*do*); then subdominant (*re*), supertonic (*si*); while submediant (*fa*), and leading tone (*sol*) are less common.

Thus, there are two statistical schemata for major and minor melodies respectively, and the statistical schema of the initial tone is shared by both modes. A series of experiments were carried out by Huron and his colleagues to examine whether perceptive schemata are identical with the statistical schemata. For the initial-tone schema, participants were asked to name a scale degree of an isolated given tone, and a harmonic cadence was used to make sure whether the mentioned scale degree really meant the one in the harmonic tonal context. As a result, dominant (*sol*) was the most preferred scale degree for the isolated tone, and subdominant (*fa*) was the least one

(Huron, 2007), which corresponded with the initial-tone statistical schema. As for event-frequency statistical schema, participants were asked to do a pitch comparison task along with the unfolded unfamiliar melodies and their responses were independent from the context effect. The perceptive result also confirmed the statistical schema (Arden, 2003). For the final tone statistic schema, the results of Krumhansl and her colleagues' studies had high correlation with it; and Arden (2003) collected the responses to the last tone but there was also a very high correlation between perceptive and statistical schema.

These studies display the consistency between objective material and subjective perception. As Krumhansl (1990) suggested, tonal schemata are collected based on statistical learning. The probe-tone paradigm can be viewed as a tool to examine the result of statistical learning, in either long-term or in short-term memory. So far, the results obtained by the probe-tone paradigm correspond to closure expectancy – especially when listeners are dealing with native musical material; and the statistical "computation" of pre-context – especially when listeners hear foreign or unfamiliar musical material. The cultural implications will be discussed later.

The studies on implicit learning and statistical learning present a temporal learning process or effect which may be longer impressed into long-term memory as different schemata, and they reflect more on bottom-up processing. But the points of how a schema develops in a longer term and how schemata react to the tonal perception will be discussed below.

11.4 Schemata in development and musical training

Temporary schemata are formed without awareness in implicit learning and statistical learning; they are stored in a short-term memory (Leman, 2000). In the first years of human life, the schemata are generally stabilized through assimilation and accommodation of cultural patterns and then stored into long-term memory. Almost all the developmental studies are focused on Western musical materials and have as a target group only the children grown up in Western culture, but few studies refer to non-Western contexts. They tend to demonstrate whether the Western tonal schema is based on acoustic relation, or the schema can be easily changed in adulthood, or whether it relates to experience and training (Cohen, 2000). Tonal schema acquisition is of "an orderly manner" (Krumhansl & Keil, 1982).

Generally, Western tonal schema is gradually formed before 11 or 12 years old. In the first year of life, infants rely more on "frequency resolution, analysis of overtones, pitch inference for complex tones, accumulation of acoustical information, sensitivity to sequential regularities" and memory (Cohen, 2000, p.444) to recognize different sounds of musical instruments (Pick, Gross, Heinrichs, Love, & Palmer, 1994), to distinguish semitone pitch difference in melodies (Cohen, et al.), to discriminate consonant and dissonant interval not depending on width (Schellenberg & Trehub, 1996), and to have better performance with repetition of tones (Schellenberg & Trehub, 1999), etc., regardless of Western music or non-Western music (Lynch, Eilers, Oller, & Urbano, 1990). Children about 5-6 years old have cultural tendency with emergence of stable tone center (Dowling). They can separate scale tones apart from non-scale tones (e.g. Krumhansl, & Keil, 1982; Schellenberg, Bigand, Poulin-Charronnat, Garnier, & Stevens, 2005); they can compare conventional contexts with more repetition (Schellenberg, & Trehub, 1999). Children over 7 years old have a sense of harmonic structure (Krumhansl, & Keil, 1982). Musical culture experience is formed around the age of 10 to 13 years old (Lynch, & Eilers, 1991), but the schema is still open and flexible to accept unfamiliar musical materials (see Cohen, 2000). In adulthood, however, acoustical information plays a lesser role in perception, maybe only within 100ms (Tekman, & Bharucha, 1992, 1998), and is not easy for the schema to acculturate new musical styles (see Cohen, 2000).

The difference between musical trained listeners and non-musical trained listeners consists mainly of a "quantitative" level, but not on a "qualitative" level. That is, both are sensitive to their native music culture and have conventional judgment or expectancy; however, their processing holds different rules. The difference of two groups may present as early as 10 years old (Lynch, & Eilers, 1991). Non-musicians cannot detect mistuned notes (Lynch, & Eilers, 1991), or cannot detect efficiently the accompaniment in another key, especially the familiar music (Kopiez, & Platz, 2009);

but they can easily detect intervals with simple ratios (Elliot, Platt, & Racine, 1987; Trainor, 1997), and rely on melodic cues (Schubert, & Stevens, 2006).

Although not all the above-mentioned studies relate to tonal perception, they demonstrate that implicit tonal knowledge can be learned through statistical strategy; and also the development of musical knowledge also has its critical period like language acquisition. In general, the musical schemata are built on the basis of frequency of tones up to scale-grouping of tones with cultural characters in the period before 12 or 13 years old (there may be other learning strategies other than statistical learning); children obtain musical knowledge mainly through assimilation, but adults obtain it mainly through accommodation. The cultural musical knowledge is shared by all listeners in their adulthood, and does not depend on their musical training and experience. Musical training and experience may only determine how well music can be perceived or how stable the tonic induction processes, but may have little relation to how accurate or different the result of key finding is, which is determined by different musical knowledge or musical schemata. The latter question referring to the cultural issue will be discussed below.

12. Cross-cultural research on tonality perception

When the perception of tonality is put into different cultural backgrounds, the investigation is not only restricted to the perceptive processing, which is generally the same for humans, but it also comprises the other factors influenced by a specific musical culture. These factors might have been explained in native music theories and they refer, for instance, to organization of music in a certain culture, the influence of language on rhythm, melody and even the absolute pitch sense, etc. These factors affect "statistical" or objective tonal schemata of a certain musical culture and further influence the tonality perception.

12.1 Cross-cultural studies (subject and musical materials)

Cross-cultural studies in tonality perception are not sufficient, and ethnological studies are even poorer. The stock of non-Western music that has been used as experimental materials in these studies comprises North Indian music (Castellano, Bharucha & Krumhansl, 1984; Curtis, & Bharucha, 2009), Finnish folk hymns and North Sami yoiks (Krumhansl, Louhivuori, Toiviainen, Järvinen & Eerola, 1999; Krumhansl, Toivanen, Eerola, Toiviainen, Järvinen, & Louhivuori, 2000; Eerola, 2004), Balinese music (Kessler, Hansen, & Shepard, 1984), Javanese music (Lynch, Eilers, Oller, & Urbano, 1990; Lynch, & Eilers, 1991), and Japanese music (Abe, & Hoshino, 1990). Researchers did not always address both native and foreign listeners, but only to Western listeners or only to native ones. As a consequence, one might speak here of four possible situations:

1) Non-Western listeners hearing native music;
2) Western listeners hearing non-Western music;
3) Non-Western listeners hearing Western music;
4) And Western listeners hearing Western music.

The last situation is the most popular situation in tonality perception; therefore it will not be mentioned here (see section 13). The research method is mainly the probe-tone paradigm (Castellano, Bharucha & Krumhansl, 1984; Kessler, Hansen, & Shepard, 1984; Abe, & Hoshino, 1990; Krumhansl, Louhivuori, Toiviainen, Järvinen & Eerola, 1999; Krumhansl, Toivanen, Eerola, Toiviainen, Järvinen, & Louhivuori, 2000; Eerola, 2004); in addition, speeded memory probe task (Curtis, & Bharucha, 2009) and priming paradigm (e.g. Bharucha, & Stoeckig, 1986; Bigand, Poulin, Tillman, Madurell, & D'Adamo, 2003) are also used (see section 14).

1) Non-Western listeners hearing native music

The experiment of non-Western listeners hearing their native music signifies a congruent cultural situation, the same as Western listeners hearing Western music. Listeners grow up with folk music and traditional music in their own culture, so they are familiar with it even though they have not learned any traditional music theory. Even if their native musical culture is more or less influenced by Western music, especially in the globalization era, their music still maintains something typical to meet their own aesthetic flavour. The native tonal schema is relatively stable to guide listeners' perception and expectancy.

The studies by Castellano, et al. (1984), Krumhansl, et al. (1999, 2000) and Abe, et al. (1990) belong to this category. Their non-Western listeners were either traditional musicians or listeners with little exposure to Western music. With the probe-tone technique, they found a consistent result that native listeners' ratings either on "well-fit" or "musical relatedness" were more influenced by their own musical culture schemata than tone distributions of prior context in short memory. It is the "top-down" function of musical culture schemata.

2) Western listeners with non-Western music

The studies of Western listeners hearing non-Western music constitute an incongruent cultural situation. Western listeners usually have little knowledge or experience with non-Western musical cultures, although some of them are musicians. Western musical schema is what Western listeners usually possess to organize musical information they hear.

The studies by Castellano, et al. (1984), Kessler, et al. (1984), Lynch et al. (1990, 1991) and Krumhansl, et al. (1999, 2000) involved Western listeners, or experts in Western music (Abe & Hoshino, 1990). Neither adults nor children with or without musical training from 10 to 13 years old, could perform well when they detected mistuned tones in Javanese pelog scales ((Lynch, Eilers, Oller, & Urbano, 1990; Lynch, & Eilers, 1991). It has been found that their ratings of probe tone had high correlation with tone distribution of prior context (Castellano, Bharucha & Krumhansl, 1984), and were also quite similar to Western tonal profiles.

3) Non-Western listeners with Western music

Another incongruent cultural situation is created when non-Western listeners hear Western music. In this case, non-Western listeners may have more than one tonal schema. Given that Western musical patterns are popular worldwide and pervasive in other cultures, the non-Western listeners more or less know it implicitly, unless they are living in remote villages with little media access. If non-Western listeners are familiar with schematic Western tonal knowledge, how they perceive Western music is still not clear. Is there any conflict between native musical schema and Western schema? Or does their native musical schema take more advantage?

Three case studies refer to this issue (Kessler, Hanen, & Shepard, 1984; Abe & Hoshino, 1990; Eerola, 2004). In the second case, it was taken with a Japanese listener who was an expert in traditional Japanese music. He presented himself "bi-musically" in the tasks, which means that his responses to melodic ending tone "shifted" according to Western tonal frame and Japanese traditional tonal frame. The researchers offered two possible explanations for this response: on the one hand, the mixed cultural background in Japan could disturb or accommodate the traditional Japanese tonal schema; on the other hand, the timbre of a Western instrument might cause a competition or conflict between two tonal schemata. Although the conclusion is not so lucid, it indicates that timbre may also be a factor for schema selection in tonality perception, for those who possess more than one tonal schema.

Non-Western listeners in Kessler et al. (1984) and Eerola (2004) studies knew only their musical tradition (Balinese habitants in remote villages; traditional healer from South Africa). They did not present any confusion in their responses, but reacted in a similar way like Western listeners to non-Western music; they were primarily affected by statistical distribution of the context and thus reflected their own tonal schema.

The results in these cross-cultural studies demonstrate that listeners depend on the tonal schema of their musical culture when they listen to native and foreign music; statistical strategies also work when they listen to foreign music; when listeners (especially musicians) have more than one tonal schema, they have the alternative of choosing a corresponding tonal schema. One might infer that Chinese listeners also follow these common laws when they listen to Western music and Chinese traditional music.

12.2 Cross-cultural research on absolute pitch

Tonal perception in cross-cultural context does not only relate to objective musical materials, but also to subjective ability of pitch perception, especially the sense of absolute pitch. Few people who possess an absolute pitch sense: the Western demographic statistics states about 0.05 percent in non-musicians and about 1-20 percent in musicians (Vitouch, 2005); while up to 50 percent of Japanese musicians possess an absolute pitch sense (Vitouch, 2003). Furthermore, recent studies (Deutsch, Henthorn, & Dolson, 2004; Deutsch, Henthorn, Marvin, & Xu, 2006) report that East Asian musicians have higher percentage of absolute pitch possessors, especially those who speak tone language; even among the people who speak the same tone language, their "absolute pitches" vary between the neighbor regions (Deutsch, Dooley, Henthorn, & Head, 2009).

From the viewpoint of statistical learning, the absolute pitch sense may be accumulated most frequently used tone pitches. For instance, in Huron and his colleagues' statistical analysis, white notes on the keyboard are used more often than black notes, and the average pitch in music is Eb above middle C (Huron, 2007). The same results are found in pitch perception: absolute pitch possessors recognize white notes easier than black notes (Miyazaki, 1990), and musicians usually imagine a tone around an average pitch height (Huron, 2007). Thus, absolute pitch sense partly reflects the result of long-term statistical learning stored in long-term memory.

Another object of research has been how absolute pitch possessors perceive tonality, and whether absolute pitch sense benefiting tonal perceptions are studied. Absolute pitch assists mistuned tone detection (Miyazaki & Rakowski, 2002; Schlemmer, 2009) either in tonal or atonal melodies. But absolute pitch possessors (if we limit ourselves only to musicians) cannot well recognize the transposed melodies, even when they are told to compare melodies in a relative way (Miyazaki, 2004), this applies to infants who can also process a sense of absolute pitch (Saffran, 2003). Non-absolute pitch possessors, however, present the opposite result. They are not good at detection of mistuned tones in atonal melody, but they have advantage on recognition of transposed melodies. This fact does not mean that absolute pitch possessors have better memory than non-absolute pitch possessors; they can only keep tones longer with meaningful musical labels, like a semitone difference (Siegel, 1978).

The strategies of non-musicians in the melody recognition task are more flexible, depending either on absolute or relative solution (Saffran, 2003); although it is still unknown whether they have absolute pitch sense or not. In parallel, it is found that non-musicians have also an absolute pitch sense for familiar melodies (e.g. Schellenberg, & Trehub, 2003; Gußmack, Vitouch & Gula, 2006).

In conclusion we can affirm that absolute pitch sense relates to long-term memory (Parncutt & Levitin, 2001) and early music training (Vitouch, 2003). Absolute pitch sense may not affect tonal perception, but tonal meaning may enhance "latent absolute pitch" (Levitin, 1994; Vitouch, 2003; Schlemmer, 2005). Therefore, the absolute pitch, especially among the non-musicians, does not constitute the main focus in the present study.

13. Tonality perception research

As it was discussed in the former parts of this study, the tonal knowledge is partly formed through statistical learning in childhood and different cultures have different tonal schemata. The question how these tonal schemata are organized is the object of research. In this section, the methods for exploring tonal knowledge will be reviewed.

13.1 Studies on tonality perception in psychoacoustics

Previous studies on tonality perception, before cognitive research methods were widely applied, show that musicologists used to explain the detection of tonic in a melody from the psychoacoustic view. Meyer (1900) and Lipps (1901) held a similar opinion that the rhythm of physical vibration could determine the tonic of a melody, which meant that the tones sharing the same "Grundrhythmus" could also share the same tonic. This thought cannot explain the process of pointing out a tone as the tonic from a melody especially in the minor mode.[23] Also the other four followers with the consideration of pitch and chord perception did not successfully solve the problem. Boomsliter and Creel (1961), starting from the analysis of sound signals, found a common long pattern of tonal combinations in chords and melodies which corresponded to Lipps' opinion. Terhardt (1982) proposed a model of pitch perception,

[23] Auhagen, W. (1994). *Experimentelle Untersuchungen zur auditiven Tonalitätsbestimmung in Melodien*. Kassel: Gustav Bosse Verlag. p.11-12.

in which he divided pitch into virtual pitch and spectral pitch: the virtual pitch acquires a holistic or synthetic mode and the spectral pitch acquires an analytic mode. This model presented an algorithm with five stages analyzing the relationship between fundamental tone and overtones (harmonic components), resulting in a sequence of pitches which showed the pitch organization to a certain tonality. Parncutt (1988, 1989) refined the algorithm more precisely on the basis of Terhardt's model and he even verified the theory in the experiments. The algorithmic theory, however, was still based on psychoacoustic reasoning which was too abstract to connect with the processing of tonality perception. Meanwhile, Parncutt had "pitch commonality" and "pitch proximity", and this marked a progression from psychoacoustic perspective to cognitive perspective.

Besides psychoacoustic analysis, Franklin (1956) dealt with the cadence of melodies. He held three rules: "law of the pure power of two", "law of falling inflection", and "law of return". He noticed the residual phenomenon in a filling base line task: listeners filled the line with fundamental tones even when these tones were not heard. It seems that tones in the same pitch class can evoke the tonic, or partial tones of a complex tone can evoke the fundamental tone. Unfortunately, he did not mention such an access to tonic or fundamental tone in a melody.

The relationship between fundamental tone and overtones is mostly on a perceptive level, although processing a complex tone is learnt after a long evolutionary journey. The perception of tones in music is similar to the perception of syllables in language, which contains tones, short and long phonemes. But to understand music and language is not as simple as to perceive tones and syllables, for it refers to a higher level processing – a cognitive processing of grammar. The perception of tones in the music also has similar two levels: perception of tones acoustically, and organizes them into grammatical levels. Listeners can figure out harmony, melody and form, etc. Is the processing at the perceptive level (in the narrow sense) for tonal perception useless? If the answer is no, how and in what extent does it work? Bharucha and Stoeckig (1987), Tekman and Bharucha (1992, 1998) found that the two processings worked in different situations of chord priming:

frequency spectra was more efficient in very short time (either the prime duration or the stimulus onset asynchrony (SOA) was less than 100ms), but chord relation of "spreading activation" was quite useful for a longer period (either the prime duration or SOA was longer than 100ms). So the processing of harmonic relationship belongs more to cognitive processing, at least in the priming paradigm.

Although it is not easy to verify the advantage of cognitive processing over perceiving processing, the tonal meaning of a tone – either pure tone or complex tone – is given in a certain relationship with other tones, but it is not given by itself with its possible overtones. So Huron (2007, p.143) pointed out that "*the ability of listeners to imagine a single tone as serving different tonal functions indicates that scale degrees are cognitive rather than perceptual phenomena*". That is, the tonal meaning of a tone can only be decoded or understood in a tonal context.

13.2 Schema theories for tonality perception studies

How can listeners find or reduce the tonic from various, complicated tonal contexts? Which elements play important roles in the perceptive processing? Is there a schema in Western music culture that is helpful in tonal perception? And how does the schema work? etc. These questions were examined for years by musicologists, music psychologists and scientists in artificial intelligence.

13.2.1 Longuet-Higgins and Steedman's study

It seems that "key-finding" was not apparently used in experiments until Longuet-Higgins' and Steedman's study (1971). They started to assign "key-finding" as tonality perception cues, using 48 fugues from Bach's *Well Tempered Clavier* as material to analyze. They conceived a harmonic algorithm, including "Tonic-dominance Preference Rule", "Semitone Rule", and "City-block Rule", which guided determination of the key. The three rules shared an assumption that all keys have equal probabilities to be the tonality of the melody, with elimination of keys that do not contain the tone in the sequence of a melody. When at the end of the melody, there are still two possible keys, then the "Tonic-dominance Preference Rule" works:

when one of the two possibilities matches the first tone of the melody, then the first tone is assigned as the tonic; if neither of the two possible keys fits to the melodic situation, then the first tone or chord is interpreted as the dominant. The "Semitone Rule" points out that, when the interval of the first two tones or the interval of the last two tones is a semitone or minor second, it is usually a part of the corresponding scale. The "City Block Rule", a metaphorical name, shows the destination of tones outside the key of melody; these tones should be put in closer relations with the key of the melody so that it would be easier to locate the tonic.

Besides the three rules, Longuet-Higgins also presented a schema with pitch relations in a diatonic scale (see Figure 9). The tones in a diatonic scale (as it is shown in C major scale) were framed in the matrix: on the x axis the interval between tones is a perfect fifth, and on the y axis the interval between tones is a major third. The tonic has an economical connection with other tones, with a minimum of steps to reach the other tones; while the other tones do not have such an advantage. That is why the tonic is considered as the key but not the dominant or other tones. The triads on tonic, dominant and subdominant are set in an *L* shape. The tritone, to which Browne (1981) and Butler (1989) paid much attention, is also considered as an important interval in this frame. If the frame is moved, either to the left or to the right, both triads on tonic, dominant and subdominant, and tritone would be changed (Auhagen, 1994). That is why they are theoretically important elements for a diatonic scale.

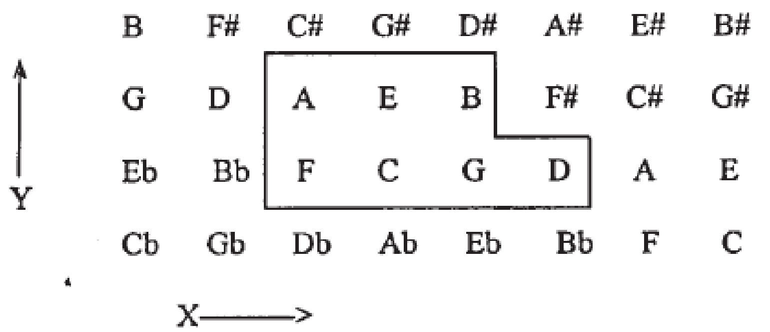


Figure 9 Mental tone space (Longuet-Higgins, 1978)[24]

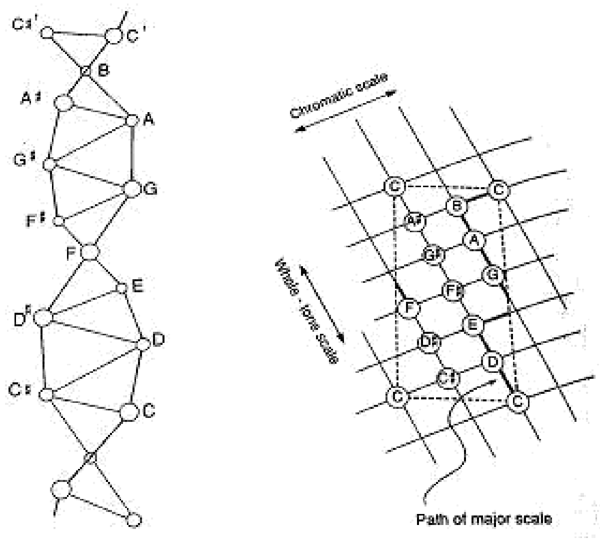
[24] Auhagen, W. (1994). *Experimentelle Untersuchungen zur auditiven Tonalitätsbestimmung in Melodien*. Kassel: Gustav Bosse Verlag. p.16.

The rules and the algorithm were concluded from note analysis and were persuasive to some degree, and researchers tried to use this algorithm to accomplish a computer translation from a musical performance to sheet music; however, the rules might be restricted to the works of Bach or at least are not suitable for other works, and suffer from lack of empirical studies. Nevertheless, they gave some clues for key finding, and more models were developed by them (e.g. Shepard's helix model (1982), Krumhansl and Kessler's four dimensional MDS, and Bharucha's MUSACT, etc).

13.2.2 Shepard's helix model

Shepard found a simple helix model in 1964 and then elaborated it. His early simple helix model presented the chromatic relations on a circle and pitch height relations on the vertical axis, which is quite similar to the helix presented by Révész (1954/2001). The elaborated helix model (Shepard, 1982) displayed the spatial representations of pitch structures. Unlike the former simple helix model, a double helix was used to illustrate the relations around the circle of fifths. So, this complex spatial model represented three aspects for five dimensions (Cross, West, & Howell, 1991): pitch height, the chroma circle and the circle of fifths.

Pitch height is uni-dimensional (pitch goes up or goes down), while the circle of fifths and the chroma circle are two-dimensional. The model is like double gene chains (see Figure 10): the in-key tones are on one chain, and the out-of-key tones are on the other chain, and the two chains helically wind round a cylinder and cross at the IV and VII degrees (e.g. C major, the two chains cross at tone F and B, see Figure 10a). The circle of fifths is the projection of the two chains on a circle, and the interval between each two tones is a perfect fifth. Taking IV and VII as two poles of diameter of the circle, then the tones on the circle are divided into two parts. On the one side are the in-key tones, and on the other side are the out-of-key tones. When the chroma circle is unrolled on the Go board (see Figure 10b), where chromatic scale takes horizontal direction (the interval between tones is a semitone), and whole-tone scale takes vertical direction (the interval between tones is a whole-tone); pitches are settled on the intersections. When one tone on an intersection is assigned, the tones around it can be induced according to the semitone and whole-tone relations. Thus, a major, from one tonic to the other tonic, goes zigzag route with three straight intersections and one turn-right intersection, and then goes further so into four intersections. Within the frame of four tonics on the Go board, all the twelve in-key and out-of-key tones are involved.



a b

Figure 10 a) Shepard's double helix model of tonal pitch; b) the double helix unrolled onto a “melodic map” / go board (Shepard, 1982; Cross, West, & Howell, 1991, p.46)

Shepard (1982) preferred to call the unfolded flat representation “melodic map”, because few harmonic relations were apparently represented. Shepard (1982, p.364) demonstrated that the advantage of this model is that it can “account for perceived similarity of proximate tones in pitch height, heightened similarity at the octave and at the perfect fifth, as well as accounting for the separability of tones within a major diatonic key from non-key tones and the rotational proximity of closely-related keys”. Though the model was “founded on music-theoretical schemes of pitch relations” and not on empirical studies and theoretical rationale for cognitive representation (Cross, West, & Howell, 1991, p.222), it still constitutes a multidimensional approach which offers several accesses to the structure of the musical cognitive representation.

Short summary:

Although Longuet-Higgins and Steedman’s model and Shepard’s model were not verified by empirical studies, their models showed the pitches in the analogue relationship cross octave, the relationship within a key and out of a key, and the relationship between close-related keys. The two models stressed the harmonic function of tonic, dominant and subdominant, the rare interval tritone, relationship between in-key tones and out-of-key tones, the close and remote key relationships in the circle of five. All these elements contributing to the tonality perception were further studied. As for the "key finding" method proposed by Longuet-Higgins and Steedman, it might inspire more discussion on note-to-note or time-to-time tonic induction, the interaction between implicit knowledge and expectancy, and bottom-up or top-down process of tonality perception.

13.3 Models derived from the studies on tonality perception

The development of studies on tonality perception has aroused debates on many aspects: whether tonality perception depends on tonal hierarchy (Krumhansl, 1990) or depends on rare intervals (Butler, 1989,1990) – which also refers to whether tonal knowledge is a prototypical scale template or a developmental schema; whether the model reflects musical structure (Deutsch and Feroe, 1981; Lerdahl, 1988) or reflects mental structure (e.g. Krumhansl, 1983); whether the tonal perception is objective or subjective (Auhagen, 1994; Huovinen, 2002); whether tonality perception is a bottom-up process (e.g. Cuddy, & Lunney, 1995) or a top-down process (e.g. Krumhansl, & Kessler, 1982). The divergences seem to be softened when both debating sides are taken into consideration (e.g. Bharucha, 1987, 1996; Oram, & Cuddy, 1995; Parncutt, & Bregman, 2000), and when further models are proposed.

13.3.1 Tonal hierarchical theory

The series of Krumhansl and collaborators' research were around the theme of perceptive and cognitive foundations of pitch relationships (Krumhansl, 1990). The studies were based on Meyer's idea (1956); or in other words, Meyer's theory was realized in these empirical studies. According to Meyer's view tonality "refers to the relationships existing between tones or tonal spheres within the context of a particular style system" (p.214). He pointed out that the major mode in Western music has three structural levels: the tonic as "ultimate rest toward which all other tones tend to move" is in the first level; the third and fifth are in the second level; then other diatonic or chromatic tones are in the third level. So, the three tones of tonic triad have important functions in the tonal hierarchy and are more stable than other tones, whether in or out of key. Krumhansl and her colleagues verified this idea; furthermore, they also explored the perceptive and cognitive structure of musical pitch, including the relationships between tones and keys, relatedness among triads, relations between chords and keys, and distance among keys, etc.

Their researching "tool" in the experiment is called "probe-tone technique". Some scholars also call it "tonal-context-and fittingness" paradigm (Cross, West & Howell, 1991). The paradigm is to rate the test tone or chord after hearing a musical context. The tasks in the paradigm used to define how well the test tone(s) follow(s) the context (usually a context with an incomplete scale), or as how well the test tone(s) fit(s) the context (usually a context with a complete scale). The contextual completion or continuous and fitness reflect the cognitive musical stability and reliability in a certain tonality. Therefore, as Krumhansl introduced, the method is a way to "quantify the hierarchy of stability" (1990, p.21).

According to the ratings of fitness to various contexts, which included major and minor scales, triads, cadences in different keys, Krumhansl and Kessler drew profiles of major and minor keys from experienced music listeners who had formal education in music for more than 5 years. The profiles are known as K-K profiles (Krumhansl & Kessler, 1982). They also formed a cone model (Krumhansl, 1990, p.128) which shows the tonal hierarchy quite similar to Meyer's description. Furthermore, high correlations were obtained between the probe-tone profiles and the tonal consonance (Kameoka and Kuriyagawa, 1969), the probe-tone profiles and the frequency distributions of tones (Youngblood, 1958; Hughes, 1977; Knopoff & Hutchinson, 1983), the probe-tone profiles and doubled pitches in triads in Western four-part harmony (Huron, 1993). The correlation between the latter two was even higher. It is supportive that the correlation between duration and probe-tone profile is a predictor for key-finding, the key which has the highest value in the duration is the key of the music. This kind of correlation of distribution of tones is called the key-finding algorithm (Krumhansl, 1990). Thus, the correlations demonstrated a consistency in acoustic system, statistical analysis and perception. Statistically, the rating profiles get high reliability with the other two methods. It could be inferred that the tonal consonance, the duration of tones and stability of tones (or rating for fitness) share something common in the tonal hierarchy, which forms the tonal hierarchies by internalization of the relative frequencies and the duration of tones (Krumhansl, 1990, p.96).

Concerning the profiles of different keys, Krumhansl and Kessler found that the profiles of twelve major and twelve minor keys are only different in mode but not different among the keys. That is, twelve major keys share a common major profile, while twelve minor keys share a common minor profile. The profiles depict the cognitive structure of pitches in major and minor keys. In the major key, tonic was rated the highest, followed by dominant, mediant and other tones of the diatonic scale, whereas non-scale tones got the lowest ratings. In the minor key the tonic was highest rated, followed by mediant, dominant and other tones in the scale, and non-scale tones got the lowest ratings. If we superpose the profiles, for instance, of a major and its parallel minor or relative minor, the similarity between them can be seen. The similarity also exists among profiles of minor and its parallel major and relative major. In parallel, there is also a similarity between close-related majors (i.e. C major and G major or F major) or close-related minors (i.e. a minor and e minor or d minor). Therefore, as the authors proposed, the similarity of rating profiles between different keys – whether major or minor – could be a predictor of relatedness of keys, i.e. of the distance between keys.

The similarity was not only evident on the graphs but also in statistics. The correlation values for the ratings of any two keys, or the correlation of the added or averaged absolute value of the difference between ratings of the two keys, or the correlation of the sum of the squared difference between ratings of the two keys. All these could be a signal of the relatedness or distance between the two keys. The correlation of ratings of the two keys was considered to be the most powerful to predict the relatedness of keys in the frame of these three values. The value of the correlation is between -1 and 1, and the larger the value is, the closer the distance between the two keys. For example, the correlation between the C major profile and the G major profile is 0.651; while the correlation between the C major profile and F# major profile is -0.683(1990, p.35). That is, G major has a closer relationship to C major than F# major. All the correlation values between C major and other keys can be calculated, as well as C minor and other keys. Given that the profiles of twelve series of majors and minors are isomorphic, the correlation value of a major with other keys or one of a minor with other keys can be adaptable to any key. That is, a certain distance between two keys corresponds to a correlation value; or inversely, a correlation value is a mark of a certain key-distance. Thus, the distance between keys could be expressed in a quantifiable way.

Based on the rating profile correlations, Krumhansl and Kessler structured a four-dimensional spatial representation of the distances between keys, with the method of "non-metric multidimensional scaling". This four-dimensional spatial representation has two components: one presents the circle of fifths within the major or minor keys, and the other presents the parallel and relative major and minor relationships. The circle of fifths, the parallel and relative relationship are the reference to set the position of keys in the model; while the correlation values are the determinants for the distance between the keys, showing the similarity between keys.

Probe-tone technique and multidimensional scaling were further used to explore the relations between chords within keys (Krumhansl, Bharucha, & Kessler, 1982; Bharucha & Krumhansl, 1983; Krumhansl, Bharucha & Castellano, 1982). They also found that the ratings for chords are with some hierarchical characters. Higher ratings were given to major triads than to minor and diminished chords, and also to the chords which contained high rating tones in the tonal hierarchy. The multidimensional scaling of chords showed that the similarity of chords is independent from the context. Nevertheless, the chords without the context which could be interpreted as belonging to the same key, were perceived closer to each other than the chords in different keys; with the key-context, like cadence IV-V-I, the chords in the same key were perceived more closely and were preferred more than the chords in different keys. So key is a factor to determine the relatedness of the two chords; in other words, "chords are perceived in terms of their functions in a system of musical keys" (Krumhansl, 1990, p.199). Krumhansl also pointed out that elements could be understood in a context, which differs in keys or the ordering sequences; and in a certain context the elements are perceived more related or unrelated than their objective relationship.

Discussion:

Compared to Shepard's five-dimensional model, Krumhansl's models derived from empirical data and were not abstract. These models stressed two layers: within a key and among keys, and both layers revealed the relationships between the tone and key, the chord and key, and between the keys itself. Given that models are obtained from various contexts (ascending or descending scale, chord sequence or cadence) – tested with experienced musical listeners, it is obvious that the major and minor profiles are independent from the context and share the common of twelve majors and twelve minors. Both independence and the common feature reflect that there is a stable musical structure named schema or perceptual tonal hierarchy, which is held by experienced listeners and such a schema may assist experienced listeners to perceive the musical structure as well as the function of tones and chords.

The reliability and validity of key profiles obtained by rating tasks in probe tone technique has been frequently discussed: whether key profiles can reversely and effectively explain the perceptual processing of tonality or key finding, or whether they can be a predictor of key-finding. These questions also refer to another aspect whether key profiles are "static" (Butler, 1989, 1990) or "dynamic" to the changeable and successive context. Krumhansl and Kessler (1982) offered their own answer. They tried to use probe-tone technique to trace the processing of chord-sequences and to explore how the sense of key was built. They prepared ten chord-sequences; two of them were with no modulation, five of them were with close-related key modulation, and the other three were with distant-related key modulation. After listening to the context, listeners rated how well the probe tone fitted the context. Each sequence was presented chord by chord in nine presentations; that is, the sequence was presented with the first chord of the sequence, with the first two chords, and so on. The participants rated the probe tone after each presentation. In the end, they got the rating profiles for one chord, for two-chord sequences and up to nine-chord sequences. Then these profiles from the sequences were compared to the probe-tone major and minor profiles – perceived tonal hierarchy, and were also compared to the profiles derived from the single-chord context. The correlations of the former showed that in the non-modulated sequences the sense of key increased as the sequence was lengthened to the end; while in the modulated sequences the sense of the first key decreased at the pivot chord (the common chord of the former key and the latter key in the modulation), but the sense of the second key increased to the top at the end of the sequence. The correlations of the latter showed that the sense of key from the chord-sequences differed from the one from a single chord, which indicated that the sense of key was developed along with the unfolded sequence with more ambiguity and local effects of chords (Krumhansl, & Kessler, 1982, p.357).

This study not only showed the utilization of probe-tone technique for tracing the sense of key, but also illustrated that the sense of key depended on the context and developed along with the context. Thus, the profiles of major and minor have a general meaning, which presents the cognitive stability of tones in the major and minor modes; they can reflect the tonal structure or schema, but they could not be used directly in the key-finding process. It might be a paradox here. If key profiles present an "instant" tonal profile, then it is reasonable to ask whether the former "standard" profiles, which were consistent among twelve major keys and minor keys, reflect only the "closure profiles" or "successive profiles". Because in the probe-tone technique, the probe tone always appears at the "end" of the context. Therefore, listeners may expect the probe-tone as the final tone of the context, whether the context is a scale or a short melody, or a chord progression; another possibility is that listeners may expect the probe-tone as a successive tone guided by proximity rule or recency effect.

Whether the key-profiles reflect the schema in long-term memory is also a controversial point (Butler, 1989; Cross, West, & Howell, 1991). There is a conflict in the process of probe-tone rating: it is hard to tell whether the rating was assisted by the schema in long-term memory, or was facilitated by the context in short-term memory (Leman, 2000; Huovinen, 2002, p.13). If the short-term memory works, the profiles are doubtful for their definite sense as tonal hierarchy (Huovinen, 2002). It seems that these contexts could arouse the function of long-term memory, as "contextual-distance principle" mentions that it "governs average psychological distance of two distinct tones"; while "contextual-asymmetry principle" (Krumhansl, 1990) is the function of short-term memory which militates against schema's function but it is influenced by temporal ordering of tones.

But Krumhansl (1990, p.19) has noted that the term "stability" is defined in an ambiguously or "loose" way. This term refers to "relative structural significance, priority, resolution (versus tension), and rest (versus activity)... an unstable effect and requiring resolution ... a stable effect and giving a sense of completion" (1990, p.19). Accordingly, it is hard to tell that such "stability" is a kind of music theory term or a sense of feeling in music, melodic or rhythmic, timbre or dynamic; despite the admission of the influences of these elements on tone stability, neither rhythmic nor dynamic elements are taken into consideration in a series of studies (Krumhansl, 1990). Furthermore, "stability" is transferred as fitness ("how well the probe-tone fit the context") or completion ("how well the probe-tone follow the context") for empirical operation. Whether the "fitness" and the "completion" well express the "stability" is not known.

Further critics, discussion and experiments are around these issues in development, cross-culture, implicit knowledge and neuro-scientific aspects, which are discussed in other sections.

Summary:

The models proposed by Krumhansl and her colleagues were based on abundant results from empirical experiments. They took the stability of tones or chords in the key as an essential point to approach the problem of cognitive structure of musical pitches, and collected ratings of fitness or completion to draw the perceived profiles of major and minor mode, which presented a tonal hierarchy in a cone model.

Similarity of keys was considered as an indication for relationship between keys. The correlations between different key-rating-profiles were calculated to show the similarity or the distance between the keys, which presented key-relationships in a four-dimensional spatial model. This gave the foundation for the tonal hierarchy theory.

Taking Schenker's theory into consideration, Krumhansl and collaborators mainly focused on the background or Ursatz of music, which is the most abstract, stable and basic level. This abstract pitch relationship may reflect implicit knowledge in the long-term memory obtained from experience in a certain culture (i.e. Krumhansl, & Keil, 1982; Krumhansl, 1990; Bharucha, 1984; etc.). The perceived tonal hierarchy, especially the K-K profiles in major and minor modes, present a robust and consistent pattern of Western music, to which listeners can make expectations for the future events. The tracing-sequence study verified two levels of Schenker and their relations how the foreground influences the middle ground. Although the K-K profiles indicate the tonal hierarchy in Western music, the probe-tone technique provides the possibility to explore the perceptual "Ursatz" in different musical cultures with native listeners; for instance, it has resulted effective in Indian music (Castellano, Bharucha, & Krumhansl, 1984), Balinese music (Kessler, Hansen & Shepard, 1984) and Finnish spiritual folk hymns (Krumhansl, Louhivuori, Toiviainen, Järvinen & Eerola, 1999; Krumhansl, 2000), etc. As Dowling mentioned, "though structural details vary from culture to culture, the musical and psychological phenomenon of tonality as an organizing principle may be all but universal across culture" (Dowling, 1984, p.417).

The whole "tonal hierarchy theory" of Krumhansl and her colleagues is rational, but still there are some limitations. These conclusions were obtained from experiments with musically experienced adults, excluding children and less-experienced or non-trained listeners, though Krumhansl and Keil (1982) had already enrolled them in their study. Both children and novice listeners do have tonal implicit knowledge as many studies concluded, and this aspect will be discussed later.

Butler argued that music perception is a dynamic process, which cannot be interpreted by "static" tonal hierarchy theory. However, when evaluating a series of studies it becomes quite clear that the tonal hierarchy theory is the representation of the stable background in the knowledge, rather than the interpretation of tonality perception processing. In other words, they strongly verified the existence of the Schenker's background in the cognition or implicit knowledge of listeners. Though the key-finding algorithm and tracing sequence studies were carried out, the former was a computational algorithm but less related to perceptual properties, while the latter was a uni-directional bottom-up process from foreground (chord sequences) to background (key profiles), it seemed that there was little hierarchical influence to perceptual or cognitive processing as top-down process.

In short, tonal hierarchy theory inspired many investigations in tonal structure and led to further discussion on the interaction between musical background and foreground, as well as between tonal implicit knowledge and tonal perception.

13.3.2 Formulaic structural model

Another structural hierarchical model was proposed by Deutsch and Feroe (1981). Even this model was greatly influenced by Schenker's theory and by gestalt theory on the studies of visual stimuli.

The authors assumed that pitch sequences were retained in a hierarchic order. They divided the hierarchies in the music into many levels: the highest level, the next highest level(s), and the lowest level. These levels corresponded to background, middleground and foreground in Schenker's theory. The difference was that in their model there was no limitation for the number of "the next highest level(s)", which could be only one level or many levels, depending on the musical context.

The model was actually a formalism which was founded on a formula system. The formula system was based on several rules they formulated. The formulas, in their words, were called alphabets which could express "the 12 major scales, the 12 harmonic minor scales, the 12 ascending and 12 descending melodic minor scales, the 12 major triads, the 12 minor triads, the 12 diminished triads, the 12 major seventh chords, the 12 minor seventh chords, the 12 half-diminished seventh chords, the 12 diminished seventh chords, the 12 dominant seventh chords, and the chromatic scale"

(Deutsch & Feroe, 1981, p.511). Thus, there were totally 145 "possible alphabets" based on 7 "over-learned structures" – the first seven 12 formulas and the chromatic scale which were assumed to be kept in the long-term memory. The formulas contained the information about intervals in scales and chords, the position of the chords, etc.; and they are flexible to show scales and chords on the basis of whether diatonic scale or chromatic scale, and the reference element – usually the dominant element in a sequence – could be changed in the formula when musical function was ignored.

For pitch sequences, the formulas represented hierarchical levels in the music. Each level could be presented by a formula, showing the dominant elements in either scales or chords, in either diatonic scale or chromatic scale, as well as the direction of the sequence, either prime or retrograde or inversion (the last terms were borrowed from twelve tone technique). The highest level in their model usually counted on the seven over-learned structures.

Considering the character of an encoding and retrieval process, they argued that the highest level was easier to be encoded for its "parsimonious" simplicity, and tones in the highest level with higher representation frequency in lower levels made retrieval of notes easier with better recall. The experiments by Deutsch (1980) showed that listeners' applying such "top-down fashion" (Deutsch & Feroe, 1981, p.514) was generated from stored representation with a retrieval process. She used recall-notation tasks to verify that the memory worked on the abstract tonal structure. However, such recalling dependency on tonal structure was substituted by temporal proximity when the conflict between temporal segmentation and tonal structure increased.

Dowling held a similar "top-down" idea to that of Deutsch and Feroe. He (1978, 1982) proposed a schema to describe a musical scale structure, which had four psychological levels: it involves a psychophysical function as the basis level, the tonal material as the second level, the tuning systems as the third level, and the mode as the fourth level. The tuning system was considered as an encoding cue (Dowling, 1982), which was similar to the "over-learned" structure proposed by Deutsch and Feroe.

Short summary:

Although the studies of Deutsch (1980) and Deutsch and Feroe (1981) did not mention that their model was specific for key-finding, the highest level in their model was based on scales and chords. As they mentioned, besides primitive perceptual principles, "the encoding of a sequence representation must also involve complex processes, in which the listeners draws on his expectations about a given musical style. Perhaps the most important of these is the process of key attribution" (Deutsch & Feroe, 1981, p.517). Their seven "over-learned" structures reflected that they conceptualized each structure as a gestalt, because they considered "key" as "the collection of notes forming a particular diatonic scale" (Deutsch & Feroe, 1981, p.509); that is, each "key" is a unit of tone collections. Since music is sometimes too complicated to be analyzed and may lead to ambiguity, the scholars present two possible interpretations for "key-finding": one is influenced by the idea of Restle (1979) that listeners actually take in the minimum information; the other is similar to the "implication-realization" model of Meyer (1973) that alternative representation will be confirmed by later sequences in the ongoing process (Deutsch & Feroe, 1981, p.519).

Discussion:

Compared to the tonal hierarchy of Krumhansl, Deutsch and Feroe's hierarchy is a "sequence-structural" model, while Krumhansl mentions a "tone-functional" hierarchy. The "sequence-structural" model neither ignores "schemata" stored in the long-term memory, nor limits itself into "static". It seems to be more about musical structure theory (Huovinen, 2002), which stresses the "top-down" function of musical background. In other words, the retrieval function of the highest level depicts a possible repeated interaction between higher levels and lower levels. The "schemata" stress the gestalt of scales and triads, and the important tones of keys in the highest level relating to their popularity in the lower level. In some sense, it is more persuasive, flexible and interpretive in illustration of tonal perceptive processing.

Temporal proximity is also an important point which differs from "tonal-functional" hierarchy. In Deutsch and Feroe's opinion, the conflict between temporal proximity and tonal structure should gain more attention, because the temporal segmentation upsets the function of tonal structure in musical perception (Deutsch, 1980). In her experiments, melodic dictation was used to detect the effects of tonal structure and temporal proximity on encoding accuracy. All the melodic sequences were controlled lasting for the same time (actually not exactly the same depending on the number of segmentations, averagely between 6300ms ~ 6900ms[25], but it seems that there was no effect on the result), which excluded the effect of tone duration in the memory; only the duration of pauses were different within and between segmentations (2, 3, or 4 segmentations). It was found that temporal segmentations affected perceived structure: the compatibility of temporal segmentation and tonal structure benefited the performance; otherwise, the incompatibility of temporal segmentation and tonal structure was not conductive to the performance. Another thing to be considered is that if that temporal proximity functions more effectively than tonal structure is true, it may only influence the recall of the gestalt of a sequence in a memory task, but may not influence the assignment of a key.

Summary:

The tonal hierarchy and the formula structure model, deeply influenced by Schenker's analysis theory, construct two possible hierarchical structures in the knowledge. Both have greatly influenced later studies on tonality perception mainly in two directions. The first one is key position finding, and the other is pattern matching. The tonal hierarchy provides "stability" as the cue for key position-finding and suggests a "bottom-up"-like process of key-finding that the heard tones fit the tonal profile with the assistance of correlation. The formula structure model offers a tone

[25] According to the Deutsch's description of the experiment materials, the duration of the sequences are calculated as the follows:
The sequence with no segmentation lasts 6900ms (=300×12(tones)+300×11(pauses));
The sequence segmented in 4 groups of 3 tones lasts 6600ms (=[300×3(tones)+150×2(within group pauses)]×4(groups)+600×3(between groups pauses));
The sequence segmented in 4 groups of 3 tones lasts 6300ms (=[300×4(tones)+100×3(within group pauses)]×3(groups)+900×2(between groups pauses));
The sequence segmented in 4 groups of 3 tones lasts 6700ms (=[300×2(tones)+100×1(within group pauses)]×6(groups)+500×5(between groups pauses)).

system or gestalt of a certain sequence as the cue for pattern matching, and suggests a "top-down"-like process of pattern-matching in which the "overlearned" representations are applied to realize a note-sequence from the highest level to the lowest level. So, the tonal hierarchy leads us to the key, and the formula structure model helps us to find the mode – key and mode are the two aspects of tonality. Neither of the two models, however, demonstrates a practical procedure of tonal perception, which may be a bi-directional processing or an interactive processing with "bottom-up" and "top-down" process. The studies by Butler and Brown made a preliminary attempt in this direction.

13.3.3 Rare interval hypothesis

Browne (1981) proposed a "rare-intervals hypothesis" to interpret the processing of tonality perception. He analysed the intervallic features of the diatonic set and counted the presentation frequency of various size intervals, which can be understood as a theoretical "interval frequency profile" of diatonic set. The rare intervals are tritone, which appears once in the major scale, and minor second, which appears twice in the major scale. Conversely, perfect fifth and perfect fourth are the common intervals which appear six times for each in the major scale. The rare intervals are not only important for their rare presentation, but also eminent for their position in the major scale. The two component tones of the tritone are the IV and VII degrees in the major scale. IV has a tendency to III, which is a semitone below it; and VII has a tendency to I, which is a semitone above it. These semitone tendencies, leading to mediant and tonic, refer to the two minor second intervals.

Besides, Butler (1980) also pointed out that the "leading-tone" or "tendency-tone"-as in chromatic progression - is not only framed in the major diatonic set, but also used for extensive needs such as "secondary dominants, model mixtures, augmented-sixth chords, Neapolitan chords, and the so-called 'altered dominants'" (Butler, 1989, p.335). These chromatic harmonics serve as perceptual cues to "signal the initial statement, confirmation, denial, or change of the tonal center" (ibid, p.336).

In order to verify the function of rare intervals in the perceptual processing of tonality, Butler and Brown made great efforts on the experimental materials. Concerning the judgment of tonic, they assume that rare intervals, on the one hand, should have advantage over other common intervals within an octave, because they possess a unique position in a local key but not in other keys; on the other hand, temporal arrangements of rare intervals may also affect tonic assignment. So they made comparisons between rare intervals and common intervals, among temporal sequences of tones in rare intervals. They did not only use the real music, but also reordered melodies from musical excerpts in order to arrange intervals and to avoid primary and recency effect of the sequence (Brown & Butler, 1981; Butler, 1982; Brown, 1988). Unlike the common rating of given probe tones, the task for participants here was to produce the tonic (Brown & Butler, 1981; Brown, 1988), through humming, whistling, singing or directly pointing out the tonic perceived. To be sure that participants could carry out the task, they were usually pre-tested and selected for their “reporting ability”, or were asked to make a force choice whether a test tone was appropriate to be the tonal center of the former context (Butler, 1982, 1988). However, they did not totally reject the rating of probe tone since they also used it for exploring their rare-interval hypothesis and temporal-order hypothesis (Brown, Butler, & Jones, 1994), although they criticized it a lot (i.e. Butler, 1989, 1990).

From the comparison between rare intervals and common intervals, Brown and Butler found out that rare intervals are prominent cues for identifying tonal centers, though the comparison seems not so fair (this will be discussed later). From the comparison among different orderings of rare intervals, they found that the sequences of tones in tritone (Brown & Butler, 1981), dyads sequences including tritone dyad (Butler, 1982) could elicit more accuracy of tonic judgment, which implied the conventions of harmonic successions in Western music. For instance, the tonic tendency is usually from the subdominant chord (presented as IV in the scale) to the dominant chord (presented as VII), or from the dominant seventh chord (presented as the dyad IV and VII) to the tonic chord (presented as the dyad III-I). Such “rare interval effects" is substantiated also in minor mode (Bulter, 1992), in which rare intervals are the augmented second and the diminished fourth. When the tones of certain musical excerpts (Brown, 1985, 1987, 1988), in which chromatic tones were also involved, were reordered, different arrangements caused different tonal judgments. Chromatic pitches had both negative and positive effect on tonic assignment, which depended on the temporal context and implied harmonic relations.

Discussion:

Thus, rare intervals are tips to reveal the harmonic and temporal perceiving process in listening to Western music. Various arrangements of rare intervals and tones in a pitch set affect "perceptual clarity or ambiguity of the listening patterns" (Butler, 1989, p.234), either making it tonally confusing or eliciting various tonal centers. That is, pitches (diatonic and chromatic) and intervals are not sufficient to elicit a sense of key unless they are presented in a temporal order, which can be interpreted by listeners in certain meaningful contexts. Stressing the importance of temporal arrangement and harmonic implications, which present in the music explicitly and are interpreted by listeners tacitly, the so-called "leading theories of tonal harmony" (Butler & Brown, 1994) bi-directionally connect the music with perceptual process at a certain degree. That is, processing of a tonal musical piece includes three aspects: encoding musical information, interpreting with tacit or implicit knowledge and eliciting perceptual tonal center. Such a cognitive processing is an interaction between "bottom-up" and "top-down" process along with the music unfolded in time. A significant example illustrated the tonal perceptual processing along the unfolded music, where rare intervals would eliminate the uncertainty caused by common intervals and would finally lead to the tonic (see Butler, 1989, p.239). This process is called "position-finding".

Although rare intervals are approved as an outstanding signal for a tonal center, rare intervals can hardly explain the phenomenon when listeners determine a tonic after hearing the first few opening tones of music pieces. The opening tones are mostly common tones, like tonic, dominant, or mediant, and they progress in common intervals, like perfect fifth, perfect fourth, major third, minor third, to name a few.

Then, there would be a “competition” of common intervals and rare intervals in the tonal perception. Auhagen (1994) retested Browne’s proposal in an experiment using forty ascending and forty descending tone sequences. The sequences were divided into three categories: some were supplied with theoretical tonal center and tritone in major scale, harmonic minor scale and melodic minor scale; some others had no tritone but could elicit more tonal centers; and the rest were merely atonal having no theoretical tonal center and any tone sequence consistent with neither major scale nor minor scale. The production of tonal center by the participants enables us to conclude that listeners did not use the pattern as Browne had expected and tritone could not effectively lead directly to the tonal center. However, participants tended to use the chordal group tones, tritone-structure and ending or cadence to induce tonal centers. In addition, the ascending or descending direction of certain tone sequences can also affect the determination of tonal center. Huovinen’s study (2002) also rejected the advantage of rare intervals, but supported common intervals like perfect fourth and perfect fifth. It is also partly because triton, for its rarity cannot easily be figured out by statistical learning. On the other side, Butler (1989) mentioned the effect of temporal arrangement, but he did not make it a clear depiction. These questions have been further investigated in depth by Auhagen (1994).

13.3.4 Inductive clues of tonality perception

As mentioned above, it was found that the tones of chordal group, tritone-structure and ending or cadence can influence the tonality induction. To determine to what extent the three aspects influence the identification of a tonal center, Auhagen (1994) did further three series studies. In the first series, the tones in the context sequences had no difference in duration and intensity, and the melodic contours were either ascending or descending. The number of tones varied from two to five within an octave; all types of the intervals in an octave, major and minor triads and their inversions, major and minor seventh and ninth and their inversions were involved. Some other arranging rules were set, considering the conflict between theoretic tonal center and the one displayed in cadence or by tritone. Listeners could hear each sequence for two or three times in order to avoid the recency effect. The tasks were clearly instructed either to produce the tonal center of the preceding context or to fill the end tone, so that the cadence effect might be separated from two other strategies for producing tonal center.

It was found that the end-filling tones usually were the tonal center (few third tone) to the prior melodic contour, which was guided by the chord cadence V-I; hence the end-filling tones can be a way to induce tonal center. This result gives support to "probe-tone" as in a task, where listeners are asked to rate the tone at the end and the responses may be affected by the cadence effect. Besides, it also stresses the traditional melodic endings, which includes ascending minor second, descending major second, descending minor third, descending perfect fourth, ascending or descending tritone, and ascending or descending perfect fifth, which lead to tonal center especially when their directions consist of contexts' direction. However, none of the rare intervals (tritone or semitone) is necessary to determine a tonal center, especially when some chordal group tones appear prior to the tritone, and the root tone of the chord would be preferred as tonal center; it seems that there is no pattern of scale function in the tonal perception. This result rejects the "rare-interval" hypothesis. Listeners also took chord structure, interval frame, tone group, starting and ending tone, and even the ascending or descending direction and put these factors into account. In other words, tonal center has many choices; it could be the solution of a tritone, the root note of a chord, a traditional melodic ending or the first sounded tone in the sequence.

The contextual materials in the second series did not simply flow in one direction, but were shaped in a "V" or inverted contour. There were no repeated tones in a sequence and the length of sequence was extended up to nine tones with the same duration and dynamic. Except the retest of results from the last experiment series, the influences of the position in the sequence, the ascending and descending directions, the combination function of chords and tritones, and the edging and turning point effect of choral root tone or solution tone were also tested. The arrangement of tones was an extremely complex task, considering the order of chords, tritones and ending intervals (ascending minor second, descending major second), the appearance of chords (tones in a chord appear after each other, or insert other tones between them), the forms of chords (original position or inversions), the position of root tones or solution tones (attentional points like the first, the turning or the last point; inattentional points), etc. The chords involved major or minor triad, major or minor seventh chord, and sixth chord.

Although the conditions of each sequence seemed too specific, some regularities were obtained from the tonal center reports. The scale schema was verified again not so helpful to judge the tonal center; the direction did not contribute enough to the judgment; while the subjective grouping played an important role in the tonal center reporting. It seemed that listeners could “split” the sequence into two or four groups according to the implied chords in the sequence, and then found the root tone of the chord in the subgroups as the tonal center, especially when the root tone appeared at the edging or turning position of the sequence; listeners preferred the earlier appearing group from which the tonal center was elicited. This result shows that the subjective grouping works with the strategies based on chords, tritone, ending intervals and the first tone of the sequence.

Considered the grouping effect in the former series, metrical aspect was taken into account in the third series. There were two metrical schemata: one was a long tone followed by a short tone, and the other was a short tone followed by a long tone. Using metrical schema aimed to change the subjective grouping and examine whether metrical factor affected the selection of tonal center or not. The sequences were about nine or ten tones long with different ending-intervals (e.g. the ascending minor second, the descending major second) and combined with metrical characters.

It was found that metrical schema did not only influence the subjective grouping, but also led to different results in ending-intervals. The metrical schema could enhance the recognition of chords as well as the function of ending-intervals. The long tone at the last position stressed the ending function of intervals; while the short tone at the last position would lead to the expectancy of another supplementing tone at the end. Both factors affected the judgment of tonal center. It was also noticed that the schema used by listeners, could be shifted from the first tone of the sequence to the second, when the sequence started from a short tone. Nevertheless, whether the sequence fitted the diatonic scale or not was ineffective to the judgment.

Short Summary:

According to the results of these experiments, the tonality judgment depends on the specific information about the sequences (intervals, positions of root tone or solution tone in the sequence, directions), and subjective tone-grouping which is affected by tone relationships (chords) and metrical schema. Some specific rules are listed as strategies of locating tonal centers in a certain condition (uni-directional five no-repetition-tones with same length, intensity, etc.). Furthermore, the traditional melodic endings of Western music are also stressed as leading to a tonal center. These findings prove that they are more efficient to explain some real compositions than Browne's theory, especially when contexts are with more chromatic tones. It partly supports Schoenberg's idea of "monotonality" (Schoenberg, 1954/1969). Thus, the tonality perception in Auhagen's view is a cyclic process of musical grouping, eliciting expectancy and yielding judgements or evaluations.

Discussion:

Different from the former studies, Auhagen focused on concrete conditions which influence the selection of a tonal center. These concrete conditions, which involve harmonic, melodic, and even metrical aspects, reveal some possible processing in our musical experience and support some other studies in some degree, which enlighten further studies. For instance, the judgment or producing the tone - "probe tone" - after a context is a way that reflects tonal center finding; the edging tones may be partly because of primacy and recency effect of a sequence, though each trial was heard three times; earlier recognized structure (in ascending) contributes more to tonal center judgment, this may partly explain how listener can tell tonality without waiting for the cadence; the subjective grouping as "stressed-unstressed" unit may be caused by the unsteadiness of attention; the frequency of tone-appearance may enhance the possibility of a certain tone judged as the tonal center; chordal progression plays an important role in grouping and cadence, which may indicate that Western listeners processing Western music based on underlying harmonic relationships, rather than distribution characters of intervals in a certain scale, etc. These arouse a question: whether our implicit knowledge builds on statistic information or on grammatical information? In another word, whether our implicit knowledge bases on form or meaning? This will be discussed in the next section.

13.3.5 Scale structure

Cross, Howell and West stressed that the function of scale structure or scale set differs from that of mode. Scale structure is more abstract than mode in musical perception. They considered that the scale structure usually contains "the set permitted pitch intervals between notes" (Cross, Howell, & Well, 1983, p.444), which are ordered in discrete pitch steps and cycle around octaves. Such a scale structure is the basis of the musical pitch organization, and it is presented as a mode in the "middle ground" (Powers, 1980); while mode is considered as "the assignment of a special salience or centrality to particular tones within the scale structure" (Cross, Howell, & Well, 1983, p.444). They proposed that the scale structure is "capable of functioning independently of mode in cognition", which plays "a primary role in the perceived coherence of melodic structure" (Cross, Howell, & Well, 1983, p.447) rather than mode which is too static to fit the changeable tones or intervals in musical sequences. The scale structure may promote the perceived coherence, facilitate memory and assist reorganization or recall of melodies, whereas the cognitive processing may affect the preference for the musical sequence. Thus, these scholars aimed to figure out whether the perception of musical sequence is influenced by scale structure or any particular mode.

In the four experiments by Cross, Howell, & West (1983), the musical sequences were ordered in four "order conformance" sequences, and four degrees of conformance were controlled. That is, for the first order conformance, each two successive tones (an interval) belonged to a major scale, the following tone of the preceding interval did not share the same major scale, but shared the same major scale with the preceding tone. In the second sequences, three successive tones other than the fourth tone shared the same major scale. The same was valid for the third and fourth sequences. Aesthetic preference and musical judgments were collected by five point scales. Taken tempo and accent in beat into consideration, they found that the conformance degrees of scale structure influenced the ability of identification of conformance and metric note-grouping, and also affected aesthetic preference and musical judgments.

In further study, Howell, West and Cross (1984) tried to find out what information listeners use for determining the scale structure, the conformance or the specificity of notes. The two aspects of notes were clearly discriminated, because they might lead to the perception of scale structure. They assumed that the conformance of notes implied the scale structure, while the specificity of notes led to a certain unambiguous scale. They used detection tasks, in which listeners were asked to report the out-of-scale notes or "wrong notes"; the notes were repeated to trace the musical sequences contributing to the perception of musical structure. Three parameters were counted: the first one was the number of notes preceding the wrong note (controlled in 4 or 5 notes), the second was the number of scales that the prior notes spread within the circle of fifths (controlled in 4, 5, 6 or 7 scales), and the last was the number of notes between the wrong note and the contradicted note (controlled in 2, 3 or 4 notes). Different conditions were compared, and the result showed that out-of-scale notes were easier to be detected when less common scale was shared; however, the scale schema did not work better than matching successive notes and identifying interval structures within or without the scale.

Another series of experiments (Cross, 1989, 1991) used three-note sequences as contexts, followed by a probe tone for rating its fitness to the preceding context. The orders of the three notes followed four types: "tritone plus one", "fifths intervals", "triads" and "pentatonic fragment". These four types were categorized by their scale commonality. The "tritone plus one" type has theoretically the least commonality – only one scale, while the other three types share five, six or eight common scales. The ratings showed that the more common scales the context sequence shared, the more ill-fitness of the out-of-scale notes could be rated. For instance, the out-of-scale notes were more likely to be rated as ill-fitness in the "pentatonic fragment" type than in the "triads" type.

Most of their experiments were done with non-musicians. They also did the experiment with musicians, and they found no difference between the two groups. Therefore, the scale structure may be considered as a conventional musical schema which may be obtained from musical culture in daily life.

Short summary and Discussion:

As Cross, Howell and West investigated whether and how scale structure or scale set plays an important role in musical sequence perception, they got a consistent result: the "common features" of the scale structure work as "pattern-matching", but not "tonal function finding" as tonal hierarchy. Because the "pentatonic fragment" type, is shared by eight possible commonalities, it is more effective for excluding the out-of-scale notes. And in some degree, they draw a similar conclusion to the results of Butler and Brown that chromatic tones or out-of-scale notes do not disturb the tonal perception but assist the tonal perception in some way. However, it seems that there is a conflicting result with Butler and Brown's, namely, the "tritone plus one" type - the rare interval and the specificity of a major scale – does not assist out-of-scale judgment in the fitness rating task. But tritone is an important cue for orientation in a scale in Butler and Brown's findings. So, it is still in doubt whether pattern matching and position finding do conflict with each other in tonal perception; or whether the rating task may lead to a more basic or abstract level (the same as the rating task in Krumhansl's studies), while producing task may lead to relative concrete levels. Nevertheless, position finding and pattern matching should not be in conflict with each other, since both may contribute to tonal perception (Krumhansl, 1990).

13.3.6 Pitch-class constellations

"Pitch-class constellations" is a term proposed by Huovinen (2002). It is defined as "atonally interpreted pitch-class set" (p.33). According to former studies, it is inquiring to know whether Western listeners use different strategies to solve the specific task, though they possess the similar schema. It relates to two aspects of tonality perception when listeners make tonal judgments: the objective and subjective perspectives when listeners make tonal judgments (Huovinen, 2002). Huovinen tried to set the two aspects apart in his six experiments. He argued that “objective” perspective is more rational or abstract criteria which reflects theoretical focus, while “subjective” perspective leads to individual or concrete criteria which reflects psychological focus, and this may differ in various music works. “Objective” and “subjective” questions from Huovinen can be understood in some way as “background” and “foreground” in Schenker’s theory, or “tonal hierarchy” and “event hierarchy” discussed by Bharucha (1984).

Huovinen tried to explore whether listeners’ “tonic finding” strategies were consistent in different conditions: the context with either rare-intervals or with the interval perfect fifth, or circle of fifths for modulation. He also tried to find out what factors affect the consistency of one’s strategies. Based on former studies, Huovinen separated the structural and the functional clues (influenced by Butler & Brown) as two types of criteria for tonal stability (p.77). The structural clue is from the view of tonal hierarchy in terms of unordered pitch-class constellations, while the functional clue refers to temporal order and/or registral features of the tones. The structural strategies got more attention than functional strategies in his experiments (Samplaski, 2005). Nearly all his experimental materials were high-speed (less than 150ms per tone) to minimize the functional strategies involved; but the registral aspect was considered in pitch arrangement that pitches were at least in three octaves.

In his first experiment, he used 18-measure rapid string, in which an arpeggio of a pentachord (including an interval-class 5=ic5, including the perfect fifth its octave complementation- the perfect fourth and their octave expansions) was repeated in 3 octaves in different order, and the pentachord did not belong to any key. He also adopted the “producing task” that the participants were asked to sing or hum the “most stable pitch” or a tone more like “tonic” in relation to the heard tones. It resulted in the finding that the root of a perfect fifth was preferred rather than other tones as tonal center, while other intervals could not work as well as the ic5. So it was concluded that the ic5 could lead to tonal center in an unfamiliar musical context efficiently.

In the second experiment, he used a comparison task for investigating the stability of the ic5 solution. Ten other alternative intervallic solutions were compared with the ic5. Each comparison task included two strings sharing the same prime interval-set form but in a different order in relation to subdominant or dominant. Participants were asked to compare which "melody sounded more like the proper 'tonic'" (p.142), rather than subdominant or dominant. It was concluded that the ic5 strategy was not always more stable than other alternative intervallic solution, but also depended on functional order conditions. For instance, the movement of semitones increased the stability of the ic5 solution. The fourth experiment further confirmed that the ic5 interacted with the semitone which affected the judgment of tonal center: when an ascending perfect fifth or a descending perfect fourth followed an ascending semitone, the root of ic5 would be considered as the tonal center.

The third experiment focused the semitone as a functional clue, compared it with other simple functional strategies; and also explored how it influenced the ic5 for the judgment of tonal center. The semitone divided the tetrachord into three two-note strings, but each measure had five notes. The tones in the tetrachord could be ascending or descending according to their position in the pitch-class, but their pitch registration were different, the last tone was always in a different register from the first tone which started the string. The listeners sang or hummed the stable tone after hearing it. Huovinen drew a similar conclusion to Auhagen's (1994) that the semitone strategy could not work alone, but depended on "the presence of structurally more stable elements" (p.191); other functional strategies acted in the same way. Furthermore, the diatonic influence increased the discrimination of certain intervals; and "rare intervals" in the particular situation, rather than the schema, played the decisive role in the judgment of tonal center.

The fifth experiment was dealing with "subjective" questions in the tonal perception, which may be affected by listeners' music experience, music training, and also by music styles or genres. The main point of the study was listeners' consistency or the flexibility of strategies. Huovinen supposed three steps of structure-building process: laying a foundation, mapping and shifting, which were similar to Auhagen's (1994) cycling processes (musical grouping, eliciting expectancy and yielding judgments or evaluations). It seems that individual consistency relates to music-theoretical knowledge, amount of music experience, absolute pitch abilities, and even childhood activity. In addition, musical or intervallic characters also affect the consistency; that is, the stability (like ic5-interval) would not be proportional to consistency. The early decision of tonal tonic (Auhagen, 1994) reconfirmed that tonal representation was built in the stage "laying a foundation" and then mapped with following notes in the string. The so-called "structure-building" ability might relate to childhood musical activity, but "not positively affected by musical training and studies of music theory" (p.267).

The last experiment tested the function of the circle of fifths when hearing a modulation. The issue also referred to "objective" and "subjective" problems. The "objective" one aims to indicate whether the circle of fifths is used like shifting strategies mentioned in musical theory; and the "subjective" one tries to explain whether the circle of fifths facilitates the judgment of tonal center in modulations. In order to follow the changes of judgment in a modulated context, which consisted of five strings, the participants were asked to report the "stable tone" after each string without correcting the reports and repeated hearing. The series of the reports were not supportive to that the circle of fifths is as a primary model to facilitate the judgment of tonal center. Listeners preferred to use the smallest interval between the strings, and pointed out the tonal tonic depending on stable structure (e.g. ic5-root).

Discussion:

The contribution of Huovinen's study is the attempt to separate individual strategies (i.e. the structural building of musical strings) from theoretical strategies. Ic5 is the most important issue among the six experiments. The results confirm Hindemith's argument (1940) that ic5-root is preferred as tonal centre, despite registral and temporal arrangements. With Huovinen's results, the gap between psychoacoustic and perceptive perspective becomes smaller. Reviewing the acoustic models, he found that the first few harmonics, involving octave, perfect fifth, perfect fourth, are stressed. These consonant intervals are also common intervals in major mode. Therefore, his conclusion turns down the rare interval theory, but supports tonal hierarchy theory based on perceptual ground; and "key-finding" refers more to "ic5-finding".

Furthermore, there are another two points leading to further studies, though they were not the main points of the study. The first one deals with the importance of childhood's musical activity in one's consistent strategy for tonal judgment and "structure-building" ability, which may be less affected by musical training. This conclusion is more or less consistent with the result in development studies, that adult and infants do not differ in some basic processes of musical hearing (Trehub, Schellenberg, & Hill, 1997). Such a childhood musical activity may form the implicit musical knowledge of a specific culture, which may facilitate the judgment unconsciously. The second one relates to two primary stages - "laying a foundation" and "mapping" - which arouse expectancy. It is still unknown which factor contributes more to the tonal judgment: expectancy or cadence. If we take the implicit musical knowledge of specific culture as the background, and the expectancy from a specific music piece as the foreground, the tonal perception would be an interactive process between the background and the foreground; when two "grounds" share common elements, then a tonal judgment could be made.

13.4 Discussion

Despite the numerous studies about tonality perception, the above-mentioned research lays a direct stress on specific tonality induction or "key-finding" issues focusing more on internal factors in music theory, but less on external causes. The scholars examined Western music theory with Western listeners' tonal perception and cognition. Given that their theoretical starting points on music were different, the results were not identical. Not only different concepts of tonality, but also "dualities in music" make these studies hard to be congruent with each other (Vos, 2000). However, there was something common in their findings.

Discussions in the music theory generally deal with two aspects of tonality: the temporal and spatial one. These two aspects are investigated by a functional and a structural approach. Although in the theory, "functional" and "structural" aspects of tonality are not easy to be interpreted separately from each other (Huovinen, 2002), they are understood and treated in experiments as dynamic ordering and static pitch-set of notes. The obtained results from each approach support the fact that both ordering of tones and character of pitch-set (like rare intervals) contribute to tonality perception. In reference to functional approach, Butler and Brown's studies showed that the function of intervallic rivalry, and the processing of inducing tonic from unfolding melody seemed like an eliminating process of uncommon tonalities, then the tonic came into mind after a "logical deduction". In reference to structural approach, perceptive stabilities of tones in pitch-set were collected, perfect fifth was stressed, and listeners had an appropriate subjective tonic with few tones not inferred from rare interval. Thus, the difference between the two approaches consists in that they both stress different information to illustrate the tonality induction: the functional approach prefers "ending (cadences) of musical composition", while the structural approach is with assistance of "opening of musical composition" (Vos, 2000, p.414). However, the two sides are not opposite, but relate to each other in some way (ibid, 2000). Ic5-intervals including perfect fifth and perfect fourth may build the bridge between the two. Perfect fifth and perfect fourth have permanent advantage in both psychoacoustic and music theory. From the psychoacoustic point of view, they sound consonant after an octave; whereas in music theory, they constitute the basic relationship in the circle of fifths and the *Ursatz*, and appear quite frequently as opening and closing intervals or cadence with an implied tonic (ascending fourth and descending fifth) (Auhagen, 1994; Vos, 1999; Huovinen, 2002).

The common point of both approaches may be not so intuitive, but can be grasped on the epistemological level. Even though tonal perception relies on structural hierarchy, *Ursatz* or highest level, or rare intervals, all these are considered as tonal schemata and remain in the background. The schemata mirror the order in which tones are organized in the background or in knowledge. In reference to structural hierarchy, the schemata are not templates, but consist of two parts: tonal hierarchy and event hierarchy (Bharucha, 1984). Here it is stressed in the relationship of triad and the circle of fifths. While rare intervals are more like a filter which sieves out the proper key. Moreover, the schemata affect the holistic perception as *Gestalt*. People usually perceive an object as an organized form or image, whether with visual, auditory, tactual or olfactory stimuli. The way these elements are organized as a gestalt depends on a schema, which is formed by learning and experience and makes the gestalt meaningful. Schemata work in the background and interact with the foreground. Visual stimuli, for instance, sometimes cause a fluctuation of perception with cognitive dynamics, especially when a stimulus has ambiguity with alternative explanations. In this circumstance, any perception is reasonable to be accepted with the context. This happens quite similar to auditory stimuli. The schemata can give judgment on the context – whether it is unitonal, bitonal or atonal. During the process of tonal perception, the fluctuation of perception in auditory may happen, in the course of which, the information in the foreground is mutually checked with schemata in the background before the key is assured. Then, tones or triads become tonally meaningful in the context. The non-tonal material in Auhagen's studies (1994) and fast-presented strings in Huovinen's studies (2002) with more repetition allowed listeners to perceive stimuli completely as a gestalt and to produce the tonic or the most stable tone with little fluctuation.

Therefore, the schemata play an important role in the tonal perception because of their two basic attributes. One is their pre-existence before perception occures; the other is their developmental and cultural context. For experienced listeners, with or without musical training, they possess relatively stable tonal schemata in their long-term memory. It can be supposed that the schemata build a subjective context. When a tone or a triad sounds, it is tonally meaningless because it does not have an objective context; however, it is tonally meaningful in the subjective schemata. Depending on the subjective schemata, information in the foreground can be compared with the background. When the information in the foreground is congruent with schemata, then processing could be faster; but when the information in the foreground is incongruent with the schemata, the processing would need some time.

Mental schemata are formed during personal development and experience in a specific cultural environment. Given that many differences exist among cultures, even schemata do also vary according to different cultures. In some sense, the schema acquired by people in a certain culture reflects their “collective unconscious” (explored by Carl Gustav Jung), or it may be genetically inherited. Till now, most studies on tonal perception have been mostly conducted with Western music and Western listeners, starting from several-month-old babies to adults. These results show that the schemata become more precise in childhood (e.g. Krumhansl and Keil, 1982). However, only a few studies deal with non-Western music addressed to Western and non-Western listeners. It is found that native listeners are more sensitive to their own culture and judge it based on their schemata, although several common points between their native and Western music might be observed (e.g. Castellano, Bharucha, & Krumhansl, 1984).

The discussion in the section about music theory re-emphasized the differences between Western and Chinese music theory. The former leans towards harmonic function, and the latter leans towards melodic mode. Even though the results from Western listeners adapt to Chinese listeners is still unknown. Different musical cultures construct different musical schemata, which propose that listeners coming from different musical cultures possess different schemata. Chinese listeners can better “understand” Chinese music than Western listeners; Western listeners may indicate “Western tonal hierarchy” when they hear Chinese music, and Chinese listeners may present “Chinese tonal hierarchy” when they hear Western music. Chinese musical schemata may differ from that of Western listeners, but the structure and meaning of Chinese schema will be explored in this study.

14. Tonal perception, priming paradigm & artificial neural network

14.1 Priming effect and priming paradigm

In addition to the methods for exploring musical schemata introduced in the last section, there is also a special method to investigate implicit knowledge, namely, the priming paradigm. Priming paradigm is based on the idea that a former presented event can more or less affect the processing of the latter event. Priming effect reflects the state of implicit memory or implicit knowledge relating to subliminal consciousness, independent from explicit memory or knowledge. The response to some stimuli is either facilitated or interfered by former stimuli, which depends on the underlying relationship between the former and the latter stimuli – the so-called relatedness priming effect, or the repetition of the former event – the so-called repetition priming effect. It usually occurs in priming paradigms, like tachistoscopic presentation, masking, degrading, shadowing, and parafoveal presentation, lexical decision task, perceptual identification, word-stem completion task, etc. (Reber, 1993). The materials can be language (words or sentences), pictures (faces or objects) and sound (ambient sounds or music).

Priming paradigms usually involve a learning phase and a test phase. For instance, in the learning phase, participants are asked to learn some words and read them aloud; in the test phase, participants should do some tasks, like completing some words only with the stems (first few letters of a word, e.g. "tab__"), or with some missing letters in a word (e.g "t_bl_"); or reading out some other words presented by tachistoscope, etc. When the materials in the test phase are the same as participants have learned (e.g. participants learn the word "table", and are tested with "tab__"), the priming paradigm is called repetition priming; when the materials in the test phase are relative or similar to what they have learned (e.g. participants learn the word "table", and are tested with "chair" presented by tachistoscope), the priming paradigm is called relatedness priming. The speed and accuracy of responses are recorded.

Semantic information plays an important role in repetition priming and relatedness priming. When repeated stimuli cannot make confusion with different contexts, the response to the stimuli may depend more on memory; while when repeated, stimuli have different meaning in different contexts, the response to the stimuli may depend more on semantic information of the context. Similarly, the related stimuli sharing a common context can be easily activated by each other.

In a musical situation, a single tone or a major or minor triad, even a common interval can be interpreted in many possible tonal contexts. The context can be explicitly shown as a pre-presented context, like the context in the probe-tone paradigm; and the context can also be an implicit one as tonal schema formed in childhood. When the explicit context matches the implicit context, the priming effect is facilitated; otherwise, the priming effect is interfered. For instance, a pitch G is presented. According to statistical analysis, G as dominant appears quite frequently in the most prevalent C major, and also dominant is the most common pitch in Western music (Huron, 2007). With such an "objective schema", Western listeners would give a faster and more accurate response in a C major context than in a D major context. Because G is the subdominant in D major, and subdominant is not frequent either as initial tone or as common tone in Western music. Musicians and non-musicians have different processing strategies, though musicians are usually consciously processing. Some tasks are applied to control the consciousness participation in tonal perception, like naming the chord category (Bharucha & Stoeckig, 1986), judgment on in-tune or out-of-tune tones (e.g. Bharucha & Stoeckig, 1986, 1987; Tekman & Bharucha, 1998), timbre discrimination, judgment on consonant or dissonant, or even judgment on vowels in texts (Schellenberg, Bigand, Poulin-Charronnat, Carnier, & Stevens, 2005), etc.

14.2 Tonal perception with priming paradigm

Meyer in his book *Emotion and Meaning in Music* (1956) mentioned that "music arouses expectation, some conscious and others unconscious, which may or may not be directly and immediately satisfied" (p.25). Reber in his book *Implicit Learning and Tacit Knowledge* (1993) argued that "*knowing* something meant being able to function within whatever domain of effective performance that something represented" (p.22). Accordingly, musical expectation and musical knowledge do not only exist and act in the musicians' consciousness, but they are also enrooted in the unconsciousness of children and non-musicians and represented through their responses (this aspect has been discussed in the former sections). The tacit knowledge works implicitly to facilitate listeners with or without musical training to form their musical expectation and musical aesthetic values.

The priming paradigm was first applied in music psychological research by Bharucha and Stoeckig (1986). They used this method to explore the cognitive process underlying chordal expectation. Later, Bharucha and his colleagues attempted to verify the advantage of cognitive processing of chordal expectation over the psychoacoustic processing (Bharucha & Stoeckig, 1987; Tekman & Bharucha, 1992; Tekman & Bharucha, 1992, 1998), and to explore the tonal implicit knowledge (Marmel & Tillmann, 2009). Besides, Bigand, Tillmann et.al. developed the chord priming based on Bharucha's paradigm, and they also focused on the studies of expectancy and implicit knowledge. They obtained the consistent results.

14.2.1 Chord priming

Chords play an important role in Western music, so the relations between the chord and key and between chords themselves are mainly investigated. The relations present tonal function in keys and harmonic progression. The closer the tonal relations of two chords are, the easier the chords interact with each other. The chord priming paradigm involves two chords presented successively. The first chord is the priming chord, which can activate a context; the second one is the target chord, which is perceived under the influence of the prior chord. There are two probable effects of the priming chord. When the two chords are closely related to each other, the priming chord is going to facilitate the perception of the target chord more quickly and accurately, because it activates the related keys and chords connecting to the corresponding keys. Conversely, when the two chords are remotely related, the priming chord is going to "hinder" the perception of the target chord more slowly and inaccurately, because they share fewer keys or nothing with each other.

Bharucha and Stoeckig (1986) investigated implicit harmonic relations of major and minor chords, and as a consequence the chord priming effect was found. They presented different chord pairs to the participants. When they asked participants to make judgment on chord categories – major or minor – it was found that with major priming chord, the responses to related major chords were faster and more accurate than the responses to unrelated major chords, and the responses to unrelated major chords were slower and less accurate than to unrelated minor chords; with minor priming chords, the responses to related minor chords were slower and more inaccurate than to related major chords, while the responses to unrelated minor chords were faster and more accurate than to unrelated major chords. It formed an inverted U-shape of the relation between chord relation and the responses that either high or low tonal congruence of the priming tone and the target tone caused better responses, while moderate incongruence of the priming tone and the target tone caused worse responses (Frankland & Cohen, 1990).

Another task seems to acquire less cognitive processing than major-minor judgment. The participants were asked to tell whether the second chord was in-tune or out-of-tune in major chord priming. Bharucha and Stoeckig found that in-tune/out-of-tune task provided a stronger demonstration of priming effect than the major/minor task, so participants, even those ones with no musical training, were involved in the experiments. By in-tune/out-of-tune judgment, they got similar results in major/minor judgment. Relatedness facilitated in-tune judgment, but interfered in out-of-tune judgment with both major priming and minor priming tasks.

Though the chord priming effect exists, it is hard to convince that the priming effect is caused only by tonal relatedness rather than overlapping frequency spectra, in other words, whether the priming effect is generated at a cognitive level or a sensory level (Bharucha and Stoeckig, 1987). The precise control of the harmonics in chords' tones is a way to solve the problem. Comparing the results with prime and target chords with no fundamental tones but sharing overlapping frequency spectra and pairs with no overlapping frequency components, the priming effect does happen in both circumstances; so frequency spectra are not a vital factor in harmonic priming. Therefore, it can be concluded that the priming effect is generated at a cognitive level through spreading activation, and such musical structure is also internalized as tacit knowledge by untrained participants.

Tekman and Bharucha (1992) studied the time course of chord priming to get to know how fast the priming effect can be induced, and whether the priming effect can be disturbed by silence or noise between the prime and target chords. They set several levels of stimulus onset asynchrony (SOA, the duration between the start of the prime chord and the start of the target chord), and found that the priming effect appeared as early as 50ms, and there were no significant differences when SOA was longer than 111ms, and interference did not work at all. However, when SOA was as short as 50ms, the reaction time became significantly slow, but accuracy did not get worse. In further experiments (Tekman & Bharucha, 1992, 1998), it was found that psychoacoustic similarity may only in quite short time (50ms) facilitate chord priming, while relatedness played a much more important role for priming and worked for longer durations. Thus, it also verified that the priming effect was not a short sensory memory, but a consequence to the spreading activation.

The main evidence in chord priming is that relatedness contributes to the sensitivity of the target chord. The target chords in "near related" pairs of chords are faster and more accurately recognized, and such priming effect lasts for some time ignoring the interference.

14.2.2 Chord progression priming

Priming chords can be substituted by chord progressions in order to investigate the relation between chord and key at two levels. Whether the tonal context built up by chord progression facilitates, chord perception or not is the main question to be focused on. Bigand, Pineau, Tillmann, and their colleagues did quite a lot in this field.

The chord progressions used as priming stimuli show unambiguous tonal context for the judgment on target chords that follow behind. A chord progression usually consists of eight chords. The eighth chord is the target chord, the chord just before the target chord is the "local context", and the first six chords are the "global context". The target chord can be either the last chord in the cadence of the whole chord progression - a tonic chord, or a chord after the cadence of the former seven chords - a subdominant chord (Bigand, & Pineau, 1997). The judgments on the target chords are the same as those ones in chord priming to avoid consciousness participation.

Following this paradigm, the researchers obtained consistent conclusions from chord priming studies. The response to the target chord was determined by both global context and local context, that is, the tonic chord was faster and more accurately detected (Bigand, & Pineau, 1997; Tillmann, Bigand, & Pineau, 1998). This happened even when listeners were exposed to chord progression with subdominant chords for some time (Tillmann, & Bigand, 2004). Cognitive processing had advantage over sensory processing even when the duration of chord is as short as 75ms in the chord progression (Bigand, Poulin, Tillmann, Madurell, & D'Adamo, 2003). Both musicians and non-musicians presented similar responses in these findings.

The chord priming and chord progression priming show a strong effect of schematic knowledge of tonal hierarchies that is acquired by both musicians and non-musicians. Such schematic tonal knowledge is not only a kind of implicit knowledge, but also works implicitly depending on semantic or harmonic meaning in tonal context, even by musicians.

14.2.3 Repetition priming & relatedness priming

As it was mentioned above, repetition priming is caused by repetition of priming stimuli, while relatedness priming is based on the relationship between priming stimuli and target stimuli. Interestingly, chord priming as well as chord progression priming depends on the relation between priming and target chords or between global context and local context and the target chords. So it is questionable whether there is repetition priming in music. The repetition priming in music is examined in four conditions: priming with single chord, chord progression (Bigand, Tillmann, Poulin-Charronnat, & Manderlier, 2005; He, 2010), single tone, multiple tones - a melody (Hutchin, & Palmer, 2008; Marmel, Tillmann, & Delbe, 2010; He, 2010).

Comparison to single chord and chord progression priming shows that harmonic relatedness priming functions dominantly, and with little interference of chord repetition in the priming stimuli (Bigand, Tillmann, Poulin-Charronnat, & Manderlier, 2005). Priming with single tones and melody shows that tonic is faster detected as ending tone than other non-tonic tones; and repeated tone in the melody is easier to be produced, and it also benefits from short prime-target distance (Hutchin, & Palmer, 2008). These results show that musical priming, either with a single tone or chord or their sequences, is mainly determined by tonal relatedness, while repetition of notes has a temporary effect. The strong function of tonal schema is verified.

14.3 MUSACT model

Bharucha and Stoeckig (1986) proposed a connectionist model based on Western music. It is “a spreading activation model of the representation and processing of harmony”, and has an advantage that it based on both input and output information covering both bottom-up and top-down processes (Tillmann, Bharucha, & Bigand, 2000). In this model, there are two layers: one is the parent-keys layer, and the other is the daughter-chords (major or minor chords) layer. Each key has several daughter chords, and each chord also faces towards several parent keys. The network built between keys and chords is based on the circle of fifths which stresses the functions of subdominant and dominant relationships. “Stable” or “related” is indicated in the model as sharing keys or chords, that is, keys sharing some chords are closely related than the keys with no common chord, and chords sharing some keys are closely related. The strength of links between keys and chords is different, and it depends on the harmonic function. The activation spreads and reverberates between key and chord layers, decaying over time. So, when a chord sounds, the keys closely related to it and the chords related to the keys would be highly activated, then the other chord in such a close network would be perceived as a stable and related one to the preceding chord and even confused with the prior one. This model is verified with their chord priming.

The two-layer model further extends to three layers, known as MUSACT model. The three layers are the tone layer, the chord layer and the key layer. The connections between three layers reflect the conventional relatedness: the tone layer is based on twelve well tempered chromatic pitch classes; the chord layer stresses the chords of tonic, dominant and subdominant, as mentioned in the music theory; the key layer is arranged according to the circle of fifths. The activation spreads and reverberates among three layers.

Therefore, this network is not only related to the “bottom-up” and “top-down” layers from special and temporal aspects, but also presents the weight of connections which is determined by tonal functions. The activation in the network spreads by self-organization and reverberation, that is, tones and chords are grouped by self-organization which is formed through extended exposure to Western music, and the strength of activation depends on the weight of connection – the tonal function, reverberating through the corresponding cluster of tones, chords and keys. MUSACT network is, in some sense, an ideal connectivity that reflects the end-state of self-organization response to a musical environment across temporal orders (Tekman & Bharucha, 1998). Such end-state of self-organization reflects the regularities in a certain musical culture. They pointed out that psychoacoustic similarity may assist the development of conventional relatedness, but its facilitation for priming can only persist in very short time; while these conventions, as implicit knowledge representing the structures, are responsible for the low-level and high-level mutual activation and have longer impact on priming effect. The sensory and cognitive processes are verified with chord priming, chord progression priming and even monophonic priming (Marmel, Tillman, & Delbé, 2010).

15. General summary

All the conclusions on the reviewed studies in Part II are mainly drawn from the background of Western classical music. It is clear to see and prove among Western listeners how the tonal knowledge is developed from infancy to childhood; and it is also evident that the tonal knowledge is acquired by both musicians and non-musicians. Based on the verified cases, one might state that tonality perception has the following features:

1) Tonal perception is driven by tonal schemata, or through priming of tonal knowledge;

2) Tonal perception starts from the initial tones; and a single tone or a chord has a priming effect for later musical events;

3) Tonal perception develops along with further coming musical events, even when a tonal sense is stabilized or modulated;

4) Tonal perception may depend more on functional hierarchy for harmonic relation is essential in Western music;

5) Tonal perception may depend less on template, because rare intervals in the template do not facilitate tonal perception more effectively than common intervals; however, there are some implicit rules in melodic cadence.

Tonal knowledge is a kind of implicit knowledge. Like language grammar, it is "revealed in task performance without any corresponding phenomenal awareness" and "is often expressed unintentionally and tapped indirectly" (Schacter, 1992), thus presenting the characters of implicit knowledge:

1) *automatic learning*: the acquisition and process of implicit knowledge is completed automatically, without the participation of conscious or attention, as a consequence, it is hard to verbalize it;

2) *abstract*: the implicit knowledge reflects not the superficial characters of stimuli, but the abstract regularity;

3) *uneasily disturbing and durable*: the implicit knowledge is independent from the way of learning and the level of information processing;

4) *long-term keeping*: the implicit knowledge can be kept for a long time, and its memory subsided slowly;

5) *cultural but not in individual differences*: this aspect is quite similar to ages, IQ, and mental health; and may represent the collective unconsciousness of a certain culture.

After knowing the general features of implicit tonal knowledge and Western tonal hierarchy, now we may turn to the question: what about Chinese listeners' tonal hierarchy or how do they organize their tonal knowledge? What is the difference between Chinese and Western tonal knowledge? This is the main purpose of this study.

Part III Aims & Hypotheses

In this study, the research aim is investigated through some sub-questions, which are specified in several hypotheses. In this chapter, the research aim is first discussed, and then the hypotheses are put forward.

16. Research aims

The aim of this study is to investigate the difference of tonal perception between Chinese listeners and German listeners, who grow up in different music cultures. Different music cultures form different tonal knowledge, either explicitly or implicitly. In Part I, the differences between tonality in Chinese music theory and Western music theory are analyzed. A kind of tonal knowledge corresponds to a certain music theory and affects listeners' tonal perception. Many perceptive and cognitive studies and cross-cultural studies mentioned in Part II support this idea, but few of them did experiments with Chinese listeners and Chinese music. So this study focuses on two main questions:

a) Whether Chinese listeners' and German listeners' tonal perception are consistent with their own music theory;

b) How listeners perceive tonality in their own way.

As discussed in Part II, tonal perception is a complex process, involving bottom-up and top-down processing. Listeners can "collect" statistical information from musical material, and can also establish the tonality as early as when they hear only four tones or four measures (Cohen, 1991). The former processing relates to the learning process and is relatively passive; while the latter processing refers to an active step of tonal "comprehension" – how listeners interpret tonal meaning of tones. In the next sections, the tonal "comprehension" and the process of interpreting tonal meaning will be discussed.

16.1 Tonal "comprehension"

This study is based on a precondition that listeners have tonal knowledge of their own music culture, whether they learn it explicitly or implicitly. When the tonal knowledge is formed in a certain musical environment, it is relatively stable. An occasional "foreign" musical piece cannot change or influence one's tonal knowledge, although statistical features of a melody may affect the tonal perception (e.g. Krumhansl, 2000; Saffran, et al. 1996, 1999). So in this study, statistical learning effect is avoided, and tonal perception is considered as an active processing in which listeners use their own tonal knowledge to "understand" music material, and unconsciously or consciously interpret the tonal meaning.

In tonal perception, tonal knowledge and musical material are objective aspects, while comprehended tonal meaning is a subjective aspect. The objective and subjective aspects mentioned here are similar to those mentioned in Huovinen's studies (2002). He (p.33) argued that:

> "*... 'objective' question of tonal perception concerning the average criteria of tonal stability employed by some reference population (such as 'Western listener'). ... a 'subjective' question concerning the individual criteria and mechanisms that are applied by different listeners.*"

One's tonal knowledge relates to a certain music culture, and contains tonal importance of scale degrees, which may be consistent with corresponding music theory – these two aspects are considered as objective aspects. Based on tonal knowledge, listeners give tonal "meaning" to the musical excerpt – this is considered as a subjective aspect. The three aspects affect responses in tonal perception. The figure below shows the idea of this proposal. There are three aspects which influence each other:

- individual criteria and cultural custom – as cultural background;
- objective aspect – a given musical context;
- subjective aspect – listeners' tonal "comprehension".

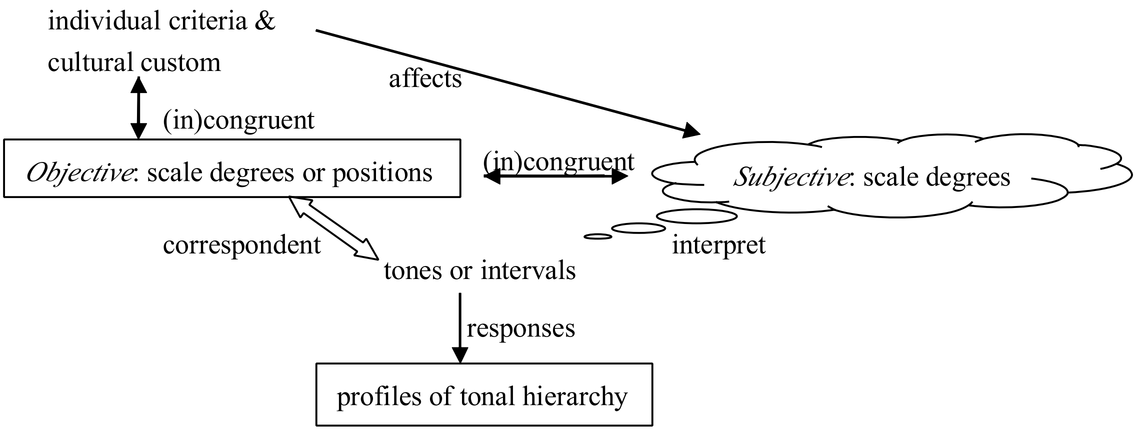


Figure 11 Subjective scale degrees assigned to tones or intervals

When individual criteria and cultural custom are congruent with the given musical context (objective), it means that listeners listen to the music from their native culture. Individual criteria and cultural custom affect one's tonal "comprehension" (subjective), and listeners may interpret the musical excerpt with a corresponding tonal meaning. The subjective tonal meaning is congruent with objective tonal features. Then the response will be consistent with the music theory in their culture.

When individual criteria and cultural custom are not congruent with the given musical context (objective), it means that listeners listen to the music from another culture. Individual criteria and cultural custom affect one's tonal "comprehension" (subjective). So, listeners may interpret their tonal meaning based on their own tonal knowledge, which is also different from the objective musical context. Then the response will be inconsistent with objective aspects, except for the common points in the two music cultures.

Therefore, this figure can be used to explain cross-cultural tonal perception. The congruence among three aspects is very important for the congruence between the response and the objective aspect; and the process of interpreting with subjective tonal meaning is a key step in the tonal perception. This study focuses on this step.

16.1.1 Subjective scale degree

Why can listeners establish the tonality sense early, as they hear only four tones or four measures? It is usually attributed to the fact that the starting tones are mostly the tonic and the dominant; and the “initial profile” – either theoretically or psychologically – presents that the V and I scale degrees are frequently used as the starting tone of a music piece in major (Huron, 2007, p.65). Such “statistical” experience has already become part of Western listeners’ tonal knowledge. However, there are always exceptions that some pieces of music do not start from the tonic or the dominant. The same phenomena exist also in Chinese music that music does not always start with the tonic or the dominant. This relates to two questions in tonal perception: how do listeners know from which scale degree the music starts? And how can listeners correctly interpret the starting tones with their subjective tonal meaning?

To be more precise, establishment of tonality depends on how listeners “comprehend” the starting tone subjectively. When a single tone is given, a subjective “scale degree” is assigned according to one’s tonal knowledge. A “scale degree” with higher rated or with more important tonal function in the tonal hierarchy would be easier assigned to the tone, as in the I (*do*) or V (*sol*) scale degree in major mode. When two successive tones are presented, the subjective “scale degrees” are assigned considering the balance between tonal functions and popularity of intervals. For instance, perfect fourth serves as a common interval that appears six times on six different scale degrees. When an ascending perfect fourth serves as a starting interval, it is usually perceived as if a perfect fourth ascends from the dominant to the tonic, other than ascends from the other five possible scale degrees. When three tones are presented, harmonic function takes a more important role in tonal perception of Western music, which has been verified in many studies. So this study focuses only on starting single tone and starting melodic interval.

16.1.2 Subjective tonal context

A subjective scale degree is assigned to a tone, meanwhile a subjective tonal context is formed; so does an interval. In other words, a single tone or an interval can activate a subjective tonal context. Whether the activated tonal context is stable or not, it depends on subjective tonal function of the starting tone or starting interval and popularity of intervals (common or rare intervals).

1) Tonal function and subjective tonal context

As for a single tone, with no context, it is difficult to tell to which key a single tone belongs, because it can be any scale degree in a major and minor key. Thus, there are seven possible majors and seven possible harmonic minors for each single tone (take pitch C as an example, see Table 4[26]).

Table 4 Pitch C and its possible keys

Tone C			
major	scale degree	harmonic minor	scale degree
C	I	a	III
G	IV	e	VI
F	V		
B^b	II	g	IV
E^b	VI	c	I
A^b	III	f	V
D^b	VII	b^b	II
		d^b	VII

When listeners interpret a tone with a subjective scale degree, this means that they have preference in some scale degrees or tonal contexts. According to Huron's study (2007, p.65), Western listeners prefer to take the first tone as a tonic or a dominant. When the coming context corresponds with the tonic or the dominant, the tonal sense is more stable. In other words, the processing of the latter context is promoted by the former tonal "comprehension". However, when the coming context does not correspond with the former subjective scale degree, the tonal sense would not be stable. In other words, the former tonal "comprehension" inhibits the processing of the latter context.

For Chinese listeners, there is no such study as reference. According to Chinese music theory, the IV (*fa*) and VII (*si*) scale degrees are less important, so it can be estimated that the two scale degrees are seldom assigned to a single tone. However, it is not easy to predict which tone in the pentatonics is frequently assigned to the single

[26] The keys are listed regarding the relatedness in the circle of fifths; the harmonic minor keys are listed corresponding to their relative majors in the same row. The scale degrees of C in these possible keys are shown in the series beside the key names. Totally, the pitch C could appear in seven majors and seven minors. That is, a pitch can be any scale degree in either major or minor.

tone, because each tone in the pentatonics can be the tonic. If considering mode distribution in traditional Chinese music, *Jue* (*mi*) can be the least one to be assigned because music in *Jue* mode is rare; *Shang* (*re*), *Zhi* (*sol*), *Yu* (*la*) and *Gong* (*do*) can be more frequently assigned.

Thus, Chinese listeners and Western listeners would have different preference or tendency on subjective scale degree.

2) Common vs. rare interval and subjective tonal context

In Western music theory, whether an interval is common or rare refers to two aspects: one is that it has high or low frequency in a scale; the other is that it is shared by more or fewer keys. Common intervals are more stable and with high frequency in a scale, e.g. perfect fifth, major third; while rare intervals are less stable and with low frequency in a scale, e.g. tritone. The table below shows the frequency of various intervals in major and harmonic minor modes, and the number of possible keys that an interval could appear. Intervals and their complementary intervals share the same set of pitches, but are only different from each other in ascending or descending directions. The number of interval and its complementary interval is the same. It is seen that the times of an interval appearing in a mode is equal to the number of its possible corresponding keys. For instance, the minor second appears twice in the major mode, and the minor second would have two possible major keys. Tritone is an exception. There is only one tritone in a major scale, but a tritone can be found in the most remote-related two keys (e.g. tritone F-B can be found in C major and F# major).

Table 5 Frequency of various intervals and the number of possible keys

	m 2nd	M 2nd	a 2nd	m 3rd	M 3rd	d 4th	p 4th	tritone
complementary	M 7th	m7th		M 6th	m 6th	a 5th	p 5th	
Frequency in major	2	5	0	4	3	0	6	1(2)
Frequency in harmonic minor	3	3	1	4	3	1	4	2
Possible major	2	5	0	4	3	0	6	2
Possible minor	3	3	1	4	3	1	4	2

(M=major, m=minor, a=augmented, d=diminished, p=perfect)

So, it seems that an interval with less frequency has clearer tonal sense. That is, a rare interval can arouse clear tonal sense, but a common interval may cause confusion of tonal sense. Tritone, as Butler and Brown argued, is the rare interval in major, so it is a useful tool for key finding. Considering tonal function, there is a conflict between stability and rarity of tritone. Tritone starts either on the IV or VII scale degree in major, which are less stable scale degrees. It can also be noticed that from scale degrees IV and VII, there are also common intervals. It is unknown, whether the common interval starting from a scale degree with more important tonal function is felt more stable than the one starting from a scale degree with less important tonal function. For instance, a perfect fourth on the V-I (*sol-do*) scale degrees may be felt more stable than a perfect fourth on the VII-III (*si-mi*), or VI-II (*la-re*) scale degrees. If so, the common intervals would not cause much tonal confusion.

The same as a single tone, subjective scale degrees of an interval can also facilitate the processing of the latter context, which corresponds with the former subjective scale degrees of an interval. Otherwise, the processing of the latter context would be inhibited.

In Chinese music theory, only two tones are missing from heptatonics, but 22 intervals are missing, and there is no tritone, minor second and major seventh (Liu, 2007). In Chinese pentatonics, major third is the rare interval; major second and minor third are relatively common, which form the "fourth frame" on *Shang* (*re*), *Zhi* (*sol*), and *Yu* (*la*) (Liu, 2007); perfect fourth (complementary interval: perfect fifth) is the common interval (see Table 6).

Table 6 Common and rare intervals in pentatonics

	m 2nd	M 2nd	m 3rd	M 3rd	p 4th	tritone
complementary	M 7th	m7th	M 6th	m 6th	p 5th	
Frequency in pentatonics	0	3	2	1	4	0

Thus, Chinese listeners and Western listeners may also have different preference or tendency on intervals and subjective scale degrees.

Based on the idea above, the difference between pre-context and post-context in the experiment is discussed below.

16.2 Pre-context vs. post-context

The Swiss linguist Ferdinand de Saussure (1986/1916, p.113) argued that "A language is a system in which all the elements fit together, and in which the value of any one element depends on the simultaneous coexistence of all the other". This statement is from a structuralism view which is also adaptable to music. In musical context, a single tone or an interval has little musical meaning other than sound. They can obtain musical sense in a context, in which presents the relationships among tones, intervals or chords. These musical elements constitute the tonal and harmonic hierarchy, and also make themselves meaningful in interaction with each other. Therefore, tonality establishment is influenced by preceding and coming musical events.

The probe-tone technique usually provides a context before a probe tone. In this circumstance, the evaluation of the probe tone is based on the preceding context. When the prior context is a sequence with a fixed number of tones, the evaluation of the probe tone or the production of a tonal center may be stable, although it may be ambiguous with cadence expectancy. The key profiles, obtained in this method, reflect the evaluation of tones in a fixed context. However, no active perceptive processing is reflected.

When the prior context is a changeable sequence with adding a tone at the end of the sequence every other time, the evaluation of probe tones can reflect a changing tonal perception in gradually varying contexts. In this condition, the change of key profiles is the result of incremental changes, either in chordal sequence (e.g. Krumhansl & Kessler, 1982) or in melody (e.g. Matsunaga & Abe, 2007). But the function of preceding tones is not mentioned; besides, the initiative perceptive processing is still unclear.

The paradigm with a preceding context cannot easily reveal how listeners comprehend tones. That is, this method can test what listeners' musical knowledge is like, but not so efficient in testing how listeners use the tonal knowledge. The process of listening to music is a process of musical knowledge application. So it would be difficult to explore the initiative perceptive processing when listeners are passive to the given context.

The priming paradigm provides a better solution for this problem. With this method, it is possible to limit the preceding context to a single chord – most experiments used chordal material, and to explore the contribution of preceding information to tonality establishment. The essential difference between the probe-tone technique and the priming paradigm is that they focus on different functions of the prior context. The former stresses a "closing" belonging to the pre-stimuli, and the prior context determines the evaluation of probe-tone; while the latter emphasizes an "opening" activation of the pre-stimuli, and interactive relations between stimuli are the determinant to evaluate the relations among chords and keys. Therefore, listeners, even non-musicians, are more active in the priming paradigm.

Based on these results, a connectionist model MUSACT was built, as introduced in the last chapter. There are three levels: tones, chords and keys. Bharucha et al. studied the relatedness between chords and keys, but little was mentioned about the relatedness between tones and two upper levels. A question proposed here is whether tones and intervals - that are basic elements of chords and keys - have the efficacy to activate tonalities, reflecting their positions in the hierarchy.

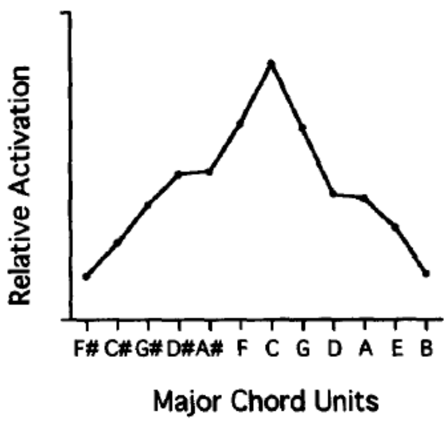


Figure 12 Relative activation of major chord units in the network following the presentation of a C major chord (Tekman & Bharucha, 1998, p. 255; Bharucha, 1987, p.20)

16.3 Musical culture background

Another research motivation is about the impact of musical culture background. There are two reasons: one is that in many tonality perception studies (not only in the priming tasks), musicians and non-musicians performed quite similar (e.g. Bharucha & Stoeckig, 1986, 1987; Bigand, Tillmann, Poulin D'Adamo & Madurell, 2001; Matsunaga & Abe, 2005; West & Fryer, 1990); the other reason is that in cross-cultural studies, listeners performed better in their traditional music and depended on their musical conventions (e.g. Castellanon, Bharucha & Krumhansl, 1984; Krumhansl, 2000; Curtis & Bharucha, 2009; Abe & Hoshino, 1990; Schellenberg, Bigand, Poulin-Charronnat, Garnier & Stevens). These results reflect that tonality knowledge can be accumulated along with musical experience, which comes with cultural features, on the one hand; and tonality knowledge for non-musicians, a kind of implicit knowledge that cannot be easily verbalized but can be perceived, on the other hand. So the influence of musical culture background on tonality perception is another issue to be focused on in this study.

In the comparison between Western and non-Western listeners perceiving non-Western music (Indian, Japanese, Finnish spiritual Folk hymn, North Sami yoiks), the native listeners performed significantly better than the Western listeners. However, native listeners may process musical information "bi-musically" (Abe & Hoshino, 1990), drifting between their own cultural tonal frame and Western tonal frame; while Western listeners may prefer to organize the non-Western music with their internalized cultural knowledge (Curtis & Bharucha, 2009). That is, Western listeners interpret non-Western music based on Western tonal hierarchy, and their musical expectancy is harmony-oriented. Therefore, it seems that listeners prefer to process musical information more or less regarding their internal tonal knowledge that is based on one's musical culture and experience.

Few studies dealt with non-Western listeners' tonal perception on Western music, which is widely spread throughout the world. However, the influence of musical culture cannot be ignored. This study involves Chinese participants, and tries to compare the difference between Chinese and Western listeners in tonality perception.

The main differences between Chinese music and Western music are in temperament, modes and melodic features. As harmonics may only affect tonal perception shortly in the very first time - about 50ms (Tekman & Bharucha, 1992), temperament difference would not be considered here. Chinese music is characterized by pentatonics in different modes. The missing IV (*fa*) and VII (*si*) in the scale are not totally avoided, but play a less important role in the tonality, mostly as passing tones; melodic feature is another aspect different from Western harmonic structure, minor third is more preferred instead of semitone anchoring. Then, how about "Chinese MUSACT", is it a two-layer model consisting of the pitch level and the key level, or is it a three-layer model with a "fourth frame" level connecting the pitch level and the key level? This hierarchy is explored in this study.

To summarize, this study takes the subjective scale degree as a starting point to investigate the processing of tonal perception. It is believed that the subjective scale degree is affected by one's musical culture background and reflects one's tonal knowledge. The processing of the post-presented musical material reflects the congruence between the correspondingly activated subjective tonal context and the objective tonal context. It is a way to find out the contribution of tonal function and interval type to tonal perception. This study also explores Chinese "MUSACT". There are two experiment series. Experiment series 1 focuses on the first two questions; and experiment series 2 examines the results from the former experiments and compares the cross-culture difference.

17. Hypotheses

The proposed hypotheses are based on the idea discussed in this chapter. This study is a cross-culture study, so the hypotheses are made for Chinese listeners and German listeners respectively.

17.1 Hypotheses for a single tone

It is supposed that a single tone is interpreted with a subjective scale degree, which corresponds to a subjective tonal context. Whether the subjective scale degree fits the objective scale degree influences the processing of objective musical context, there are three conditions:

a) When a single tone is interpreted as an important subjective scale degree (for instance V in major mode, based on Western music theory), and the tone is also on the same important objective scale degree in the given musical material, then the processing of the objective context is facilitated.

b) However, when a single tone is interpreted as a less important subjective scale degree (for instance IV in major, based on Western music theory), and the tone is also on the same less important objective scale degree in the given musical material, then the processing of the objective context is not facilitated as fast or accurately as the scale degree with more important tonal function.

c) When a single tone is interpreted as a subjective scale degree, but the tone is not on the same objective scale degree in the given musical material, then the processing of the objective context is inhibited.

Considering the difference of music cultures in Chinese music and Western music, the hypothesis is made as follows:

Hypothesis 1 (Chinese): Chinese listeners do not prefer interpreting a single tone with *fa* or *si*. They may prefer interpreting a single tone with *Shang* (*re*)*, Zhi* (*sol*)*, Yu* (*la*) or *Gong* (*do*). When these subjective scale degrees are the same as objective scale degrees, the processing of musical material would be much faster or more accurate.

Hypothesis 1 (German): German listeners prefer interpreting a single tone with dominant, tonic or mediant. That is, when these subjective scale degrees are the same as objective scale degrees, the processing of musical material is much faster or more accurate; while the other subjective degrees (II, IV, VI, VII) do not have such of an advantage.

17.2 Hypotheses for a successive interval

Only successive tritone and perfect fifth are involved in the experiment series 1; perfect fourth and minor second are added in the experiment series 2. Tritone is considered as a vital element in the theory of interval rivalry, because of its uniqueness in the major mode, but not in the minor mode. While perfect fifth is considered as the most stable and common interval in both major and minor modes. So the tritone is a low frequency interval, shared by two keys; but the perfect fifth is a high frequency interval, shared by several keys.

Hypothesis 2: it is hard to predict whether tritone or perfect fifth would facilitate tonal context processing.

Here are three reasons:

a) According to frequency of appearance or popularity. From the studies in psycholinguistics, the frequency of words - the used frequency of words in written language - is the most essential factor that affects perception of words (Zhu, 2000, p.406). Generally speaking, the word with high frequency can be recognized faster than the word with low frequency. In musical circumstances, perfect fifth - either in duration or in frequency of appearance - is more common than tritone. Thus, if only the frequency of appearance is taken into account, the response to perfect fifth would be faster and more accurate than the response to tritone.

b) According to shared keys. Perfect fifth has more possible keys than tritone has, but more choices of keys may slow down the speed of decision making. In this case, the response to tritone would be faster and more accurate than the response to perfect fifth, because fewer possible keys of tritone could lead to clearer tonal sense.

c) According to scale degree. It seems that the two points mentioned above are in conflict with each other, but also are prerequisite for each other. If both factors have effects on tonal perception, their effects would counteract in the processing, then scale degree would be an important factor for the response. Take the tonal hierarchy as a reference, it is assumed that perfect fifth starting from I (bidirectional), V (bidirectional), IV (ascending), and even II (descending) would show faster and more accurate responses than perfect fifth starting from other scale degrees; perfect fifth and tritone starting from IV, the response to perfect fifth would be faster and more accurate than the response to tritone, because the scale degrees of perfect fifth (IV-I) get a higher rating of tonal function than those of tritone (IV-VII) in the tonal hierarchy.

However, for perfect fifth, it can be hypothesized:

Hypothesis 3 (Chinese): Chinese listeners prefer interpreting the first tone of perfect fifth with *Shang* (*re*)*, Zhi* (*sol*)*, Yu* (*la*), because only these three scale degrees have both perfect fifth above and below. While the perfect fifth starting from *Gong* (*do*) and *Jue* (*mi*) do not have such advantage.

Hypothesis 3 (German): German listeners prefer interpreting the first tone of perfect fifth with tonic, dominant and subdominant, which imply harmonic tonal functions.

17.3 Ascending vs. descending

The order of tones is also a factor which influences the establishment of tonality sense (e.g. Deutsch & Feroe, 1981; Auhagen, 1994; Huovinen, 2002), but only in some conditions. It is difficult to make a clear hypothesis, but the directions would be compared in two conditions. In the first condition, it is going to compare the ascending and descending of intervals consisting of the same pitch classes (for example, II ascends to VI, and VI descends to II); the other condition is to compare the ascending and descending of intervals starting from the same scale degree (for example, II ascends to VI, and II descends to V). If there is an interaction between intervals' direction and starting scale degree, but no main effect of direction, it would illustrate that direction effect depends on the starting scale degree of an interval.

17.4 Incremental effect

The tonality identification would be derived or changed along with more musical information unfolded (e.g. Krumhansl & Kessler, 1982; Cohen, 1991; Matsunaga & Abe, 2007). Then the hypothesis of incremental effect is:

Hypothesis 4: the responses to intervals would be faster and more accurate than the responses to single tones.

17.5 Chinese "MUSACT"

As mentioned the differences between Western music and Chinese music, Chinese music is characterized with "fourth frame" and modes. There it is no chord level between the tone level and mode level. It is unknown whether the tone level connects the mode level directly or with a connection of the "fourth frame". This study explores whether the "fourth frame" is perceived as a stable structure by Chinese listeners. This will be helpful to construct Chinese "MUSACT" with cognitive data.

In this chapter, the research aims are proposed and discussed in different aspects; four hypotheses are put forward featuring their aims. In this study, the connectionist model is the foundation of research idea; the priming paradigm is the experimental method; the subjective perception of tones or intervals is the main issue to be focused on; and the application of musical culture knowledge is the basic perspective.

Part IV Experiment Series 1

This study is to investigate how subjective scale degree and subjective context affect the processing of an objective context. Huron (2007, p.65) asked listeners to report a scale degree of a given single tone, which resulted in that listeners did have a subjective scale degree for a tone. But the experiment did not verify the influence of a subjective context on the processing of latter musical material. This experiment series makes an attempt.

Here is a figure which shows the idea of this study: the degree of congruence between subjectively assigned scale degrees and objective context can influence the response. The degree of congruence refers to the tonal function of a given tone as an in-key degree in the post-context, and the similarity between the subjective context and the latter objective context. For instance, when a given tone is assigned as a tonic and it is coincidently the tonic in the latter context, this is considered as congruence between the subjectively assigned degree and the context. Such congruence would speed up the response, or enhance the accuracy of the response. However, when a given tone is assigned with a subdominant, and it is the tonic in the latter context, this is considered as incongruence between the subjectively assigned degree and the context. Such incongruence would slow down the response, or reduce the accuracy of the response.

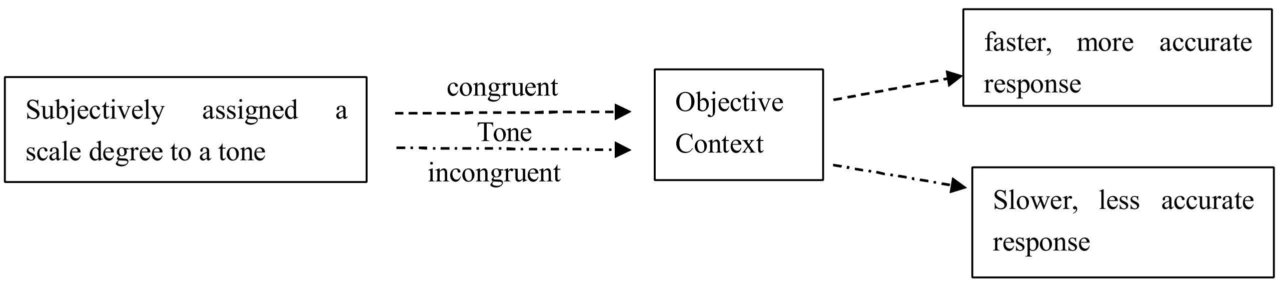


Figure 13 Idea of (in)congruence between subjectively assigned degree and objective context

Considering the subject factor, some studies illustrated that there was no difference between the performance of musicians and non-musicians in the tonal tasks, most of which were implicit tasks; while other studies verified that musicians could explicitly use the music theoretical knowledge in the tonal judgment, and their performances were better than that of non-musicians in a deeper way of processing musical information. Thus, there are two statements that can be confirmed. One is that both implicit task and explicit task can elicit musicians' tonal knowledge. Therefore, in the experiment series 1 including 3 experiment sets, only musical trained Chinese students are involved so that it is possible to see whether Chinese students have the similar key profiles to that of Western listeners. The other statement is that implicit task can elicit non-musicians tonal knowledge. Then, the experiment series 2 would compare Chinese and German participants' performances in a revised implicit task.

Experiment I & II & III

18. Method

As mentioned in the discussion of former studies, most of them showed a context (a scale or a short musical excerpt, etc.) first, with which the tonal perception has already been formed. In this study, the context would be presented after the "probe tone" in order to trace the process of forming the tonal perception. The priming paradigm was used. The methods in experiments I and III were the same – "stem-completion"-like task, which consisted of priming stimuli, and bi-modality (aural and visual) stimuli for associating with a tonal context. In the trial, the post-context was given indirectly, only showing a tone as the tonic with a color square. The bi-modality stimulus was used to trigger a certain tonal context, and allowed participants more freedom to imagine a corresponding tonal context, without limit to only an ascending or a descending scale learned in the training session, though they might be important clues for judgments. Thus, free completion of a tonal context might avoid the sequence effect (primary effect and recency effect). The method in experiment II used a clear tonal context – musical excerpts without color squares, which had a clearer tonal sense than a single tone with a color square. The function of musical excerpts was also to provide a tonal context or an interval to compare with the subjective tonal context. The task for participants was to report whether the priming tone(s) belonged to the post tonal context. The speed and the accuracy of the responses were recorded.

19. Design

19.1 Experiment I

Experiment I included two experiment sets: the major trial set and the minor trial set. Each experiment set was a within-group design 7 (scale degrees) × 3 (pitch-classes); participants were between-group factors (playing Western instruments or playing Chinese instruments and folk songs).

Each participant listened to the two trial sets including 21 trials in major mode and 21 trials in minor mode, and other 4 out-of-key trials in each set. Each subject should make judgments on a total of 50 trials. They all did the major trials first and then did the minor trials. But the orders of the trials in the two sets were random.

19.2 Experiment II

Experiment II included 21 in-key trials with either major or minor excerpts, and 4 out-of-key trials for controlling listeners' speculation. The trials were randomly shown. The within-group factor was scale degree, while the factors of mode and pitch-classes were not well controlled. Playing Western instruments or Chinese instruments was a between-group factor.

19.3 Experiment III

Experiment III was also divided into two trial sets: the perfect fifth trial set and the tritone trial set. As for the perfect fifth set, it was a within-group design 6 (scale degrees) × 2 (direction) for major mode, and 4 (scale degrees) × 2 (direction) factorial design for minor mode, participants were between group factors. As for the tritone set, only direction was considered for major mode, and 3 (scale degree) × 2 (direction) factorial design for minor mode, participants were between group factors.

Each participant listened to 12 trials in the major and 8 trials in the minor, a total of 20 trials in the perfect fifth set; and 2 trials in the major, and 6 trials in the minor, in the tritone set. Totally, each participant should make judgments on 26 trials.

Participants all did the perfect fifth trials first and then did the tritone trials. But the order of the trials in the two sets was random.

20. Stimuli

20.1 Training and pre-test

Before the experiments, there was a training session for participants to build association between the color squares and modes: orange was for major mode, and purple was for minor mode; the major or minor scale either ascended or descended. The association between color and tonal context is based on aesthetic feelings. Major feels usually bright, so here a warm color orange is chosen; while minor feels usually dull, so here a cold color purple is chosen. The color square was shown on the computer screen along with the corresponding scale. The length of priming tone was 250ms; and the duration between the prime tone and the scale was 250ms. The tempo of the scales sequences was set in 120bpm with sixteenth notes, so each tone was 125ms, a total of 1000ms. All the sounds were in the piano timbre.

After learning the associations, there was a matching task to make sure that the participants could correctly respond to a certain color square with a certain mode. The procedure of each trial was similar to the procedure of trials in the experiment. The priming tone came first, and then followed the post-context, which consisted of a color square and a musical context, either a scale or a musical excerpt. Participants were asked to respond on whether the color square matched the musical context.

20.2 Experiment I

The stimuli used in the first experiment set consisted of a priming tone and a target bi-modality stimulus in aural and visual domain. The priming tone could be any pitch-class from the twelve chromatic tones in an octave. The post-context could be either a major or minor context determined by the color of the square – the orange stood for major, or the purple stood for minor – with a given tone. According to the color square, participants were asked to associate a corresponding tonal context with the given tonic, so the context was associated, but not referred to a concrete given scale. For instance, a purple square with a pitch-class D, then listeners could associate a "D minor scale" or a "D minor triad".

The priming tone and the "tonic" in the post-context were in one octave. The priming tone could be either in-key tone or out-of-key tone of the post-context, but only a few out-of-key tones were involved to control listeners' speculation. For in-key tones, three tones were randomly chosen from twelve chromatic tones for each scales degree. That is, a scale degree was tested with three pitch-classes.

The length of each priming tone was 250ms; and the length of post-context's tonic with a color square was 500ms. There was a 500ms silence between the two stimuli to separate two pitches apart and to avoid eliciting the sense of the interval between the two sounds. That is, the aim of the 500ms interstimulus intervals (ISI) was to lead listeners to perceive the prime tone as a unit and the post-context as another unit, so that the "implicit" interval between the prime tone and the "tonic" in post-context was limited. Since there was no significant difference of priming effect between SOA (stimulus onset asynchrony) from 111ms (at shortest) to 2500ms (at longest), and priming effect was independent from disturbance (silence or white noise, Tekman & Bharucha, 1992) for activating cognitive level, each probe tone was presented for 250ms, followed with 500ms silence. Thus, SOA in this experiment series was 750ms.

All the sounds were artificial. The sounds were in piano timbre, generated by Sibelius 5 as MIDI files, and then transferred into WAV files for the experiments programming by software Presentation 0.71.

The materials used in the trial set are listed in the following tables.

Table 7 Matches of priming tone and context with tonic

a. Matches of priming tone and context - major trial set

prime	B	B^b	$C^\#$	E	$G^\#$	$F^\#$	$D^\#$	G	F	D	$G^\#$	A
context	B	B^b	$C^\#$	A	$C^\#$	B	B^b	D	C	B^b	E	F
degree*	I	I	I	V	V	V	IV	IV	IV	III	III	III
prime	A	D	$D^\#$	$F^\#$	B^b	C	B	E	$C^\#$			
context	G	C	$C^\#$	A	$C^\#$	E^b	C	F	D			
degree*	II	II	II	VI	VI	VI	VII	VII	VII			

prime	$F^\#$	$F^\#$	$F^\#$	$F^\#$
mis-context	C	B^b	E^b	F

b. Matches of priming tone and context - minor trial set

prime	B	B^b	$C^\#$	E	$G^\#$	$F^\#$	$D^\#$	G	F	D	A^b	A
context	B	b^b	$c^\#$	a	$c^\#$	b	b^b	d	c	b	f	$f^\#$
degree*	I	I	I	V	V	V	IV	IV	IV	III	III	III
prime	A	D	$D^\#$	$F^\#$	B^b	C	B	E	$C^\#$			
context	g	c	$c^\#$	$a^\#$	d	e	c	f	d			
degree*	II	II	II	VI	VI	VI	VII	VII	VII			

prime	$F^\#$	$F^\#$	$F^\#$	$F^\#$
mis-context	c	a	d	f

(Capitals stand for the tonics of major modes; small letters stand for the tonics of minor modes)

20.3 Experiment III

The method of experiment III was the same as experiment I, only the priming single tone was changed into a priming successive interval. The stimuli used in the third experiment set were priming intervals and target contexts, which was a tonic with a color square. The intervals and the "tonic" tones were in piano timbre, generated by Sibelius 5 as MIDI files and then transferred into WAV files.

The priming intervals involved the perfect fifth and the tritone in both ascending and descending directions. A perfect fifth is shared by six majors and four minors. Only the perfect fifth G-D (ascending) and D-G (descending) were used as the priming interval, and the tonic of six majors and four minors were presented to be associated with corresponding contexts. The tritone is shared by two majors and four minors. Only the tritone F-H (ascending) and H-F (descending) was used as the priming interval, and the tonic of one major and three minors were presented to be associated with corresponding contexts. The priming intervals were all in-key intervals, and no out-of-key intervals were involved.

The length of the prime interval was 250ms, and 125ms for each component tone; the length of target context's tonic with a color square was 500ms. There was a 1000ms silence between the prime interval and the post-context. Thus, SOA in this experiment was 1250ms.

These files were programmed by software Presentation 0.71.

Table 8 Experiment III - perfect fifth trial set

prime	G-D (ascending)									
context	G	F	E^b	D	C	B^b	d	c	b	g
Starting degree*	I	II	III	IV	V	VI	IV	V	VI	I
prime	D-G (descending)									
context	G	F	E^b	D	C	B^b	d	c	b	g
Ending degree+	I	II	III	IV	V	VI	IV	V	VI	I

Table 9 Experiment III - tritone trial set

prime	F-H (ascending)			
context	C	a	c	$d^{\#}$
degree*	IV	VI	IV	II
prime	H-F (descending)			
context	C	a	c	$d^{\#}$
degree+	IV	VI	IV	II

* scale degree of the starting tone of the interval in the context

+ scale degree of the ending tone of the interval in the context

20.4 Experiment II

The method of experiment II was not quite the same as experiment I and III. The priming tones were the same as the ones in the Experiment I, generated by Sibelius 5 as MIDI files and then transferred into WAV files. While the bi-modality contexts were changed into uni-modality stimuli – musical excerpts with no color square, which could provide clearer tonal sense. Musical excerpts were classical piano pieces by Bach, Haydn, Mozart, Beethoven, Schubert and Chopin, selected from commercial CDs (see Appendix 3).

The priming tone could be any pitch-class in the twelve chromatic tones in an octave. The post-context could be either a major or minor musical excerpt (11 in major and 10 in minor). The priming tone could be either an in-key tone or out-of-key tone to the post-context, but only a few out-of-key tones were involved to control listeners' speculation. For in-key tones, 3 tones were randomly chosen from twelve chromatic tones for each scale degree, but the number of major and minor trials on each scale degree was unequal.

Table 10   Matches of priming tone and context with musical excerpt

prime	B	B^b	$C^{\#}$	E	$G^{\#}$	$F^{\#}$	$D^{\#}$	G	F	D	G	$G^{\#}$
context	B	B^b	$c^{\#}$	a	$C^{\#}$	B	b^b	D	c	B^b	e	f
degree*	I	I	I	V	V	V	IV	IV	IV	III	III	III
prime	A	D	$D^{\#}$	F	B^b	C	B	E	$C^{\#}$			
context	G	C	$c^{\#}$	a	$C^{\#}$	E^b	c	F	d			
degree*	II	II	II	VI	VI	VI	VII	VII	VII			

prime	$F^{\#}$	$F^{\#}$	$F^{\#}$	$F^{\#}$
mis-context	c	B^b	d	F

(Capitals stand for major modes; small letters stand for minor modes)

The length of each prime tone was 250ms; the length of the excerpts depended on the length of musical motive in 3-10s. There was a 1000ms silence between the two stimuli. Thus, SOA in this experiment was 1250ms.

These files were programmed by software Presentation 0.71.

Here lists the musical excerpts used as target-context:

Table 11   List of musical excerpts

Major	Minor
Mozart - Sonate C major K.Nr.545	Mozart - Sonate a minor K. Nr. 310
Bach - Prelude $C^{\#}$ major BWV 848	Chopin - Nocturne b^b minor Op.9 No.1
Mozart - Sonate D major K.Nr. 576	Chopin - Waltz b minor Op.69 No.2
Mozart - Sonate E^b major K. Nr. 282	Beethoven - Sonate c minor No.8 Pathetique
Mozart - Sonate F major K. Nr. 533	Chopin - Waltz $c^{\#}$ minor Op.64 No.2
Mozart - Sonate G major K. Nr. 283	Mozart - Fantasia d minor K. Nr. 397
Mozart - Sonate A major K. Nr. 331	Haydn - Sonata e minor Nr. 53
Mozart - Variationen B^b major K. Nr. 500	Schubert - Moments musicaux f minor D 780, Opus 94, No.3
Bach - Prelude B major BWV 868	

(The notes of music excerpts are listed in the Appendix 4)

21. Procedure

At first, participants were asked to fill out a form about their individual information, including name, age, years of musical training, major, playing instrument, musical preference, absolute or relative musical sense, and whether they have music theory knowledge.

21.1 Training and pretest

Participants were asked to do the training session to learn the relation between the color squares and the two modes. After that, they did pre-test to check whether they could respond correctly to a certain color square with a certain mode. This session helped participants to get familiar with the process of the experiments. When the accuracy of their responses in the pretest got to 90% of the 20 color squares, participants could start with the experiment trials.

21.2 Experiments

The experiments began 3 minutes after the pretest. Participants were instructed to take the latter tone as the tonic and to associate the corresponding mode which was indicated by the color square. The strategy of association should not be limited to the learned scale; any clues related to a certain mode could be acceptable. Thus, it is similar to the "stem-completion" task with words. For example, if the priming single tone is C, and the following context is orange square with G, then participants should take G as the tonic and imagine G major (either ascending or descending scale or such a tonal context). As C belongs to G major, the response should be "Yes". When a musical excerpt is given, participants should make judgment on whether the tone belongs to the tonal context or not.

All the participants did the three experiments from experiment I to experiment II, and finished with experiment III. Experiment I involved a major set and a minor set, each has 21 trials; experiment II included 21 trials; and experiment III involved a perfect fifth set (20 trials) and a tritone set (6 trials). So, there were a total of 89 trials, and only trials in each experiment set were randomly shown. The sequence of experiment series 1 is shown in Figure 14b.

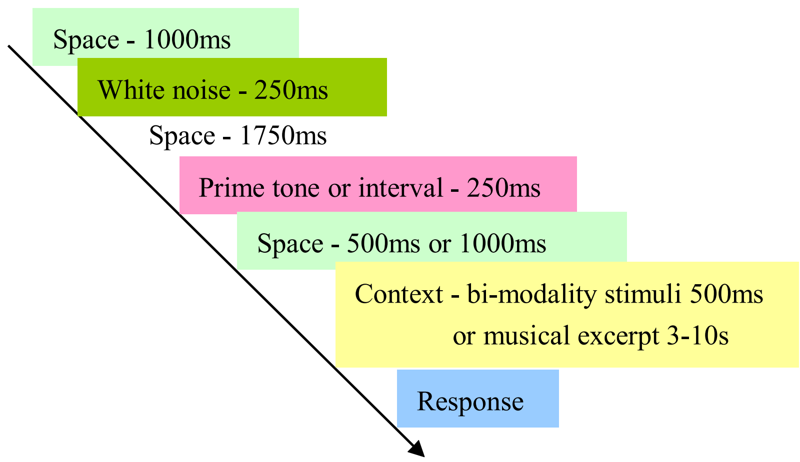
For trials, all the priming tones lasted 250ms; the ISI in experiment I lasted 500ms, while in experiment II and III lasted 1000ms; the indirect post-context (a color square with a tone) lasted 500ms, while the direct post-context (musical excerpt) depended on the length of the musical phrase. Every next trial began after the response to one trial, so the intervals between two trials were not equal, but depended on participants' response time. A 250ms white noise was inserted between every two trials to eliminate the impression of the former trial.

Participants were asked to respond as quickly and accurately as they could, and to make the decision on whether the preceding tone appeared in the post context by pressing keys: yes, no or not sure. To avoid participants spending more time on thinking of theoretical issues, which evoked more semantic processing with less perceptual processing, the instruction was modified as whether the preceding tone appears in the post-context, instead of asking whether the former stimulus belongs to the post-context.

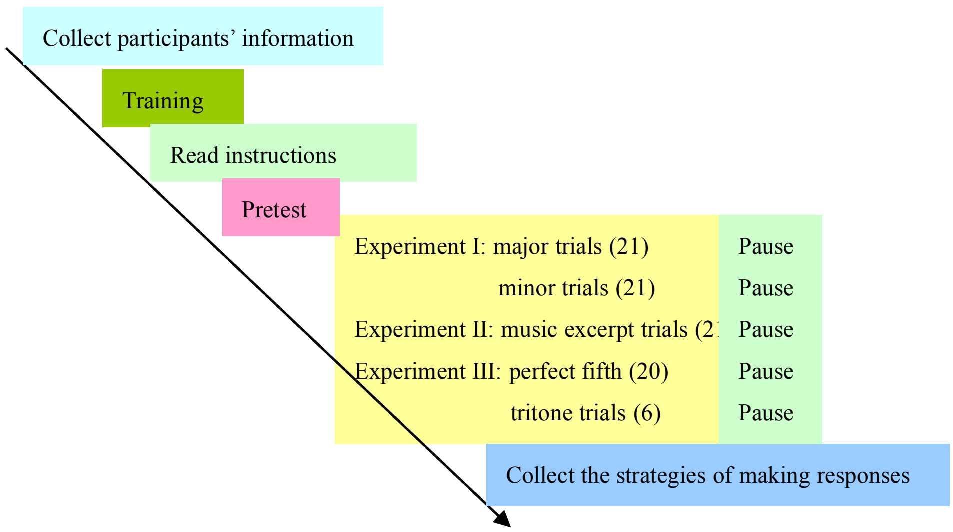
The procedure of each trial is presented as the following Figure 14a.

Trials in experiment II and III were the same as the ones in experiment I, only the ISI was extended to 1000ms. In experiment II, participants were asked to respond after the musical motive ended.

After the experiments, listeners were asked to describe the strategy of their response making. Finally, participants obtained a small gift for their participation in the experiment. The duration of the whole experiment was about 45-90mins, depending on participants' response time. The experiment series 1 was done with Chinese participants during December 2008.



a. Procedure of a trial



b. Procedure of experiment series 1

Figure 14 Procedure of experiment series 1

22. Participants

Participants included 4 undergraduate students and 9 graduate students from the College of Music, Capital Normal University (Beijing, China), and a doctoral student from Beijing Normal University (Beijing, China).

8 of them were female and 6 of them were male. The average age was 25 years old (mean age = 25.23).

As to musical training or musical experience, all of them studied instruments and vocal for at least 7 years, five of them studied for more than 15 years. Four of them played traditional Chinese instruments: er hu (two-stringed fiddle), guqin (seven-stringed zither), guzheng (13-26 stringed zither with movable bridges) and pipa (4-5 stringed with fretted fingerboard); two of them studied Chinese folk singing; and the others played Western instruments: piano, clarinet, guitar or jazz drum. All of them have studied both Western music theory and Chinese music theory.

According to their self-report, six of them had relative pitch sense, three of them had absolute pitch sense, and the other five said that they had both pitch senses. However, absolute pitch sense was not tested.

Furthermore, musical preference was also different among them. Two Chinese instrumentalists, one Western instrumentalist and one Chinese folk singer were fond of Chinese music; one Chinese instrumentalist and six Western instrumentalists were fond of Chinese music; the others liked both. Generally speaking, the musical preference was influenced by the instrument they were playing.

Table 12 Participants' information

gender		instruments & vocal		Western & Chinese		absolute pitch sense		
female	male	instr.	vocal	W.	Ch.(vocal)	AP	non-AP	both
8	6	12	2	8	6	3	6	5

As discussed in the last part, participants were divided into two groups, a Western group and a Chinese group, according to their instruments and vocal styles. Chinese instrumentalists and folksingers were considered to be with less-Western music background – learning less-Western music in a non-Western country, they were quite familiar with Chinese music through playing and singing; and Western instrumentalists were considered to be with a quasi-Western music background, they were quite familiar with Western music through playing, though learning Western music in a non-Western country.

Though pitch sense was less mentioned, it could be considered as a factor to see whether pitch sense affected tonal perception or not.

Results

This section shows the findings of the experiment series 1. The results include the analysis of the main effects of scale degrees, modes, instrument or pitch sense, interactions among these factors, and it is also compared the difference between responses of trials with priming single tone and with priming interval, etc.

23. Pretest

Each participant, after learning the relation between the two color squares (orange and purple) and the two modes (major and minor) in the training session, was tested with the matching tasks. All of them got accuracy over 90% in the pretest, but their response time was not recorded. Such high accuracy indicated that the bi-modality association was easy to learn in the exercise phase, which provided concrete scales.

24. Experiment I

24.1 Major set

24.1.1 Percentage of accuracy of each subject

There were 14 participants in total and 13 of which responded above chance (here 50% was taken as chance level), and only one of them was below chance (Table 13). So the data of the 13 participants were taken in the analysis.

Table 13 Percentage of accuracy of each subject

S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
84%	76%	60%	88%	92%	60%	70%	64%	*45.5%*	87.5%	80%	52%	72%	64.7%

24.1.2 Percentage of error and response time in each trial

The percentage of errors (PE) on each scale degree was analyzed, and the number of unsure responses was collected; but only the response time (or reaction time, RT) of correct responses was involved in the analysis of response time, excluding the reaction time which was greater than three standard deviations from the mean of each scale degree.

Table 14 shows the percentage of errors and the average reaction time of correct responses on each pitch-class (only in-key trials are involved). The results showed that when the priming tone had the function of tonic (I), supertonic (II) or submediant (VI) in the post-context, participants did not make “not sure” response; when the priming tone had the function of mediant (III), dominant (V) or leading tone (VII) in the post-context, participants were not quite sure to make judgment (1 or 2 “not sure” responses); when the priming tone had the function of subdominant (IV) in the post-context, there were 4 “not sure” responses. Comparing the responses to three random selected three pitch-classes for each scale degree, there was no significant difference among the response time of three pitch-classes of each scale degree ($p>0.5$).

Table 14 RT (reaction time) and PE (percentage of errors) on pitch-classes

S	P	average RT (0.1ms)	PE(%)	not sure	F	Sig.
I	B	24322	0	0	0.470	0.629
	B^b	17239	0	0		
	$C^\#$	24634	18.18%	0		
II	A	39183	18.18%	0	0.174	0.841
	D	35319	36.36%	0		
	$D^\#$	42947	27.27%	0		
III	D	79361	50.00%	1	2.889	0.082
	$G^\#$	48519	18.18%	1		
	A	35948	18.18%	0		
IV	$D^\#$	77259	27.27%	1	1.000	0.383
	G	45313	9.09%	2		
	F	55835	18.18%	1		
V	E	55229	30.00%	0	0.275	0.761
	$G^\#$	67595	0	1		
	$F^\#$	54039	20.00%	0		
VI	$F^\#$	57775	36.36%	0	0.271	0.765
	B^b	46771	10.00%	0		
	C	60074	30.00%	0		
VII	B	50063	50.00%	0	0.150	0.862
	E	52800	27.27%	0		
	$C^\#$	45043	27.27%	1		

(S=scale degree of the priming tone in the latter context (objective context); P=pitch-class of the priming tone; RT=response time or reaction time; PE=percentage of error; not sure=uncertain response)

Table 15 shows the percentage of errors, and the average reaction time of correct responses of each scale degree. The percentage of false responses was fewer when the priming tone had the function of tonic (I), and only one error was made; few errors were made when the priming tone had the function of dominant (V), subdominant (IV) or supertonic (II); when the priming tone had the function of other scale degrees mediant (III), submediant (VI) or leading tone (VII), false responses were increased.

Table 15 RT (reaction time) and PE (percentage of errors) on scale degrees

	I	II	III	IV	V	VI	VII
RT(M, SD, 0.1ms)	24013 (23677)	38773 (25701)	47809 (33740)	54731 (41193)	58684 (44870)	55430 (36104)	49093 (28571)
PE	2.56%	18.92%	35.29%	14.71%	13.51%	35.90%	35.14%

However, the profile of the response time was quite different from the profile of error percentage. The profile of the reaction time was like a bow. The priming tone as tonic in the post-context showed the fastest response, while the priming tone as subdominant showed the slowest response. Besides, the degrees in the middle of the scale responded slower, but the degrees at the edge of the scale responded faster. The sequence of scale degrees from the fastest to the slowest is I, II, III, VII, VI, IV, V (see Figure 15). The correlation between K-K major profile (Krumhansl, 1990, p.30) and the profile of RT in this study was not significant (r=-0.475, p>0.05); however, there was a significant high negative correlation between K-K major profile and the profile of PE (r=-0.753, p<0.05).

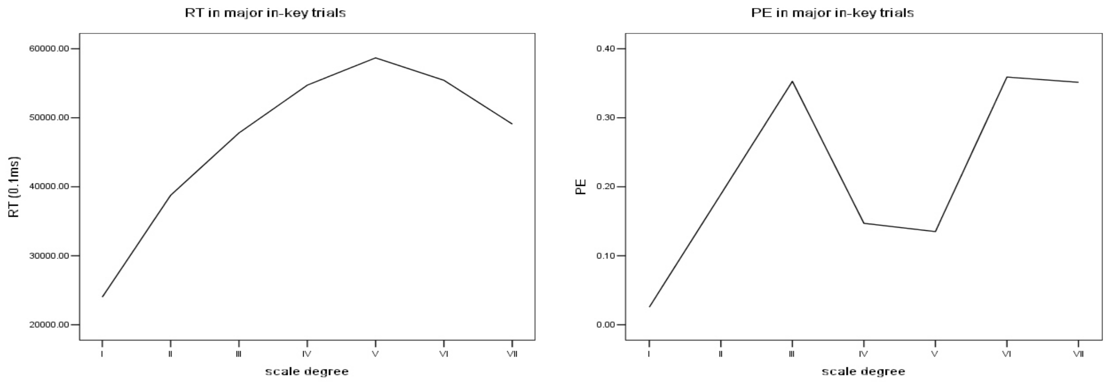


Figure 15 RT and PE profiles of major in-key trials in experiment I

24.1.3 Univariate analysis of variance

The response time was further analyzed by univariate analysis of variance. Taking pitch-class as a nested factor of scale degree, the difference among responses to different "probable" scale degrees were significant (F(6,194)=4.121, p<0.01). Further differences between every two scale degrees were analyzed by the least-significance-difference method (LSD). The response to the "probable" tonic was significantly faster than the responses to other five scale degrees (III, p<0.05; IV, V, VI, VII, p<0.01), and the response to the "probable" supertonic was significantly faster than the response to the "probable" dominant (p<0.05). There was no other significant difference of response time among other degrees (see Table 16).

Table 16 Significant differences between scale degrees

(I) degree	(J) degree	Mean Difference (I-J)	Std. Error	Sig.
I	III	-23796.123(*)	9341.526	.012
	IV	-30718.784(**)	8755.868	.001
	V	-34671.830(**)	8265.507	.000
	VI	-31417.001(**)	8856.966	.000
	VII	-25080.278(**)	8965.201	.006
II	V	-19911.369(*)	8645.727	.022

However, when taking subject factors (playing instrument and possessing pitch sense) into account, there were neither significant main effects of scale degree [$F(6,194)=1.696$, $p>0.05$], pitch-class (as nested factor of scale degree, $F(14,194)$]=1.571, $p>0.05$), instrument [$F(1,194)=1.230$, $p>0.05$], nor significant interaction effect between scale degree and subject factors ($p>0.05$). There was a significant main effect of pitch sense – according to their self-report [$F(2,194)=3.951$, $p<0.05$, see Table 17]: participants, who reported that they possessed absolute pitch sense, responded significantly faster than other participants who reported that they possessed relative pitch sense or had both pitch senses; but there was no significant difference between the latter two groups. Besides, there was also a significant interaction between instrument playing and pitch sense [$F(2,194)=6.776$, $p<0.02$, see Figure 16]: participants playing Western instruments and possessing RP responded a little bit faster than those with AP, while those possessing both AP and RP responded quite slowly than the former two groups; participants playing Chinese instruments or singing Chinese folk songs and possessing AP responded much faster than those with RP, and participants possessing both AP and RP responded at the "middle" speed between AP possessors and RP possessors.

Table 17 Significant main effect of pitch sense

participants	RT (M, SD, 0.1ms)
AP	32919.36(18609.21)
RP	46917.86(34027.84)
AP & RP	52289.90(42221.46)

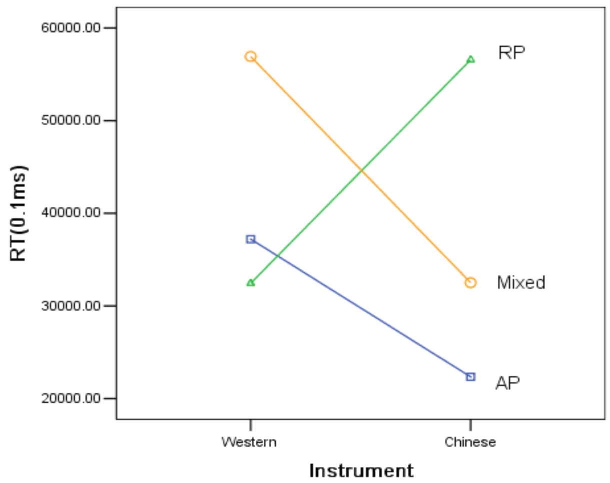


Figure 16 Significant interaction between instrument and pitch sense in major

24.2 Minor set

24.2.1 Percentage of accuracy of each subject

Among 14 participants, 11 of them responded above chance (here 50% was taken as chance level), and 3 of them were below chance (Table 18). So only the data of 11 participants were taken in the analysis.

Table 18 Percentage of accuracy of each subject

S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
76%	79%	*47%*	84%	88%	*16%*	57%	74%	58%	78%	76%	72%	72%	*43%*

24.2.2 Percentage of error and response time in each trial

The percentage of errors (PE) on each scale degree was analyzed, and the number of unsure responses was collected; but only the response time (or reaction time, RT) of correct responses was involved in the analysis of response time, excluding the reaction time which was greater than three standard deviations from the mean of each scale degree.

Table 19 shows the percentage of errors and the average reaction time of correct responses on each pitch-class (only in-key trials are involved). The results showed that when the priming tone had the function of tonic (I), supertonic (II), mediant (III) or submediant (VI) in the post-context, participants did not make “not sure” response; when the priming tone had the function of dominant (V), submediant (VI) or leading tone (VII) in the post-context, there was one "not sure" response to each scale degree. Comparing the responses to three random selected three pitch-classes for each scale degree, there was no significant difference among the response time of three pitch-classes of each scale degree (p>0.5).

Table 19 RT (reaction time) and PE (percentage of errors) on pitch-classes

S	P	average RT (0.1ms)	PE(%)	not sure	F	Sig.
I	B	13603	7.69%	0	0.011	0.989
	B^b	13193	0	0		
	$C^\#$	13501	0	0		
II	A	34000	0	0	1.185	0.326
	D	34221	16.67%	0		
	$D^\#$	56175	41.67%	0		
III	D	66978	54.55%	0	0.075	0.928
	$G^\#$	80308	40.00%	0		
	A	85014	15.38%	0		
IV	$D^\#$	72998	25.00%	0	0.489	0.619
	G	52609	10.00%	0		
	F	72109	8.33%	0		
V	E	45603	15.38%	0	0.709	0.503
	$G^\#$	57089	9.09%	0		
	$F^\#$	98567	15.38%	1		
VI	$F^\#$	84805	23.08%	0	0.237	0.791
	B^b	95870	46.15%	0		
	C	70295	38.46%	1		
VII	B	37235	46.15%	1	0.123	0.885
	E	43964	33.33%	0		
	$C^\#$	39077	25.00%	0		

(S=scale degree of the priming tone in the latter context (objective context); P=pitch-class of the priming tone; RT=response time or reaction time; PE=percentage of error; not sure=uncertain response)

Table 20 shows the percentage of errors and the average reaction time of correct responses on each scale degree. The percentage of false responses was fewer when the priming tone had the function of tonic (I), only two errors were made; few errors were made when the priming tone was considered as dominant (V), or subdominant (IV); when the priming tone had the function of other scale degree submediant (VI), supertonic (II), mediant (III), and leading tone (VII), the false responses were increased (see Figure 17).

Table 20 RT (reaction time) and PE (percentage of errors) on scale degrees

	I	II	III	IV	V	VI	VII
RT(M, SD, 0.1ms)	13435 (6367)	40816 (42403)	79151 (80316)	65150 (49581)	66759 (91892)	84719 (71134)	40500 (40500)
PE	6.06%	27.27%	28.13%	18.18%	16.13%	25.81%	34.38%

The profile of reaction time was not quite similar to the profile of percentage of errors. Though minor's profile of RT is not bow-shaped as major's, the degrees at the edge of the scale showed faster response, especially when the priming tone had the function of tonic in the post-context, then supertonic and leading-tone follow behind; the degrees in the middle of the scale also showed slower response, among which mediant and submediant showed much slower responses than subdominant and dominant. The correlation between K-K minor profile (Krumhansl, 1990, p.30) and the profile of RT in this study was not significant (r=-0.281, p>0.05); there was also no significant correlation between K-K major profile and the profile of PE (r=-0.685, p>0.05).

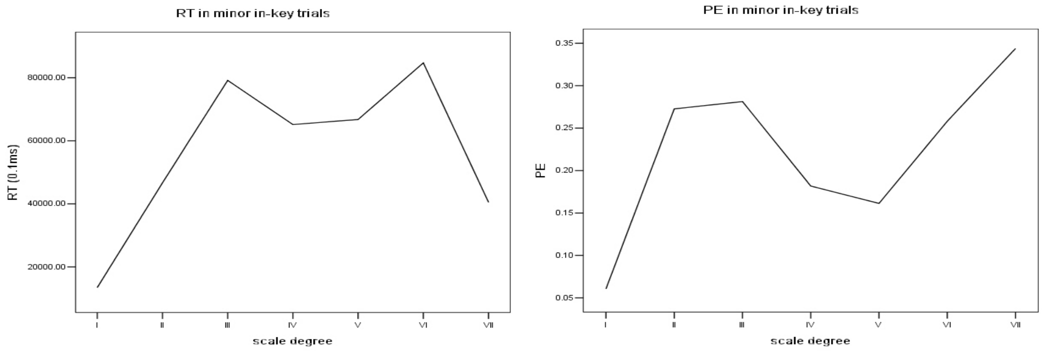


Figure 17 RT and PE profiles of minor in-key trials in experiment I

24.2.3 Univariate analysis of variance

The data were further analyzed by univariate analysis of variance. Taking pitch-class as a nested factor of scale degree, the difference among responses to different "probable" scale degrees was significant [$F(6,172)=4.671$, $p<0.01$]. Further differences between every two scale degrees were analyzed by the least-significance-difference method (LSD). The response to the "probable" tonic was significantly faster than the responses to other five scale degrees (II, p<0.05; III, IV, V, VI, p<0.01), the response to the "probable" supertonic was significantly faster than the response to the "probable" subdominant (p<0.05); besides, the response to the "probable" leading tone was significantly faster than the response to the "probable" mediant and submediant (p<0.05). There was no other significant difference of response time among other degrees (see Table 21).

Table 21 Significant differences between scale degrees

(I) degree	(J) degree	Mean Difference (I-J)	Std. Error.	Sig.
I	II	-33241.100(*)	16099.16	.041
	III	-65715.886(**)	16725.82	.000
	IV	-51714.563(**)	15594.35	.001
	V	-53323.638(**)	15751.40	.001
	VI	-71283.513(**)	16292.43	.000
II	VI	-38042.413(*)	17153.47	.028
III	VII	38651.000(*)	18141.69	.035
VI	VII	44218.6273(*)	17742.93	.014

However, when taking subject factors (playing instrument and pitch sense) into account, there was no significant main effect of pitch-class [as nested factor of scale degree, $F(14,172)=0.759$, $p>0.05$], and no significant interaction between scale degree and subject factors ($p>0.05$). There were significant main effects of scale degree [$F(6,172)=3.077696$, $p<0.01$], instrument [$F(1,172)=5.179$, $p<0.05$]: participants playing Western instrument responded slower than participants playing Chinese instrument or singing Chinese folk songs; and a significant main effect of pitch sense [$F(2,172)=3.572$, $p<0.05$]: participants who reported they possessed absolute pitch sense responded significantly faster than other participants who reported they possessed relative pitch sense or have both pitch senses ($p<0.01$); but there was no significant difference between the latter two groups ($p>0.05$). Besides, there was also a significant interaction between instrument playing and pitch sense [$F(2,172)=5.525$, $p<0.01$, see Figure 18]: participants playing Western instruments and possessing AP responded faster than those who possessed RP, while those possessing both AP and RP responded quite slowly than the former two groups; participants playing Chinese instruments or singing Chinese folk songs and possessing AP or both AP and RP responded much faster than those RP possessors.

Table 22 Significant differences in instruments and pitch senses

Instrument (*)	RT (M, SD, 0.1ms)	Pitch sense (*)	RT (M, SD, 0.1ms)
Western	62541.45(71037.50)	AP (**)	27844.61(16331.06)
Chinese	45946.26(48798.57)	RP	59796.98(51884.92)
		AP & RP	67000.79(81038.41)

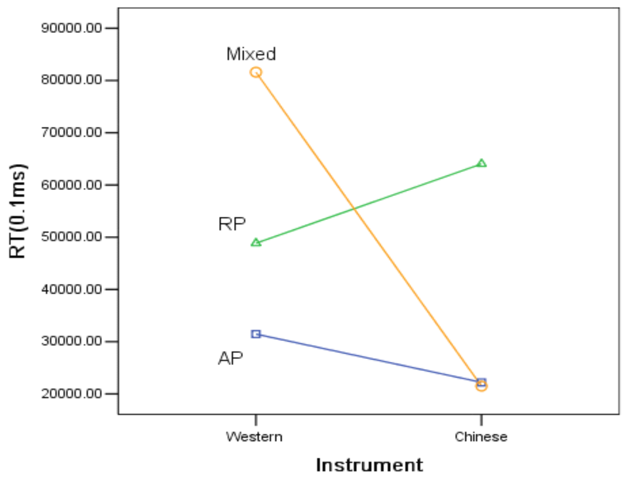


Figure 18 Significant interaction between instrument and pitch sense in minor

24.3 Comparison between major and minor

Only 10 participants' data were valid in both major and minor sets, so the comparison of response time of the two modes was based on the data of these 10 participants.

As the same series of priming tones were tested in both major and minor sets with the corresponding "proper" scale degrees, the comparison between major and minor set was actually the comparison between major and its parallel minor modes. For example, pitch B was tested as tonic either in B major or in b minor. The data were analyzed by partial correlations. The correlation between major and its parallel minor was significant ($r=0.327$, $p<0.001$); that is, the parallel keys were correlated with each other. Besides, there was no significant difference between the reaction time to the two modes ($t=-1.666$, $p>0.05$).

Considering the subject factors, it was resulted that there was a significant main effect of pitch sense [$F(2,320)=7.436$, $p<0.001$]: participants possessing AP sense responded significantly faster than participants possessing RP or both AP and RP ($p<0.001$), but there was no significant difference of RT between the latter two groups, although participants with RP responded the slowest. There was also a significant interaction between instrument and pitch sense [$F(2,320)=9.483$, $p<0.001$]: participants playing Western instruments and possessing AP responded faster than those with RP, while those possessing both AP and RP responded quite slowly than the former two groups; participants playing Chinese instruments or singing Chinese folk songs and possessing AP or both AP and RP responded much faster than those RP possessors. However, there was no significant main effect of mode and no significant interaction between mode and subject factors.

Table 23 Significant main effect of pitch sense

participants	RT (M, SD, 0.1ms)
AP	30500.00(17642.85)
RP	60635.37(45228.92)
AP & RP	59623.64(65699.76)

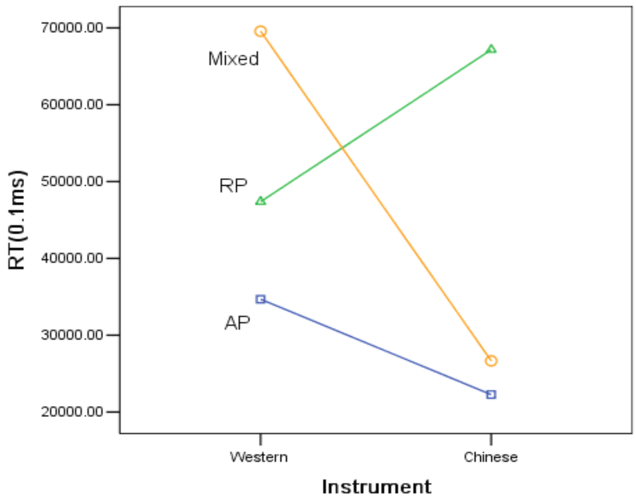


Figure 19 Significant interaction between instrument and pitch sense in experiment I

25. Experiment II

25.1 Percentage of accuracy of each subject

There were 14 participants, and 12 of them responded above chance (here 50% was taken as chance level), and two of them were at chance (Table 24). So only the data of 12 participants were taken into analysis.

Table 24 Percentage of accuracy of each subject

S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
64%	84%	*50%*	84%	70%	60%	67%	60%	68%	76%	54%	68%	72%	*45%*

25.2 Percentage of error and response time in each trial

The analysis was similar to the analysis in experiment 1. The percentage of errors (PE) on each scale degree was analyzed, and the number of unsure responses was collected; but only the response time (or reaction time, RT) of correct responses was involved in the analysis of response time, excluding the reaction time which was greater than three standard deviations from the mean of each scale degree.

Table 25 shows the percentage of errors and the average reaction time of correct responses on each pitch-class (only in-key trials are involved). The results showed that only when the priming tone had the function of supertonic (II), or subdominant (IV) in the post-context, there was one "not sure" response for each; when the priming tone had functions of other scale degrees, there was no "not sure" decision. The data of each scale degree were analyzed by univariate analysis, in which pitch-class was as the nested factor of mode. There was no significant main effect of mode on seven scale degrees; but there was a significant main effect of pitch-class on the II scale degree [$F(1,27)=6.695$, $p<0.05$], III [$F(1,17)=4.664$, $p<0.05$], IV [$F(1,30)=10.524$, $p<0.01$], and VII [$F(1,26)=9.435$, $p<0.01$], and responses to the two pitch classes of scale degrees IV ($p<0.01$) and VII ($p<0.05$) in minor were significantly different.

Table 25 RT (reaction time) and PE (percentage of errors) on pitch-classes

S	Mode	P	average RT (0.1ms)	PE(%)	not sure	F	t_M or t_m
I	M	B	69047	16.67%	0	2.155	-1.427
	M	Bb	82377	33.33%	0		
	m	C#	88374	50.00%	0		-
II	M	A	79563	25.00%	0	6.695*	2.099
	M	D	43463	25.00%	0		
	m	D#	72354	9.09%	1		-
III	M	D	72768	27.27%	0	4.664*	-
	m	G	120897	41.67%	0		1.631
	m	G#	73422	41.67%	0		
IV	m	D#	106118	33.33%	0	10.524**	3.519**
	M	G	62084	0	1		-
	m	F	61057	8.33%	0		3.519**
V	m	E	71570	0	0	3.355	-
	M	G#	53866	8.33%	0		-1.826
	M	F#	80094	8.33%	0		

VI	m	F	67775	33.33%	0	0.732	-
	M	Bb	57868	16.67%	0		-0.803
	M	C	67809	41.67%	0		
VII	m	B	57258	33.33%	0	9.435**	-2.666*
	M	E	84759	25.00%	0		-
	m	C#	119146	25.00%	0		-2.666*

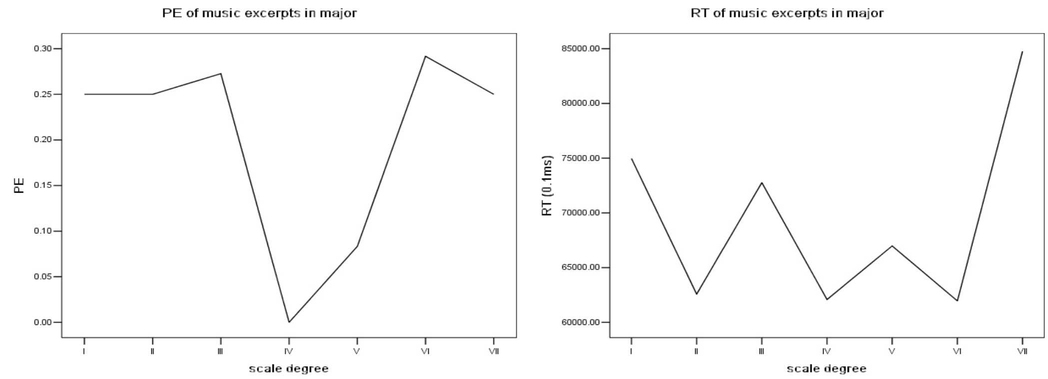
(S=scale degree of the priming tone in the latter context (objective context); M=major, m=minor; P=pitch-class of the priming tone; RT=response time or reaction time; PE=percentage of error; not sure=uncertain response; *p<0.05, **p<0.01)

Table 26 shows the percentage of errors and the average reaction time of correct responses on each scale degree. In the trials with major excerpts, there were no false responses when the priming tone had the function of subdominant; fewer errors were made when the priming tone had the function of dominant; when the priming tone had the function of other scale degrees tonic, supertonic, leading tone, mediant and submediant, false responses were increased. In the trials with minor excerpts, there were no false responses when the priming tone had the function of dominant; fewer errors were made when the priming tone served as supertonic; when the priming tone had the function of other scale degrees, such as subdominant, leading tone, submediant, mediant, tonic, and false responses were increased.

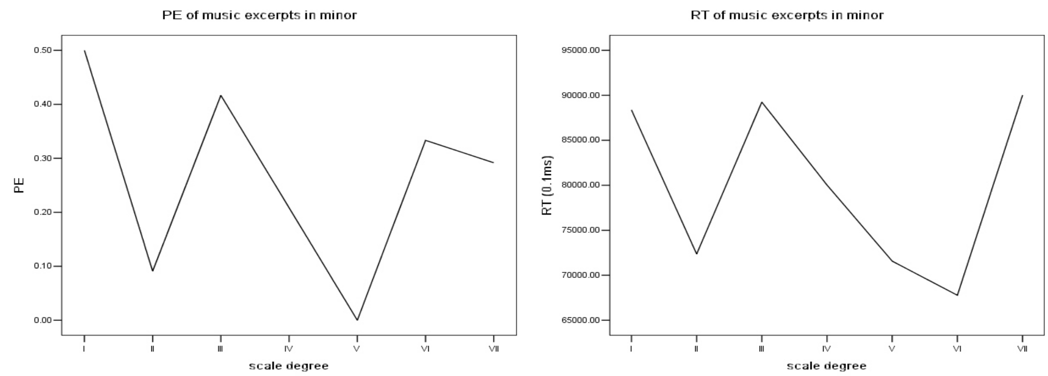
Table 26 RT (reaction time) and PE (percentage of errors) on scale degrees

Major	I	II	III	IV	V	VI	VII
RT(ms)	74972	62575	72768	62084	66980	61961	84759
PE	25%	25.00%	27.27%	0	8.33%	29.17%	25.00%
Minor	I	II	III	IV	V	VI	VII
RT(ms)	88374	72354	89247	80030	71570	67775	90022
PE	50.00%	9.09%	41.67%	20.83%	0	33.33%	29.17%

The contours of RT and PE profiles were similar in either major or minor, that is, the faster the responses were, the more accurate the results were. There was no great change in the profiles of RT in both major and minor; while the profiles of PE in both major and minor presented some differences among scale degrees. It was surprised that the priming tone as tonic in major and minor showed neither the fastest nor the most accurate responses. There was no significant correlation between K-K profile and any of the profiles in major and minor. Generally, the response time of major was significant shorter than the response time of minor (t=-2.951, p<0.01).



a. PE and RT profiles in major



b. PE and RT profiles in minor

Figure 20 PE and RT profiles in experiment II

25.3 Univariate analysis of variance

The response time was further analyzed by univariate analysis of variance. The response time was also affected by the starting tone and the ending tone of a musical excerpt, but the starting tone and the ending tone were not well controlled. So in virtue of statistics, these two factors were as covariates to explore whether they contributed to the responses or not. The starting tone had three variations: starting from tonic, mediant or dominant; the ending tone also had three variations: authentic cadence ending on tonic chord (including inverted chords), half cadence ending on dominant chord or seventh (including inverted chords), or without cadence.

Generally, there was a significant main effect of cadence [$F(1,183)=4.763$, $p<0.05$]: the response to trials without cadence was significantly faster than the response to trials with authentic cadence or half cadence ($p<0.05$), but there was no significant difference of responses between the latter two cadence groups. Although there were no other significant main effects of mode and scale, and no significant interaction between them, the Figure 21 shows:

- the fastest response was given to the musical excerpts starting from mediant, and ending without authentic or half cadence;
- the slowest response was given to the musical excerpts starting from mediant, and ending with half cadence;
- the responses to the musical excerpts starting from tonic with different cadences were similar;
- the responses to the musical excerpts starting from dominant and ending with authentic cadence were slower than the responses to the musical excerpts starting with dominant with half cadence or without cadences.

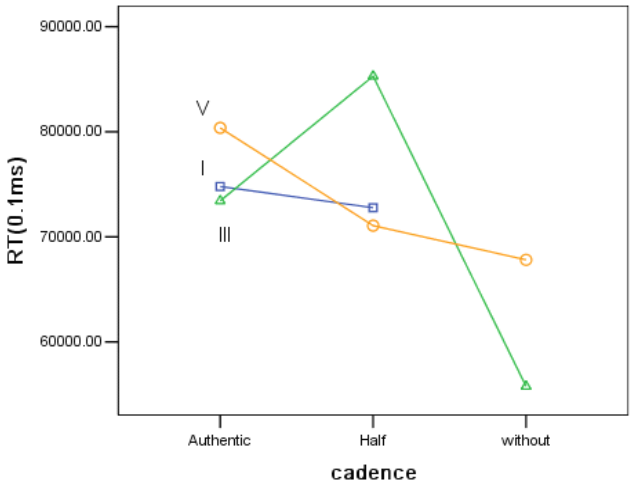


Figure 21 Interaction between starting tone and cadence

For major excerpts, there was a significant main effect of starting tone [$F(1,102)=11.189$, $p<0.001$]: the response to trials starting with dominant was significantly slower than the response to trials starting with tonic ($p<0.05$) or mediant ($p<0.01$), but there was no significant difference of responses between the latter two groups. There was no significant main effect of scale degree.

For minor excerpts, there was a significant main effect of starting tone [$F(1,81)=24.573$, $p<0.001$]: the response to trials starting with dominant was significantly faster than the response to trials starting with tonic ($p<0.05$); significant main effects of cadence [$F(1,81)=13.866$, $p<0.001$] and scale degree [$F(6,81)=4.022$, $p<0.01$].

When taking subject factors into account, there was not only a significant main effect of scale degree, but also a significant main effect of instrument [F(1,183)=4.535, p<0.05]: participants playing Western instruments responded faster than participants playing Chinese instruments or singing folk songs (t=-.2.040, p<0.05). Although interaction between instrument and pitch sense was not significant, Figure 22 shows that the responses of AP possessors playing different instruments were quite different, while the responses of RP possessors playing different instruments were quite similar; AP possessors playing Western instrument responded faster than RP possessors, while RP possessors playing Chinese instrument responded faster than RP possessors.

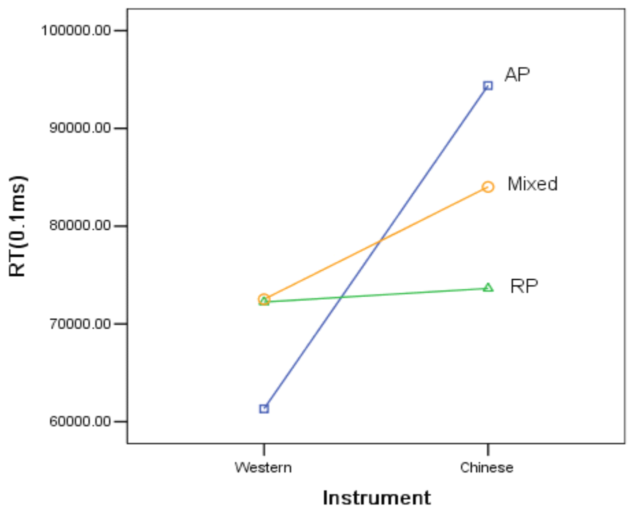


Figure 22 Significant interaction between instrument and pitch sense in experiment II

26. Experiment III

26.1 Perfect fifth set

26.1.1 Percentage of accuracy of each subject

There were 14 participants, 10 of them responded above chance (here 50% was taken as chance level), and 4 of them were at or below chance (Table 27). So the data of 10 participants were taken into analysis.

Table 27 Percentage of accuracy of each subject

S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
77%	59%	64%	73%	*45%*	*50%*	*34%*	77%	64%	81%	76%	64%	82%	*37%*

26.1.2 Percentage of error and response time in each trial

The percentage of errors (PE) on each scale degree was analyzed, and the number of unsure responses was collected; but only the response time (or reaction time, RT) of correct responses was involved in the analysis, excluding the reaction time which was greater than three standard deviations from the mean of each scale degree.

Table 28 shows the percentage of errors and the average reaction time of correct responses on each scale degree. The results showed that when the perfect fifth descending from D to G had functions of VI-III or I-IV, there was one "not sure" response for each situation. When the perfect fifth G-D served as VI-III in the latter minor, there was a strong positive correlation between the responses to G-D (VI-III) and D-G (III-VI). However, there was no other significant correlation between the responses to two directions of G-D on other scale degrees in both major and minor, and there was also no significant difference between responses of two directions.

Table 28 RT (reaction time) and PE (percentage of errors) of interval G-D

S	Dr	average RT (0.1ms)	PE (%)	not sure	t	Cor..
I	↑	23339	0	0	1.380	-.075
	↓	19038	10.00%	0		
II	↑	54510	20.00%	0	1.244	0.666
	↓	33472	11.11%	0		
III	↑	43844	55.56%	0	-0.528	-0.870
	↓	47580	40.00%	1		
IV	↑	40931	11.11%	0	1.157	0.789
	↓	41818	33.33%	1		
V	↑	24839	33.33%	0	0.364	0.463
	↓	47568	22.22%	0		
VI	↑	60688	30.00%	0	0.326	0.631
	↓	53328	20.00%	0		
Im	↑	22111	30.00%	0	-0.895	0.383
	↓	34925	0	0		
IVm	↑	43312	62.50%	0	-1.355	0.866
	↓	63716	11.11%	0		
Vm	↑	61559	22.22%	0	-0.131	-0.148
	↓	98318	70.00%	0		
VIm	↑	56298	60.00%	0	-0.985	1.000**
	↓	98649	40.00%	0		

(m=minor context; S=scale degree of the priming tone in the latter context (objective context); Dr=direction of interval, ↑ =G-D, ↓ =D-G; RT=response time or reaction time; PE=percentage of error; not sure=uncertain response; cor.=correlation; *p<0.05, **p<0.01)

Table 29 shows the percentage of errors and the average reaction time of correct responses on each scale degree. The percentage of false responses was fewer when the priming interval G-D served as I-V in the latter major context; few errors were made when the G-D served as II-VI, IV-I, VI-III or V-II; when G-D served as III-VII, false responses were increased. The percentage of false responses was fewer when the priming interval G-D had the function of I-V in the latter minor context; more errors were made when the G-D served as IV-I, V-II, VI-III.

Table 29 RT (reaction time) and PE (percentage of errors) on scale degrees

Major	I	II	III	IV	V	VI
RT(ms)	21188	43991	46086	41311	37078	56763
PE	5.00%	15.79%	47.37%	22.22%	27.78%	25.00%
Minor	I			IV	V	VI
RT(ms)	29649			58615	72586	81709
PE	15.00%			35.29%	47.37%	50.00%

In the major context (Figure 23), the profiles (both PE and RT) of responses to trials with priming ascending G-D were not quite the same as the profiles of responses to trials with priming descending D-G. Especially, when priming G-D had the function of IV-I in major, few false responses were made for ascending G-D than descending D-G, but response time was quite the same in the two conditions; when priming G-D had the function of II-VI in major, faster responses were made for descending G-D than ascending D-G, but fewer false responses were made; when priming G-D served as V-II in major, faster responses were made for ascending G-D than descending D-G. However, when G-D served as I-V, either ascending or descending, faster and more accurate responses were elicited. There was no significant difference of responses to G-D on different scale degrees [$F(5,85)=2.013$, $p>0.05$].

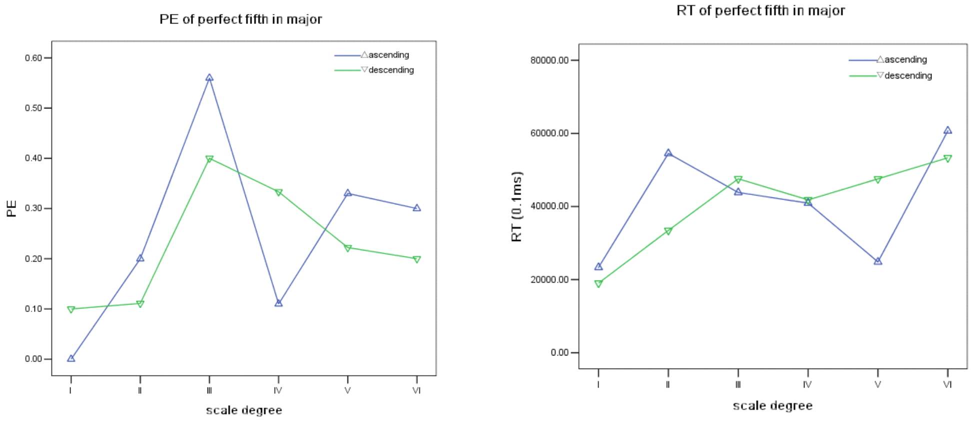


Figure 23 PE and RT of perfect fifth in major on 6 scale degrees

In the minor context (Figure 24), the PE and RT profiles of ascending were quite different, but the PE and RT profiles of descending shared similar tendency. PE profile of responses to priming ascending G-D was quite different from PE profile of responses to priming descending D-G: when PE profile of priming ascending G-D across scale degrees (as IV-I, V-II, VI-III) went up, PE profile of priming descending D-G went down, except G-D as I-V. However, RT profiles of responses to priming ascending G-D and descending D-G had the same tendency: responses to trials with priming ascending G-D got faster or slower, so did the same of responses to trials with priming descending D-G. However, when G-D served as I-V, either ascending or descending, faster and more accurate responses were elicited. There was a significant difference of responses to G-D on different scale degrees [$F(3,48)=3.125$, $p<0.05$], especially responses to G-D as I-V were significantly faster than responses to G-D as V-II ($p<0.05$), or VI-III ($p<0.01$).

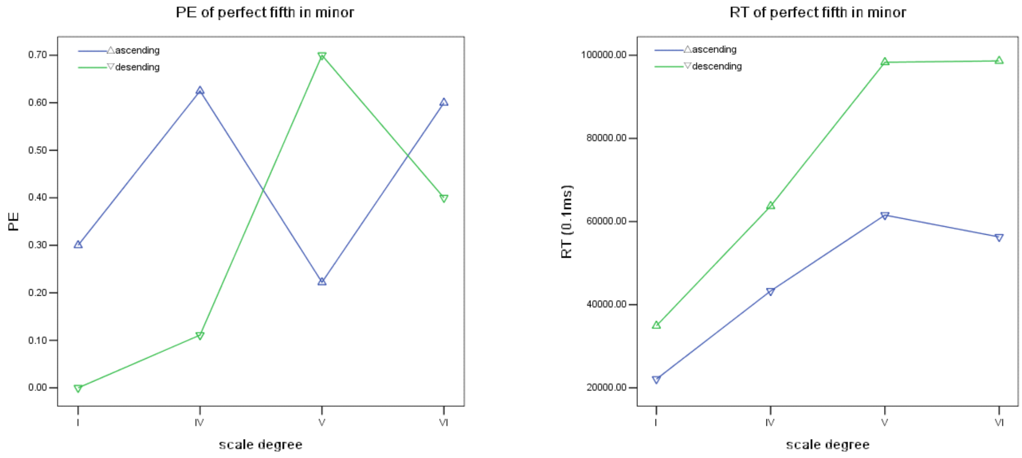


Figure 24 PE and RT of perfect fifth in minor on 4 scale degrees

26.1.3 Univariate analysis of variance & correlation

The response time was further analyzed by univariate analysis of variance. The response time was compared in three different ways:

a) Comparing the perfect fifth G-D with the same scale degrees in ascending or descending directions. For example, ascending G-D had the function of I-V – tonic went upwards to dominant, and descending D-G had the function of V-I – dominant went downwards to tonic. In this condition, the scale degrees from which perfect fifth starts and to which it ends were the same.

There was a significant main effect of mode [$F(1,135)=6.712$, $p<0.05$]: responses to trials with major context were significantly faster than responses to trials with minor context; and a significant main effect of scale degree [$F(5,135)=3.821$, $p<0.01$]. There was no significant main effect of direction, but a signification correlation between the two directions ($r=0.638$, $p<0.001$), in both major ($r=0.666$, $p<0.001$) and minor ($r=0.626$, $p<0.05$).

When taking subject factors (playing instrument and possessing pitch sense) into account, there was a significant main effect of mode [$F(1,135)=4.297$, $p<0.05$] and scale degree [$F(5,135)=3.598$, $p<0.01$]; and a significant interaction between playing instrument and pitch sense [$F(2,135)=4.048$, $p<0.05$] (see Figure 25): AP possessors and RP possessors playing Western instruments responded at the same speed, but slower than both AP and RP possessors; while AP possessors playing Chinese instruments or singing Chinese folk songs responded much faster than other groups.

There was also a significant interaction among scale degree, mode and instrument [F(3,135)=2.851, p<0.05] (see Figure 26): in trials with major context, participants playing Western instruments responded faster than participants playing Chinese instruments or singing folk songs; it was quite the same in trials with minor context, only except when G-D as VI-III in minor, participants playing Chinese instruments responded faster.

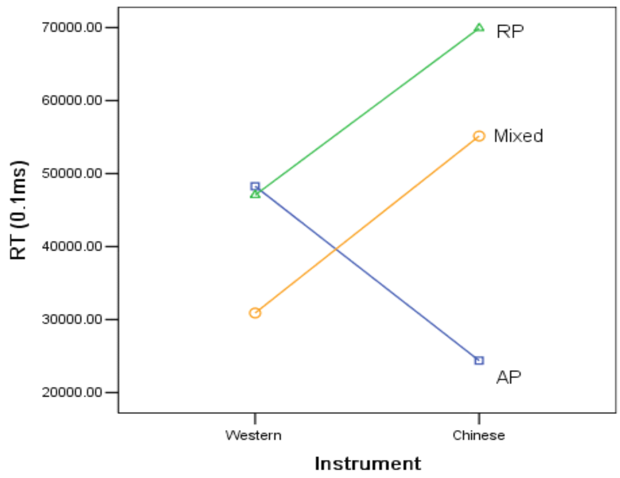
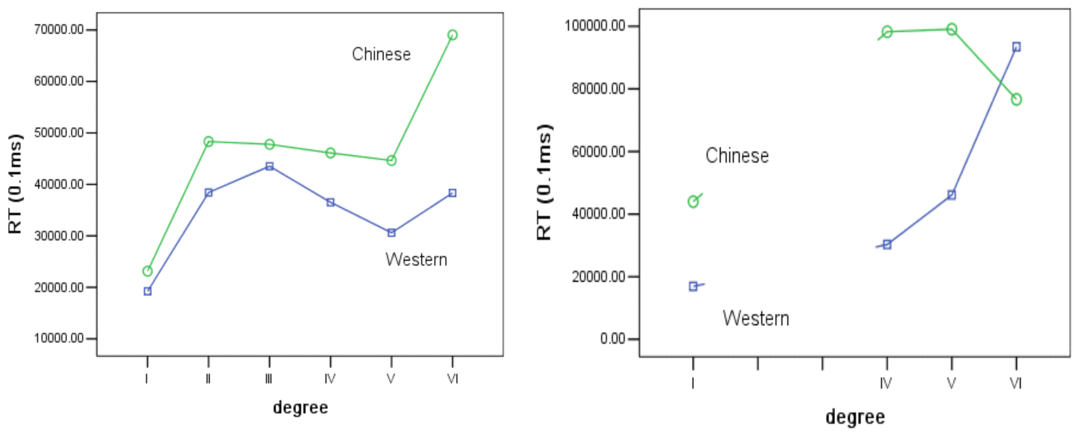


Figure 25 Significant interaction between instrument and pitch sense in perfect fifth set



a. major b. minor

Figure 26 Significant interaction among mode, scale degree and instrument

The other two comparisons of perfect fifths that were with different scale degrees:

b) Comparing the perfect fifth ascending or descending G-D starting from the same scale degree. For example, G in ascending G-D and D in descending D-G both had the function of tonic, that is, ascending G-D served as I-V – from tonic upwards to dominant, and D-G served as I-IV – from tonic downwards to subdominant.

Generally, there was only a significant main effect of mode [$F(1,135)=6.267$, $p<0.05$], but no other significant main effect or interaction. In both major and minor context, there was also no significant main effect of direction or starting scale degree; but in minor context, there was a significant interaction between direction and starting scale degree [$F(1, 49)=4.122$, $p<0.05$, Figure 27]: when G in ascending G-D (I-V) and D in descending D-G (I-IV) both had functions of tonic, responses to ascending interval were faster than responses to descending interval; when G in ascending G-D (V-II) and D in descending D-G (V-I) both had functions of dominant, responses to ascending interval were slower than responses to descending interval. Besides, responses were faster when G had function of tonic in ascending G-D (I-V) than G had functions of other scale degrees, and also when D had function of dominant in descending D-G (V-I) than D had functions of other scale degrees.

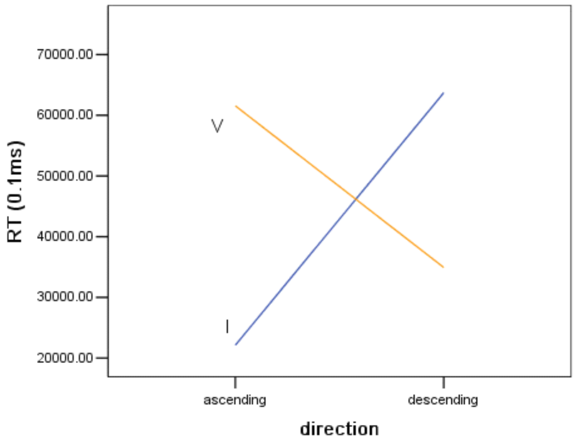


Figure 27 Significant interaction between direction and starting scale degree

For correlations, generally, there was a signification correlation between the two directions ($r=0.313$, $p<0.05$) with significant difference of responses: responses to ascending interval were faster than those to descending interval ($p<0.05$), but only in minor ($r=0.552$, $p<0.05$), not in major ($r=0.307$, $p>0.05$).

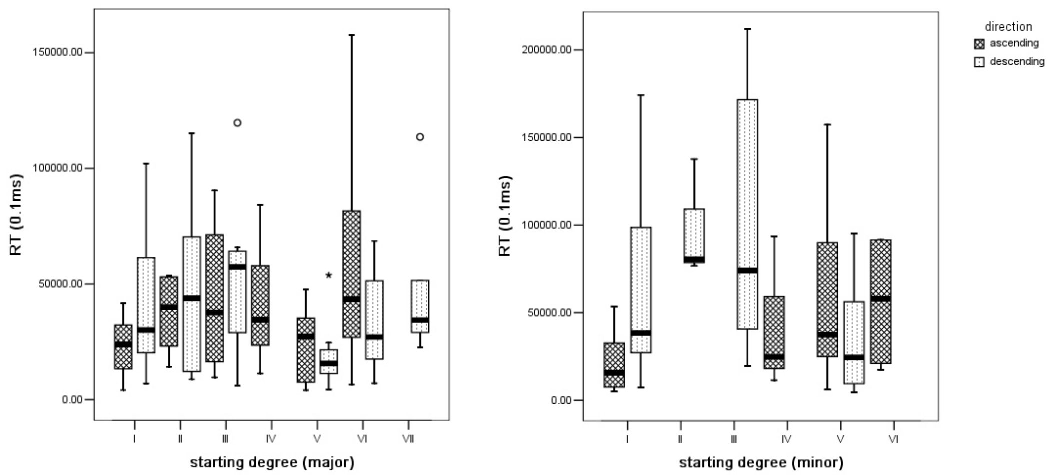


Figure 28 Response to the perfect fifth starting from the same scale degree in major and minor

c) Comparing the perfect fifth ascending or descending G-D ending on the same scale degree. For example, D in ascending G-D and G in descending D-G both had functions of dominant, that is, ascending G-D had the function of I-V – from tonic upwards to dominant, and D-G had the function of II-V – from supertonic downwards to dominant.

Generally, there was only a significant main effect of mode [$F(1,135)=7.083$, $p<0.01$], but no other significant main effect or interaction. In both major and minor context, there was also no significant main effect of direction or ending scale degree and interaction between them.

For correlations, generally, there was a signification correlation between the two directions ($r=0.434$, $p<0.01$) with significant difference of responses: responses to ascending interval were faster than those to descending interval ($p<0.01$), but only in major ($r=0.458$, $p<0.01$), not in minor ($r=0.356$, $p>0.05$).

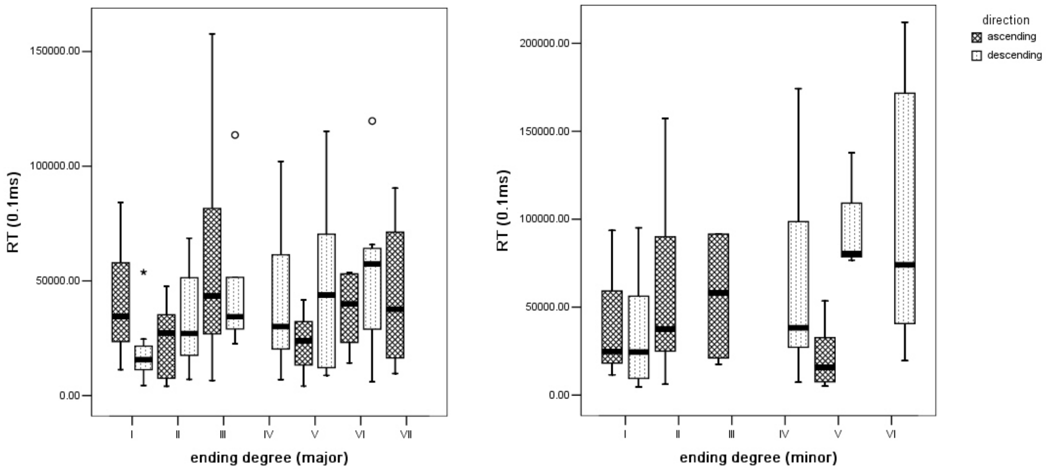


Figure 29 Response to the perfect fifth ending on the same scale degree in major and minor

26.2. Tritone set

26.2.1 Percentage of accuracy of each subject

There were 14 participants, 13 of them responded above chance (here 50% was taken as chance level), and one of them was at chance (Table 30). So only the data of 13 participants were taken into analysis.

Table 30 Percentage of accuracy of each subject

S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
56%	80%	78%	60%	67%	70%	67%	60%	67%	80%	*50%*	70%	80%	60%

26.2.2 Percentage of error and response time in each trial

The percentage of errors (PE) on each scale degree was analyzed, and the number of unsure responses was collected; but only the response time (or reaction time, RT) of correct responses was involved in the analysis, excluding the reaction time which was greater than three standard deviations from the mean of each scale degree.

Table 31 shows the percentage of errors and the average reaction time of correct responses on each scale degree. There was no “not sure” response, so tritone may be a cue for the establishment of tonality perception. When the tritone F-B ($E^{\#}$-B) had the function of II-VI in the latter minor, there was a significant positive correlation between the responses to F-B (II-VI) and B-F (VI-II). However, there was no other significant correlation between the responses to two directions of F-B on other scale degrees in both major and minor, and there was also no significant difference between responses of two directions.

Table 31 RT (reaction time) and PE (percentage of errors) of interval F-H

S	Dr	average RT (0.1ms)	PE (%)	not sure	t	Cor.
IV	↑	41233	15.38%	0	-0.125	0.160
	↓	36567	18/18%	0		
IIm	↑	70487	18.18%	0	1.505	0.980*
	↓	42897	53.85%	0		
IVm	↑	38719	69.23%	0	-0.152	-0.907
	↓	46646	27.27%	0		
VIm	↑	48529	7.69%	0	-2.284	0.191
	↓	46353	41.67%	0		

(m=minor context, otherwise, major context; S=scale degree of the priming tone in the latter context (objective context); Dr=direction of interval, ↑ =G-D, ↓ =D-G; RT=response time; PE=percentage of error; not sure=uncertain response; cor.=correlation; *p<0.05, **p<0.01)

Table 32 shows the percentage of errors and the average reaction time of correct responses on each scale degree. The percentage of false response was fewer when the priming interval F-B served as VI-II in the latter minor context; more false responses were made when F-B served as II-VI, or IV-VII.

Table 32 RT (reaction time) and PE (percentage of errors) on scale degrees

Major		IV	
RT(ms)		39268	
PE		16.67%	
Minor	II	IV	VI
RT(ms)	59451	44004	47727
PE	37.5%	50.00%	24.00%

In the major context, there was only one trial for tritone, so here only the responses to the priming ascending F-B and descending B-F were compared, and the correlation between two directions was examined. As mentioned above, there was no significant difference and no significant correlation between directions.

In the minor context (Figure 30), the profiles of PE and RT were quite different. PE profile of responses to priming ascending F-B was quite different from PE profile of responses to priming descending B-F: when PE profile of priming ascending F-B across scale degrees (as II-VI, IV-VII, VI-II) went up, PE profile of priming descending B-F went down. Besides, PE profile of responses to priming ascending F-B was quite different from its corresponding RT profile: less errors cost more time to respond. However, the response time of the priming descending B-F was quite similar cross scale degrees. For instance, when ascending F-B had functions of II-VI or VI-II, there were more accurate responses, which cost more time; while when F-B served as IV-VII, there were less accurate responses, which cost less time. Neither the difference among scale degrees nor the difference between two modes was significant.

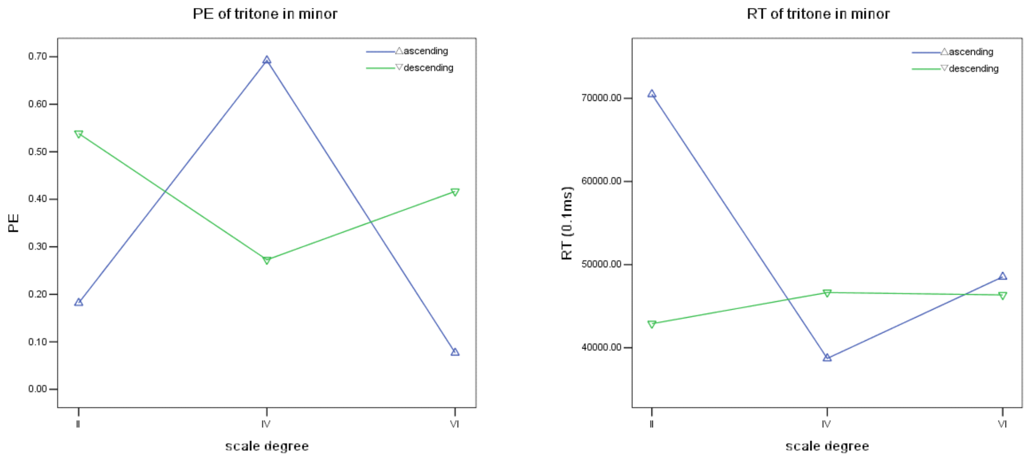


Figure 30 PE and RT of tritone in minor on 4 scale degrees

26.2.3 Univariate analysis of variance

The response time was further analyzed by univariate analysis of variance. There was no significant main effect of direction, mode, scale degree, and no interaction between these factors. When taking subject factors (playing instrument and possessing pitch sense) into account, there was no significant main effect of subject factors and no significant interactions either.

26.3 Perfect fifth vs. tritone

The data of 9 participants that were valid in both perfect fifth set and tritone set were analyzed to compare the differences between the two intervals.

As the number of the samples in perfect fifth set and tritone set was unequal, the difference of responses to the two intervals was analyzed by Mann-Whitney U test, which was a nonparametric test for independent samples. There was no significant difference between the responses to intervals ($U=3147$, $p>0.05$).

Even compare perfect fifth G-D and tritone F-B having functions of IV-I and IV-VII, with same starting scale degree subdominant (IV), there was still no significant difference between the responses of two intervals ($U=132$, $p>0.05$).

27. Single tone vs. interval

As the number of the samples in priming tone set and priming interval set was unequal, the difference of responses to the two intervals was analyzed by Mann-Whitney U test, which was a nonparametric test for independent samples. There was a significant difference between response time of single tone and intervals ($U=24014$, $p<0.05$). The responses to interval (average RT = 4081.8ms) were significantly faster than the responses to single tone (average RT = 5212.7ms).

Summary

Here summarizes the results of the experiment series 1:

Experiment I

1) The responses were faster when the post-context was major than minor;

2) There was no significant difference of response time among pitch-classes on each scale degree in both major and minor;

3) The priming tone serving as tonic in the post-context – both major and minor – showed the fastest and the most accurate responses;

4) The priming tone serving as subdominant or dominant in the post-context – both major and minor - responded correctly but slowly;

5) The priming tone serving as mediant or submediant in the post-context – both major and minor – responded with more errors and took longer response time;

6) The priming tone serving as supertonic or leading tone in the post-context – both major and minor – responded faster but with more errors;

7) PE profile in major context had a significant correlation with K-K major profile, while RT profile in major was a bow-shaped;

8) Neither PE profile nor RT profile in minor context had correlation with K-K minor profile;

9) Responses to major and its parallel minor had a significant correlation;

10) For subject factors, generally speaking, in the trials with associated context – no matter major or minor context, AP possessors responded faster than mixed pitch sense possessors regardless of what instrument they played; these two groups playing Western instrument responded slower than those playing Chinese instrument. RP possessors playing Western instrument responded faster than those playing Chinese instrument. Besides, AP and mixed pitch sense group playing Chinese instrument responded faster than RP possessors playing Chinese instrument.

Experiment II

11) In trials with musical excerpt context, the responses were faster when the post-context was major than minor;

12) There was no significant difference of response time among scale degrees, but a significant difference of responses between pitch classes, when the priming tone functioned as subdominant (IV) and leading tone (VII) in minor;

13) The priming tone serving as tonic in the post-context - both major and minor - showed neither the fastest nor the most accurate responses;

14) The priming tone serving as subdominant or dominant in the post-context – both major and minor – responded more accurately;

15) The priming tone serving as mediant or submediant in the post-context – both major and minor – responded with more errors;

16) No profile correlated significantly with K-K profile;

17) Starting tone and cadence of musical excerpts contributed to responses, generally speaking, responses to trials with no-cadence context were faster than responses to trials with authentic or half cadence – regardless of starting tone; responses to trials with congruence of starting tone and cadence were faster than responses to trials with incongruence of starting tone and cadence;

18) Responses to trials with major context starting with tonic were faster; while responses to trials with minor context starting with dominant were faster;

19) For subject factors, the results were quite different from the results of experiment I (the trials with associated context): there was no difference of responses between RP possessors playing Western instrument or Chinese instrument; however, AP possessors and mixed pitch sense possessors playing Western instrument responded faster than those playing Chinese instrument. Besides, AP possessors playing Chinese instrument responded slower than RP possessors and mixed pitch sense possessors playing Chinese instrument; conversely, AP possessors playing Western instrument responded faster than RP possessors and mixed pitch sense possessors playing Western instrument.

Experiment III

20) For priming perfect fifth, the responses were faster when the post-context was major than minor; however, for priming tritone, there was no significant difference of responses between major and minor;

21) For priming perfect fifth, there was a significant difference among scale degrees; but for priming tritone, there was no significant main effect of scale degree;

22) There was no significant main effect of direction and no correlation between responses to the same interval with different direction, except G-D as VI-III in major and F-H as II-VI in minor;

23) The priming perfect fifth serving as I-V in the post-context - both major and minor - showed the fastest and the most accurate responses;

24) The ascending priming perfect fifth serving as I-V or IV-I in major showed more accurate response than its descending direction; while the descending priming perfect fifth serving as VI-II, VII-III, or II-V responded faster than its ascending direction;

25) The priming perfect fifth serving as III-VII in major – ascending and descending - responded with more errors;

26) The ascending priming perfect fifth serving as V-II in minor showed more accurate response than its descending direction; while the descending priming perfect fifth serving as V-I, I-IV, or III-VI responded faster than its ascending direction;

27) The priming perfect fifth serving as V-II in minor – ascending and descending - responded slower;

28) For subject factors in perfect fifth trials, the results were similar to the results of experiment I (priming single tone), the only difference was that mixed pitch sense possessors responded quite similar, but faster than RP possessors, regardless of what instrument they played. These two groups playing Western instruments responded faster than those playing Chinese instruments. AP possessors playing Western instrument responded slower than those playing Chinese instrument. Besides, AP possessors playing Chinese instrument responded faster than RP possessors and mixed pitch sense possessors playing Chinese instrument;

29) Generally, participants playing Western instruments responded faster than those playing Chinese instruments, in both major and minor, only except VI in minor which responded faster by participants playing Chinese instruments;

30) The ascending priming tritone functionsing II-VI, or VI-II in minor responded more accurate than its descending direction; while the descending priming tritone serving as VII-VI responded faster than its ascending direction;

31) There was no significant difference between responses of perfect fifth set and tritone set;

32) The responses to priming single tone were slower than the responses to priming interval.

Discussion

This part discusses the results of the experiment series 1. The discussion refers to the explanation of the results, the comparison between the current results and the results from former studies, the limitation of the method and the suggestion for further experiment, etc.

28. General discussion

28.1 Major

28.1.1 Key profiles of major set

As shown in the results, there are two kinds of tonal profiles obtained, one is the profile of percentage of errors, and the other is the profile of response time. An interesting phenomenon is that the two kinds of profiles are quite different in major mode. In other words, the percentage of errors does not change proportionately with response time on different scale degrees.

The profile of percentage of errors presents a tonal hierarchy of scale degrees, and it can be roughly divided into three levels: tonic is on the top, which is preferred with the fewest errors; dominant, subdominant and supertonic follow behind, with similar fewer percentage of errors than the other three degrees; and the third level includes mediant, submediant and leading tone, with the most errors.

While the profile of response time is a bow shape, the scale degrees near the tonic responded faster than the scale degrees far from the tonic. It reflects the proximity effect around the tonic. The reaction time of tonic is significantly shorter than the reaction time of other scale degrees.

Thus, there was a conflict between the accuracy and the reaction time, especially when the priming tone had a tonal function of dominant or subdominant in the latter context. The responses to them were at the slowest, but with much accuracy. Participants used more time to consider whether these scale degrees were in the scale. This incongruence between the PE profile and the RT profile in this experiment is quite different from the congruence between stableness rating and reaction time of scale degrees in the former studies (e.g. Janata & Reisberg, 1988), which used probe-tone technique. This result may be caused by the different task – "stem-completion"-like task. If listeners used scale or arpeggio as strategy to complete the associated context, the proximity effect is a good explanation for RT profile, because the dominant and the subdominant are the most remote diatonic scale degrees from the tonic; while tonal function or stableness of scale degrees is a good explanation for PE profile because of the significant strong negative correlation between the PE profile in this study with K-K major profile (Krumhansl, & Kessler, 1982). It indicates that participants did assign their subjective scale degree to a single tone – if they used scale or arpeggio as strategy, and tonic, subdominant, dominant and supertonic can easily activate a tonal context, which reflects the importance of their tonal function or stableness in the implicit tonal knowledge. That is, the more important a scale degree is, the fewer false responses are made. Although the instruction was to complete the context freely by a scale or arpeggio, the interval between the priming tone and the given "tonic" of the context could also contribute to listeners' responses. If it was the case, it could infer that interval-class fifth (including perfect fifth and perfect fourth), minor second and major second play important roles in participants' tonal perception and tonal knowledge.

Besides the profiles, there is no significant difference among three pitch-classes on each degree, which indicates that participants do not have preference of pitch-classes for some scale degrees. In other words, there is also no preference of any subjective scale degree assigned to a certain pitch-class (e.g. take C always as tonic).

28.1.2 Key profiles of perfect fifth set

Priming with intervals is more complex than priming with single tones. Three aspects should be taken into account: the directions of interval, the scale degree from which the interval starts, and the scale degree on which the interval ends. In major mode, there are six possible perfect fifths starting from 6 scale degrees, which means they also end on 6 scale degrees.

The profiles of perfect fifth present the responses to perfect fifth sharing same scale degrees in different directions (e.g. from tonic to dominant and from dominant back to tonic). Generally speaking, either ascending or descending, the profiles of percentage of errors and the profiles of response time are not quite similar, except when the perfect fifth had the function of I-V/V-I, to which responses were the most accurate and the fastest. While the responses of ascending and descending were similar, except when the perfect fifth had the function of II-VI/VI-II, or V-II/II-V in RT, and when the perfect fifth had the function of III-VII/VII-III, or IV-I/I-IV in PE. Although there was no significant statistical difference among scale degrees or between directions, participants presented preference of scale degree, and preference of direction on some scale degrees. For instance, when the perfect fifth was subjectively interpreted with the I-V/V-I degrees, the associated context was easier to be activated, and showed correct and fast responses; while when the perfect fifth was subjectively evaluated with III-VII/VII-III, the associated context was more difficult to be activated, and showed incorrect and slow responses; when the perfect fifth was subjectively interpreted with IV-I/I-IV, the associated context was easier to be activated, correctly responded with its ascending interval, but not with its descending interval. Thus, the direction preference had a tendency towards ending on scale degrees with more stableness or important tonal function.

Considering the given “tonic” of the post-context, the priming interval can form an implicit three-tone sequence with the “tonic”. Some of the three-tone sequence sound melodic; and the others sound harmonic. For instance, when the priming interval had the function of VI-III in the latter context, followed by the given “tonic”, the three tones formed a minor triad on submediant of latter context; while the other three-tone sequences were more melodic. Besides, there were also two exceptions that there were repeated tones (either at the same pitch or over an octave) in the three-tone sequence: one was the perfect fifth as I-V/V-I, and the other served as IV-I/I-IV. Both harmonic and repetitive features could facilitate the responses, and the responses to these trials would be shorter or more accurate than other trials. Although the subject was instructed to complete the post-context with association and the priming interval was set 1000ms apart from the given “tonic”, analysis of “implicit” three-tone sequence could make it more clear whether participants processed the priming interval harmonically or melodically.

Reviewing the results of perfect fifth set in major, it is not exactly the case, especially in RT. The only one harmonic “three-tone sequence” that got more accurate responses, but took a longer time for judgment; while the two repetition “sequences”, only the perfect fifth as I-V/V-I got both more accurate and shorter responses, and the perfect fifth as IV-I (only ascending) got more accurate responses, but the response time was similar to the response time of its descending interval which got more false responses. However, another “three-tone” sequence should be noticed – the perfect fifth served as II-VI/VI-II, both directions got more accurate responses – better than VI-III/III-VI and even I-IV (descending), though the response time was not quite short. Thus, either harmonic or repetition feature can only partly explain the former two phenomena, but none of them can explain the last phenomenon. So it is inferred that participants might partly take advantage of harmonic or repetitive features of "implicit three-tone sequence", but they also processed information melodically because VI-II-I implies the "fourth frame" in Chinese music.

The results which compared the response time in three ways (responses to perfect fifth in two directions with the same scale degree (SSD), perfect fifth with the same starting tone (SST), perfect fifth with the same ending tone (SET), see Table 33) showed that there were significant difference and correlation between responses to perfect fifths with SET, and only a significant correlation between responses to perfect fifths with SSD, but no significant difference and correlation between responses to perfect fifths with SST. It could infer that perfect fifths with the same scale degrees in two directions are perceived quite similar, and the same scale degrees contribute to the responses, but directions may not affect responses. Different ending tones in perfect fifths with SST may not cause a significant correlation; and different starting tones in perfect fifths with SET may cause the difference, as the order of two pitches does not affect the response a lot. So, the subjectively evaluated scale degree of the starting tone may affect the speed of further major tonal processing, and the subjectively evaluated scale degree of the latest tone may affect tonal judgment making.

Table 33 Two directions of perfect fifth in three ways in major mode

Same scale degree (r*)		Same starting tone		Same ending tone (r*, t*)	
↑	↓	↑	↓	↑	↓
I-V	V-I	I-V	I-IV	IV-I	V-I
II-VI	VI-II	II-VI	II-V	V-II	VI-II
III-VII	VII-III	III-VII	III-VI	VI-III	VII-III
IV-I	I-IV	IV-I			I-IV
V-II	V-II	V-II	V-I	I-V	V-II
VI-III	III-VI	VI-III	VI-II	II-VI	III-VI

These findings suggest that the participants take a melodic interval as a gestalt to process, but not take the same starting tone or the same ending tone as the reference. Because perfect fifths with SSD in two directions are perceived related to each other and have no difference; otherwise, the responses to perfect fifth with SST or SET would be similar or related. Besides, subjective scale degrees also present some tonal features, at least, the intervals relate to tonic responded more accurately and faster than other scale degrees. Processing of intervals is complex, which may be influenced by melodic, harmonic and repetition features in the stimuli.

28.1.3 Key profiles of tritone set

There are two possibilities of tritone in major mode, on the fourth and the seventh scale degree in two remote-related keys (e.g. F-B/E#-B in C major and F# major). But only one circumstance was tested - ascending IV-VII and descending VII-IV, rather than ascending VII-IV and descending IV-VII. Unlike perfect fifth, there is no significant correlation or difference between tritone with SSD, so tritone may not have advantages on either the scale degrees or directions. Another possible reason may be that tritone plays a less important role in Chinese music, so participants were not so sensitive to it.

28.1.4 Key profiles of experiment II

The musical excerpt context is applied to examine the results that were obtained in the experiment with the associated context. Musical excerpt provides more practical musical context. However, the profiles in musical excerpt are different from the ones in experiment I. In the PE profile, only priming single tone as subdominant and dominant responded correctly in major mode, while the other scale degrees - even the tonic - were not correctly responded. In the RT profile, there is no significant difference among seven scale degrees. Neither of them correlates significantly with K-K major profile. These phenomena can be explained in three aspects: 1) frequency and duration distribution of scale degrees in music excerpts; 2) interaction between starting scale degrees and cadence of musical excerpt; 3) disturbance of pitch memory.

1) frequency and duration distribution of scale degrees in music excerpts

The frequency and duration profiles of scale degrees of 9 major excerpts are shown in Appendix 4. There is high correlation between the frequency and duration distributions in each major excerpt (see Figure 31); and there is also high correlation between the average frequency and duration profiles and K-K major profile ($r_{frequency}$=0.870*, $r_{duration}$=0.910**). But neither PE profile nor RT profile in this study shows a significant correlation with the average frequency and duration profiles. However, not all major excerpts' frequency and duration profiles are "standard", for instance, the ones in C-sharp major and B major composed by Bach are with less dominant proportion, and in G major composed by Mozart are with less tonic proportion. The statistical information could more or less affect the responses.

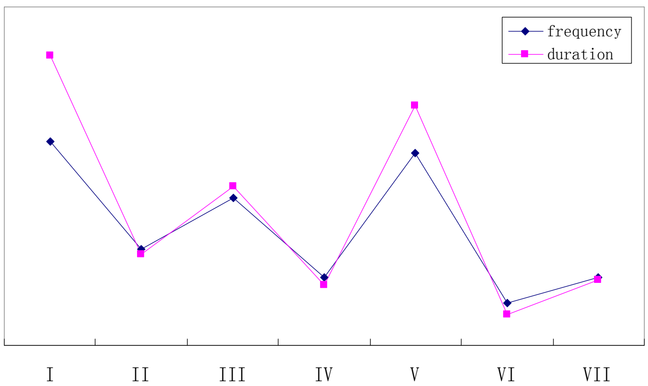


Figure 31 Average frequency and duration profiles of major musical excerpts

The distributions of common intervals and rare intervals in melodic and harmonic directions were also collected (see Figure 32). Melodic intervals were counted intervals between successive tones in a horizontal way; harmonic intervals were counted intervals between lower and upper tones in chords. It seems that in the melodic direction, small intervals (minor second, major second) were more frequent than large intervals; in large intervals, perfect fourth and perfect fifth were more frequent than other intervals; while tritone was less used (only once in F major excerpt by Mozart). In the harmonic direction, octave, major third, perfect fourth, and perfect fifth were more frequent than other intervals; tritone appeared sometimes in dominant seventh chord.

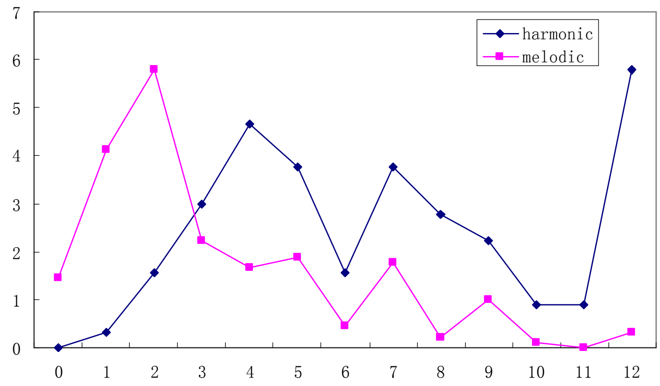


Figure 32 Average frequency of harmonic and melodic intervals in major musical excerpts

However, the responses to F major were not facilitated by the appearance of melodic tritone, but slower than any excerpts in other keys, especially slower than the responses to G major and B major ($p<0.05$). So it was not consistent with the result of Butler and Brown experiments (1994).

2) Interaction between starting tone and cadence of musical excerpt

The musical excerpts starts on 3 scale degrees: tonic, mediant and dominant; and ends with authentic cadence on the tonic, half cadence on the dominant, and without cadence.

As recency effect was frequently discussed, here the main effect and interaction between starting tone and cadence were investigated. The significant main effect of starting tone was observed. Although the interaction between starting tone and cadence was not significant, the responses to musical excerpts with different starting tone and cadence were quite different. That is, the congruence of starting tone and cadence facilitated the responses, except the excerpts without cadence, which responded fast regardless of the starting scale degree.

Maybe the recency effect can explain this phenomenon. The recency effect is investigated with word material quite a lot, and mainly discussed the influences of word frequency, accessibility and list composition on recency effect. The word frequency refers to the frequency of use in daily articles; the accessibility refers to the association from a word, whether it is easily activated or not; the list composition refers to the involvement of pure high-frequency or low-frequency word or the mix of both kinds of words. In word materials, it is found that in pure lists, high-frequency words were better recalled than low-frequency words, but in mixed lists, low-frequency words were better recalled than high-frequency words (Overschelde, 2002; Zhou, & Liu, 2005). The musical phenomena in this study could be also explained by the frequency of tones. Tonic, dominant and mediant are viewed as high-frequency tones - either in melodic (e.g. Hudge, 1977; Krumhansl, 1990) or harmonic relations (Huron, 1993), which are already verified in statistical studies with Western classic works (from Bach, Mozart, Schumann, Schubert, etc.), and other scale degrees as low-frequency tones. Authentic cadence and half cadence are taken as a high-frequency event, and without cadence is taken as a low-frequency event. Then, music excerpts are mixed “lists” of high-frequency and low-frequency events. That participants responded faster to musical excerpts without cadence, which is a mixed musical list ending with low-frequency tones than with high-frequency tones (no matter which priming scale degree it was), is quite similar to the result from word experiments that low-frequency event can be better recalled.

While a priming single tone and a given “tonic” can be viewed as a pure list, because the subjective evaluated scale degree would be an implicit high-frequency event, and the given “tonic” is an explicit high-frequency event. So in such a pure list, high-frequency event should show better response than the low-frequency event.

3) pitch memory

Unlike the trigger “tonic” in post-context of the experiment I, the musical excerpts in experiment II last 3 -10 seconds depending on the length of the motive, which seem to have much stronger interference on the memory of the priming pitch. Besides, there is also a 1000ms silence between the priming tone and the context. Although there is only 500ms extended compared to the SOA in experiment 1, the complex structures of musical excerpts (even the shortest motive was only 3 seconds) interfere with the memory of priming pitch quite a lot.

In the studies of pitch memory, the interfering tones were at maximum six tones, either in the same octave of the test tone or in the octave below or above the test tone (Deutsch, 1974). The tones in the same octave caused the strongest interference of pitch memory (Deutsch, 1974). In the experiment with music excerpts, the tones in melodic line were in the same octave of the priming tone, with accompaniment in lower octaves. That is why the responses in experiment II were generally longer than the responses in experiment I; and most participants reported that they could not remember the priming tone after hearing the motive, so they made responses according to the musical intuition, or according to the consonance between the priming tone and the musical excerpts.

28.2 Minor

Fewer former studies were done with minor than major materials, so there were fewer references. Here the results in minor are discussed.

28.2.1 Key profiles of minor set

Different from the profiles of major mode, the profile of percentage of errors and the profile of response time of minor mode are similar to each other, only except the VII scale degree. That is, the percentage of errors almost changes proportionally with response time of scale degrees, except the response time of the VII scale degree, which took less time but got more errors.

The profile of percentage of errors roughly presents a three level tonal hierarchy of scale degrees: tonic is on the top, which is preferred with the fewest errors; then the dominant and the subdominant follow behind, with similar fewer percentage of errors than other three degrees; and the third level includes supertonic, mediant, submediant and leading tone, with the most errors. This hierarchy is similar to description in Western musical theory, and has a significant correlation with the PE profile of major mode (correlation=0.889, $p<0.01$).

The profile of response time is not like a bow shape, in which subdominant and dominant show shorter responses than mediant and submediant. Nevertheless, there is still some proximity effect that the responses to supertonic and leading tone – around the tonic – are only slower than the response to tonic. The reaction time to tonic is still significantly shorter than the reaction time to other scale degrees. The profile has a significant correlation with the RT profile of major mode (correlation=0.826, $p<0.05$).

These findings suggest that there is higher correlation between major and its parallel minor. The I, IV, and V scale degrees responded easily in minor mode, that is, the three subjective scale degrees were easily assigned to a single tone, which reflected the importance of their tonal function or stableness in the implicit tonal knowledge. However, neither PE profile nor RT profile in minor has a significant correlation with K-K minor profile ($p>0.05$).

There is also no significant difference among three pitch-classes on each degree, which indicates that participants do not have preference of pitch-classes on some scale degrees.

28.2.2 Key profiles of perfect fifth set

There are four possibilities of perfect fifth in minor mode, on tonic, subdominant, dominant and submediant. The profiles show the responses to perfect fifth sharing same scale degrees in different directions (ascending I-V and descending V-I). Generally speaking, PE profile and RT profile of descending perfect fifth had similar tendencies; PE profile and RT profile of ascending perfect fifth were different; furthermore, RT profiles of ascending and descending had similar tendencies, and the response to ascending perfect fifth were faster than the response to descending perfect fifth. The perfect fifth on I-V/V-I got more accurate responses with shorter time; the perfect fifth on V-II/II-V cost longer response time, although its ascending V-II got fewer errors; the perfect fifth on VI-III/III-VI got more errors and cost longer time.

Considering the given "tonic" of the post-context, the priming interval can form an implicit three-tone sequence with the "tonic". Some of the three-tone sequence sound melodic; and the others sound harmonic. There were also three conditions: melodic (perfect fifth as II-VI/VI-II), harmonic (perfect fifth as VI-III/III-VI) and repetition sequence (perfect fifth as I-V/V-I, or IV-I/I-IV). Comparing the three conditions, it seems that responses to repetition sequences were faster than responses to melodic and harmonic sequences, regardless of repeated tone appearing as the starting tone or as the ending tone of the perfect fifth; repetition and harmonic sequences got fewer errors with much longer response time in descending perfect fifths, but the response time of melodic sequences was shorter in ascending perfect fifths. So it is hard to say which condition effectively influenced the responses.

The results which compared the responses in three ways (responses to perfect fifth with the same scale degree (SSD), perfect fifth with the same starting tone (SST), and perfect fifth with the same ending tone (SET), see Table 34) showed that there was significant difference and correlation between responses to perfect fifths with SST, and only one significant difference between responses to perfect fifths with SSD, but no significant difference and correlation between responses to perfect fifths with SET, which were different from the result in major. It could infer that perfect fifth with the same scale degrees in two directions were not similar which might be caused by directions. Different starting tones in perfect fifths with SET might not cause a significant correlation; and different ending tones in perfect fifths with SST might cause the difference, if regardless of the direction of intervals. So, it is difficult to say whether the subjectively evaluated scale degree of the ending tone or the direction of interval affects further major tonal processing. Thus, the processings of perfect fifth in major and minor modes are different.

Table 34 Two directions of perfect fifth in three ways in minor mode

Same scale degree (t*)		Same starting tone (r*, t*)		Same ending tone	
↑	↓	↑	↓	↑	↓
I-V	V-I	I-V	I-IV	IV-I	V-I
IV-I	I-IV	IV-I			I-IV
V-II	V-II	V-II	V-I	I-V	V-II
VI-III	III-VI	VI-III			III-VI

28.2.3 Key profiles of tritone set

There are four possibilities of tritone in minor mode, on the second, the fourth, the sixth and the seventh scale degree. But one circumstance (ascending VII-IV and descending IV-VII) was missing in the trials. There is no significant correlation or difference either among the tritones on the three scale degrees, or between the tritones with SSD in two directions.

PE profile and RT profile of responses to tritone in minor mode were quite different. The accuracy of responses was quite different in two directions on each scales degrees; while response time was quite similar regardless of direction and scale degree, except for the ascending tritone as II-VI which took a longer time than others. When the tritone had the function of II-VI/VI-II, or VI-II/II-VI, although they shared the same scale degrees, the ascending tritone got fewer errors. Conversely, descending tritone VII-IV responded more accurately than ascending tritone IV-VII. So PE profile presented tonal functions of scale degrees of tritons, while RT profile presented the same interval size.

28.2.4 Key profiles of experiment II

The minor profiles in experiment II are also different from the profiles obtained in minor set of experiment I. In minor mode, the tonic is still with many errors as in major mode; while dominant, subdominant and supertonic have more correct responses than other scale degrees.

The profile of reaction time seems to have the similar trend to the profile of percentage of errors - the slower the response was, the more errors occured, though they are not significantly correlated. It seems that the reaction time is quite similar among scale degrees, which is similar to the situation in major mode because of memory interference. The profile of reaction time in minor mode has a significant correlation with the RT profile of major mode (correlation=0.815, $p<0.05$). Besides, the responses to minor mode are significantly slower than the responses to major mode ($t=-4.995$, $p<0.01$). However, neither PE profile nor RT profile correlates significantly with K-K minor profile. These phenomena can be explained in three aspects: a) frequency and duration distribution of music excerpts; b) interaction between the starting scale degrees and cadence of musical excerpt; c) the disturbance of pitch memory. The latter two points are already mentioned in the major part, so here only the frequency and duration distributions of music excerpts are discussed.

The frequency and duration profiles of scale degrees of 8 minor excerpts are shown in Appendix 4. The frequency and duration distributions of each minor excerpt have high correlation (see Figure 33); only the average duration profiles has a significant high correlation with K-K minor profile ($r_{duration}$=0.814*). But neither PE profile nor RT profile in this study has a significant correlation with the average frequency and duration profiles. However, not all minor excerpts' frequency and duration profiles are "standard", for instance, the ones in C minor composed by Mozart are with less mediant proportion. The statistical information could more or less affect the responses.

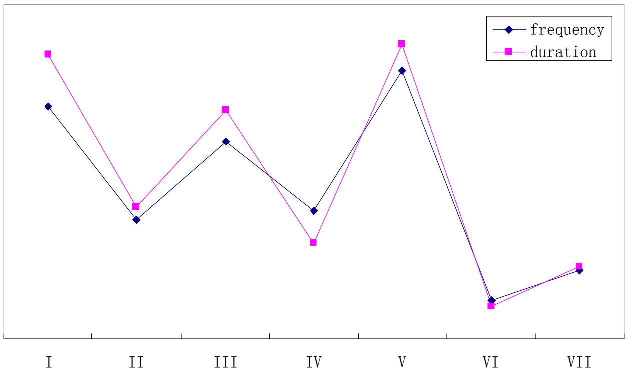


Figure 33 Average frequency and duration profiles of minor musical excerpts

The distributions of common intervals and rare intervals in melodic and harmonic directions were also collected (see Figure 34). Melodic intervals were counted intervals between successive tones in a horizontal way; harmonic intervals were counted intervals between lower and upper tones in chords. It seems that in the melodic direction, small intervals (minor second, major second) were more frequent than large intervals; few large intervals (perfect fourth and perfect fifth) were involved; no tritone or augmented second was used. In the harmonic direction, octave, major third, perfect fourth, perfect fifth were more frequent than other intervals; tritone appeared sometimes in a dominant seventh chord. Thus, it is hard to tell whether tritone or augmented second facilitates responses or not in minor.

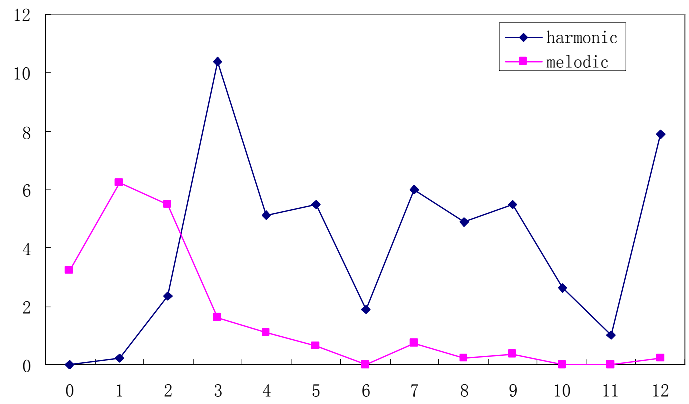


Figure 34 Average frequency of harmonic and melodic intervals in minor musical excerpts.

These findings suggest that subjective tonal hierarchy has advantage, for assigning scale degrees on priming single tone or priming interval. The "subjective" tonic is the easiest one to be activated; subdominant and dominant, which are perfect-fifth-interval apart from the tonic downwards or upwards, and even supertonic, are easier to be activated in both major and minor modes. There is no significant difference between the responses to priming perfect fifth and priming tritone.

29. Response time

29.1 Comparison with former studies

Although the response time in the three experiments reflects some tonal function of scale degrees – especially the significantly faster and more accurate responses to priming tone as the tonic, a distinguished difference between the response time in this study and in the former studies is that Chinese students took much longer time than the participants in the former studies did, who were mostly Western listeners. The Chinese students spent an average of about 3-8 seconds, while the participants in the former studies responded within 2 seconds.

The difference resulted from various experiment designs and tasks for the participants. The response time, used as dependent variable in the experiments with probe-tone technique, was short as within 2 seconds. For instance, Janata & Reisberg (1988) asked the participants to make judgment on "whether the test tone is in the key implied by the scale or chord". There was no time limitation for response time, but participants were told to react as quickly and accurately as they could. Frankland & Cohen (1990) asked the participants to make judgment on whether the test tone fit the pre-context (8 diatonic tone in the key of C), and the participants were allowed to use criteria freely because they had a wide range of music training, but the researchers hoped that the participants could be as "natural or instinctive" as possible. There was also no time limitation for response time, and the judgments were made around 1 second.

While in the experiments with priming task, response time is an essential dependent variable for tonal perception (e.g. Bharucha & Stoeckig, 1987). Judgments on timbre, consonance or dissonance of a chord, intonation of a tone, syllable of lyrics, etc. cost even less time, which was usually around 1 second or less than 1 second. Most of the tasks were set with a limited response time; participants should make responses within 2 seconds, and were also asked to respond as quickly and accurately as they could (e.g. Tekman & Bharucha, 1992, 1998).

Thus, whether the limited response time is set or not does not influence the response time a lot, but the difficulty of task plays an important role in making decisions. It implies whether musical semantic information is used in the processing or not. The task, comparing the "stableness" of post-presented test tones in the former tonal context, refers more or less to music theory knowledge, although participants were expected to base responses on their intuition; other priming tasks, relating little to the tonal knowledge, influence the responses implicitly. Probe-tone tasks do not require much resource of memory, so participants do not need to remember carefully what the context exactly is, they only need to grasp the general tonal feature; for priming tasks, the attention paid on the context may even be less; and less resource is explicitly activated. So the response time is short, as less than 2 seconds or even within 1 second.

However, as mentioned above, the task in this study may be too complex. It seems that the task aroused more memory work, including short-term memory of the priming tone's pitch and long-term memory of scale which is used to complete the post-context. Though participants were told to use strategy freely and also use their intuition, their self-reports indicated that they seemed to depend on their intuition only when there was no clear clue or no strategy for making judgment. So, most of the participants making their judgments were based on explicit knowledge, with more participation of consciousness in processing of musical information.

So there are three factors which influence the response time, one is the feature of pitch memory, the other is the strategy that is used for the judgment, and the third is the number of priming tones.

1) Pitch memory

The task in this study was to make judgment on whether the preceding tone appears in the post-context. The ideal way to make the judgment is to remember the priming tone, and then search the tone in the associated context. This process refers to the memory of priming tone: how long the pitch can be kept until the latter context appears, and how it can avoid the influence or interference of the post-context.

In the experiments with priming single tone, 500ms-long silence was set between the priming tone and the "tonic" of target context. According to the results of research on pitch memory, the pitch memory depends on the relationship between the tones and the tone duration (e.g. Bachem, 1954; Harris, 1952; Deutsch, 1970, etc.). The pitch memory can last about 6 seconds without significant performance decrement, unless there is interference between the two pitches; the memory performance goes down when interference is quite similar to the target stimuli in pitch (especially pitches in the same octave, Deutsch, 1974) and when the same pitch appears late; but pitch memory is not influenced by other modalities' stimuli (as in visual stimuli, Pechmann & Mohr, 1992).

Reviewing the process of the experiments with priming single tone, the association task itself can be seen as interference to the memory of the priming single tone. The visual color square may not disturb the memory of the priming tone, but the "tonic" may influence it more or less. When the priming tone has the function of the tonic in the latter context, it fits the prerequisites – the same pitch and earlier appearance (comparing 500ms with 6 seconds), which has little interference to the priming tone memory. Other contexts' "tonic" may interfere with the memory of the priming tone, because they are the tones in the same octave of the priming tone. So the priming "tonic" can respond more quickly than other scale degrees, which can also be interpreted by repetition effect. Thus, the profile of response time may partly reflect the interference in the memory.

2) Participants' strategies

The strategies used by participants may also affect the results. The strategies refer to how participants completed the context, and how participants processed the implicit interval between the priming tone and the given "tonic" (either in melodic or harmonic way). Participants were told to use the strategy freely, depending on either melodic relationship or harmonic relationship.

According to participants' self-report of strategies and their explicit behavior in the experiment, most of them preferred to use scale as the strategy. That is, some of them (8 of 14 participants) hummed the scale upwards or downwards to find the memorized priming tone in the scale. In this way, the responses to the fourth and the fifth degree would be slower than other scale degrees, because the fourth and the fifth degrees are in the middle of the scale, either upward or downward from the tonic, and they cost more time to reach. While 3 of 14 participants reported that they tried to take the intervals between the priming tone and the "tonic" in the latter context as a reference for making judgment; and another three participants reported that their judgment depended on the intuition, especially when they were not sure about the judgment.

As discussed above, participants depended more on melodic relationship or proximity to make responses. The closer the priming tone around the given "tonic" was, the faster the responses were made; the same size of intervals caused similar responses on different scale degrees, especially the responses to tritones. So the RT profiles reflected either the proximity or the size of interval, and even repetition of a priming tone.

Another unexpected factor is the participants' state during the experiment, which may affect the reaction time. Although the participants were told to be relaxed in the experiment, they felt so nervous. Some of them reported that they took the task as a listening skill test, and they were worried about their performance.

3) The number of priming tones

There was a significant difference between responses to priming single tone and responses to priming interval. The responses to priming interval were faster than to priming single tone. The implied keys of an interval are fewer than the implied keys of a single tone, which is similar to the relation between point, line and plane. So, the incremental effect is verified.

29.2 Comparison with Western tonal hierarchy

In these three experiments, PE profiles presented some features of tonal function. There are two discriminating features which are different from the results concluded from Western listeners with Western music (e.g. Krumhansl, 1990). One distinction is that the I, IV and V scale degrees seem to be more important than the I, III, V scale degrees, in both major and minor modes with priming single tone and interval; the other is that the III scale degree is not preferred by the Chinese participants, also in both major and minor modes with priming single tone and interval.

The I, IV and V scale degrees are stressed in some music theories, since Castil-Blaze (1821). He named “tonalité” for the “cordes tonales” (tonal tones) including the tonic, the fourth (subdominant), and the fifth (dominant); and other tones were called “cordes melodiques” (melodic tones). The relationship among the three scale degrees is also presented in the chord level of MUSACT model; while the relationship among I, III, V is presented in the tone level of MUSACT model. So according to MUSACT model, which is built on the basis of Western music, I, III, V should have a connection between the tone level and the chord level, as many studies resulted from Western listeners (e.g. Krumhansl, 1990). However, it was not the case in this study. According to the response time in this study, the processing is more of melodic relationships, so the tonal hierarchy of tone level is activated. It is inferred that the I, IV, V scale degrees with more accuracy reflect Chinese listeners’ tone level, which may be different from Western listeners’ tonal hierarchy. However, one curious phenomenon is that IV is not a stable tone in Chinese pentatonics. A possible explanation for this can be that I, IV, V reflect not the exact scale degrees, but the relationship among the scale degrees corresponds to the relationship among *Shang, Zhi* and *Yu*, which is viewed as the core relationship in Chinese music. But this interpretation is only an assumption that can be further studied.

The slower and less accurate responses to mediant are also verified. It happened in priming single tone trials with both associated context and musical-excerpt context, and also in priming perfect fifth set starting from and ending on the mediant. So it could not be an accidental phenomenon, it should be caused by some cultural reasons from listeners.

Summary:

The three experiments involve more explicit effort of musical theoretical knowledge, which cost too much time in making judgment. In this circumstance, reaction time, as a dependant variable, may not be sensitive to reflect the tonal hierarchy, only provides a proximity hierarchy with the tonic; while the accuracy of response can effectively reflect the tonal relationship in the scale, and also cultural features of tonal hierarchy, which can be divided into two levels: tonic and other diatonic tones, or more precisely divided into three levels: tonic, and V, IV, II, and other diatonic tones.

30. Cross-cultural aspect

Compared with the studies done with non-Western music, e.g. studies on tonal hierarchy of Indian music (Castellano, Bharucha, & Krumhansl, 1984), of Indonesian music (Kessler, Hansen, & Shepard, 1984), of Scandinavian North Sami yoiks (Krumhansl, et al. 2000), of Japanese music (Abe & Hoshino, 1990) and of Korean music (Nam, 1998), the common point of these studies is that participants who are native listeners and are familiar with specific music can rate the tones corresponding to the theoretical tonal prediction. Participants from different cultures would perceive the music from other cultures according to participants' own tonal hierarchy system (e.g. Krumhansl, 1990; Curtis & Bharucha, 2009).

The music in these cultures is different from Western music, but there are some similarities among them. For example, although Indian music sounds quite different from Western music in melody and rhythm, the tones in both music cultures are centered around "tonic" (sung as *Sa* in Indian music, and sung as *do* in Western music), and "dominant" (sung as *Pa* in Indian music, and sung as *sol* in Western music), which play important roles in both music cultures. Western listeners could judge the fit of a tone in Indian musical context according to proximity of the last tone in the context or on the basis of Western tonal hierarchy.

As two Chinese pieces were analyzed in Part I, regardless of which mode, the importance of scale degrees is on the basis of the circle of fifths, rather than the relationship of triad. The scale degrees close to the tonic in the circle of fifths are more important or stable than the ones remote to the tonic in the circle of fifths. Thus, it would not be so confusing with the results of Chinese students, generally speaking, that subdominant and dominant are preferred. The major mode is similar to *Gong* mode, subdominant and dominant are one-step of the circle of fifths away from the tonic; and even supertonic is preferred, because it is one-step of the circle of fifths away from the dominant; while mediant is four steps of the circle of fifths away from the tonic, so it shows slower response and more errors. So is the same in minor mode which is similar to *Yu* mode. With the Chinese tonal hierarchy, the I, IV and V scale degrees are more easily activated than other scale degrees.

31. Participants

There are significant interactions between pitch sense and instruments in the three experiments. It is interesting to notice that in different conditions possessors with different pitch sense and different instrumentalist responded differently. Western instrumentalists with AP responded faster to the trials with priming single tone than Western instrumentalists with RP; while Chinese instrumentalist with AP responded faster to the trials with "stem-completion" context than Chinese instrumentalists with RP. So, regardless of pitch sense, it seemed that Western instrumentalists depended on priming stimuli, but Chinese instrumentalists depended on post-contexts. The processing ways of two groups were quite different; the familiarity of major and minor contexts made them focus on different stimuli in the experiment.

Besides, AP possessors playing Western instruments responded slower to trials with “stem-completion” context than AP possessors playing Chinese instruments; while RP possessors playing Western instruments responded faster to trials with “stem-completion” context; but there was no difference between RP possessors playing different instruments in trials with musical excerpts. Regardless of instruments, AP and RP possessors both depended on post-context. However, the responses to the trials with musical excerpts were relatively equal for all RP possessors, but different for AP possessors, especially the responses of AP possessors playing Chinese instruments were very slow. For RP possessors, it might be because in “stem-completion” tasks, Western instrumentalists were able to faster recall major and minor modes than Chinese instrumentalists, but in musical excerpts they did not need to activate much tonal knowledge. For AP possessors, it might be because AP possessors playing Chinese instruments were not “absolutely” field-independent, that is, they could not ignore the interference of the contexts.

The third group of pitch sense involves listeners with both AP and RP sense (mixed pitch sense). It is interesting to find that these listeners playing Chinese instruments responded always at the “middle” speed – between AP possessors and RP possessors playing Chinese instruments; while mixed pitch sense possessors playing Western instruments responded slower to the trials with priming single tone, but responded faster to the trials with priming interval than the other two pitch sense groups playing Western instruments. Furthermore, Western instrumentalists with mixed pitch sense responded only slower than Chinese instrumentalists with mixed pitch sense in trials with priming single tone and “stem-completion” context. So, it seemed that listeners with mixed pitch sense were reluctant to depend on their AP sense, and might be more hesitant to make response; however, when there was a reference, they preferred to depend on their RP sense.

32. Limitations and suggestions

As discussed above, the limitations of the first three experiments would be avoided in the experiment series 2.

32.1 Method

The method used in these three experiments is different from any former studies: the probe tone - as priming stimuli, the context - as target. The tasks involve too much effort of memory, which is also interfered by the tasks themselves. The memory task may also arouse the theoretical analysis of tonal hierarchy, so it is more like an explicit task which costs much longer time, rather than an implicit task. In explicit tasks, the reaction time seems to be ineffective to reflect tonal hierarchy; while in implicit tasks, based on musical priming studies, the reaction time is valid as a measurement for exploring tonal hierarchy.

Therefore, the next experiment series is set with an implicit task to avoid evoking tonal knowledge and memory, for instance, timbre judgment task. With this precondition, participants in the consequent experiments can also involve listeners with none or little musical training.

32.2 Participants

The former three experiments were done only with Chinese students, but no Western listeners as comparison. Therefore, it is reasonable to doubt whether the results are the consequence of the method or the reflection of musical culture background, especially the responses to the III scale degree. So in further experiments, it would be examined with both Chinese and Western listeners to see whether the mediant is a distinctive scale degree for both cultural groups. If mediant is still not preferred by Chinese listeners, but by Western listeners, it would indicate that Chinese tonal hierarchy differs from Western tonal hierarchy. Otherwise, it would be the result caused by the method.

Besides, Frankland and Cohen (1990) summarized the former studies that participants with different training levels may present different hierarchy. Participants with more musical training may have three-level hierarchy - tonic triad, non-diatonic tones and non-tonic triad (the former two levels responded faster than the third, because they meet the consistency of expectation); participants with less musical training may have two-level hierarchy - diatonic and non-diatonic hierarchy, or proximity hierarchy (near or far from the last note of the context). So the hierarchy of Chinese musical listeners and non-musical listeners can also be compared.

Part V Experiments Series 2

Based on the discussion of the results from the experiment in series 1, the experiments in series 2 tried to overcome the limitations in the former experiments, and set further hypotheses in tonality perception. The experiment series 2 focused on tonal implicit knowledge which plays an important role in the tonality perception (e.g. Bharucha, et.al. 1998, 2001). The aim was to investigate the difference of the implicit knowledge which is acquired by listeners from different musical cultures. Chinese and German participants were only involved in this experiment series.

33. Hypotheses

One result from experiment series 1 is that the third degree (III) seems to be the most "controversially" perceived degree, which for Chinese listeners is less important, while for Western listeners is an important tone in the tonic triad. Such a distinction may be caused by the differentiation of the musical implicit knowledge which is formed in different musical culture environments. Thus, the main hypothesis in the experiment series 2 is that the tonal implicit knowledge acquired by Chinese listeners and German listeners is different.

The hypothesis was investigated based on the MUSACT model (Bharucha, 1987), which showed the relationship among tones, chords and keys in a connectionist network. Most studies dealt with the relationship between the two upper levels (chords and keys), because harmonies and keys are the core issues in Western music. At the tone level, which relates to the chord level in forms of major or minor third and perfect fifth, it was also verified that Western listeners prefer to encode the tones in a harmonic triad relationship (Deutsch, 1981; Auhagen, 1994).

However, the harmonic triad relationship may not be important to Chinese listeners. Chinese music is characterized by pentatonic mode, although IV (*fa*) and VII (*si*) do exist in heptachord scales (*Zhengsheng diao*/old scale, *Xiazhi diao*/new scale, *QingYu* scale) (Li, 2004, p.10-11). *Fa* and *si* have different solutions in Chinese music that they are not solved with minor second: *fa* to III (*mi*) and *si* to I (*do*) as tonic triad in Western major mode (Zhao, 1964), but are solved with major thirds: *fa* goes major third up to *Yu* (*la*) and *si* goes major third down to *Zhi* (*sol*) (Zhang, 2002/1989, p.282). In Chinese pentatonic mode, the major third between tones *Gong* and *Jue*, which is equivalent to I (*do*) and III (*mi*) in Western major and minor modes, is the "rare" interval. Thus, the Chinese tonal hierarchy may be different from the Western tonal hierarchy, and Chinese listeners' MUSACT network may also be different from Westerns' MUSACT model.

Nevertheless, an essential idea stressed in MUSACT model is that the degrees in a closer tonal relationship could be easily activated by each other. In other words, the easier a tone is activated by the other one, the closer relationship they share; the closer the tones are related, the faster responses to the tones can be made. In the experiment series 2, the priming paradigm was used; relationship between tones was taken as a variable, considering the tonal importance of scale degrees; and response time was taken as an indicator for measuring the relationship among tones in Western heptachord and Chinese pentatonic scales. The implicit task was timbre judgment.

For tones in tonic triad, Chinese listeners may perceive differently from K-K profiles (Keil & Krumhansl, 1982). What Chinese listeners perceive may be similar to the feature of Chinese music, because the culture experience can influence the perception of new musical material (Krumhansl, 2002). Chinese music stresses the three tone sequence in a fourth frame formed by a major second and a minor third, for instance II-III-V (*re-mi-sol*), V-VI-I (*sol-la-do*), VI-I-II (*la-do-re*), or III-V-VI (*mi-sol-la*). So, instead of tones in tonic triad, the tones in the fourth frame might be perceived as a "unit" with faster response time by Chinese listeners.

Conversely, German listeners may have also kept their "habit" when listening to Chinese pentatonic melodies. That is, the tones in the tonic triad would be still perceived as the "stable" ones, which share the harmonic function and activate each other faster than other degrees.

Besides, the participants in both musical culture backgrounds involved both musicians, whose major were music, and non-musicians, who studied other subjects. Musicians were highly trained so that they would process pitch and timbre information separately, and their timbre judgments could not be disturbed by pitch variations, so their responses on scale degrees would be quite similar; while non-musicians might not be sensitive to timbre, and they would process pitch and timbre information together, so their timbre judgments would be impacted by pitch variations, and their responses on scale degrees would be different which reflect their implicit tonal knowledge.

Finally, the hypotheses are listed here:

H1. Chinese listeners' key profiles are different from German listeners' key profiles (in major, minor, Chinese pentatonics);

H2. The relationship among three degrees II-III-V, or V-VI-I, or VI-I-II, or III-V-VI perceived by Chinese listeners is closer than perceived by German listeners;

H3. The relationship among tones in tonic triad, or dominant triad, or subdominant triad perceived by German listeners is closer than perceived by Chinese listeners;

H4. Musicians' responses are quite similar among degrees; non-musicians' responses are quite different among degrees;

H5. Musicians respond faster than non-musicians;

H6. "Cadence effect" facilitates responses.

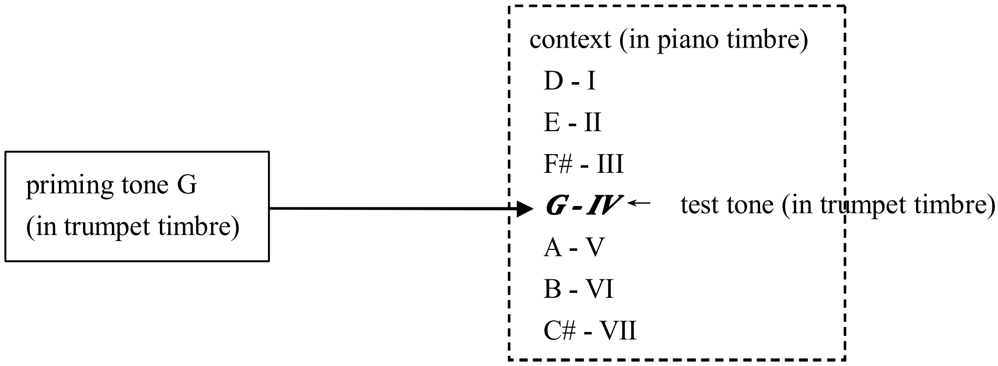
34. Method

In the experiment series 2, the "vectors" between one degree and other degrees in the tonal relationship were measured. The "vectors" did not only explicitly refer to the direction and distance of the interval, but also implicitly reflected the perceived relationship between the two degrees which was shown as reaction time and could be represented in a multidimensional scale.

The pattern "priming tone(s) - context with test tone" was still used, but the task was different from the one in the experiment series 1. In this series, participants were asked to make "timbre judgment". The priming tone was played in trumpet sound; while the following context was played mainly in piano sound, but the test tone in the context was played in trumpet sound. The task for the participants was to detect whether there was a trumpet tone in the context or not.

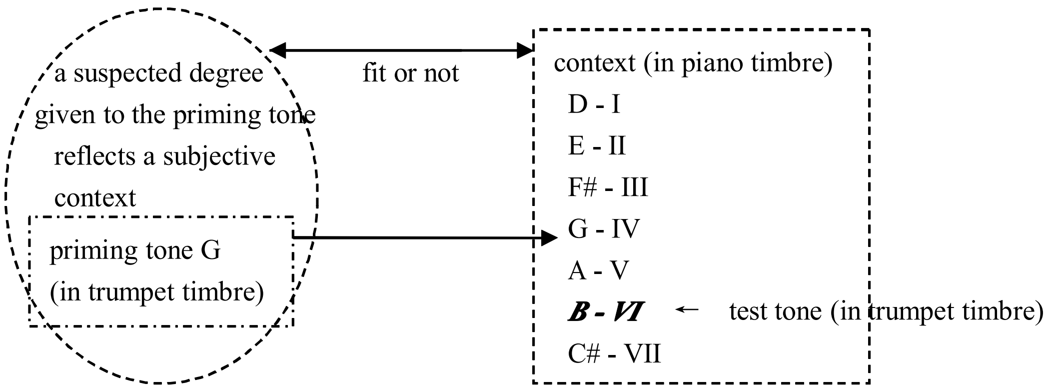
There were two ways to obtain the “vectors” between the two scale degrees. One was a direct or absolute method (Figure 35a), and the other was a relative method (Figure 35b). The direct way assumed that listeners had a tonal hierarchy which related to a certain musical culture, and in such tonal hierarchy some scale degrees were more important than others. The more important the degree was, the faster a response would be made. The given priming tone was isolated without any tonal sense, but it obtained its tonal meaning in the following context, which was a tonal sense “giving” process. When the “given” tonal sense in the context matched an important scale degree in the tonal hierarchy, it would take little time to respond; otherwise, when the “given” tonal sense matched a less important degree, it would take some time to make a decision.

Thus, the test tone – played in trumpet sound – appearing in the post context had the same pitch as the priming tone, and it could be any in-key degree in the tonal context. For example, a priming tone G (in trumpet sound), it is the IV (subdominant) in D major; if taking an ascending D major scale as a context, then D, E, F#, A, B, C# are played in piano timbre, but G played between F#, and A is in trumpet timbre. When G as the priming tone shows faster response than C# as the priming tone with the same post-context D major, then the subdominant (G in D major) can be considered more important than the leading tone (C# in D major). The “vector” can be viewed as the relationship between non-degree or unknown-degree sense and scale degree sense in context. The more important scale degree can be more easily perceived for its stableness, so the response would be faster. Then it is possible to get to know which scale degree has important tonal function according to its response. That may reflect one’s implicit tonal knowledge: the shorter the response time is, the more important tonal function the scale degree has.



(if the priming tone and test tone both are changed into C#, the response may be slower than they are in G.)

a. direct method



(if only the test tone is changed into C#, the response may be slower than it is in B, because of the popularity or closer relationship of major third G-B than tritone G-C#.)

b. indirect method

Figure 35 Direct and indirect methods

The relative way measured the perceived distance between the two degrees. It was supposed that the given priming tone could promote or interfere in the response of another scale degree, which depended on the importance of intervals in the tonal hierarchy. And when the responses of the same interval started from different degrees were different, they might be caused by the tonal sense according to one's implicit tonal knowledge. In this circumstance, the priming tone would be interpreted with some tonal sense automatically and implicitly before the following context appeared.

Thus, the test tone, played in trumpet sound and appearing in the post context, had different pitch from the priming tone, and it could be any scale degree in the tonal context other than the scale degree of priming tone in the certain context. For example, a priming tone G (in trumpet sound), it is the IV (subdominant) in D major; if taking an ascending D major scale as a context and B as the test tone, then D, E, F#,G, A, C# are played in piano timbre, but B played between A and C# is in trumpet timbre. When B as the test tone shows faster response than C# as the test tone, then major third (G-B) can be considered more important than tritone (G-C#) – the shorter the response time is, the closer the relationship they have; when B priming with G (IV) shows slower response than F# priming with D (I), then D can be considered more important than G in tonal function – the shorter the response time is, the more important tonal function they have. The “vector” can be viewed as the relationship between an implicitly suspected degree – by implicit knowledge – and the test scale degree in the context. The more important the interval and scale degree can be, the more easily it is perceived for its popularity and stableness, so the response would be faster. Then it is possible to get to know the importance of interval and activation of a certain scale degree, which can be represented in a multidimensional scale.

For priming with successive intervals experiments, only the direct method was used, and only major mode was involved. There were common intervals in major: the perfect fourth and the perfect fifth; and rare intervals in major: the minor second and the tritone. It investigated whether the response could be faster when one tone of the priming successive interval was on some important scale degree – the result could be compared with the indirect method with priming single tone; whether the direction of successive interval could facilitate the response; and whether a common interval could promote the response.

35. Design

The experiments series 2 consisted of two exercises and six experiments, which were all within subject factorial design. Every subject did all exercises and experiments. The two exercises aimed to let participants get familiar with the timbres of materials and the task. The five experiments (experiment 1 - 5) were with a priming single tone; only one experiment (experiment 6) was with a priming melodic interval. All the priming tones were played in trumpet timbre; while the contexts were played mainly in piano timbre, with only the test tone in trumpet timbre. But not all the contexts involved a test tone, which were used as signal detection. The task for participants was to respond whether there was a "trumpet tone" in the context or not.

35.1 Priming single tone

The whole experiment design was a nested design, which was based on three modes – major, minor and pentatonics. The degree was viewed as a nested factor of the mode, because in each mode they have different tonal functions. Then the perceived profiles of the three modes could be compared.

The experiments in different modes were with different methods considering different factors. All three modes were tested with direct method; major and pentatonic modes were also investigated with indirect method.

As for the direct method, in the major and minor modes, there were three factors – exclusive to the degree as the nested factor of mode – were taken into account:

a) The position of the test tone, which was either in the middle or at the end of the context. The response to the test tone in the middle of the context was viewed as "melodic-driven", but the response to the test tone at the end of the context was viewed as "cadence-driven". It was to compare the tonal hierarchical difference between "melodic-driven" and "cadence-driven";

b) The starting tone of the context, which formed an interval with the priming tone. The context started either from a tone four degrees away from the priming tone (the interval between the priming tone and the starting tone of the context was perfect fourth or tritone), or from a tonic or a dominant of the context. It tried to investigate the function of the "implicit starting" interval;

c) The cadence of the context, which ended on tonic or dominant, or even an "expected" cadence which ended neither on tonic nor dominant but elicited to tonic – according to melodic tendency in cadence (ascending minor second from VII, descending major second from II, etc. see 36.3), or without cadence. With or without cadence was to investigate whether a clearer tonal context could promote activation of tonal hierarchy or not.

When all the four factors (including the degree) were taken into the factorial design, there would be so many trials for the participants and the experiments would last very long. So only the three factors were set in the uniform design (2(positions of test tone) × 2(start tone of context) × 2(cadence)), but only five conditions were involved (see Table 35). Because these five conditions were enough to compare the effects of factors and also save time in the experiment. Major was tested in the five conditions; while minor was tested only in four conditions.

Table 35 Five conditions across three factors

Test tone	Middle of the context				End of the context			
	s1c1	s1c2	s2c1	s2c2	s1c1	s1c2	s2c1	s2c2
major	√	√		√	√		√	
minor	√	√			√		√	

(s1=start tone was four or seven degrees away from priming tone; s2=start on tonic or dominant; c1= without cadence; c2= either cadence ending on tonic or dominant or "expected" cadence)

In the pentatonic mode, the starting tone of context and the cadence was not considered, because any tone in the pentatonic scale could be the tonic and there was no specific cadence "pattern". So the design of pentatonic mode was much easier than that of major and minor modes, only two factors were taken into account: 5 (degrees) × 2 (position of test tone).

Short melodies were a completely random design of the degree in the three modes, which was to compare the activation of each degree in a certain musical circumstance.

As for the indirect method, only major and pentatonics were involved. It was also a completely random design of seven or five degrees, with the same "implicit start interval" between the priming tone and the starting tone of the context and no cadence indication. All the test tones were set in the middle of the contexts, and the context involved only ascending scales.

35.2 Priming successive interval

In this experiment, only major mode was included. In the major scale, perfect fifth and perfect fourth were viewed as common intervals, while tritone and minor second were viewed as rare intervals. It was a two factorial design; one factor was the degree on which the interval could appear, and the other factor was the direction of the interval, that is, 2 (degree) × 2 (direction of priming interval). The context involved only ascending scale without considering the starting tone and cadence, and the test tone was set on corresponding scale degree on which the interval started or ended.

36. Material

The sound materials were created with Sibelius 5 and were exported in MIDI files, and then transformed into WAV files by WinGroove for the use in software Presentation. Every priming tone or interval and the coming context was made together as one case, but here they were introduced separately. The key of each trial was randomly selected.

36.1 Priming tones

The priming tone(s) – a single tone or two successive tones (melodic interval) – were played in the trumpet timbre, and lasted 500ms. That is, each single test tone lasted 500ms, and each tone in a melodic interval lasted 250ms.

The register of priming tone was between c^1 and e^2, in which it is easy to distinguish the difference between trumpet and piano sound. The melodic intervals included tritone, perfect fifth, perfect fourth, and minor second, because tritone and minor second are considered as the "rare" intervals (which do not exist in Chinese pentatonic mode), and perfect fifth and perfect fourth are considered as the "common" intervals in the major mode (Browne; Butler, Brown, etc.).

36.2 Contexts

The contexts, which could be an ascending or a descending scale or a short monophonic melody, were played mainly in the piano timbre, with only one test tone in trumpet timbre that appeared either in the middle or at the end of the context.

Each tone in the scale lasted 125ms. The scales included Chinese pentatonic scale which was shown with five tones in 625ms, and major and minor scales which were shown with seven tones in 875ms. There was no repetition of any tone in the scale context. The test trumpet tone appeared in the middle of the scale – the third tone in the five-tone context, or the fourth tone in the seven-tone context, lasting 125ms; the test tone at the end of the scale lasted also 125ms. Doing so was to reduce the repetition effect.

The monophonic melodies were revised from some real music (see Appendix 5), lasting about 4 to 6 seconds, and repetition of tones was allowed. The test tone was set in the middle when it appeared first time in the context, lasting about 200-400ms.

36.3 Relationship between priming tone and context

The scales did not always start from the tonic. The starting tone was taken into account with the relationship between itself and the priming tone. Here are the rules to make the contexts (the notes can be found in Appendix 6). For scales, there were five arrangement rules:

Test tone in the middle of the scale:

- Ascending scales: the starting tone of the context kept four degrees from the priming tone. That is, a scale started from a tone which was lower than the priming tone about four degrees, so the interval between the priming tone and the starting tone of the scale could be a perfect fourth or a tritone. Then the scale ascended degree by degree. For example, the priming tone is G, if it is the II (supertonic) degree in the context, then the context would ascend from D, E, F, G, A, Bb until C, and G is played in trumpet timbre.
- Descending scales: the starting tone also kept four degrees from the priming tone. That is, a scale started from a tone which was higher than the priming tone about four degrees, so the interval between the priming tone and the starting tone of the scale could be a perfect fourth or a tritone. But the scale ended with a cadence, either on tonic or dominant, or at least led to an expectation, e.g. VII (leading tone) or II (supertonic) tending to I (tonic) (Auhagen, 1994). In this case, the scale descended degree by degree, but at the end with a broken harmonic cadence. For example, the priming tone is G, if it is the II (supertonic) in the context, then the context would

descend from C, Bb, A, G, F, D and until E. As we can see that F to D can be a broken harmony of D triad, and at the end goes up to E – the leading tone in F major – that gives an expectation to the tonic F.

- Tonal scales: they were revised from the descending scales described above, so they also had a descending tendency. They started not from a tone four degrees apart from the priming tone, but from either the tonic or the dominant. In this case, the scales could be more clear in tonal sense that with a tonal indicator at the beginning and a tonal expectation at the end. For example, priming tone is G, if it is the III (mediant) in the context, then the scale would start with Bb, Ab, F, G, Eb, C, and until D, with an expectation to Eb.

Test tone at the end of the scale:

- Ascending scales: the starting tone of the context kept seventh with the priming tone. That is, a scale started from a tone which was seven degrees lower than the priming tone, so the interval between the priming tone and the starting tone of the scale could be a minor seventh or a major seventh. Then the scale ascended degree by degree. For example, the priming tone is G, if it is the II (supertonic) in the context, then the context would ascend from A, Bb, C, D, E, F, and until G, and G is played in trumpet timbre.

- Descending scales: the tones in the scale were higher than the test tone. When the ending tone was set the same as the priming tone, it is difficult to make such "cadence" with strong expectancy or make it into standard cadence. In this case, a tonal indicator or expectation guidance was set at the beginning of the scale. That is, the starting tone was either the tonic or the dominant which was higher than the priming tone. The tonic or the dominant went up to the highest degree in the way of broken harmony to avoid a large interval jump, then descended to the test tone. For example, the priming tone is G, if it is the III degree (mediant) in the context, then the context would start from Eb, and goes up to F – the highest tone in the descending scale above G, then falls to D, C, Bb, Ab, and until G. No tones are repeated.

Furthermore, the scale contexts for the priming intervals were only major scales. The test tone in the context referred only to the "target" degree of the interval. For example, a perfect fourth starts from G – ascending from G to C or descending from C to G, if G is the II (supertonic) in the context, then the context would start from D, E, F, G, A, Bb, and until C, only G is in trumpet timbre.

The rules mentioned above showed examples in major and minor modes. For Chinese pentatonic scales or short melodies, the methods were the same as the heptatonic scales, but without control on the starting tone and cadence of the context. For melodies:

- The revised monophonic melodies were within 6 seconds. They started and ended on either tonic or dominant. The test tone appeared in the middle of the melody. The test tone was arranged on the downbeat or sub-downbeat and could repeat after the "test position".

36.4 Grouped experiments

The two exercises were differently presented as introduced above:

Exercise 1:

Exercise 1 involved 7 major scale-pairs. In each case, the priming tone came first, then the scale-pair which consisted of two scales. One was with the test tone, and the other was with no test tone. The test tone was set in any position in the scale. This exercise was to let subject know the difference between the contexts with and without the trumpet tone.

Exercise 2:

Exercise 2 involved 14 minor trials, 7 of them were with the contexts including test tones and the other 7 trials with the contexts without test tone. But the contexts in the trials were not as same as the ones in the experiment. The test tone was set in any position in the scale, but not only in the middle of the tone sequence. The task for participants was to report whether trumpet tone appeared in the post-context. The trials in this exercise were quite similar to the trials in the experiment, through which subject could get familiar with the process of experiment.

The scale-like trials were mixed into four experiments, and in each experiment they were presented randomly. Here is a list showing the trials in each experiment.

Experiment 1:

Experiment 1 included 28 "direct" major trials, 12 "indirect" major trials and 14 major trials without the test tone.

◇ Direct: the pitches of the priming tone and the test tone in the context were the same, the contexts included:

- 7 ascending scales. The context started from four degrees lower than the priming tone and the test tone was in the middle of the context;
- 7 descending scales. The context started from four degrees higher than the priming tone, ended with a cadence or with a tonic expectation, and the test tone was in the middle of the context;
- 7 ascending scales. The context started from seven degrees lower than the priming tone and the test tone was at the end of the context;
- 7 descending scales. The context started from a tonic or a dominant, ended with a cadence or a tonic expectation, and the test tone was at the end of the context;

◇ Indirect: the pitches of the priming tone and the test tone in the context were different, The contexts were:

- 6 ascending scales. The priming tone was the "tonic" of the context, the contexts were without control of the opening tone, and the test tone could be on any degree other than the tonic in the middle of the context;
- 6 ascending scales. The priming tone was the "supertonic" of the context, the contexts were without control of the opening tone, and the test tone could be on any degree other than the supertonic in the middle of the context;

◇ 14 trials were with no test-tone context, which consisted of 7 ascending scales and 7 descending scales.

Experiment 2:

Experiment 2 included 28 "direct" minor trials, 12 "indirect" major scales and 14 minor trials without the test tone.

◇ Direct: the pitches of the priming tone and the test tone in the context were the same, the contexts included:

- 7 ascending scales. The context started from four degrees lower than the priming tone and the test tone was in the middle of the context;

- 7 descending scales. The context started from four degrees higher than the priming tone, ended with a cadence or a tonic expectation, and the test tone was in the middle of the context;

- 7 ascending scales. The context started from seven degrees lower than the priming tone and test tone was at the end of the context;

- 7 descending scales. The context started from a tonic or a dominant, ended with a cadence or a tonic expectation, and the test tone was at the end of the context;

◇ Indirect: the pitches of the priming tone and the test tone in the context were different:

- 6 ascending scales. The priming tone was the "mediant" of the context, the contexts were without control of the opening tone, and the test tone could be on any degree other than the mediant in the middle of the context;

- 6 ascending scales. The priming tone was the "subdominant" of the context, the contexts were without control of the opening tone, and the test tone could be on any degree other than the subdominant in the middle of the context;

◇ 14 scales were with no test tone, which consisted of 7 ascending scales and 7 descending scales.

Experiment 3:

Experiment 3 included 20 "direct" pentatonic trials, 20 "indirect" pentatonic trials and 10 trials without the test tone.

◇ Direct: the pitches of the priming tone and the test tone in the context were the same, the contexts included:

- 5 ascending scales. The context started from four or three degrees lower than the priming tone and the test tone was in the middle of the context;

- 5 descending scales. The context started from four or three degrees higher than the priming tone and the test tone was in the middle of the context;

- 5 ascending scales. The context started from seven or six degrees lower than the priming tone and the test tone was at the end of the context;

- 5 descending scales. The context started from seven or six degrees higher than the priming tone and the test tone was at the end of the context;

◇ Indirect: the pitches of the priming tone and the test tone in the context were different:

- 4 ascending scales for each priming tone. The priming tone was the "*Gong*"(or *Shang*, or *Jue*, or *Zhi*, or *Yu*) of the context, the contexts were without control of the opening tone, and the test tone could be on any degree other than the degree of the priming tone in the middle;

◇ 10 scales were with no test tone, which consisted of 5 ascending scales and 5 descending scales.

Experiment 4:

Experiment 4 included 14 "direct" major trials, 18 "indirect" major trials and 14 trials without the test tone.

◇ Direct: the pitches of the priming tone and the test tone in the context were the same, the contexts included:

- 7 major scales. The context started from a tonic or a dominant, ended with a cadence or a tonic expectation, and the test tone was in the middle of the context;

- 7 minor scales. The context started from a tonic or a dominant, ended with a cadence or a tonic expectation, and the test tone was in the middle of the context;

◇ Indirect: the pitches of the priming tone and the test tone in the context were different:

- 6 ascending scales for each priming tone. The priming tone was the "dominant" (or submediant, or leading tone) of the context, the contexts were without control of the opening tone, and the test tone could be on any degree other than the degree of the priming tone in the middle;

◇ 14 scales were with no test tone, which consisted of 7 major scales and 7 minor scales.

Experiment 5:

Experiment 5 included 7 major short melodies, 7 minor melodies and 5 pentatonic melodies.

- 7 major scales. The context started from a tonic or a dominant, ended with a cadence or a tonic expectation, and the test tone was in the middle of the context;

- 7 minor scales. The context started from a tonic or a dominant, ended with a cadence or a tonic expectation, and the test tone was in the middle of the context;

- 5 pentatonic scales were with the test tone in the middle of the context;

Experiment 6:

Experiment 6 included 10 perfect fifth trials, 10 perfect fourth trials, 4 tritone trials and 8 minor second trials in major.

- 10 perfect fifths as priming interval, including 5 ascending and 5 descending perfect fifths; the contexts were ascending scales starting from four degrees lower than the test tone;

- 10 perfect fourths as priming interval, including 5 ascending and 5 descending perfect fourths; the contexts were ascending scales starting from four degrees lower than the test tone;

- 4 tritones as pretext interval, including 2 ascending tritones, and 2 descending tritones; the contexts were ascending scales starting from four degrees lower than the test tone;

- 8 minor seconds, including 4 ascending minor seconds and 4 descending minor seconds; the context were ascending scales starting from four degrees lower than the test tone.

37. Procedure

Before the exercises, the participants were asked to fill out a table about their information, including name, gender, age, university, major, music experience which referred to whether they learned some instrument or sang in a chorus, or even learned music theory by themselves, music flavor or preference, and email or telephone number.

Then they were going to read the instruction of tasks in the two exercises and six experiments. Participants who got the accuracy over 90% in the exercise 2 could do further experiments. In the first exercise, listeners got familiar with the materials, so the accuracy of the response was not very important; in the second exercise, listeners got familiar with the tasks which were the same as the tasks in the experiments.

The sequence of five experiments with a priming single tone was random, and the experiment with a priming successive-interval was always the last experiment. Subject could have rest between experiments when they needed.

Each trial started with 250ms long noise, and followed by 1500ms long silence. The priming tone(s) lasted 500ms. The context appeared after another 500ms long silence. Participants should make their responses as fast and accurate as possible. There was about 3s long silence between each two trials (see Figure 36).

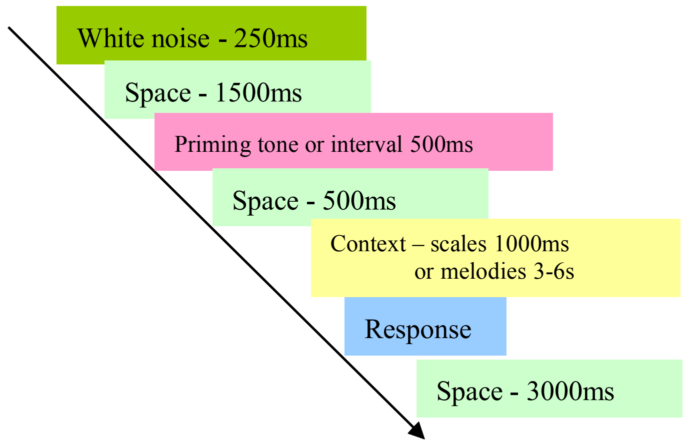


Figure 36 Procedure of experiment series 2

After the experiments, listeners were asked to rate the difficulty of the task and the performance how they felt they had done in the tasks, and to describe the strategy of their response making. Finally, they obtained a small gift for their participation in the experiment. The duration of the whole experiment was about 45-50 mins.

The experiment series 2 was done with Chinese participants during September 2010, and with German participants during October and November, 2010.

38. Participants

In the experiment series 1, only musicians – students in music major – were involved because of the need of professional knowledge. While in the experiment series 2, non-musicians were mainly considered. For one reason, there was no music theoretical terminology in the instructions; for the other reason, the task was used to investigate the implicit tonal knowledge.

There were 26 Chinese listeners, 15 females and 11 males, mainly from two universities: Capital Normal University and North China Electric Power University. 7 of them were undergraduate students, and 16 of them were postgraduate students, and 3 of them were teachers in their 40-50s. The average age was 26.69 (SD=10.18) years old.

18 listeners were non-music-major students, majoring in English language and literature (8), electrical engineering and automation (3), information and computer science (2), electronic and information engineering (1), hydrology and water resources engineering (1), basic psychology (2), curriculum and didactics (1); 3 teachers were in English language and literature, library science and personnel management; the other 5 listeners were postgraduate students in music psychology.

There were 16 German listeners who were all students from Martin-Luther-University Halle-Wittenberg, including 11 females and 5 males. The average age was 22.56 (SD=4.52) years old. Only two of them were postgraduate students, and others were in their first year of bachelor. Each of them had one or two majors. Their majors covered psycholinguistic and linguistic in an intercultural context (Sprechwissenschaft, Berufsorientierte Linguistik im interkulturellen Kontext (BLIK)), median and communication (Medien & Kommunikation) linguistics and intercultural studies between Europe and American (Sprachwissenschaft, Interkulturelle Europa- und Amerikastudien (IKEAS)), Romance und Arabic, economics and business (BWL), sociology and Japanese studies, history and philosophy, geography and astronomy, psychology, etc.; two of them studied musicology.

For music experience, few Chinese non-musicians learned instruments or sang in a chorus, or even played with self-interest; while some of German non-musicians said they learned piano in music school (Musikschule) or sang in a chorus, or played guitar for self-interest; only 3 reported that they did not play any instrument or sing in a chorus.

For music “taste”, 13 Chinese participants preferred Chinese music (old songs and pop songs), 5 of them preferred Western classic music, 1 liked heavy metal music and punk rock, and the others had “mixed taste” of Chinese and Western pop music. German listeners provided more specified categories about what they preferred – nearly each listener had their own categories, including classic, jazz, pop (hip-hop, blues, soul, R&B), rock (industrial, metal, grunge, core, punk, indie, alternative), Spain live music, dance music (house).

Therefore, the musical culture backgrounds of Chinese listeners and German listeners were different. Chinese listeners preferred Chinese music which is based mainly on pentatonics, while German listeners preferred Western music which is based on heptatonics and harmonic features, although some pop music and rock music are more of rhythmic and dynamic characters.

Results

This chapter presents the results of the experiment series 2. The analysis consists of three parts: the analysis of two exercises, the analysis of priming single tone trials and the analysis of priming successive interval trials. Musical culture background (Chinese music or Western music) and musical training (music students or non-music students) were the between-subject factors. Musical training was observed as a nested factor of the musical culture background. Scale degree and mode (five scale degrees in Chinese pentatonics and seven scale degrees in major and minor), position of the test tone in the context (in the middle or at the end), tonal indication (no tonal indication, tonal indication at the end, or at both the start and the end of the context) and matched pitches between the priming tone and the test tone (the pitches were same or not) were within-subject factors. Scale degree was viewed as a nested factor of the mode, because scale degrees in different modes have different importance of tonal functions. Correct response time was as the dependent variable to be analyzed. Participants with over 70% of correct responses were included in the further statistical analyses.

Besides, the trials with "signal" – the test tone – and the trials without the test tone were used in each experiment, which worked as signal detection. According to signal detection theory (SDT), the sensitivity index d' and the response bias ß were obtained. These two parameters can provide more information from the responses of the participants. The sensitivity index d' shows the difficulty of the detection of the target stimulus in a certain background; the response bias ß shows the probability of the judgment whether the stimulus presents or not. Thus, it is possible to compare whether listeners from different musical culture background or with different music training have the same sensitivity in different musical contexts.

39. Exercises

39.1 Exercise 1

The first exercise aimed to let listeners get familiar with the materials in two timbres (piano and trumpet). In the exercise 1, there were two Chinese participants (S2 and S9), and one German listener (S10) were confused with the task, they either missed most of trials or did not make any responses; while the others had no problem with the task.

Although the task was different from the one in later trials and some participants did not well in this exercise, the responses were recorded as a reference for further exercise and trials. Percentage of correct response, mean and standard deviation of correct response of Chinese and German listeners on each in-tonal degree are listed separately:

Table 36　Correct responses of Chinese listeners in exercise 1

degree	I	II	III	IV	V	VI	VII
Accuracy	69.57%	70.00%	78.26%	80.95%	80.95%	85.71%	95.24%
RT(SD)	1.52 (0.74)	1.38 (0.50)	3.32 (1.77)	2.12 (1.11)	2.15 (1.48)	1.11 (0.57)	2.23 (1.22)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

Table 37 Correct responses of German listeners in exercise 1

degree	I	II	III	IV	V	VI	VII
Accuracy	83.33%	100.00%	100.00%	92.86%	75.00%	100%	100%
RT(SD)	1.34 (0.63)	1.48 (0.84)	2.82 (1.37)	2.70 (1.58)	3.13 (1.51)	1.16 (0.73)	2.83 (1.58)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

From the tables above, German participants responded more correctly than Chinese participants, only except the responses to the V degree; but it seemed that there was no great difference between the response time of the two groups (t=0.591, p>0.05).

39.2 Exercise 2

The aim of exercise 2 was to let participants get familiar with the task, which was the same as the task in the six experiments. Although it was instructed that participants could do further experiments when their accuracy of responses should be over 90% in the exercise 2, the accuracy above 75% was acceptable. That is, they could make less than 3 (include 3) false responses of 14 trials.

There were three Chinese participants (S2, S20, S26) who were asked to do the exercise 2 again, because their accuracies were too low (see Table 38). In their second time, S2 improved to 69.2%, S20 and S26 got 92.3% correct responses. S2 was not asked to quit, but kept on doing the following trials – for her wish as well. The accuracies of German participants were all above 80%.

Table 38 Accuracy of Chinese listeners in exercise 2

Subjects	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
Accuracy	100%	*38.5 %*	100%	100%	100%	100%	100%	92．3%	100%	100%	100%	84.6 %	76.9 %
Subjects	**S14**	**S15**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**	**S23**	**S24**	**S25**	**S26**
Accuracy	92.3 %	100%	100%	84.6 %	100%	100%	*69.2 %*	92.9 %	100%	92.3 %	92.3 %	76.9 %	*46.2 %*

In the exercise 2, there were 7 trials with test tone in the context and 7 trials without test tone in the context. The following tables show the accuracy, the mean and the deviation of the correct response time in trials with or without test tone on each scale degree of Chinese and German listeners.

Table 39 Correct responses in exercise 2

a. Chinese listeners

With test tone	I	II	III	IV	V	VI	VII
Accuracy	96.00%	92.31%	80.77%	95.83%	91.67%	100.00%	96.00%
RT(SD)	0.84 (0.47)	1.22 (0.38)	1.20 (0.76)	0.88 (0.37)	0.93 (0.37)	0.99 (0.44)	0.84 (0.27)
No test tone	I	II	III	IV	V	VI	VII
Accuracy	95.83%	91.30%	86.36%	78.26%	84.00%	87.50%	84.62%
RT(SD)	0.88 (0.53)	0.94 (0.59)	0.59 (0.26)	0.76 (0.96)	0.82 (0.44)	1.19 (1.09)	0.90 (0.61)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

b. German listeners

With test tone	I	II	III	IV	V	VI	VII
Accuracy	86.67%	100.00%	93.75%	100.00%	93.33%	100.00%	93.33%
RT(SD)	1.01 (0.52)	1.22 (0.66)	1.00 (0.46)	0.91 (0.49)	1.03 (0.77)	1.31 (0.96)	1.06 (0.84)
No test tone	I	II	III	IV	V	VI	VII
Accuracy	100.00%	100.00%	100.00%	93.33%	92.86%	100.00%	93.33%
RT(SD)	0.77 (0.42)	0.80 (0.41)	0.81 (0.63)	0.86 (0.55)	0.82 (0.75)	1.19 (1.01)	0.90 (0.48)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

Comparing with the average response time on each scale degree with the ones in the exercise 1, participants made faster responses in 1 second ($t=5.498$, $p<0.01$), although the tasks in the two exercises were different. This indicated that participants got used to the material and tasks after the practice in exercise 1.

For the responses to the contexts with or without test tone, both Chinese and German listeners responded faster to the contexts without test tone, especially German listeners ($t=3,001$, $p<0.05$, see Table 40), which indicated that timbre judgment task needs one's cognitive processing which takes some time. But there was no significant difference of correct response time between Chinese and German listeners ($t=-0,733$, $p>0.05$).

Table 40 Comparison of the responses (exercise 2: with or without test tone)

Context	With test tone	Without test tone
Chinese	0.98 (0.45)	0.88(0.66)
German	1.08 (0.68)	0.87(0.63)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

The sensitivity index d’ and the response bias ß are listed as a reference for further trials. There was no significant difference between Chinese and German in sensitivity ($t=0.574$, $p>0.05$) and response bias ($t=-0.100$, $p>0.05$).

Table 41 Sensitivity index and response bias in exercise 2

	d’	ß
Chinese	3.11 (1.70)	0.22(0.36)
German	3.16 (1.40)	0.16(0.28)

40. Experiments

The six experiments consisted of five experiments with priming single tone and one experiment with priming two successive tones. In the five single priming tone experiments, materials in the three modes (major, minor and Chinese pentatonics) were mixed in the experiments. In the analysis, the trials were grouped into four categories according to the contexts in order to see the differences between Chinese and German participants in various conditions:

Group 1: “direct” trials[27] with context without tonal indication;

Group 2: “direct” trials with context with tonal indication;

Group 3: “direct” trials with musical context;

Group 4: “indirect” trials – unmatched pitches of the priming tone and the test tone in the context.

In the first three groups, the difference of correct response time was observed with the main effects and interactions of four factors – subject factor, modes, test tone position and tonal indication; while the correct response time of the last group was analyzed by multidimensional scaling. The differences of sensitivity index d’ and the response bias ß among modes were also analyzed.

In the priming interval trials, materials in major were grouped into four categories according to the type of the interval: 1) perfect fourth; 2) perfect fifth; 3) minor second; 4) tritone. The difference of correct response was examined with the main effects and interactions of four factors, which included subject factor, type of the

[27] “direct” cases (see Experiment Series 2, 34 Method) are the cases with priming tone and test tone sharing the same pitch. The degree sense of priming tone is “given” by the context directly.

priming interval, direction and scale degree of the interval.

For subject factor, musical culture background was the main factor: participants were from China and Germany; music training was set as a "nested factor" of musical culture background. For modes, the type of mode was the main factor, and scale degree was set as a "nested factor" of mode, because the tonal functions of scale degrees were different in different modes.

One Chinese subject (S2), who did not well in the former two exercises, also got low accuracy (under 50%) in the six trials. So her record was excluded from all the analysis, then there were actually 25 valid Chinese participants' records.

40.1 Single priming tone

40.1.1 Group 1: context without tonal indication

In this group, three modes (major, minor, pentatonics) were involved. In each mode, there was the same number of trials with test tone in the middle of context and of trials with test tone at the end of context. That is, in each heptatonic mode (major or minor), the test tones in 7 trials appeared in the middle of the context, and the test tones in another 7 trials appeared at the end of the context; in pentatonic mode, 5 trials were with test tone in the middle of the context, and the other 5 trials were with test tone at the end of the context.

In the major mode, one Chinese subject's (S10) record was lost because of an accidental software problem. In the minor and the pentatonic modes, there was no record missing.

40.1.1.1 Test tone in the middle of the context

The following three tables list the accuracy of responses, the means and the deviation of correct response time in the three modes with the test tone in the middle of the context (see Table 42). German listeners made nearly all correct responses on all scale degrees in the three modes, which were better than Chinese listeners; they also responded significantly faster than Chinese listeners ($t=3.581$, $p<0.01$), especially on V (fifth degree) in major ($t=2.171$, $p<0.05$) and pentatonics ($t=2.176$, $p<0.05$).

Table 42 Correct responses in group 1: test tone in the middle

a. major

Major-Middle		I	II	III	IV	V	VI	VII
C	Accuracy	95.83%	83.33%	96.00%	96.00%	87.50%	92.00%	95.83%
	RT(SD)	0.81 (0.39)	0.81 (0.31)	0.87 (0.39)	0.70 (0.26)	0.86 (0.47)	0.80 (0.30)	0.81 (0.27)
Major-Middle		I	II	III	IV	V	VI	VII
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	RT(SD)	0.88 (0.58)	0.78 (0.48)	0.70 (0.32)	0. 73 (0.29)	0.58 (0.25)	0.66 (0.27)	0.71 (0.31)

(RT = response time; SD = standard deviation; C=Chinese listeners; G=German listeners. RT and SD are shown in seconds)

b. minor

Minor-Middle		I	II	III	IV	V	VI	VII
C	Accuracy	96.15%	84.62%	81.77%	96.00%	88.00%	96.15%	100.00%
	RT(SD)	0.74 (0.26)	0.78 (0.31)	0.83 (0.27)	0.77 (0.34)	0.83 (0.32)	0.97 (0.74)	0.83 (0.38)
Minor-Middle		I	II	III	IV	V	VI	VII
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	RT(SD)	0.68 (0.36)	0.68 (0.42)	0.70 (0.28)	0.83 (0.63)	0.72 (0.37)	0.79 (0.37)	0.65 (0.28)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

c. pentatonics

Pentatonics-Middle		I	II	III	V	VI
C	Accuracy	96.15%	100.00%	91.67%	96.15%	96.00%
	RT(SD)	0.74 (0.31)	0.74 (0.21)	0.93 (0.43)	0.94 (0.45)	0.72 (0.22)

Pentatonics-Middle		I	II	III	V	VI
G	Accuracy	100.00%	100.00%	100.00%	93.75%	100.00%
	RT(SD)	0.70 (0.44)	0.66 (0.30)	0.81 (0.68)	0.65 (0.30)	0.63 (0.28)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

In a further ANOVA analysis, scale degree was viewed as a “nested” factor of mode, and music training as a “nested” factor of participants’ musical culture background. The result showed that there was indeed a main effect of musical culture background [F(1,730)=28.825, p<0.01] and a main effect of music training [F(2,730)=13.755, p<0,01]: participants studying music responded faster than non-music participants. But there was no significant main effect of mode [F(2,730)=0.116, p>0.05] and scale degree [F(16,730)=1.052, p>0.05], and also no significant interaction was found between musical culture background and modes [F(2,730)=0.106, p>0.05].

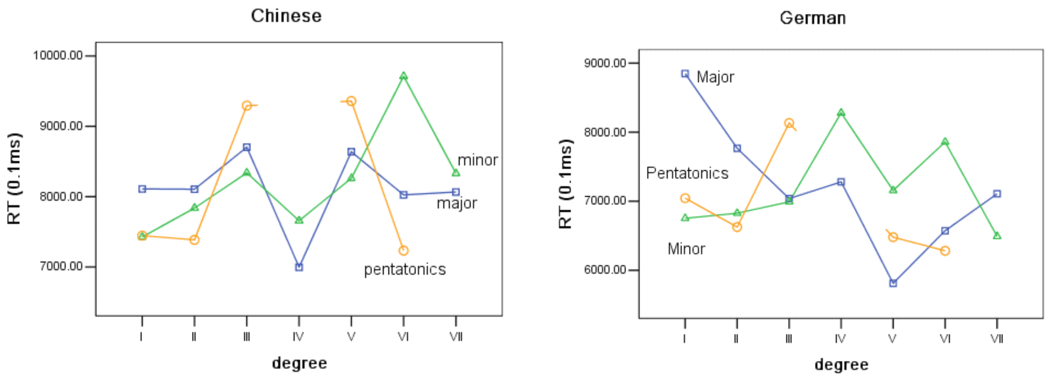


Figure 37 RT profiles with musical culture difference (group 1: with no tonal indication, test tone in the middle)

The figures above show the response time of three modes among Chinese and German participants separately. There was no significant main effect of music training in Chinese group [F(1,432)=1.838, p>0.05]; but a significant main effect of music training in German group was found [F(1,299)=24.444, p<0.01], especially on VI in minor (t=2.172, p<0.05). There were no other significant main effects or interactions.

40.1.1.2 Test tone at the end of the context

The following three tables list the accuracy of responses, the mean and the deviation of correct responses in the three modes with test tone at the end of the context (see Table 43). German listeners still made fewer false responses in the three modes, and they responded faster than Chinese listeners, especially on VI (submediant degree) in major (t=2.187, p<0.05) and in minor (t=2.293, p<0.05). But generally the difference of response time between Chinese and German participants was not significant (t=1.648, p>0.05).

Table 43 Correct responses in group 1: test tone at the end

a. major

Major-End		I	II	III	IV	V	VI	VII
C	Accuracy	95.83%	96.00%	91.67%	96.00%	95.83%	92.00%	100.00%
	RT(SD)	0.63 (0.17)	0.64 (0.19)	0.79 (0.48)	0.67 (0.44)	0.68 (0.28)	0.75 (0.34)	0.63 (0.22)
Major-End		I	II	III	IV	V	VI	VII
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	RT(SD)	0.51 (0.21)	0.64 (0.49)	0.83 (0.69)	0. 71 (0.44)	0.56 (0.20)	0.54 (0.17)	0.66 (0.31)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

b. minor

Minor-End		I	II	III	IV	V	VI	VII
C	Accuracy	96.00%	96.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	RT(SD)	0.59 (0.17)	0.67 (0.23)	0.74 (0.19)	0.63 (0.20)	0.68 (0.23)	0.65 (0.18)	0.59 (0.28)
Minor-End		I	II	III	IV	V	VI	VII
G	Accuracy	100.00%	93.75%	100.00%	100.00%	100.00%	93.33%	100.00%
	RT(SD)	0.52 (0.21)	0.71 (0.37)	0.64 (0.22)	0. 54 (0.20)	0.83 (0.72)	0.53 (0.17)	0.57 (0.24)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

c. pentatonics

Pentatonics-End		I	II	III	(IV)	V	VI	(VII)
C	Accuracy	88.46%	96.15%	100.00%		96.15%	96.15%	
	RT(SD)	0.69 (0.23)	0.65 (0.21)	0.75 (0.26)		0.69 (0.19)	0.75 (0.26)	
Pentatonics-End		I	II	III		V	VI	
G	Accuracy	87.50%	93.33%	100.00%		100.00%	93.33%	
	RT(SD)	0.59 (0.22)	0.61 (0.17)	0.81 (0.66)		0.63 (0.29)	0.62 (0.25)	

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

A further ANOVA showed that there was indeed a main effect of scale degree – the nested factor of mode [$F(16,738)=1.781$, $p<0.05$]. The main effect was further examined in each mode. In major mode, there was a significant difference of response time between the III scale degree and other four scale degrees (I, II, V, VII). The response to the III scale degree was much slower than the response to other four scale degrees; while the response to the I scale degree was significantly faster than the V scale degree.

In minor mode, there were significant differences of response time between the I scale degree and other three scale degrees (II, III, V), and also between the V and other three scale degrees (IV, VI, VII). The response to the I degree was much faster than the response to other three degrees; while the response to the V degree was significantly slower than to other three degrees.

Table 44 Significant difference among degrees in group 1: test tone at the end

a. major

Major	I	II	III	IV	V	VI	VII
I			0.006**				
III	0.006**	0.042*			0.032*		0.048*

(**: significance is at 0.01 level; *: significance is at 0.05 level.)

b. minor

Minor	I	II	III	IV	V	VI	VII
I		0.045*	0.030*		0.005**		
V				0.018*		0.030*	0.012*

(**: significance is at 0.01 level; *: significance is at 0.05 level.)

In pentatonic mode, there was a significant difference of response time between the II and III degrees ($p=0.036$). The response to the II degree was much faster than the response to the III degree.

Besides, there was also a significant main effect of musical culture background [$F(1,738)=7.841$, $p<0.01$]: German participants responded faster than Chinese participants; and a significant main effect of music training [$F(2,738)=3.443$, $p<0.05$]: participants studying music responded faster than non-music participants. But there was no significant main effect of mode [$F(2,738)=1.153$, $p>0.05$], and no interactions between subject factor and modes [$F(2,738)=0.071$, $p>0.05$].

The figures show the response time of three modes of Chinese and German participants separately.

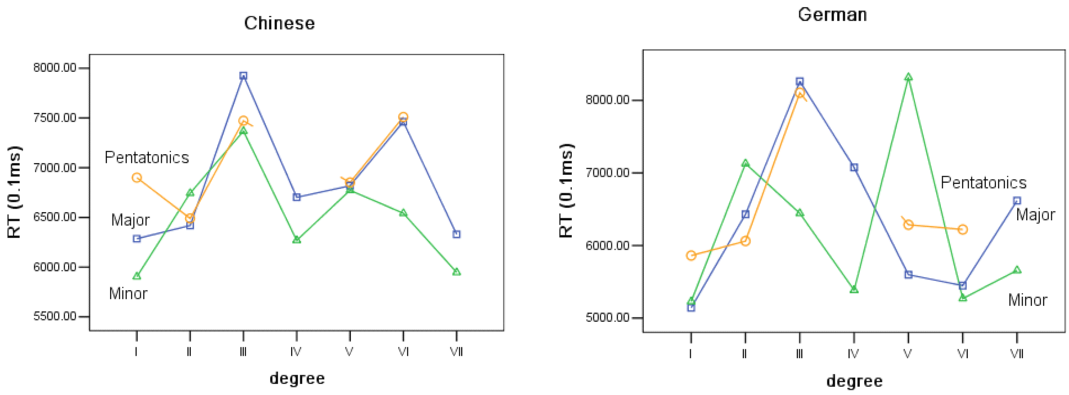


Figure 38 RT profiles with musical culture difference (group 1: with no tonal indication, test tone at the end)

In Chinese group, there was no significant main effect of music training [$F(1,446)=0.088$, $p>0.05$]; and no significant main effect of mode and scale degree in each mode was found. When subject factor was not considered, there was a significant main effect of degree [$F(6,446)=2.129$, $p<0.05$], especially between III and I ($p<0.05$), as well as III and VII ($p<0.05$) in minor: III was responded slower than I and VII. There were no other effects. While in German group, there was a significant main effect of music training in German group [$F(1,292)=4.937$, $p<0.05$], especially on I in major ($t=2.084$, $p<0.05$).

40.1.1.3 Position effect

When considering the factor of test tone position, a further ANOVA analysis showed that there was a significant main effect of test tone position [$F(1,1469)=32.271$, $p<0.01$]: the test tone at the end showed faster response than in the middle; a significant main effect of music background [$F(1,1469)=35.105$, $p<0.01$]: German listeners responded faster than Chinese listeners; and a significant main effect of music training [$F(2,1469)=16.349$, $p<0.01$]: participants studying music responded faster than non-music participants. But no significant main effects of mode [$F=(2,1469)=0.191$, $p>0.05$] and degree [$F=(2,1469)=1.540$, $p>0.05$] were found. There was no significant interaction among factors.

In Chinese group, a significant main effect of test tone position was found [F(1,879)=20.797, p<0.01], but no other main effects or interactions. However, in German listeners group, a significant main effect of music training was found [F(1,593)=25.730, p<0.01], and also a significant interaction between music training and test tone position [F(1,593)=4.495, p<0.05]: non-musicians responded slower to test tone in the middle than test tone at the end of the context, while musicians responded slower to test tone at the end. However, in German non-musician group, the test tone position was observed with a significant main effect [F(1,519)=8.684, p<0.01]. Other significant main effects or interactions were not obtained.

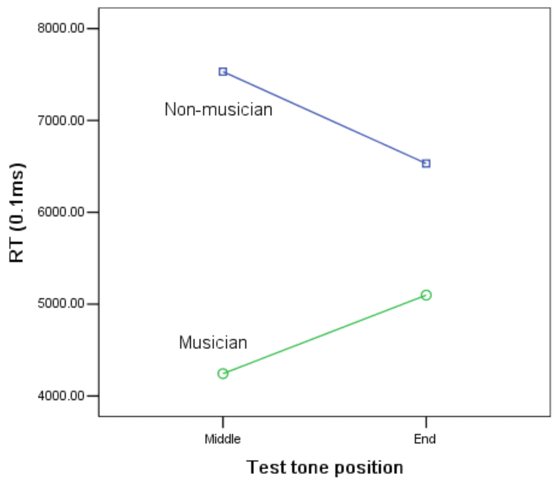


Figure 39 Interaction between music training and test tone position with German listeners (group 1: with no tonal indication)

40.1.2 Group 2: context with tonal indication

In this group, two modes (major, minor) were involved. In both modes, the tonal indication was presented either only at the end of the context as cadence or at both the start and the end of the context; the test tone in the context with tonal indication at the end was set either in the middle or at the end. Each modes included 7 trials were with cadence indication and test tone in the middle of the context; 7 trials were with start tonal indication and test tone at the end; 7 trials were with bi-tonal-indication and test tone in the middle.

40.1.2.1 Tonal indication at the end of the context, test tone in the middle

The percentage of correct response, the mean and the deviation of correct responses in major and minor trials with tonal intonation at the end, and test tone in the middle are listed (see Table 45). German listeners made fewer false responses than Chinese listeners, and they responded faster than Chinese listeners, especially on the V scale degree in major (t=2.823, p<0.01).

Table 45 Correct responses in group 2: tonal indication at the end

a. major

Major - Middle		I	II	III	IV	V	VI	VII
C	Accuracy	100.00%	88.00%	88.00%	95.83%	92.00%	91.67%	92.00%
	RT(SD)	0.82 (0.53)	0.89 (0.44)	0.82 (0.24)	0.66 (0.20)	0.89 (0.38)	0.81 (0.24)	0.77 (0.37)
Major-Middle		I	II	III	IV	V	VI	VII
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	RT(SD)	0.71 (0.28)	0.67 (0.32)	0.64 (0.22)	0. 79 (0.45)	0.67 (0.26)	0.91 (0.61)	0.73 (0.42)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

b. minor

Minor – Middle		I	II	III	IV	V	VI	VII
C	Accuracy	92.31%	92.31%	96.15%	96.15%	96.00%	96.15%	88.46%
	RT(SD)	0.66 (0.21)	0.77 (0.26)	0.75 (0.31)	0.72 (0.29)	0.68 (0.22)	0.79 (0.40)	0.78 (0.31)
Minor - Middle		I	II	III	IV	V	VI	VII
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%	93.33%	100.00%
	RT(SD)	0.70 (0.41)	0.73 (0.40)	0.66 (0.30)	0. 64 (0.30)	0.83 (0.71)	0.68 (0.29)	0.73 (0.45)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

In ANOVA analysis, scale degree was viewed as a "nested" factor of mode, and music training as a "nested" factor of participants' musical culture background. The result showed that there was a significant main effect of musical culture background [F(1,545)=18.196, p<0,01] and main effect of music training background [F(2,545)=11.299, p<0.01]: participants studying music responded faster than non-music participants. But no significant main effect of mode [F(1,545)=2.234, p>0.05] and scale degree [F(12,545)=1.494, p>0.05] , and also no significant interaction were found between subject factor and modes [F(1,545)=0.649, p>0.05].

The figures show the response time of two modes among Chinese and German participants separately. In Chinese group, there was no significant main effect of music training [F(1,322)=0.138, p>0.05]; but when this subject factor was not considered, there was a significant main effect of mode [F(1,322)=3.901, p<0.05]: minor trials responded faster than major trials, especially on V (t=2.258, p<0.05). There were no other significant effects. While in German group, there was a significant main effect of music training in German group [F(1,223)=18.399, p<0.01]; no other effects were found.

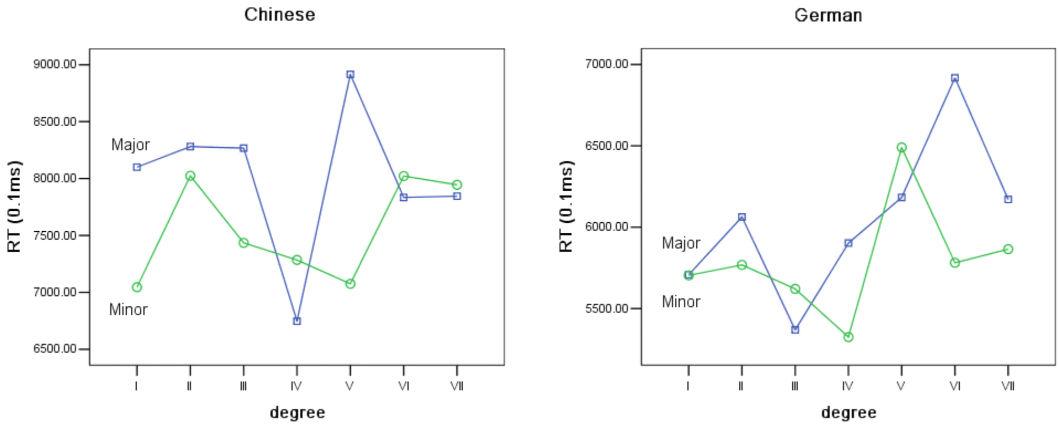


Figure 40 RT profiles with musical culture difference (group 2: cadence indication, test tone in the middle of the context)

40.1.2.2 Tonal indication at the start of the context, test tone at the end

The following two tables list the response accuracy, the means and the deviation of correct responses in major and minor trials with tonal intonation at the start and test tone at the end of the context (see Table 46). German listeners still made fewer false responses, and they responded faster than Chinese listeners (t=2.842, p<0.01), especially on the I scale degree in major (t=2.078, p<0.05) and on VI in major (t=2.781, p<0.01).

Table 46 Correct responses in group 2: tonal indication at the start

a. major

	Major-End	I	II	III	IV	V	VI	VII
C	Accuracy	92.00%	96.00%	96.00%	100.00%	96.00%	96.00%	95.65%
	RT(SD)	0.71 (0.52)	0.63 (0.18)	0.66 (0.32)	0.57 (0.15)	0.81 (0.78)	0.73 (0.35)	0.69 (0.18)
	Major-End	I	II	III	IV	V	VI	VII
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	93.75%
	RT(SD)	0.53 (0.17)	0.57 (0.19)	0.58 (0.26)	0. 64 (0.28)	0.53 (0.26)	0.57 (0.21)	0.68 (0.46)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

b. minor

	Minor-End	I	II	III	IV	V	VI	VII
C	Accuracy	91.67%	96.15%	100.00%	96.15%	100.00%	100.00%	100.00%
	RT(SD)	0.64 (0.24)	0.66 (0.20)	0.60 (0.21)	0.60 (0.18)	0.90 (0.69)	0.61 (0.22)	0.88 (0.37)
	Minor-End	I	II	III	IV	V	VI	VII
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	RT(SD)	0.54 (0.22)	0.57 (0.35)	0.66 (0.41)	0. 57 (0.37)	0.58 (0.31)	0.60 (0.42)	0.60 (0.42)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

The same as the trials with cadence indication and test tone in the middle of the context, there were significant main effects of musical culture background [F(1,547)=10.521, p<0,01], and music training background [F(2,547)=3.840, p<0.05]: participants studying music responded faster than non-music participants. But there was no significant main effect of mode [F(1,547)=0.177, p>0.05], and no interactions between subject factors and modes [F(2,547)=0.332, p>0.05].

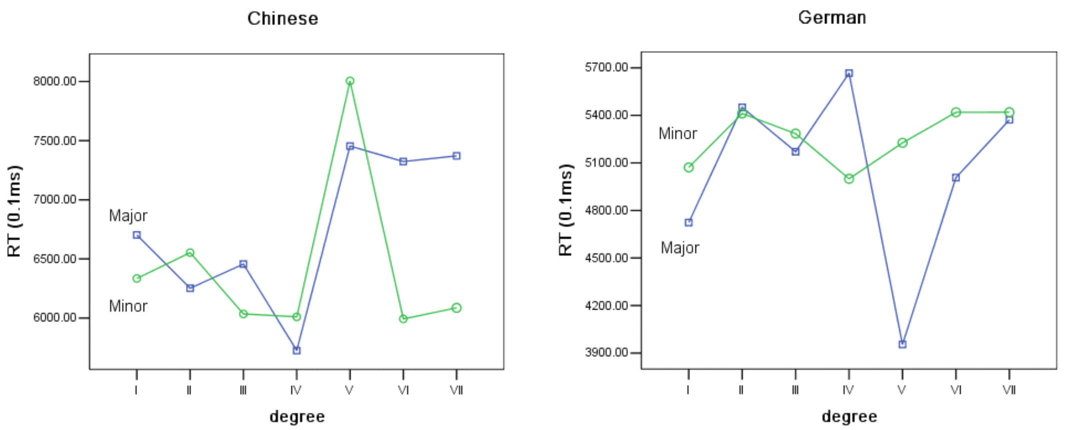


Figure 41 RT profiles with musical culture difference (group 2: start tonal indication, test tone at the end of context)

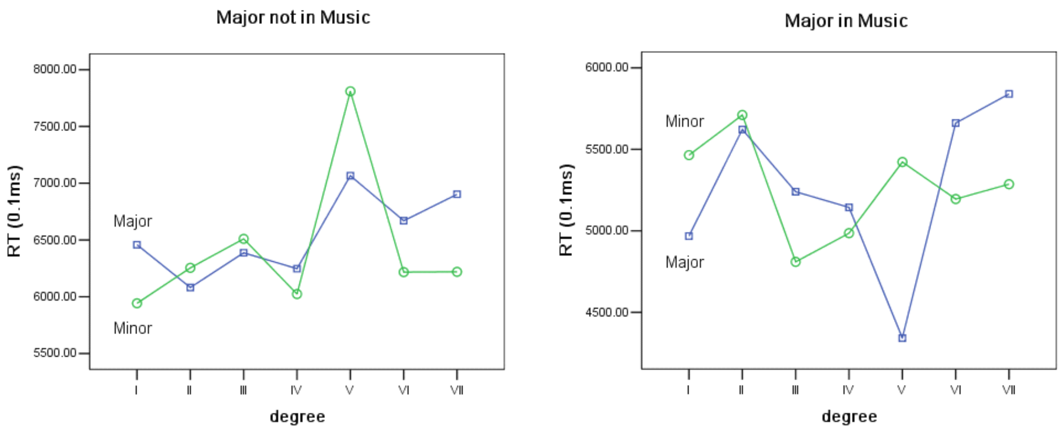


Figure 42 RT profile with music training difference (group 2: start tonal indication, test tone at the end of context)

The figures show the response time of two modes among Chinese and German participants separately. In Chinese groups, there was no significant main effect of music training [F(1,327)=1.195 p>0.05]; but when subject factor was not considered, there was a significant main effect of scale degree [F(6,327)=2.443, p<0.05]: V was slower responded than other scale degrees, especially in minor [F(6,163)=2.566, p<0.05, see Table 47]. There were no other significant effects. While in German groups, there was a significant main effect of music training in German group [F(1,219)=8.144, p<0.01]. There were no other main effects or interactions.

Table 47 Significant difference among scale degrees in minor in Chinese listeners (group 2: start tonal indication, test tone at the end)

Minor	I	II	III	IV	VI	VII
V	0.007**	0.012*	0.002**	0.002**	0.003**	0.003**

(**: significance is at 0.01 level; *: significance is at 0.05 level.)

40.1.2.3 Tonal indication at both the start and the end of the context

The following two tables list the accuracy of responses, the mean and the deviation of correct responses in major and minor trials with tonal intonation at both the start and the end, and the test tone in the middle (see Table 48). German listeners still made fewer false responses in the two modes, and they responded faster than Chinese listeners, but not significant (t=1.440, p>0.05).

Table 48 Correct responses in group 2: tonal indication at the start and the end

a. major

	Major	I	II	III	IV	V	VI	VII
C	Accuracy	96.00%	95.65%	96.15%	100.00%	100.00%	91.67%	100.00%
	RT(SD)	0.65 (0.22)	0.65 (0.16)	0.83 (0.41)	0.64 (0.20)	0.87 (0.59)	0.71 (0.28)	0.68 (0.24)
	Major	I	II	III	IV	V	VI	VII
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	RT(SD)	0.65 (0.33)	0.80 (0.63)	0.63 (0.33)	0. 79 (0.46)	0.57 (0.26)	0.73 (0.67)	0.63 (0.34)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

b. minor

	Minor	I	II	III	IV	V	VI	VII
C	Accuracy	100.00%	92.31%	96.15%	100.00%	92.31%	96.00%	95.83%
	RT(SD)	0.75 (0.25)	0.78 (0.29)	0.65 (0.27)	0.61 (0.17)	0.67 (0.24)	0.63 (0.18)	0.71 (0.40)
	Minor	I	II	III	IV	V	VI	VII
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%	93.33%	100.00%
	RT(SD)	0.71 (0.34)	0.60 (0.30)	0.71 (0.38)	0. 64 (0.35)	0.56 (0.24)	0.59 (0.24)	0.65 (0.35)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

In ANOVA analysis, the result showed that there were significant main effects of musical culture background [$F(1,546)=10.402$, $p<0,01$] and music training background [$F(2,546)=6.929$, $p<0.01$]: participants studying music responded faster than non-music participants. But there was no significant main effect of mode [$F(1,546)=1.931$, $p>0.05$], and no interactions between subject factors and mode.

The figures show the response time of two modes among Chinese and German participants separately. There was a significant main effect of music training in German group [$F(1,221)=10.288$, $p<0.01$], but not in Chinese group [$F(1,325)=0.293$, $p>0.05$]. There were no other main effects or interactions.

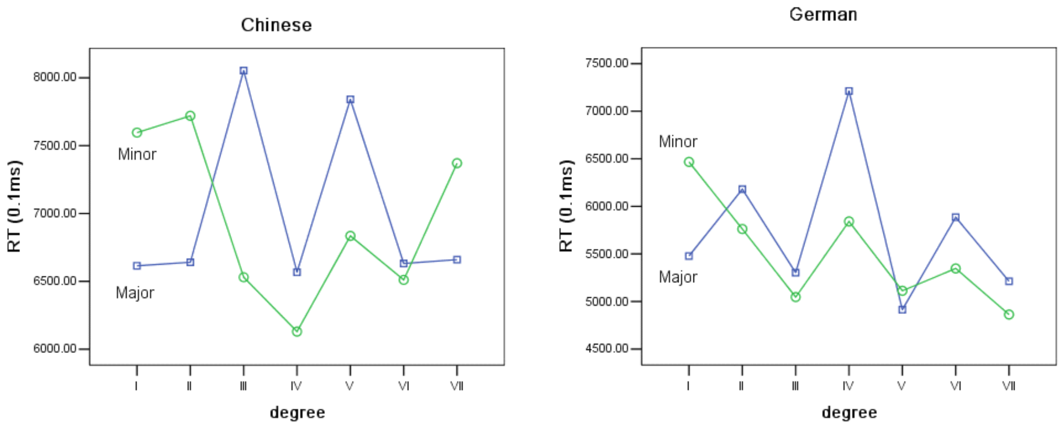


Figure 43 RT profiles with musical culture difference (group 2: tonal indication at the start and the end)

40.1.2.4 ANOVA with test tone position and tonal indication

Comparing the test tone position in the major and minor trials with one tonal indication(either at the start or at the end), it was resulted that there was a significant main effect of test tone position [F(1,1093)=28.070, p<0.01]: the test tone at the end of the context responded quite faster than the test tone in the middle of the context; a significant main effect of musical culture background [F(1,1093)=28.532, p<0.01] and music training [F(2,1093)=13.521, p<0.01]. But there were no other significant main effects and interactions.

In Chinese groups, there was a significant main effect of test tone position in the context [F(1,650)=12.443, p<0.01], but no other significant effects; however, in German groups, there was a significant main effect of music training [F(1,444)=26.590, p<0.01]; in German non-musician group, there was a significant main effect of test tone position [F(1,389)=16.066, p<0.01]. Other effects were not found.

Comparing the two kinds of tonal indications (with one or two indication) in the major trials, it was resulted that there were significant main effects of tonal indication [F(1,807)=4.217, p<0.05], and test tone position [F(1,807)=16.539, p<0.01]: tonal indication at both start and the end of the context showed faster responses than tonal indication at the end of the context; significant effects of test tone position

[F=(1,807)=16.539, p<0.01], musical culture background [F(1,807)=18.323, p<0.01] and music training [F(2,807)=11.093, p<0.01]; and a significant interaction between scale degree and musical culture background [F(6,807)= 2.891, p<0.01, see Figure 44], especially on III (t=2.051, p<0.05) and V (t=2.098, p<0.05): German participants responded faster than Chinese participants. Other main effects and interactions were not significant.

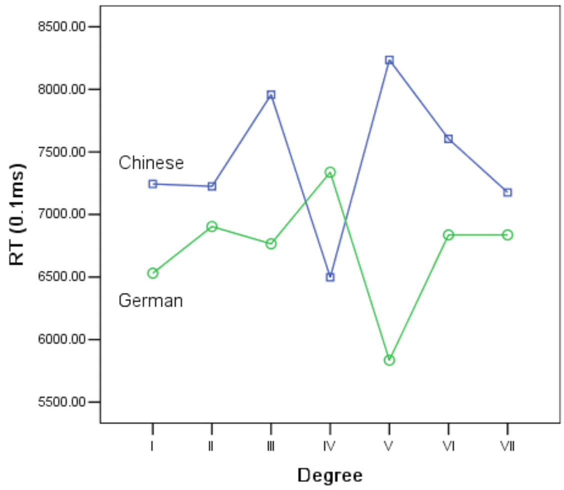


Figure 44 Interaction between scale degree and musical culture background in major (group 2: with tonal indication)

In Chinese groups, there was still no significant main effect of music training [F(1,475)=1.478, p>0.05]. When subject factor was not considered, there were significant main effects of tonal indication [F(1,475)=4.398, p<0.05], test tone position in the context [F(1,475)=8.048, p<0.01], and scale degree [F(6,475)=2.345, p<0.05]: IV showed faster response than III, V, VI, and V showed slower response than I, II, IV and VII, especially in trials with tonal indication at both the start and the end of the context. But there were no other interactions.

In German groups, there was only a significant main effect of music training [F(1,331)=11.679, p<0.01], but no other main effect or interactions. In German non-musician group, there was only a significant main effect of test tone position [F(1,290)=8.702, p<0.01], but no significant main effect of tonal indication [F(1,290)=1.149, p>0.05].

Comparing the two kinds of tonal indications in the minor trials, it was resulted that there were significant main effects of tonal indication [F(1,832)=4.502, p<0.05], test tone position [F(1,832)=11.891, p<0.01], musical culture background [F(1,832)=19.919, p<0.01] and music training [F(2,832)=9.978, p<0.01]. Other significant main effects and interactions were not significant.

In Chinese groups, there was still no significant main effect of music training [F(1,500)=0.002, p>0.05]. When subject factor was not considered, there was no significant main effects of tonal indication [F(1,500)=2.169, p>0.05], but a significant main effect of test tone position in the context [F(1,500)=5.363, p<0.05], and a significant interaction between test tone position and scale degree [F(6,500)=2.647, p<0.05]. There were no other interactions.

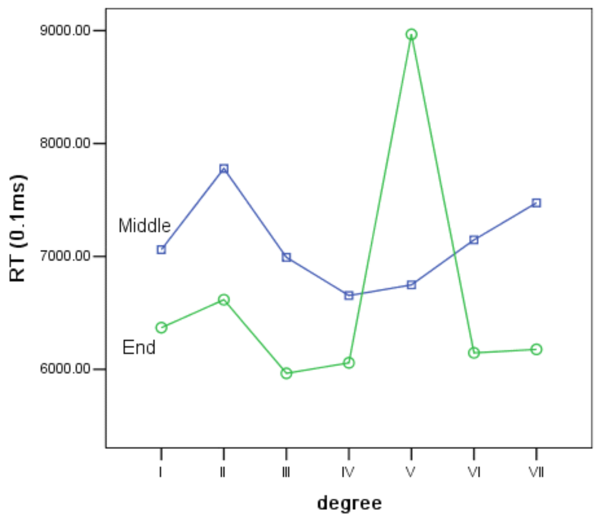


Figure 45 Interaction between scale degree and test tone position with Chinese listeners in minor (group 2: with tonal indication)

In German groups, there was only a significant main effect of music training [F(1,330)=6.497, p<0.05], and a significant interaction between tonal indication and music training [F(1,330)=4.377, p<0.05]: non-musicians responded slower to tonal indication at the end than tonal indication at both start and the end, while musicians responded slower to bi-tonal indication. Other main effects or interactions were not significant. In German non-musician group, there was significant main effects of test tone position [F(1,288)=5.490, p<0.05], and tonal indication [F(1,288)=4.011, p<0.05]. But no other significant effects were obtained.

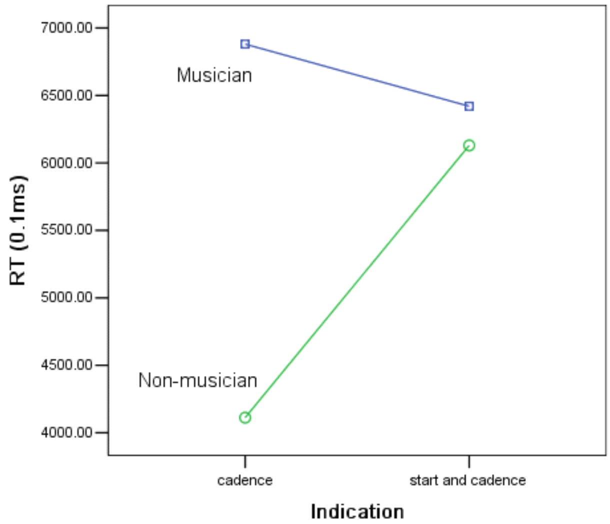


Figure 46 Interaction between tonal indication and music training with German listeners in minor (group 2)

40.1.3 No tonal indication vs. tonal indication

When compared the results of group 1 and group 2 considering the factor of indication and participants, in major, an ANOVA showed a significant main effect of musical culture background [F(1,1338)=26.011, p<0.01]: German participants responded faster than Chinese participants; and a significant main effect of music training [F(2,1338)=14.437, p<0.01]: participants studying music responded faster than participants studying other subjects; a significant main effect of test tone position [F(1,1338)=27.089, p<0.01]: when test tone at the end of the context, it showed faster response than test tone in the middle of the context; tonal indication [F(2,1338)=3.029, p<0.05]: the more tonal indication were given, the faster the responses were; and a significant interaction between musical culture background and scale degree [F(6,1338)=3.415, p<0.01]: German participants and Chinese participants responded differently on scale degree. However, there was no significant main effect of scale degree, and no interactions among other factors.

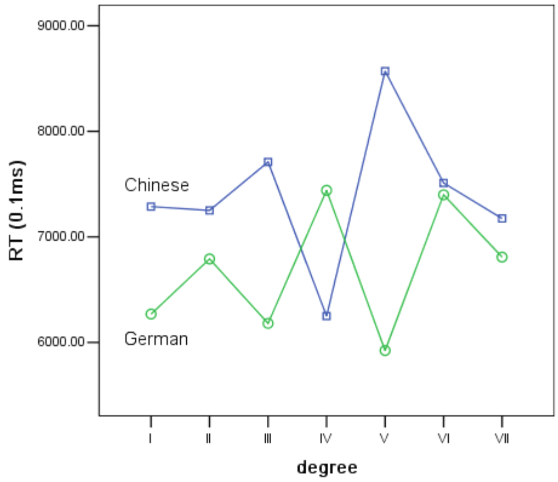


Figure 47 Interaction between musical culture background and scale degree in major (group 1&2)

While in minor context, there was a significant main effect of tonal indication [F(2,1384)=6.621, p<0.01]: the more tonal indication were given, the faster the response were made; a significant main effect of test tone position [F(1,1384)=32.906, p<0.01]: test tone at the end responded faster than in the middle; a significant main effect of musical culture background [F(1,1384)=30.352, p<0.01]: German listeners responded faster than Chinese; and a significant main effect of music training [F(2,1384)=16.875, p<0.01]: participants studying music responded faster than non-music participants. But no significant main effect of scale degree and no interactions among these factors were found.

In Chinese group, there were significant effects of indication, test tone position and scale degree. In the trials with test tone in the middle, there were significant differences among three kinds of tonal indications in both major [F(2,469)=3.095, p<0.05] and minor [F(2,490)=7.012, p<0.01]. In major, bi-tonal indication responded faster than no tonal indication (p<0.05) and single indication (p<0.05); in minor, no tonal indication responded slower than single tonal indication (p<0.05) and also slower than bi-tonal indication (p<0.01).

However, in German listeners group there was only a significant main effect of test tone position, but no other effects.

40.1.4 Group 3: musical context

Musical context group involved three modes (major, minor and pentatonics). There were 7 trials in major and minor modes respectively, and 5 trials in pentatonic mode. In each context, the test tone in the context was presented only in the middle.

The following tables list the percentage of correct responses, the mean and the deviation of correct responses in the three modes (see Table 49). Both German listeners and Chinese listeners responded to musical context slower than to the artificial scale-like context ($t=-20.353$, $p<0.01$). There was a significant difference of response time among three modes [$F(2,731)=8.988$, $p<0.01$]: responses to minor were quite faster than to major ($p<0.01$) and to pentatonics ($p<0.01$), but there was no significant difference between responses to major and pentatonics. German participants still made fewer false responses in the three modes; while their response time was not significantly faster than Chinese listeners' ($t=-1.364$, $p>0.05$).

Table 49 Correct responses in group 3: musical context

a. major

	Major	I	II	III	IV	V	VI	VII
C	Accuracy	100.00%	96.00%	92.00%	80.77%	96.15%	96.15%	83.33%
	RT(SD)	1.17 (0.62)	1.54 (0.86)	1.13 (0.42)	1.30 (0.52)	1.32 (0.78)	1.69 (0.86)	2.52 (1.34)
	Major	I	II	III	IV	V	VI	VII
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	RT(SD)	1.31 (0.71)	1.55 (0.72)	1.16 (0.61)	1.05 (0.44)	1.57 (0.96)	1.92 (0.85)	2.68 (1.43)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

b. minor

	Minor	I	II	III	IV	V	VI	VII
C	Accuracy	100.00%	92.31%	100.00%	100.00%	100.00%	100.00%	88.00%
	RT(SD)	1.32 (0.65)	1.22 (0.67)	1.23 (0.57)	1.25 (0.75)	1.22 (0.64)	1.41 (0.76)	1.03 (0.39)
	Mino	I	II	III	IV	V	VI	VII
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	RT(SD)	1.44 (0.67)	1.30 (0.75)	1.23 (0.58)	1.48 (0.74)	1.36 (0.82)	1.55 (0.79)	0.97 (0.44)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

c. pentatonics

	Pentatonics	I	II	III	(IV)	V	VI	(VII)
C	Accuracy	96.15%	100.00%	92.31%		96.15%	84.62%	
	RT(SD)	1.48 (0.96)	1.28 (0.69)	1.43 (0.62)		1.76 (0.77)	1.63 (0.78)	
	Pentatonics	I	II	III		V	VI	
G	Accuracy	100.00%	100.00%	100.00%		93.75%	100.00%	
	RT(SD)	1.83 (1.07)	1.49 (0.91)	1.37 (0.78)		1.64 (1.06)	1.57 (0.81)	

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

In ANOVA analysis, scale degree was viewed as a “nested” factor of mode, and music training as a “nested” factor to participants’ musical culture background. The result showed that there was no main effect of musical culture background [F(1,733)=0.365, p>0.01]; but a significant main effect of music training [F(2,733)=10.108, p<0,01]: participants studying music responded faster than non-music participants; and significant main effects of mode [F(2,733)=10.648, p<0.01] and scale degree [F(16, 733)= 6.839, p<0.01]. There was a significant interaction between mode and scale degree [F(18,733)=7.028, p<0.01], especially I, III and V (all of the three scale degrees: p<0.05) responded slower in pentatonic than in major trials, the VII scale degree showed faster response in minor than in major trials (t=6.549, p<0.01, see Figure 48). There was no interaction between subject factors and modes [F(2, 733)=0.028, p>0.05].

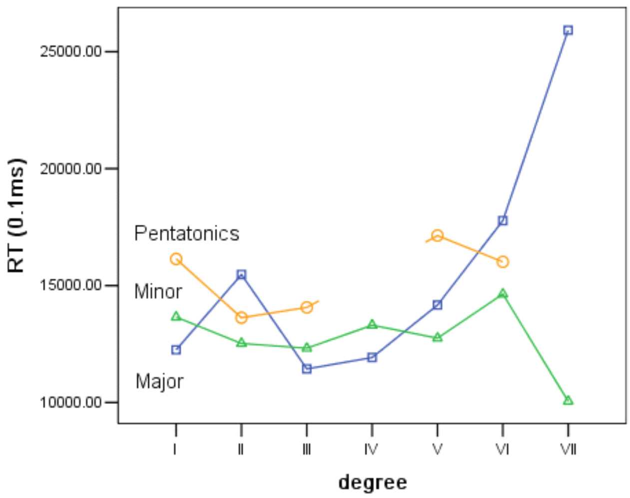


Figure 48 RT profiles of three modes in trials with musical context

In Chinese groups, there was a significant main effect of music training [F(1,441)=16.158, p<0.01]: musicians responded faster than non-musicians; there was also main effect of mode [F(2,441)=3.281, p<0.05]: minor context responded faster than major and pentatonic context; a significant interaction between mode and scale degree [F(18,441)=4.109, p<0.01]: V responded slower in pentatonic than in major trials (p<0.05) and minor (p<0.05), and a significant main effect of scale degree [F(16,441)=4.010, p<0.05]: responses on VII took longer time than other scale degrees.

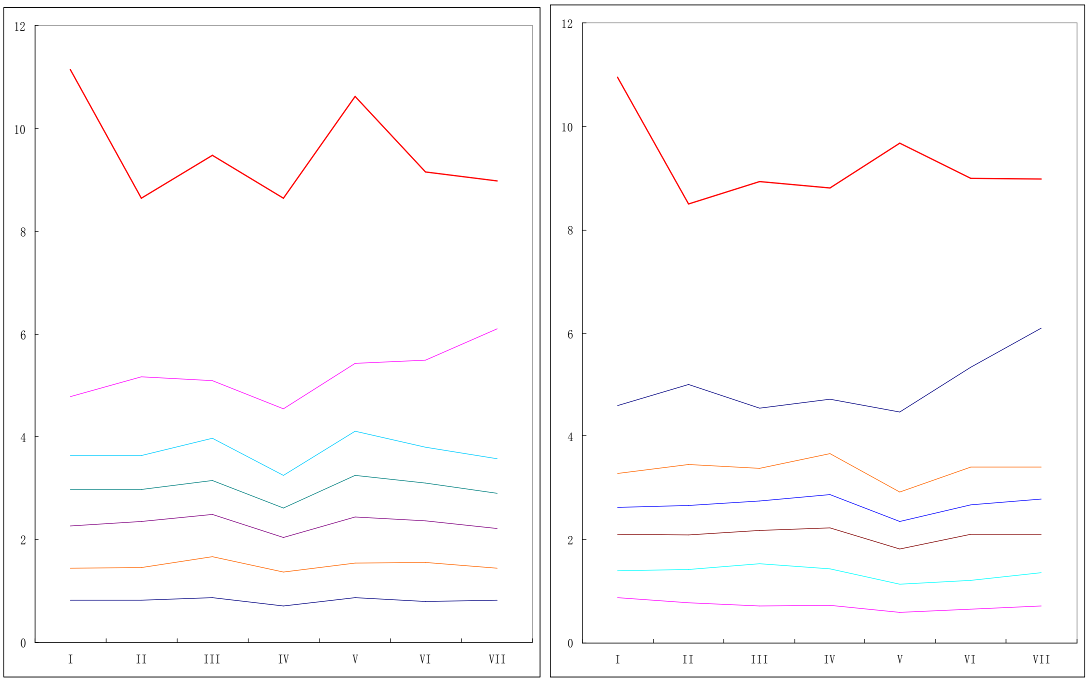
In German groups, there were significant main effects of music training [F(1,291)=6.637, p<0.05] and scale degree [F(16,291)=3.076, p<0.01]. In German non-musician group, there was a significant main effect of mode [F(2,254)=4.081, p<0.05]: minor context responded faster than major and pentatonic context, but there was no great difference between the response time of major and pentatonic trials; a main effect of scale degree [F(16,254)=2.538, p<0.05]; and also a significant interaction between mode and scale degree [F(18,254)=3.729, p<0.01]: responses on VII showed faster response in minor than in major trials.

40.1.5 Tonal profile

None of major or minor profiles of Chinese listeners and German listeners in trials with either scale-like contexts or musical excerpt had a significant correlation with K-K profiles. However, the profiles of Chinese listeners and German listeners still had some difference (Figure 49). The red line in each chart is the K-K major or minor profile. The following lines at the bottom of each chart are the profiles obtained from different conditions in this experiment series. The profiles from bottom to above are profiles of trials with no-indication context and test tone in the middle, trials with no-indication context and test tone at the end, trials with cadence-indication context and test tone in the middle, trials of start-indication context and test tone at the end, trials with bi-indication context and test tone in the middle, and trials with music excerpt and test tone in the middle.

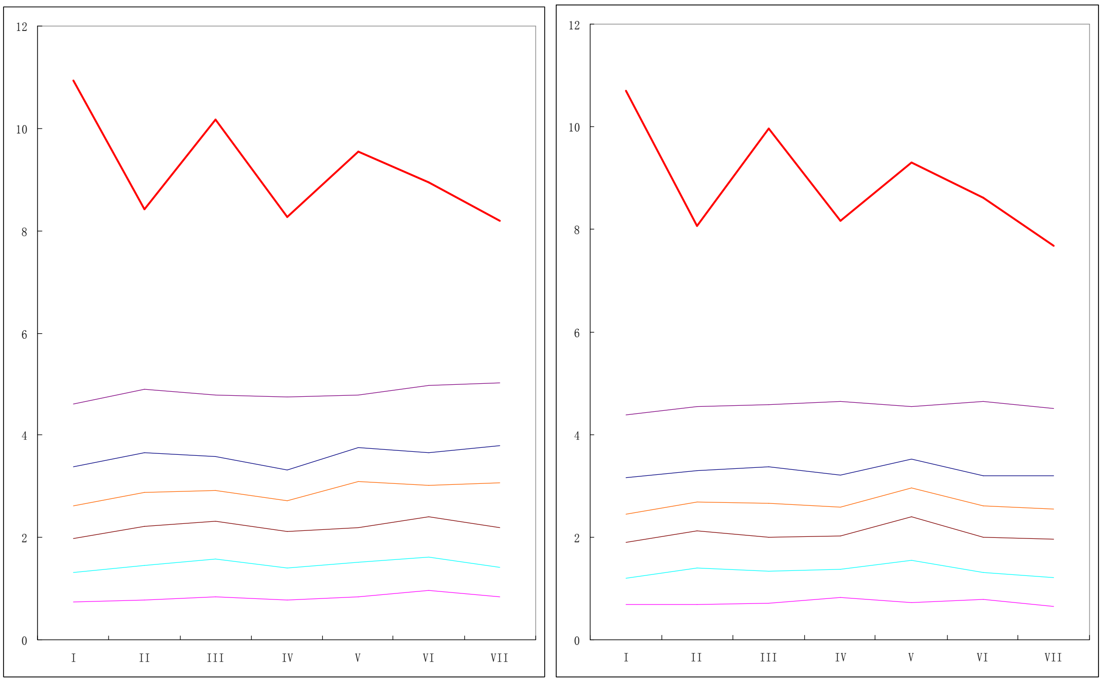
In major charts, the contours of Chinese listeners' profiles are similar to the K-K profile's contour, which means that the more important a scale degree is, the much more response time takes. This is quite different from what it was hypothesized. However, the contours of German listeners' profiles are different from the K-K profile's contour: the more important a scale degree is, the less response time takes. This result corresponds to the hypotheses.

Chinese German



a. major

Chinese German



b. minor

Figure 49 Tonal profiles in experiment series 2 and K-K profiles

In minor charts, both Chinese listeners' profiles and German listeners' profiles are ambiguous, which means there is no great difference among scale degrees. But it seems that both of them spent more time in judgment when the priming tone had the function of V.

40.1.6 Group 4: unmatched priming tone and test tone

Unmatched group consisted of trials in major and pentatonic modes, in which the priming tone and the test tone in the context were not in the same pitch. In major, there were 42 trials – 6 trials in each scale degree; and in pentatonics, there were 20 trials – 4 trials in each scale degree. In each circumstance, the trials could be divided into two sub-groups: lower degrees aroused higher degrees, for instance: the priming tone was II, and the test tone in the context was VII; and conversely, higher degree aroused lower degrees, but pitch was independent from the scale degrees. The test tone was set only in the middle of the context.

The correct response time of two sub-groups would be compared as paired samples. Multidimensional scaling (MDS) was used to analyze the relationship among scale degrees in the two modes perceived by Chinese listeners and German listeners. MDS is "a statistical technique to visualize dissimilarity data"[28] that can present the similarities or dissimilarities in distances among different things in a two-dimensional or three-dimensional space. One German subject was excluded because of her low accuracy.

40.1.6.1 Difference among scale degrees

One-way ANOVA analyzed the difference of response time of trials with the test tone that had different tonal functions when the priming tone had the same tonal function in the post-context (e.g. comparing the responses to the trials with the priming tone had the function of tonic and the test tone was the II, or III, or IV degree, etc. in the context, the profiles see Figure 50). Meanwhile, the trials in Group 1 with test tone in the middle were also involved in the comparison. It was found that in the major mode, there were significant differences in the trials with a priming tone as III [$F(6,239)=4.434$, $p<0.01$, VII showed slower response than other degrees primed with III] and the trials with a priming tone as VII [$F(6,268)=3.026$, $p<0.01$, I and VI were more difficult aroused by VII]. While in the pentatonic mode, there were significant differences in the trials with a priming tone as I [$F(4,184)=5.396$, $p<0.01$, the I degree itself responded slower than other degrees primed with I] and the trials with a priming tone as V [$F(4,177)=4.712$, $p<0.01$, the V degree itself also responded slower than other degrees aroused by V].

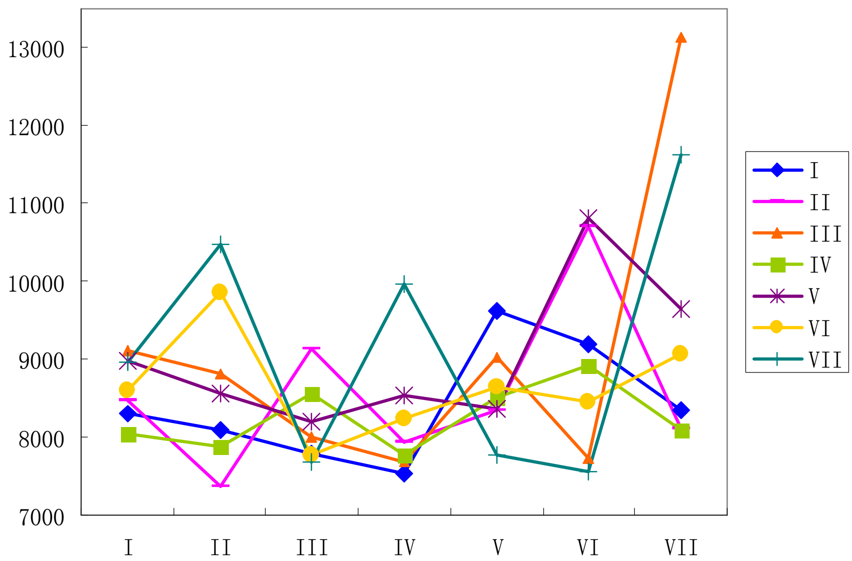
In Chinese group, there were the same phenomena in the major mode: there was a significant difference in the trials with priming tone as III [$F(6,142)=3.322$, $p<0.01$] and the trials with priming tone as VII [$F(6,156)=3.570$, $p<0.01$]; in pentatonics, there was a significant difference in the trials with priming tone as I [$F(4,112)=4.631$, $p<0.01$] and the trials with priming tone as V [$F(4,109)=5.819$, $p<0.01$]. But in German group, there were no such significant differences in any degree trials.

[28] Groenen,P.J.F. & van de Velden,M.(2004).Multidimensional Scaling. *Econometric Institute Report EI* ,15.

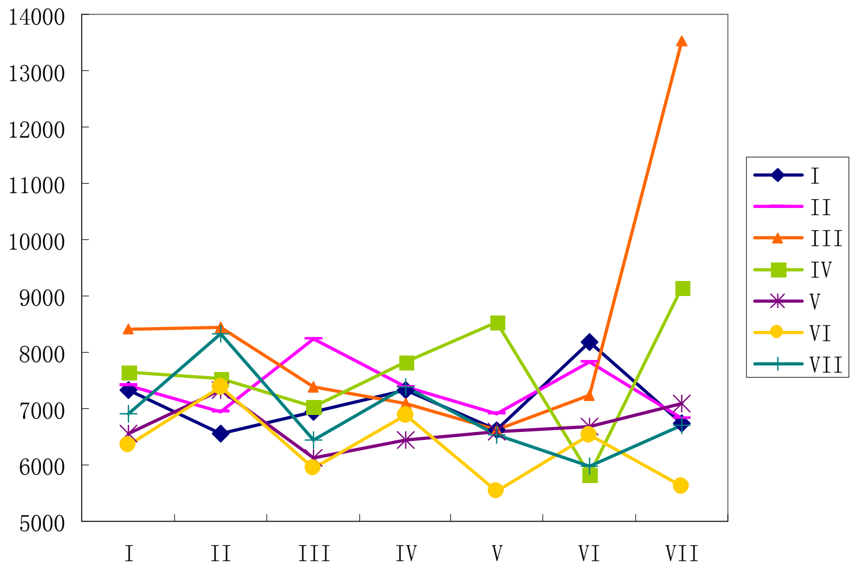
40.1.6.2 Paired trials

In the paired comparison, it was found that in major between the I and VII degrees in two directions (comparing the responses to the trial with the priming tone served as tonic and the test tone was the VII degree in the context with the response to the trial with the priming tones as VII and test tone was I in the context) showed different responses ($t=-2.056$, $p<0.05$), but response time of the III and IV degrees, which is also minor second, did not have such difference in two directions; the other significant difference was between II and VI ($t=2.059$, $p<0.05$), and as well as between III and VII ($t=2.524$, $p<0.05$), between IV and VII ($t=2.329$, $p<0.05$), between V and VII ($t=2.125$, $p<0.05$), and between IV and V ($t=2.073$, $p<0.05$). In pentatonics, there was only one significant difference between I and III ($t=-2.598$, $p<0.05$).

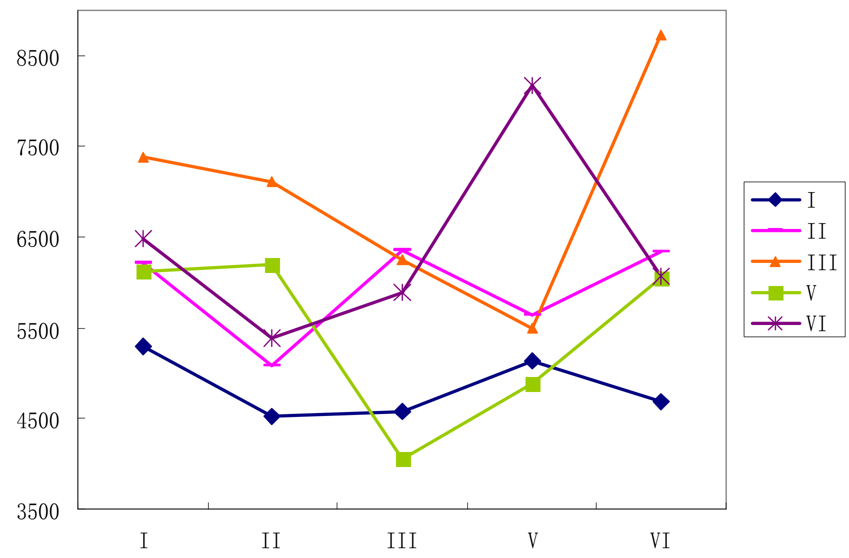
In Chinese group, there was a significant difference between V and VI ($t=2.063$, $p<0.05$) in major, but no significant differences were found between any other two degrees in major; and significant differences between I and III ($t=-3.477$, $p<0.01$), and between II and VI in pentatonic trials ($t=2.210$, $p<0.05$). In German group, there was only one significant difference between III and VI in pentatonic trials ($t=-2.415$, $p<0.05$), but no other significant differences.



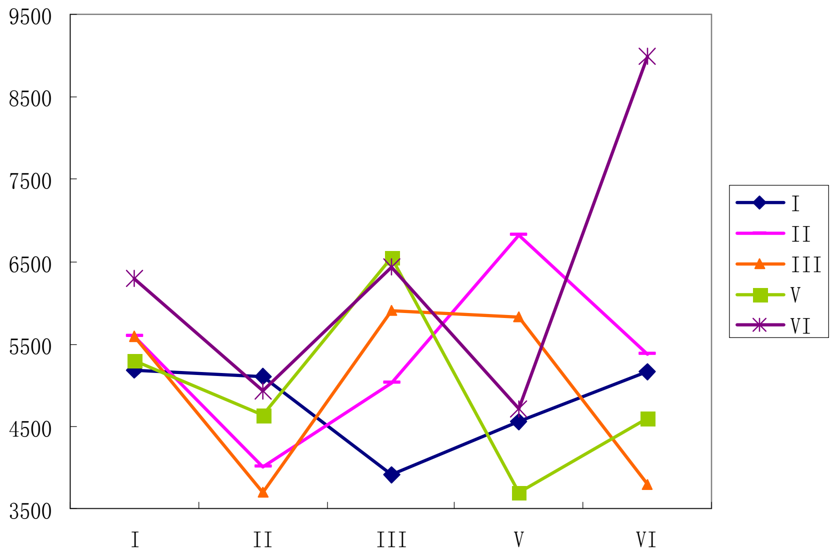
a. major – Chinese listeners



b. major – German listeners



c. pentatonics – Chinese listeners



d. pentatonics – German listeners

Figure 50 Profiles of same priming scale degree

40.1.6.3 Analysis of variance

When considering subject factors, it was found that in major there was a significant main effect of musical culture background (F=4.171, p<0.01): German participants responded all faster than Chinese listeners; but there was no significant main effect of music training and degree, and other interactions. While in pentatonics, there was a significant main effect of degree (F=4.053, p<0.01): especially on I [F(4,129)=3.747, p<0.01], V [F(4,129)=3.489, p<0.01] and III [F(4,129)=2.621, p<0.05] as priming tones; but no other main effects and interactions were found.

In Chinese group, there was no significant main effect and interaction in major; but there was a significant main effect of scale degree in pentatonics (F=3.311, p<0.01), especially on I [F(4,78)=3.051, p<0.05] and V [F(4,78)=3.890, p<0.01]. In German group, there was no significant main effect and interaction in both major and pentatonics.

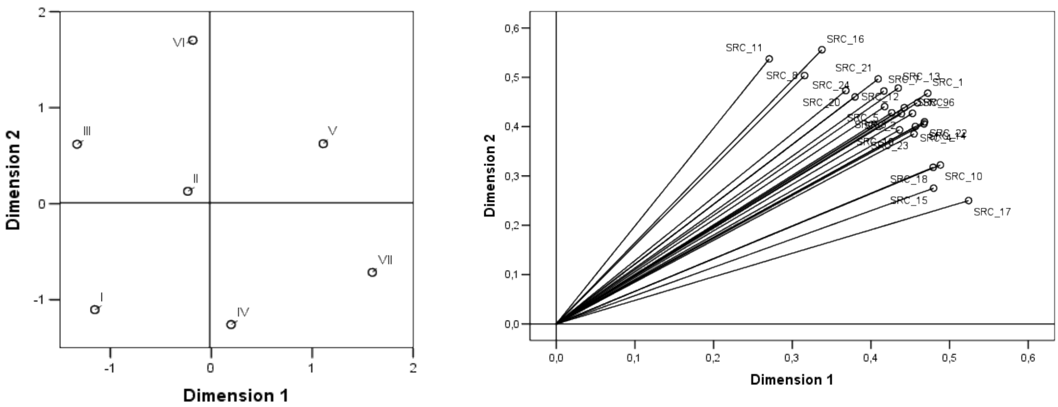
40.1.6.4 Multidimensional scaling

Multidimensional scaling (MDS) is a statistical method to present the similarities or dissimilarities among items in two- or three- dimension figures (Kruskal, & Wish, 1978). It is frequently used in psychological studies, presenting the subjective judgment in visualized figure. The distance shown in MDS corresponds to the relations of objects. The computation can be done with SPSS software, which can give out the *stress* value and RSQ (or D.A.F, Dispersion Accounted For) value of different dimensions after iteration. The RSQ (or D.A.F) value shows how well the dimension presents the relatedness; when its value near 1, it means that the dimension scaling can well present the relatedness among items. The *stress* value shows the goodness of fit between observed value and expected value; when its value is less than 20%, the fitness is acceptable. The explanation for the dimensions, the group of items, and the distance among items in the scaling should base on professional knowledge (Zhang, & Dong, 2004). Proximity scaling is one of multidimensional scaling technique. It is used for analysis of either similar or dissimilar data; and can either consider or neglect the individual differences.

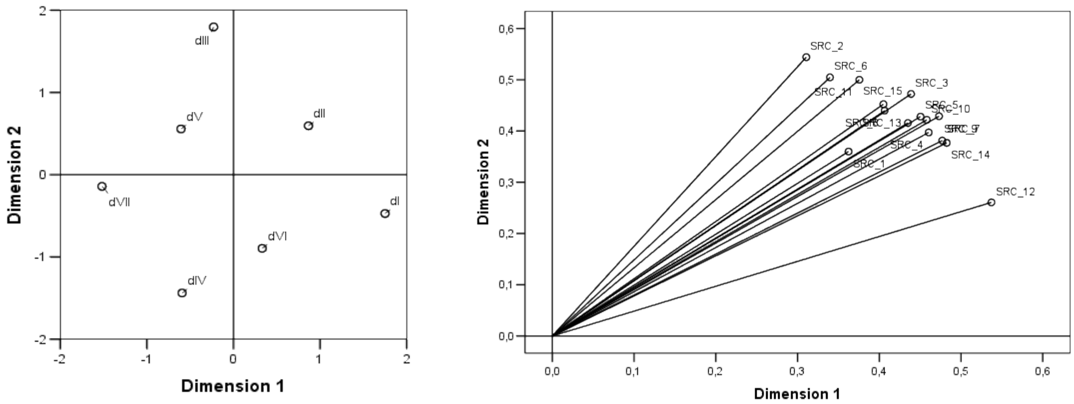
MDS is used to explore the psychological relations among scale degrees. All pairs of in-key degrees were paired of priming tone and test tone in the experiment, and then the perceptual response time was collected for each pair. According to the hypothesis, here supposing that the longer response time was, the larger psychological distance between the degrees was showed on the MDS. Here only major and pentatonic modes were involved. It was resulted that two dimensions can well illustrate the relatedness among scale degrees, so only two-dimension scaling were involved. MDS could also present cultural differences of listeners' tonal knowledge.

1) Major

In major trials, in the sub-group that a higher degree aroused a lower degree, the stress of MDS of Chinese participants was less than 20% (stress=0.17213, dispersion accounted for (D.A.F)=0.82787), which could be accepted though it was not so fair; the stress of MDS of German participants was also acceptable (stress=0.14696, dispersion accounted for (D.A.F)=0.85304). Here the charts of Chinese and German participants are shown respectively.



a. Chinese participants



b. German participants

Figure 51 Multidimensional scaling in major (high-low)

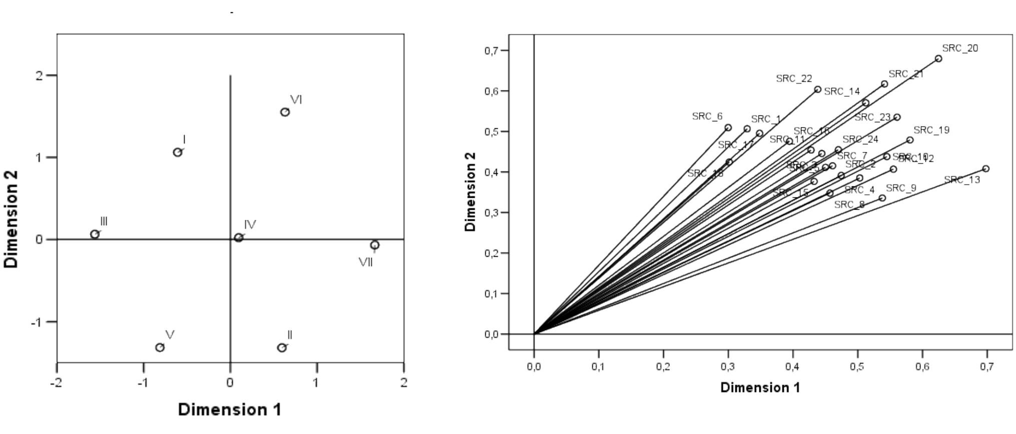
According to the two dimensional scales, Chinese and German participants showed different tendency. In Chinese listeners' MDS, I and V were apart in quite different two quadrants, III, II and VI gathered in one quadrant, which was different from the quadrant of IV and VII. An interesting phenomenon is that when the points in the diagonal direction from upper left to the lower right are connected, it seems that there are three layers: I at the bottom left, III, II and IV in the middle, which "four-degree-away partners" VI, V, VII on the upper right – the degrees scatter in scale-like relationship; III, VI and IV, VII are symmetry with the middle axis I, II and V; and pentatonic tone-groups (I-II-III-V-VI, IV-V-VI-I-II, V-VI-VII-II-III) can be circled in a "trapezoid" shape. The individual differences among 24 Chinese participants were not dispersed.

It seems dimension 1 (x axis) presents some characters of pitch series that I, IV and VII cannot be in the same pentatonics, although this figure presents the relation of degrees in major. And dimension 2 (y axis) seems to refer to the “common-tone” or popularity of degrees, because at the lower level, I, IV and VII appear in different pentatonic series, the upper level III, II, V and VI have more tonal “tolerance”.

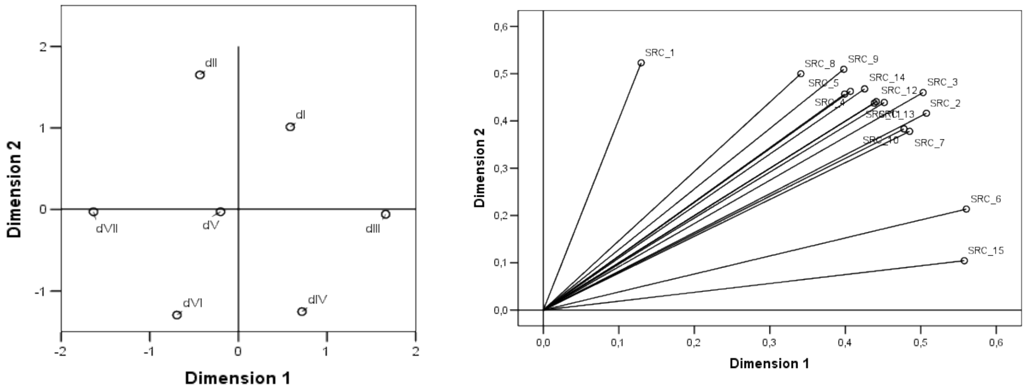
In German listeners’ MDS, II was alone in a quadrant, which was opposite to the quadrant which included VII and IV, and III and V were in the same quadrant, which was opposite to the quadrant of VI and I. An interesting phenomenon is that when the points in the direction from upper left to the lower right are connected, there seems to be three layers – but these are different from Chinese three layers: VII and IV at the bottom left, V and VI in the middle, and III, II, I on the upper right; VII, V, III and IV, VI, I are symmetry with the middle point II; but not all three pentatonic tone groups can be circled in a trapezoid shape. The individual differences among 15 German participants were not dispersed.

However, the two dimensions are less meaningful. Dimension 1 seems to refer to a transition from dominant to subdominant and to tonic, but dimension 2 is difficult to tell.

In the sub-group that a lower degree aroused a higher degree, the stress of MDS of Chinese participants was less than 20% (stress=0.17340, dispersion accounted for (D.A.F)=0.82660), which could be accepted though not so fair; the stress of MDS of German participants was also acceptable (stress=0.14554, dispersion accounted for (D.A.F)=0.85446). The charts of Chinese and German participants are shown respectively.



a. Chinese participants



b. German participants

Figure 52 Multidimensional scaling in major (low-high)

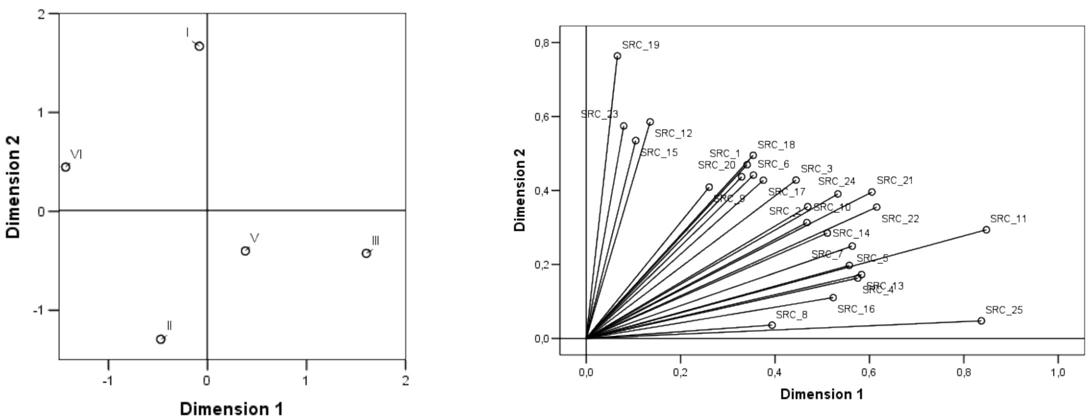
According to the two dimensional scales, Chinese and German participants showed different tendency, and also not quite the same as their scales of the first sub-group.

In Chinese listeners' MDS, V was alone in one quadrant, which was opposite to the quadrant of IV and VI; I and III gathered in one quadrant, which was opposite to the quadrant included VII and II. IV was nearly at the origin of the coordinates, the triad of VI on the upper left and the triad of V on the lower right; III, IV and VII were also blur on dimension 2, standing on the axis. Compared with the scale of the other sub-group, it seems that there are still three layers: I, III-IV-VI, V-II-VII, but the positions of II and VI were changed. That is, the distance between I and II is larger, but the distance between I and VI is smaller than the other sub-groups. The 2 trapezoid shapes of pentatonic tone group were replaced bow shapes, and the other was substituted by "X" shape. The individual differences among 24 Chinese participants were dispersed on dimension 1. But the senses of two dimensions are difficult to tell.

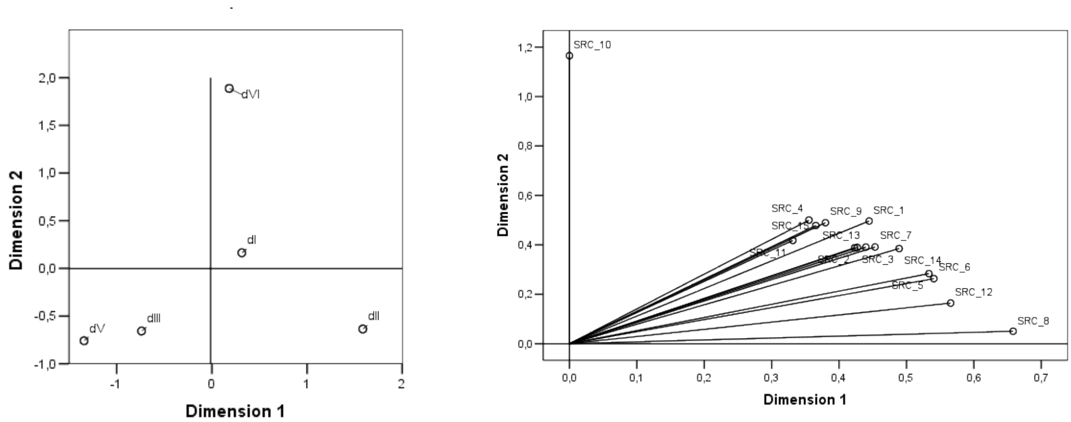
In German listeners' MDS, I was alone in a quadrant, which was next to the quadrant of II; III and IV were in the same quadrant, which was next to the quadrant of VII, VI and V. It seem that there is no great difference from the trials of arousing from higher degree to lower degree, there are still three layers with I, II and III in the same line – though the positions are changed between I and II; V and IV on the second line, VII and VI are the last, with the position changes between VI and IV. VII, V, and III are blur on dimension 2, standing on the axis. The individual differences among 15 German participants were not dispersed in two dimensions, except 3 participants. But the senses of two dimensions are difficult to tell.

2) Pentatonics

For pentatonics, in the sub-group that a higher degree aroused a lower degree, and the stress of MDS of Chinese participants was less than 20% (stress=0.18253, dispersion accounted for (D.A.F)=0.817), which could be accepted though it is also not so fair; the stress of MDS of German participants was also acceptable (stress=0.12577, dispersion accounted for (D.A.F)=0.874). The charts of Chinese and German participants are shown respectively.



a. Chinese participants



b. German participants

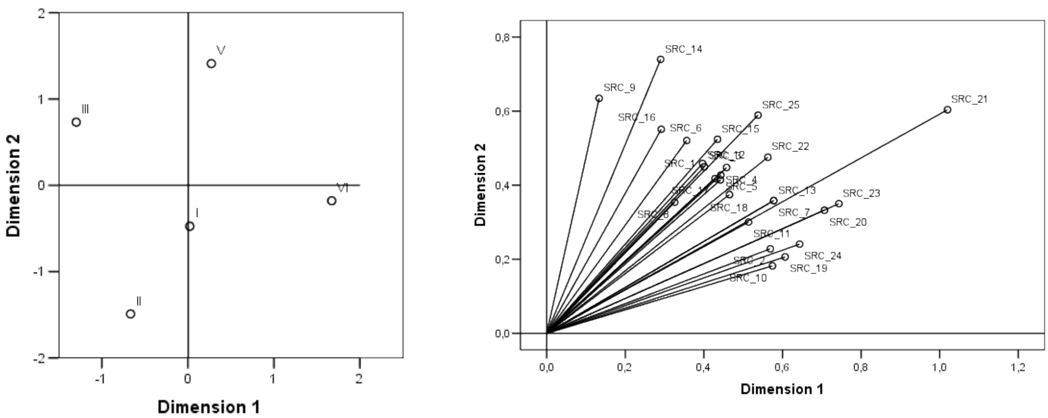
Figure 53 Multidimensional scaling in pentatonics (high-low)

According to the two dimensional scales, Chinese and German participants showed different tendency. In Chinese listeners' MDS, II was alone in one quadrant, I and VI gathered in one quadrant, which was opposite to the quadrant included V and III. I, II and V stand almost in a line, which is quite similar to their figure in major with high degree arousing lower degree, but the positions of II and V were changed. And I was not close to II and III, but close to VI and V instead; II, V, III were closer to each other. The individual differences among 24 Chinese participants were dispersed in two dimensions.

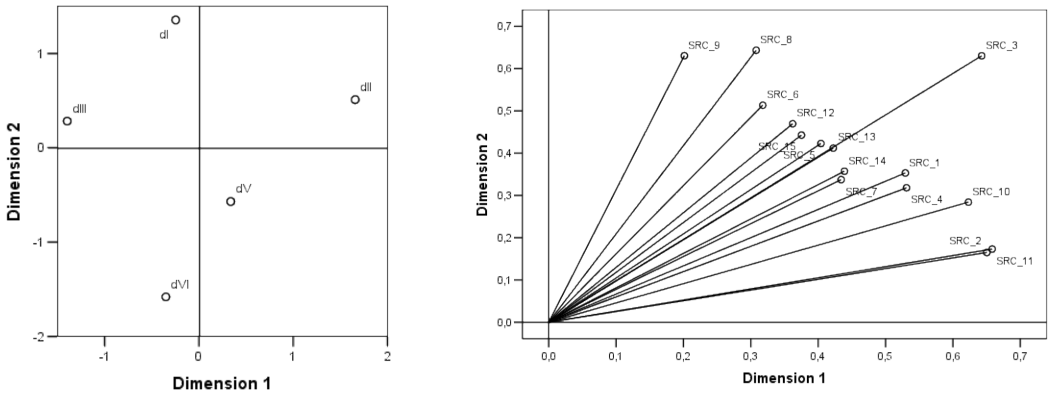
In German listeners' MDS, II was alone in a quadrant, I and VI, and III and V were in the same quadrant, which was opposite to the quadrant of VI and I. The separation of five tones by quadrant was a little bit similar to Chinese listeners' MDS showed above; but quite different from the scale in major with high degree arousing lower degree, but III and V were kept in one quadrant. I was close to III, and kept same distance to II, V, and VI. The individual differences among 15 German participants were dispersed in dimensions 1, and tended to one side of dimension 2.

However, the meaning of dimensions are difficult to tell.

In the sub-group lower degree arouse higher degree, and the stress of MDS of Chinese participants was less than 20% (stress=0.12722, dispersion accounted for (D.A.F)=0.87278), which could be accepted though not so fair; the stress of MDS of German participants was also acceptable (stress=0.13169, dispersion accounted for (D.A.F)=0.86831). The charts of two groups are shown respectively.



a. Chinese participants



b. German participants

Figure 54 Multidimensional scaling in pentatonics (low-high)

According to the two dimensional scales, Chinese and German participants showed different tendency. In Chinese listeners' MDS, II, III, V and VI were respectively in the four quadrants; I was nearly at the origin of the coordinates, and kept the distance to other four degrees nearly the same; I, II and V were still nearly on a line, only the positions of point I and V were changed. But the scale was quite different with the scale in major with lower degree arousing higher degree. The individual differences among 24 Chinese participants were more dispersed in dimension 2.

In German listeners' MDS, only I and III were in one quadrant, while II, VI and V were respectively in other three quadrants. The distribution of five tones by quadrant was quite different from Chinese listeners' MDS showed above, especially the distance between I and VI which was larger than Chinese; and it was also quite different from their figure in major with lower degree arousing higher degree, the distances between I and VI, between V and III were stretched. The individual differences among 15 German participants were dispersed in two dimensions. Dimension 2 seems to refer to the scale degree distance.

40.2 Priming intervals

The priming tone with successive tones – melodic interval was only investigated in major mode. Four intervals, including common intervals and rare intervals in two directions, were involved: perfect fourth (10 trials), perfect fifth (10 trials), minor second (8 trials) and tritone (4 trials). The test tone was set in the middle of context.

The following tables list the percentage of correct responses, the mean and the deviation of correct responses for four kinds of intervals (see Table 50-53). German participants still made fewer false responses than Chinese listeners, and their response time was significantly faster than Chinese listeners (t=4.031, p<0.01). There were no significant differences among scale degrees of perfect fourth, perfect fifth, and minor second, but there was a significant difference between two scale degrees of tritone [F(1,157)=6.729, p<0.01], and this was observed only with German listeners [F(1,60)=4.718, p<0.05].

Table 50 Correct responses to priming perfect fourth

Perfect 4th		I	II	III	V	VI
		ascending				
C	Accuracy	96.00%	80.77%	92.31%	92.31%	91.67%
	RT(SD)	0.79 (0.43)	0.83 (0.34)	0.68 (0.21)	0.75 (0.29)	0.74 (0.24)
G	Accuracy	100.00%	93.75%	100.00%	93.75%	100.00%
	RT(SD)	0,62 (0.30)	0,65 (0.30)	0,69 (0.41)	0.60 (0.29)	0,65 (0.33)
Perfect 4th		I	II	III	V	VI
		descending				
C	Accuracy	92.31%	88.00%	92.31%	84.62%	92.31%
	RT(SD)	0.74 (0.31)	0.78 (0.26)	0.69 (0.27)	0.77 (0.32)	0.78 (0.28)
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%
	RT(SD)	0.73 (0.41)	0.87 (0.62)	0.68 (0.32)	0.68 (0.35)	0.63 (0.26)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

Table 51 Correct responses to priming perfect fifth

Perfect 5th		I	II	III	V	VI
		ascending				
C	Accuracy	100.00%	73.08%	96.00%	80.77%	83.33%
	RT(SD)	0.77 (0.37)	0.82 (0.44)	0.74 (0.25)	0.87 (0.53)	0.86 (0.59)
G	Accuracy	100.00%	100.00%	100.00%	100.00%	100.00%
	RT(SD)	0,78 (0.45)	0,69 (0.35)	0.70 (0.41)	0,76 (0.43)	0,64 (0.30)

Perfect 5th		I	II	III	V	VI
		descending				
C	Accuracy	96.15%	84.00%	92.31%	76.00%	87.50%
	RT(SD)	0.75 (0.30)	0.81 (0.33)	1.01 (0.77)	0.91 (0.88)	0.77 (0.24)
G	Accuracy	100.00%	100.00%	100.00%	100.00%	93.75%
	RT(SD)	0.81 (0.64)	0,64 (0.36)	0.61 (0.29)	0.65 (0.35)	0.60 (0.26)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

Table 52 Correct responses to priming minor second

Minor 2nd		I		III		IV		VII	
		as	de	as	de	as	de	as	de
C	Accuracy	96.00%	96.15%	96.00%	92.31%	96.00%	96.15%	80.77%	96.15%
	RT(SD)	0.77 (0.33)	0,74 (0.38)	0.66 (0.24)	0.72 (0.23)	0.68 (0.26)	0.68 (0.24)	0.85 (0.35)	0.74 (0.28)
G	Accuracy	100.00%	100.00%	100.00%	100.00%	93.33%	100.00%	93.33%	100.00%
	RT(SD)	0,60 (0.30)	0.65 (0.33)	0,68 (0.45)	0,63 (0.38)	0.63 (0.35)	0.71 (0.41)	0,91 (0.58)	0.64 (0.38)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

Table 53 Correct responses to priming tritone

Tritone		IV		VII	
		as	de	as	de
C	Accuracy	92.31%	100.00%	92.31%	96.15%
	RT(SD)	0.71 (0.38)	0.74 (0.32)	0.91 (0.35)	0.76 (0.24)
G	Accuracy	93.75%	100.00%	100.00%	87.50%
	RT(SD)	0.58 (0.27)	0.60 (0.25)	0,77 (0.45)	0,79 (0.37)

(RT = response time; SD = standard deviation. RT and SD are shown in seconds)

In ANOVA analysis, scale degree was considered as a “nested” factor of interval; music training was considered as a “nested” factor to participants’ musical culture background. The result showed that there was a main effect of musical culture background [F(1,1222)=13.971, p<0.01], and a significant main effect of music training [F(2,1222)=6.149, p<0,01]: participants studying music responded faster than non-music participants; but there were no other significant main effects or interactions.

In Chinese listeners group, there was no significant effect of music training [F(1,727)=3.616, p>0.05]. When subject factor was not considered, there was a significant main effect of interval type [F(1,727)=2.641, p<0.05]: four intervals showed different responses. The further comparison showed that the responses to perfect fifth were significantly slower than the response to perfect fourth (p<0.05) and minor second (p<0.01). But there were no other significant effects or interactions.

In German listeners group, there was a significant main effect of music training [F(1,494)=6.898, p<0.01]. There were no other significant effects or interactions.

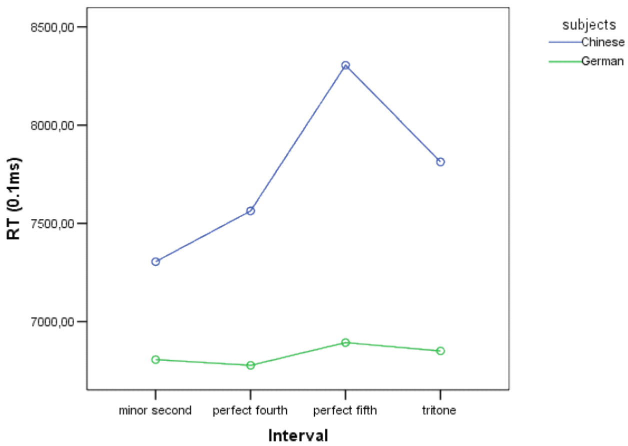


Figure 55 Responses to priming intervals

41. Test tone vs. no test tone

41.1 Sensitivity index d' and the response bias ß

In the first three trials, the percentage of signal presentation – contexts with test tone (excluded "indirect" trials) – was set at 66.67%. For the sensitivity index d' and the response bias ß in the three modes (see Table 54), it seemed that the sensitivity d' of Chinese participants was lower than that of German participants in major and minor mode, but it was a little higher than German listeners' in Chinese pentatonics.

Table 54 Sensitivity index and response bias in single priming tone trials

modes	Major (66.6%)		Minor (66.6%)		Pentatonics (66.6%)	
	d'	ß	d'	ß	d'	ß
Chinese	3.23 (1.28)	0,16(0,29)	3.28 (1.18)	0.11(0,20)	3.32 (1.24)	0.17(0,34)
German	3,87 (0.55)	0,01(0.05)	3,73 (0.75)	0,02(0.07)	3,22 (1.24)	0,12(0.24)

The differences among them were analysed by one-way ANOVA: the sensitivity index d' had no significant difference among the three modes [$F(2,119)=0.408$, $p>0.05$], and so was the response bias ß [$F(2,119)=0,990$, $p>0.05$]. Comparing the Chinese and German participants, it was found that there was a significant difference in the response bias ß ($t=2,280$, $p<0.05$), but no significant difference in sensitivity ($t=-1.661$, $p>0.05$). Another ANOVA also found the similar result: there was no significant main effect of mode on the sensitivity, but there was a main effect of musical culture background on the response bias [$F(1,121)=4.096$, $p<0.05$, $MSE=0.236$]. So, Chinese listeners and German listeners had similar sensitivity in the three modes, but with different response bias.

41.2 Test tone vs. non-test tone

There were trials that did not have test tones in trials. The accuracy of responses to these trials was high. Chinese made over 90% correct responses and German were nearly 100% correct. Whether there were differences between the responses to trials with test tone and the responses to trials without test tone reflected the cognitive processing. So the comparison between the two group trials was made.

In priming single tone trials, in major trials, there was a significant difference between response time of the trials without test tone and the trials without tonal indication ($t=2.270$, $p<0.05$), and trials with tonal indication at the end ($t=2.635$, $p<0.01$), and also trials with tonal indication at both start and end of the context ($t=2.006$, $p<0.05$). That is, the trials without test tone responded faster than the trials with test tone. However, in minor trials, no significant differences were found in the responses to the trials with no tonal indication trials ($t=-1.139$, $p>0.05$), with tonal indication at the end ($t=0.347$, $p>0.05$), and with tonal indication at both start and end of the context ($t=0.638$, $p>0.05$). In pentatonic trials, there was also no such significant difference ($t=1.775$, $p>0.05$).

Considered the subject factors, there was still a main effect of musical culture background. In Chinese group, in major trials, a significant difference was found between trials without test tone and trials without tonal indication ($t=2.539$, $p<0.05$)

and with tonal indication at the end ($t=2.656$, $p<0.01$); but there was no significant difference in trials with bi-tonal indication. There was no significant difference in minor and pentatonic trials. There were no differences between the responses in musicians and non-musicians. In German listeners group, there was only one significant difference in major with bi-tonal indication ($t=2.130$, $p<0.05$); but no difference in other situations was found.

In priming interval trials, there was a significant difference between the responses to the trials with and without test tone ($t=6.503$, $p<0.01$): the trials with no test tone showed faster response than the trials with test tone. This was found in both Chinese group and German group.

Summary

1) German participants made less errors than Chinese participants;

2) German participants responded faster than Chinese participants;

3) There was no significant main effect of music training in Chinese listeners group, but a significant main effect of music training in German listeners group;

4) In major, trials without test tone responded faster than any trial conditions with test tone; but it was not found in minor and pentatonics;

5) Test tone at the end of context responded faster than in the middle of the context;

6) Trials without tonal indication responded slower than trials with tonal indication, especially Chinese listeners and non-music German listeners;

7) The more tonal indication were given, the faster responses were made in major and minor;

8) In major, German participants responded faster than Chinese participants when the priming tone had the function of III and V in trials with indication;

9) In major, Chinese participants responded differently depending on tonal indication and test tone position, non-music German listeners responded differently depending on test tone position;

10) In minor, non-music German listeners responded differently depending on tonal indication and tone position, Chinese participants responded differently depending on

test tone position;

11) A significant effect of degree happened only in trials with test tone at the end and no tonal indication, and in trials with music excerpts;

12) In the trials with musical excerpts, there was a significant interaction between mode and degree in Chinese listeners group: I, III,V responded slower in pentatonic melody than in major melody;

13) In the trials with musical excerpts, minor trials showed faster responses than major and pentatonic trials;

14) The trials with unmatched priming tone and test tone responded not all the same in different directions;

15) In major indirect trials, response time of the trials with the priming tone served as III or VII were quite different in Chinese participants;

16) Tonal profiles of major and pentatonic mode in indirect trials were different between Chinese listeners and German listeners;

17) In pentatonic indirect trials, I and V primed by themselves responded slower than primed by other scale degrees in Chinese participants;

18) Multidimensional scaling (MDS) were presented differently in Chinese and German participants in major and Chinese pentatonic mode;

19) MDS of two "direction" sub-groups of major were quite similar in German participants;

20) MDS of two "direction" sub-groups of pentatonics were quite similar in Chinese participants;

21) In MDS of Chinese participants, I, II and V were kept in a line;

22) Responses to priming perfect fifth were quite slower in Chinese listeners;

23) There was no significant main effect of direction in priming intervals;

24) There was no significant main effect of degree in priming intervals, except tritone, only in German participants;

25) There was a significant difference of response bias between Chinese and German participants but similar sensitivity in the responses.

Discussion

This part discusses the results from the experiment series 2. The discussion refers to the examination of the hypotheses, the influence of musical factors in three modes respectively, and the comparison between the current results and the results from former studies.

42. Participants

42.1 Age & musical culture background

Regarding musical culture background, the results showed that there was a significant difference of response time between Chinese participants and German participants in all the trials. That is, German participants responded quite faster than Chinese participants in major, minor and Chinese pentatonic conditions. It could be caused by three possible reasons, one is the age factor, the other is the mouse used in the experiments, and the third is the response bias influenced by cultural musicality.

For the factor of age, the main age of Chinese participants was 26.69 (SD=10.18), including three teachers in their 40s and 50s. While the main age of German participants was 22.56 (SD=4.52) which was younger than the main age of Chinese participants. In a reaction time study using tones as stimuli – detection of a 1000Hz, 70dB tone, it was found that the increase of simple reaction time per decade was only 2ms (Gottsdanker, 1982); in another longitudinal reaction time research, it was found that reaction time to auditory stimuli – high tone in 1000Hz and low tone in 250Hz, the simple reaction time (responses to either high or low tones after warning signals) increased 0.5ms per year and the disjunctive reaction time (responses only to high tones in complex contexts) increased 1.6ms per year from the age of 20, and also more errors occurred (Fozard, Vercruyssen, Reynolds, Hancock & Quilter, 1994). In the present task, the reaction time can be considered as a disjunctive reaction time, during which participants reported whether there was a trumpet tone in the context. Chinese participants made responses within 0.3s (mostly less than 0.1s), which was slower than German participants. The difference of response time between Chinese and German groups was much more beyond the general gerontological difference, so it may be concluded that the difference between German and Chinese participants did not depend on age.

As for the mice used in the experiments, the refresh rate of responses of the mice depends on the parameter DPI (dots per inch) which is usually about 8 ms, and there is little difference between two mice from one brand or from two brands. So the response of a mouse did not affect the difference in responses of participants a lot.

For the factor of response bias ß, generally, it varies depending on the ratio of signal presentation or participants' expectation for signals, and the bonus-penalty to participants (Zhu, 2000). In the present study, the percentage of signal was set, and there was the same bonus-penalty for both Chinese and German groups. Then the difference of response bias ß may result from different musical culture backgrounds, which affect participants' expectation for signals. Western listeners are almost mono-musical, because they mainly grow up in Western musical culture; while Chinese listeners are mostly bi-musical, because both Western musical culture and Chinese musical culture are prevalent in China. That is, Western listeners have one musical schema, and Chinese listeners have two musical schemata. In musical expectations, Western listeners anticipate directly according to their mono-musical schema, but Chinese listeners may implicitly choose a proper schema for a certain musical situation for further expectation. The selection of musical schema may cost some time, so the response time of Chinese participants was longer. This can be further investigated in later studies. And Western timbres (piano and trumpet) may lead either cultural confusion between timbre and tonal schema (Abe & Hoshino, 1990) or stricter "standard" for making judgment. In the present study, Chinese participants would not like to respond unless they felt "so sure" about the appearance of the trumpet tone in the context. So, it is concluded that timbre may play a role in tonal perception. The congruence of timbre and tonal schema can facilitate responses; otherwise, the incongruence of timbre and tonal schema will interfere with responses.

Although there were no significant differences of sensitivity index d' between Chinese participants and German participants in each of the three modes, the sensitivity indexes of major and minor with German participants were slightly higher than with Chinese participants; however, the sensitivity index of Chinese pentatonics with Chinese participants was slightly higher than with German participants. So the Chinese group was more sensitive than the German group to Chinese pentatonics, but was less sensitive to major and minor, who might be influenced by the implicit tonal knowledge formed during daily music exposure. This result is consistent with the results in other cross-cultural studies, for instance, in cross-cultural studies with Japanese traditional music (Abe & Hoshino, 1990), Indian raga music (Castellano, Bharucha, & Krumhansl, 1984), Finnish spiritual folk hymns and North Sami yoiks (Krumhansl, 2000; Krumhansl, Toivanen, Eerola, Toiviaien, Järvinen, & Louhivuori, 2000). The perception of native listeners who were from the local culture and the perception of Western musicians who were unfamiliar with the certain musical culture were compared. It was found that participants with different musical backgrounds showed a different familiarity of the musical style, and were only sensitive to the common features of foreign and native musical cultures (Castellano, Bharucha, & Krumhansl, 1984; Kessler, Hansen, & Shepard, 1984); while musical perception of "local" people was consistent with their musical theoretical description. So the sensitivity index seems to relate to musical culture differences, but the response bias reflects whether judgment standards are loose or strict.

As to the more specific differences between Chinese and German participants, the results indicated that musical culture background or tonal schema worked stably and significantly in different tonal indications: German participants responded quite faster than Chinese participants on the III and V degrees, as well as other degrees (but not significantly), only except IV which responded slower than Chinese listeners. So tonal indication, either only at the end as cadence, or at both the start and the end of the context, could arouse the tonal implicit knowledge possessed by German listeners, especially the tones in tonic triad: I, III, V. However, such tonal indications had little effect on Chinese listeners. At least, they did not present any harmonic "preference" as German participants showed, because harmonic relations do not play an important role in Chinese music, this will be further discussed in the following sections. It can be concluded that the foreground is not the main factor for tonal perception, but tonal schema determines tonal perception.

42.2 Musical training

Musical training in the present study was taken as a nested factor of musical culture background, because it was supposed that whether participants were trained in music or not, they were influenced quite deeply by the daily exposure of their own musical culture. Former studies showed that there was no great difference between musicians and non-musicians in either tonal hierarchy (e.g. Bigand, 1997; Tillmann, 2005) or in musical expectancy (e.g. Hébert, Peretz, & Gagnon, 1995; Schellenberg, 1996); there was only one exception that there was a significant difference between two groups in tonal hierarchies (Halpern, Kwak, Bartlett, & Dowling, 1996). In Hébert's study (1995), there was no significant difference in tonal ending perception between musicians and non-musicians; and in Schellenberg's study (1996), no significant difference was found between Western musicians and non-musicians in musical expectancy of British folk songs. Thus, the similarity between musician and non-musician could also happen with Chinese listeners.

The participants involved in both Chinese group and German group were mainly non-musicians. There were only 5 students who majored in music in the Chinese group – about 20% of the participants; and only 2 students studied music in the German group – about 12.5% of the participants. Such small involvement of musicians may not present the perceptive features of the majority of musicians and could not sufficiently show the difference from the perception features of non-musicians, although the comparison between the two musical training groups was still made in the results analysis respectively in Chinese and German groups. In addition, the results of Chinese non-musicians could be compared with the results from experiment series 1, which was done with Chinese music students; and the results of German non-musicians could be compared with former studies which were done with the results from Western musicians.

The present results showed that in Chinese groups, there was no significant difference of response time, sensitivity index and response bias between musicians and non-musicians in the three modes with all conditions, and no significant interaction between music training and any musical factors. This result verified again the conclusions from other studies that there is little difference in musical training. However, it does not mean that Chinese musicians and non-musicians responded quite the same on degrees in the three modes; at least, musicians responded a little bit faster than non-musicians generally. This may be due to the musicians' familiarity with the trumpet timbre.

While in German groups, there was a significant difference of response time between musicians and non-musicians, and a significant interaction between music training and test tone position in non-tonal indication contexts, and also a significant interaction between music training and tonal indication in minor mode. These results reveal that musicians and non-musicians depended on different clues to make their judgment. Musicians replied faster to the non-tonal indication contexts with the test tone in the middle, and also faster to the contexts with cadence indication in minor mode; while non-musicians responded faster to the non-tonal indication contexts with the test tone at the end. A possible explanation is that musicians might take the explicit timbre judgment just as a timbre discrimination task, and were not influenced by other musical attributes (e.g. pitch, duration, intensity), so they could respond faster than non-musicians when the test tone was in the middle of the context. The task might be like a timbre memory task for musicians, the test tone appeared earlier in the middle than at the end of the context, so it would be easy for them to recall; but the comparison of the timbre of the priming tone and the test tone at the end of the context might cost more effort. While non-musicians seemed to find it difficult to grasp musical elements within the context, but preferred to make judgment on a "global" view of the context. They took the context as a whole, the test tone at the end of the context was easier for them to make decisions because of its recency effect, but the test tone in the middle of the context might cause effort to recall. Thus, the priming tone is used differently by musicians and non-musicians. Musicians may take it as a temporary part in the context, but non-musicians may take it as a part separated from the context. These results may be more or less consistent with short memory studies with musicians and non-musicians (Jakobson, Cuddy & Kilgour, 2003; Williamson & Baddeley, & Hitch, 2010) that musicians prefer temporal order processing, while non-musicians depend on pitch proximity.

In minor with tonal indication, non-musicians seemed to rely on more tonal clues to make responses, so they responded faster to the trials with bi-tonal indication than to the trials with cadence indication. Musicians presented conversely that they responded faster to the contexts with only cadence indication. This may also reflect that non-musicians depend on "global" meaning of the context more than musicians. However, with unbalanced participation of the two groups, these results can be studied further in the future.

43. Key profiles in the three modes

43.1 Key profiles in major mode

There were mainly four conditions of major mode: non-tonal indication context, cadence indication context, bi-tonal indication context and music excerpts. The former three conditions were with scale-like contexts. The difference of response time among these three conditions could show the effect of tonal indication on the tonal perception. Besides, the test tone in each condition was set differently: the test tone in non-tonal indication context and cadence indication was set either in the middle or at the end of the context; while the test tone in bi-tonal indication context and melodic context was set only in the middle. The difference of response time between two test tone positions could present whether listeners' tonal knowledge depended more on melodic or proximity information in the middle of a tone sequence, or depended more on ending expectation in a tone sequence.

The major key profile, which was obtained by Krumhansl and Kessler (1982) and reproved by other scholars (e.g. Janata, & Reisberg, 1988; Huron, 1993; Cuddy, & Badertscher, 1987; Frankland, & Cohen, 1990; Parncutt & Bregmann, 2000), shows a stronger "preference" of the degrees tonic, mediant and dominant (see Figure 56) than other diatonic tones and out-of-key tones. In the present study, only diatonic tones were involved, so only diatonic major profiles in different conditions were compared with Krumhansl and Kessler's result.

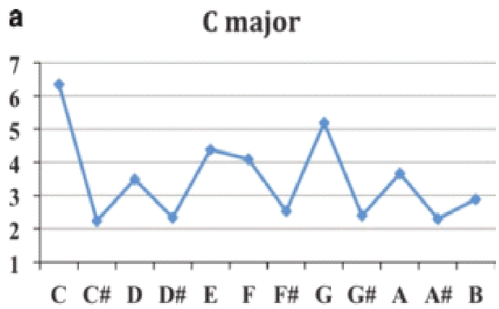


Figure 56 Key profiles of C major (Krumhansl & Kessler, 1982; Krumhansl & Cuddy, 2010)

1) In trials without tonal indication

It was hypothesized that a single tone could activate the tonal hierarchy, in which the more important a degree was, the faster the response could be made; conversely, the less important a degree was, the slower the response could be made. In non-tonal indication, the profiles might also depend on the position of the test tone in the context.

As the results, it was shown that there was a significant main effect of test tone position with Chinese participants and German non-musicians. The response time of test tone at the end of the context was not only faster than the response time of test tone in the middle of the context, but also the profiles of responses to two test tone positions were different.

When the test tone was in the middle of the context without tonal indication, neither of the response time profiles of Chinese participants and German participants was similar to K-K major profile. Chinese participants responded faster to IV, then a little bit slower to the I, II, VI, VII degrees, and much slower to III and V, there was no significant difference between every two degrees; while German participants responded faster to the V degree, then a little bit slower to III, IV, VI, VII, II, and significantly slower to I. So the tones in the tonic triad presented no significant tonal function which could promote the reaction time. The profile of German listeners was partially (seven degrees except the I and II degrees) consistent with the distribution of scale degrees in major keys resulted by Aarden (2003, also see Huron, 2007), in which the V degree is the most popular, then III, I, II, IV, VI, VII.

When the test tone was at the end of the context, there was a significant main effect of degree, and the profiles of Chinese participants and German participants were more similar to K-K major profile. Chinese participants responded faster to the I, II, VII degrees, then a little bit slower to IV and V, and much slower to III and VI, there was no significant difference between every two degrees; while German participants responded faster to the I, V, VI degrees, then a little bit slower to II, VII, IV, and significantly slower to III. Tonic and dominant presented some significant tonal function which could promote the reaction time, and German participants might take the context ending on VI as natural minor mode.

The profiles of non-tonal indication contexts with test tone in two positions showed that the activated tonal knowledge depended on the tone positions in the context. The profile of test tone in the middle of the context reflected general frequency of occurrence of scale degrees, and the profile of test tone at the end of the context reflected frequency of occurrence as final tone. The profiles were partially similar to the results from Huron and his colleagues.

The response time of test tone at the end of the context was shorter than the response time of test tone in the middle. One reason could be the recency effect, as mentioned above. When the test tone was at the end of the context, participants might need little effort to recall, and there was no further disturbance after the test tone. With the test tone in the middle, the timbre judgment needed some cognitive effort, which might depend on the speed of the tone sequence. In a study on perceptual interactions between pitch and timbre by Krumhansl and Iverson (1992), they used 7-tone sequences with intertone interval of 360ms, which had different pitches with less strong tonal impression and different timbres. They found that pitch and timbre had no interaction with each other, that is, the perception of pitch would not be affected by the changing timbres of surrounding tones, and the perception of timbre would also not be affected by the changing pitches of surrounding tones; furthermore, the perceived timbre in relation to the context timbres was weak, unless pitch was constant. While in another study of Singh (1987), each tone in the material lasted

150ms, which was close to the tone duration in the present study. In Singh's study, it was found that pitch and timbre both contributed to "stream segregation", in other words, both attributes interfered with each other in the complex sequence. Therefore, in the present study, each tone lasted only 125ms in the context, which can be considered as a "streaming" sequence; the memory of the sequence were influenced by both pitch and timbre attributes, which could not be so easily separately encoded. Thus, the timbre perception of test tones in the middle – with the mixture of former and latter inconstant timbres and pitches in the sequence – took a longer time than the test tone at the end.

The other reason for faster responses to the trials with test tone at the end can be the expectancy. Such expectancy could be musical and could also be non-musical. The non-musical expectancy is based on the detection of the context. When there was no trumpet tone in the former tones of the context, listeners would expect that the next coming tone would be in trumpet sound. The more non-trumpet tones passed, the greater expectation of trumpet tones came. The expectation of the trumpet tone increased until the last tone sounded. So the responses were faster to the test tone at the end when their expectation was met. Meanwhile, musical expectancy also accompanied, but it might not be as strong as non-musical expectancy with the control of no tonal indication. That would be a reason why the profile was not quite similar to K-K profiles.

However, even if without tonal indications in the context, but only stepwise ascending or descending diatonic scale, the tonal knowledge was more or less activated. So, tonal indication or cadence is not as prerequisite for activating tonal knowledge, but as "catalytic" for activating tonal knowledge effectively. That is, the tonal knowledge is relatively independent from specific musical context, and it is formed in listeners' (most were non-musicians in the present experiments) long and casual exposure to the music environment. While the influence of musical context involving various pitch and duration distribution of tones and tonal indications, which may facilitate the response time, will be discussed later.

As for the priming function of a single tone, in a direct way without tonal indication, the tonal sense of the priming single tone was obtained in the context. The more important tonal sense was, the faster and easier the tonal "value" was recognized. So the I scale degree was of more importance than other degrees for both Chinese participants and German participants, and so was the V scale degree for German participants; however, the III scale degree was unexpectedly the slowest response time with German listeners, this may be an accidental event. This result of Chinese participants was consistent with the result from experiment series 1 with Chinese listeners (but in different contexts).

An interesting phenomenon was the interaction between music training and test tone position. However, this would not make for further discussion because of too little involvement of German musicians.

2) In trials with tonal indication

It was hypothesized that tonal indication could assist activating tonal knowledge, at least assist finding the tonic; and the more clues of tonal indication presented, the easier tonal knowledge could be activated. Many studies showed that listeners could tell the tonic after hearing a few opening tones (e.g. Cohen, 1991), which began mostly from tonic or dominant; and also listeners' cadence expectancy led to tonic or dominant (e.g. Krumhansl, 1990; Arden, 2003). Besides, the factor of test tone position was still investigated in contexts with cadence indication.

As to the results, it was shown that there was a significant main effect of test tone position by both participant groups; furthermore, there was a significant main effect of tonal indication and degree with Chinese participants, and there was only a significant main effect of tonal indication with German non-musicians, although response time profiles of two groups were not quite the same in major and minor trails with the two tonal indications.

In the trials with cadence indication, when test tone was in the middle of the context, Chinese participants again responded quite faster on the IV degree, then a little bit slower on the VI, VII, I, II and III degrees, but the slowest on the V degree; German participants showed faster responses to the III degree, which followed by I, IV, II, V, VII, but quite slower responses to VI.

When the test tone was at the end of the context, the profile of Chinese listeners was quite similar to their profile of trials with test tone in the middle: the fastest response was on the IV degree and the slowest response on the V degree; and the responses to the II, III and I degrees were a little bit faster than to the VI and VII degrees. But the profile of German listeners seemed different from their profile of trials with test tone in the middle, but similar to the one of test tone at the end of non-tonal indication context, the advantage of tonic and dominant appeared again, then followed VI, III, VII and II; IV showed the slowest responses (all differences were not significant).

Fast responses on the IV degree

It was so interesting that in the profiles of Chinese listeners, in trials either with or without tonal indication, and either with the test tone in the middle or at the end of the context, the IV degree always responded faster than other degrees; and little "advantage" of tones in tonic triad was shown. There are two possible reasons, one is that these phenomena may be caused by the exposure to Chinese music, characterized by pentatonics. Although heptatonic scale also plays an important role in Chinese traditional music, and there are also six-tone, eight-tone and nine-tone scales, these more than five-tone scales are developed from pentatonic scale and stress the basic pentatonic relationship, and the tones out of pentatonic relationship in the scale are usually used as passing tone or neighboring tone. So in this sense, the IV and VII degrees are less important than other degrees for Chinese listeners. However, the responses to these two degrees were not both as slow as supposed: the response to VII was not quite in the same situation as the response to IV.

As mentioned above, maybe there are two kinds of expectations for judgment making, one is musical and the other is non-musical. For musical expectation, activation of more important degrees costs little effort, and the activation of less important degrees would take some efforts; when the efforts is too much to hinder the response making, then the efforts would be given up and another easier solution would be used. If this is reasonable, then only non-musical expectation works, which concentrates only on timbre discrimination. The faster response to the IV degree can be explained that the activation of the IV degree costs too much effort, so that pitch environment is neglected but only timbre is focused. However, the response to VII was not quite in the same situation as response to IV.

When considering the materials used in the experiment, it should be noticed that the contexts of IV in non-tonal indication condition actually did not avoid tonal indications. In non-tonal indication condition with IV in the middle, the opening tone of the context was the tonic and the ending tone was the leading tone, which made expectancy to the tonic; in non-tonal indication condition with IV at the end, the opening tone of the context was dominant and a IV degree at the end, which made expectation of a stable solution either going semitone down to the mediant or a whole tone up to the dominant. So it is clear that the contexts of the IV degree had unique tonal "advantage" over the contexts of other degrees. However, such implicit tonal "advantage" was not intended to occur, it was the result of controlling the interval between the priming tone and the opening tone of the context.

Slow response on the V degree

Another interesting phenomenon with Chinese participants was that the response to V was quite slow in trials with cadence indication. This result was distinctive from former studies with Western participants, and was also quite different from studies with non-Western listeners hearing Western music. Although non-Western listeners depended on their cultural tonal schemata to perceive Western music and their key profiles were different from the profile of Western listeners, dominant was mostly rated with the highest stability or showed the fastest response than other degrees. In other words, dominant is prevalent in most music cultures. As presented earlier, dominant is also important in traditional Chinese music in both frequency and duration distributions.

Furthermore, the context with priming tone as the V degree also had tonal advantage in the non-tonal indication condition. When the test tone was the V degree in the middle of the context and the ending tone was tonic, Chinese participants made nearly the slowest responses to it. It seemed that Chinese participants were not sensitive to these “implied” indications, or in other words, these so-called Western tonal indications might not work in the same way on Chinese listeners as on German listeners, there might be other “tonal indication” for Chinese listeners. While German participants were more sensitive to tonal indications, especially to the context in which tonic was at the end. So, tonal indication did facilitate tonal perception with German participants.

The other explanation could be that the Chinese participants in the experiment were just a small sample, and the results from Chinese participants in this study were inconsistent with statistical learning rules and could not be easily explained with features of contexts. So, here it was just viewed as an occasional event.

In bi-tonal indication condition, there was no significant difference in response time between Chinese and German participants; but the profiles of Chinese and German listeners were quite different. Chinese participants presented relatively equal faster response time of the I, II, IV, VI and VII degrees, but quite slower response time of the V and III degrees. While German participants presented “classic” major profile of their response time, that is, the tones in tonic triad responded faster, as well as VII, and the II, VI and IV degrees responded slower. So, bi-tonal indication facilitated German listeners’ judgments that were directed by their tonal schema; while Chinese did not take this benefit, no function of tonic triad was shown in their profile.

When considering the test tone position and tonal indication, there were significant main effects of test tone position and tonal indication with Chinese participants and German non-musicians; besides there was also a significant main effect of degree with Chinese listeners. Thus, for German non-musicians, it was concluded that the single priming tone activating the tonal knowledge depended on tonal indications. Cadence indication alone could not work so efficiently on the activation for tonal knowledge; with the “cooperation” of tonal indication of opening tone, the activation for tonal knowledge could be more effective. So the tonal consistence of opening tone and cadence are both important for tonality perception, which support the conclusion by former studies, which investigate with only a few opening tones or bars of musical excerpts by Bach (Cohen,1991), and also with harmonic cadence (e.g. Deutsch, 1984; Arden, 2003).

For Chinese listeners, their profiles were neither quite stable nor the same as major profile concluded by Krumhansl and Kessler. The distinctive feature in their profiles was the fastest responses to the IV degree, and the slowest responses to the III and V degrees. It seems that harmonic relationship plays a less important role in their schema, and the judgment may rely more on specific context, but may not limit to tonal rules, like cadence. Here is one possible explanation for this phenomenon. Chinese music is unlike Western music based on harmony, but it is based on melody. Considering Western music, MUSACT model has three layers: tone layer, chord layer and key layer. If considering Chinese music, the chord layer between the pitch layer and the key layer can be faded from the schema, and there may be another layer (maybe the fourth frame) between the pitch layer and the key layer or mode layer. As the context with tonal indications, unlike pure ascending or descending scales, the context is more likely perceived as melody. The melody can activate higher level in the schema, so, the chord level for German listeners is activated – tones in the tonic triad are more important than other in-key tones. One phenomenon should be noticed that the cadences of these contexts with bi-tonal indication were not controlled: some of them ended on VII leading the expectancy to the tonic, some of them on the III, IV or VI degrees, but the profile did reflect hierarchy in tonal knowledge (or frequency of occurrence for scale degrees) other than the cadence expectancy.

While for Chinese, the mid-level - the fourth frame was activated. Although the IV and VII degrees showed faster responses, the responses to the I, II, and VI degrees were also fast. These three degrees form a fourth frame including a major second and a minor third. So the I, II and VI degrees can be viewed as more important or common tones, their relationship is especially important; which the IV and VII degrees can be viewed as less important or common tones in the tonal context. According to an inverted U-shape relation between the expectancy or popularity and reaction time (Bharucha, & Stoeckig, 1986; Frankland, & Cohen, 1990), this phenomenon can be explained that the moderate important or common tones - like the III and V degrees - were slower activated than those much more or much less important tones.

Furthermore, the profile of Chinese participants did not reflect cadence expectancy either.

3) In trials with short melodies

The profiles of Chinese and German participants were quite similar to contexts of short musical excerpts, but not quite similar to K-K major profile. Participants responded faster to the I, III, IV, V degrees, slower to the II, VI degrees, and the VII degree responded quite slowly.

When reviewing the musical excerpts used in the experiment, the test tones were about 125-250ms long. Their pitches were in the range from f^1 to c^2, and they were set in the third to fifth beat of the context; the number of tones before the test tone was about 4-10; the contexts had at least one tonal indication. It seemed that the difference of response time among degrees was not caused by pitch, tone duration, or the number of tones appeared before the test tone or tonal indication, but the position of the test tone. The later the test tone appeared in the context, the slower the response was made. This is because of short memory. When the test tone appeared earlier in the context, it would be easy to compare the difference between priming tone and the test tone; however, when the test tone appeared later in the context, the memory of the priming tone might become blurred with the interference of opening tones in the context.

43.2 Key profiles in minor mode

There were three conditions for minor mode: non-tonal indication context, cadence indication context and music excerpts. The former two conditions were with scale-like contexts. The test tone in each condition was set differently: the test tone in non-tonal indication context and cadence indication was set either in the middle or at the end of the context; while melodic context was set only in the middle. Here minor profiles in different conditions were also compared, which illustrated Chinese and German listeners' dependency and tendency of judgment.

The minor key profile, which was obtained by Krumhansl and Kessler (1982), shows more "fitness" or "stability" on the degree of tonic, mediant and dominant (see Figure 57) than on other diatonic tones and out-of-key tones. In the present study, only diatonic tones were involved, so only diatonic minor profiles in different conditions were compared with the result of Krumhansl and Kessler.

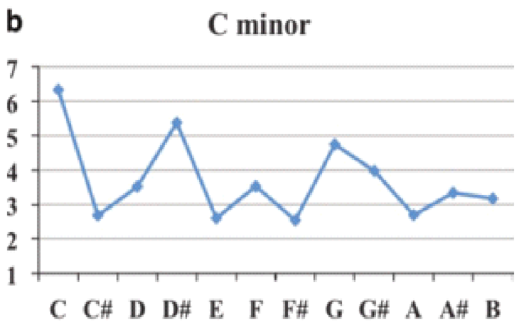


Figure 57 Key profiles of C minor (Krumhansl & Kessler, 1982; Krumhansl & Cuddy, 2010)

1) In trials without tonal indication

Chinese and German participants also presented different profiles of minor contexts with different test tone positions. The results showed that there was a significant main effect of test tone position with Chinese participants and German non-musicians. Test tone at the end of the context responded faster than test tone in the middle of the context. The profiles in the two conditions were not quite the same with Chinese listeners and German listeners.

When the test tone was in the middle of the context, the profile of Chinese participants was not the same as K-K minor profile. Chinese participants responded faster to the I, II, IV degrees, then a little bit slower to the III, V, VII degrees, and much slower to VI, but all differences were not significant. German participants presented similar profile as other Western listeners in former studies, they responded faster to I, II, III, VII, V, then a little bit slower to IV and VI, but all differences were not significant. So, it seemed that the tones in the tonic triad did not have tonal "advantages" with Chinese participants; while I, II, IV reflected the typical three-tone row (major second + minor third) which is used quite frequently in Chinese music (Li, 2004).

When the test tone was at the end of the context, there was a significant main effect of scale degree. Chinese participants responded faster to the I, IV, VII degrees, then a little bit slower to II, V, IV, and significantly slower to III; while German participants responded faster to I, IV, VI, VII, then a little bit slower to III, II, and significantly slower to V. Both Chinese and German participants presented quite different profiles from K-K minor profile and also different from each other. But something should be noticed that the tonic presented significant tonal function which could promote the reaction time by both Chinese and German groups. Again, the first three responded degrees (if IV and VII are not included) with Chinese listeners formed a three-tone-row relationship.

Unlike the result in major mode, it seemed that German listeners' profile of minor context with test tone in the middle was more similar to K-K minor profile, but less similar to tone frequency distributions in minor by Arden (2003). It may illustrate that the processing of major and minor musical sequence were different. Processing of major musical sequence relied on more information at the end of the context, but processing of minor musical sequence relied on more information in the middle.

For Chinese participants, if say, major scale is quite similar to *Gong* or *Zhi* mode; then minor scale is quite similar to *Shang, Zhi* or *Yu* mode. But there are two tones missing in Chinese pentatonic mode, and three-tone row plays an important role. The three-tone row consists of a major second and a minor third, regardless of its temporal ordering. Thus, the three-tone row is a flexible and basic frame in the five basic modes, but does not point to relationship of specific degrees. It works as "cadence schema" V-I or IV-V-I in Western music, but does not lead to tonic. The flexible three-tone row is the common thing resulting from both major and minor contexts with no tonal indications with Chinese listeners, and it should be a melodic schema.

2) In trials with tonal indication

As the results were shown, there was still a significant main effect of test tone position with both Chinese participants and German non-musicians; furthermore, there was no main effect of tonal indication with Chinese participants, but only with German non-musicians. This result indicated that Chinese participants did not rely on tonal indication to make their decisions in minor mode, but depended more on the test tone position. While German participants relied on tonal indications, the more tonal indication included in the context, the faster the response could be made. So the contexts with tonal indication in opening tone and cadence showed faster responses than the contexts with only cadence. It indicated again that German participants as "native" Western listeners could grasp the tonal meaning of the indication, but Chinese participants as "foreign" listeners to Western music could not easily get the tonal meaning in the indication.

In the cadence indication cases, when the test tone was in the middle of the context, Chinese participants responded faster on the I, V, IV, III degrees, then a little bit slower on II, VI, VII, all differences were not significant; German participants presented faster responses to IV, followed by I, II, III, VI, VII, and the slowest response to V.

When test tone was at the end of the context, Chinese listeners made the fastest response on III, IV, VI, VII, responses to I, II were a little bit slower, and the slowest response to V. While German listeners made faster responses to degrees I and IV, then followed by III, V, II, VI, VII (all differences were not significant).

The profiles of both listener groups in the two conditions of test tone position had some similarity, that is, the profiles from the degree I to IV were quite the same in the two conditions, however, the profiles from the degree V to VII changed quite a lot. For Chinese participants, the response to V was relatively slower when the test tone was at the end, but the responses to VI and VII were faster. Conversely, for German participants, the response to V was relatively faster when test tone was at the end, while the responses to VI and VII changed little compared with other degrees.

Though the profiles of Chinese and German participants were not quite similar to K-K minor profile, the difference between the two groups was quite clear, especially on the V degree. The V degree is sung in movable-do system as *mi*. The ending tone in Chinese music usually indicates the mode. For instance, when the ending tone is on the dominant of major mode, *Zhi* mode is activated. In traditional Chinese music and folk songs, there are basically five modes: *Gong, Shang, Jue, Zhi, Yu*. *Zhi* mode is the most popular mode in China, *Jue* mode is the least popular mode (only popular in Zhejiang province, and also in Xinjiang Uygur Autonomous Regions which are influenced by Persian and Arabic music), and the other three modes are less popular than *Zhi* mode and have different popularity in different parts of China (Zhou, 2009). When the context ended on *mi*, it was more likely to activate *Jue* mode to Chinese listeners. But it may not fit for Chinese ears, and Chinese listeners would feel it strange and spent longer time in judgment. Besides, it is interesting to notice that in the profile of test tone at the end of Chinese participants, the ranking of faster responded five tones formed a *Yu* mode. But such phenomenon was not found in major. So it could be further inferred that Chinese listeners preferred to perceive minor more similar to Chinese *Yu* mode guided by their cultural tonal knowledge. It may be because *Yu* mode started from *la* which is a minor third lower to the major tonic *do*. While for German listeners, ending on the V degree was quite adaptable to Western ears, because V is frequently used as half cadence. So, German participants responded faster to the V degree than other degrees.

Thus, when the ending tone of the context was on mediant (III), this supposition could also explain why V (in the middle of context with cadence indication) showed slower response with Chinese participants, because the context ended on the mediant. Furthermore, there is probably another feature of tonal perception with Chinese participants: the most popular mode and the least popular mode take a longer time to process than the modes in moderate popularity. This forms an inversed U-shape relation between the popularity of mode and reaction time.

In bi-tonal indication condition, there was no significant difference of response time between Chinese and German participants; but the profiles of Chinese and German listeners were different. Chinese participants responded faster to the IV, III, VI, V degrees than the VII, I, II degrees. It seems that there was no specific feature of their profile, and just the contour was a little bit similar to the one of cadence context with test tone at the end. The result can be also explained by the former mentioned possible reasons.

German non-musicians responded faster to the III, V, VII degrees, but slower to VI, IV, II, I. It was interesting to notice that although the profile of German participants was not quite similar to K-K minor profile, the degrees they responded faster to were just the tones in tonic triad of its relative major. It may reflect that non-musicians cannot distinguish major and minor quite well, but take the relative major and minor modes as one unit, which are mainly based on the tonal function in major mode, or at least, they process minor melodic with movable-do system. From the other side, it also partly indicates the region concept proposed by Schoenberg (1954/1969, p.19). Relative major and minor modes are in the close regions from each other, and they can be considered as monotonality in a musical piece.

Generally speaking, the minor mode for Chinese participants was relatively unfamiliar, so their judgments depended less on tonal indication in the opening tone and cadence; with the assistance of the test tone position, their tonal knowledge became more active with test tone at the end, and guided their judgment. It reflects the connection between tone layer with key layer or mode layer, and also reflects mode popularity which is learned from daily musical exposure. For German non-musicians, tonal indication played an important role for their judgment making. Compared with the result of major mode, it seemed that German participants needed more clear clues to activate their tonal knowledge; only cadence indication did not work efficiently as it functions in major mode, and the opening tone was an important clue for tonal perception.

3) In trials with short melodies

There was no great difference of response time between Chinese and German participants. The response time of Chinese participants were equally faster on the II, III, IV, V degrees; the I and VI degrees showed slower responses; the VII degree responded fastest among degrees, this is quite different from their major profiles. The profile of German participants was more zigzag – the VII, III, II, V degrees showed faster responses, I, IV, VI showed slower responses; and it was quite similar to their profile of trials with bi-tonal indication.

Reviewing the musical excerpts used in the experiment, the test tones were about 125-250ms long, which pitches were in the range from f^1 to b^1, and they were set in the third to eighth beat of the context; about 4-10 tones appeared before the test tone; the contexts were with at least one tonal indication. The effect of test tone position seemed also stronger than other factors (pitch, tone duration, the number of tones appearing before the test tone or tonal indication, see discussion in major).

43.3 Key profiles in pentatonics

There were two conditions for pentatonic mode: scale-like context and music excerpt. The former condition was with two test tone positions: in the middle or at the end of the context; while the test tone in melodic context was set only in the middle. Here it was also compared pentatonic profiles in different conditions, which illustrated Chinese and German listeners' dependency and tendency of judgment.

1) In trials with scale-like context

In the scale-like context with test tone in the middle, Chinese participants responded faster to the I, II, VI degrees, but slower to the III, V degrees; while German participants responded equally faster to the I, II, V, VI degrees, but slower to III.

In the scale-like context with test tone at the end, Chinese participants responded faster to the II, I, VI degrees, but slower to the III, V degrees; while the profile of German participants changed little from the profile of trials with test tone in the middle.

The pentatonic profiles of Chinese and German participants were quite similar to their major profiles. This may indicated that German dealt with pentatonic materials as major tonal relationship, but Chinese dealt with major tonal relationship partly as pentatonic tonal relationship. The three-tone-row relationship appeared again, so it was again verified that the fourth frame is important for Chinese listeners' tonal hierarchy.

2) In trials with short melodies

Reviewed the musical excerpts used in the experiment, they were more complex than scale-like contexts. The test tones were about 125-250ms long, which pitches were in the range from f^1 to b^1, and they were set in the third to eighth beat of the context (either in down-beat or in on-beat) in order to make it easy to detect; the number of tones appeared before the test tone was about 5-8; the contexts were with at least one tonal indication.

In pentatonic musical contexts, the response profile of pentatonics of Chinese listeners was similar to the profiles in other conditions. The fastest response was on the II degree, but the slowest response was on the V degree. The profile of German listeners was also similar to the profiles in other conditions, only except the III degree showed faster response, and the I degree showed relatively slower response. So the distinction between Chinese and German participants was the response to the II and III degrees: Chinese participants responded faster on the II degree, and German participants responded faster on the III degree. This result supports the tonal difference in Chinese music theory and Western music theory, that the II degree or *re* or *Shang* is the core tone in Chinese music theory, and the III degree or *mi* is a component in the tonic triad in Western music theory.

Summary of three modes:

In cases with tonal indication, the results showed that minor cases responded faster than major and pentatonic cases, such results happened also with musical excerpts context. It could be inferred that major mode and pentatonic mode caused more cognitive effort in the processing; while minor caused less cognitive effort in the processing. In major musical contexts, the I, III, IV, V degrees were faster than other degrees, and the VII degree responded quite slowly with both Chinese and German listeners. In minor musical contexts, there was no great difference among degrees – especially with Chinese listeners, only the VII degree responded a little bit faster.

44. Multidimensional scaling

In the present study, an indirect method of priming tone was used. The priming tone was not used for its repetition in the context, but for exploring close or distant tonal relationship among other in-key tones. Thus, the perceived distance among degrees could be obtained. It was hypothesized that the closer tonal relationship between two degrees, the faster response could be made.

For Chinese participants, it was found that in major contexts, there was a significant difference when the priming tones had the function of III and the test tone was the VII degree in the following context: the response time was longer when the priming tone was the III degree in the following context and the test tone was VII; the same results happened also when the priming tone had the function of VII and test tone was I and was VI. These three intervals all related to one degree VII, which has little importance in Chinese pentatonic mode. So, although the interval between III and VII is a perfect fifth, according to Chinese tonal knowledge, the interval perfect fifth between III and VII is not as important as perfect fifth between I and V, II and VI; and it could infer that the participants indeed interpreted the priming tone as the third degree in the latter context. This result is consistent with the result from the context with repeated priming tone that the ending tone on III responded slower. One important reason of the least popularity of *Jue* mode in Chinese music is because its lack of the fifth tone in the Chinese pentatonic scales (Lin, 2003). The perceptive results of Chinese listeners support this idea, not only the ending tone on III (indicating *Jue* mode) shows slower response, but also the perfect fifth between III and VII. There are two points in perception of Chinese listeners that should be noticed. One thing is that Chinese participants perceive musical context with movable-do system. The degrees in Roman numerals in either major mode or pentatonic mode are corresponded to relative singing names, like solfège syllables (I-*do*, II-*re*, III-*mi*, IV-*fa*, V-*sol*, VI-*la*, VII-*si*). Chinese listeners are aware of the relative names of tones in a certain tonal context, but maybe unconsciously. The sense of relative singing plays an important role in Chinese music, because a melody can be sung with movable-do system in any key, but only one is theoretically and perceptually reasonable (see example in Part I, Figure 6). The other thing is that common interval can also be "rare". This may be the special feature in Chinese music that differs from Western music. The interval perfect fifth is a common interval in Chinese pentatonic scale (4 times: *Gong-Zhi*, *Shang-Yu*, *Zhi-Shang*, *Yu-Jue*), however, the fifth on *Jue* is not common, because it involves a non-pentatonic tone, which corresponds to the III degree in major scale (*mi*). This "rare" perfect fifth is difficult to activate Chinese participants' tonal schema. It indicates that their judgment is not simply on feature of intervals, but also takes the importance of pentatonic tonal sense into account. So, common interval is not a strict reference for Chinese listeners' tonal perception.

For the slower responses to VII-I and VII-VI, one reason is the little tonal importance of VII, the other reason is the lack of minor second in Chinese pentatonics. Listeners might compare the VII degree with III degree, which also could ascend minor second to IV and descend major second to II, but III is an in-key pentatonic tone, while VII is an out-of-key pentatonic tone, so VII has less important tonal function than III. Therefore, another minor second interval III-IV responded relatively faster, but the judgment on the VII degree took more time.

While for German participants, there was no significant difference on any degrees. It was indicated that the major mode completely matched their implicit knowledge, and the tones heard in the experiment were nothing strange for them.

1) Major MDS

MDS is a way to compare the theoretical distance and perceptive distance of two objects. Krumhansl et.al (1982) presented the multidimensional scale of major mode, which showed the perceived relationships among chords within a key (Figure 58). These perceptual relations of chords were obtained by probe tone technique (a tonal context followed by two successive chords). However, there was no multidimensional scale showing the relationship among in-key tones. In the present study, the priming tone was used to activate the tonal knowledge so that the relationships among in-key tones could be shown. MDS can show whether in-key tones are perceived closer in harmonic relationship or in melodic relationship. It was also necessary to compare the in-key tone multidimensional scale with the chord multidimensional scale, especially those of German participants, so that it would be possible to get to know whether their judgment was based on harmonic function even hearing the single tones, or based on other clues.

In the chord MDS of C major and G major, the chords on I, IV and V degrees were close in the center, then the chords on the II and VI degrees were also close to the center, but the III and VII chords were relatively farther away from the center.

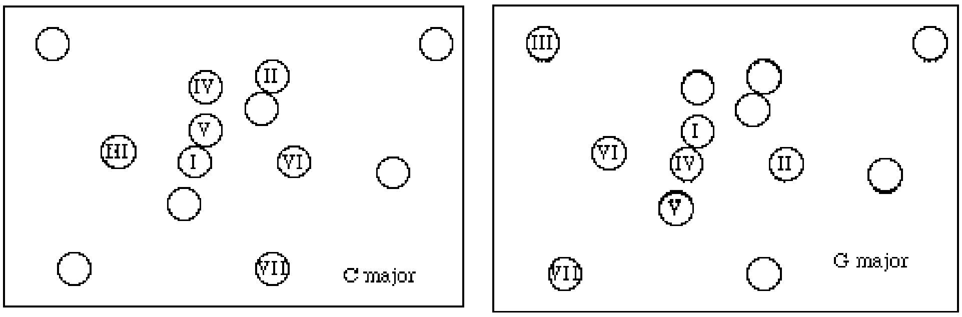


Figure 58 Relations between chords within keys (Krumhansl, Bharucha, & Kessler, 1982)

In the present study, the in-key tone MDSs were drawn in two conditions: one was with the priming tone on a higher degree and the test tone on a lower degree; the other was with the priming tone on a lower degree and the test tone on a higher degree. The distance between each two tones in the multidimensional scales indicated close or remote musical relationship between the two tones. The relation could be either harmonic or melodic or both function in a tonal hierarchy.

For German participants, the multidimensional scales in the two conditions were quite similar. Here were some common features:

- Dominant and subdominant were located in different sides or dimensions;

- the distance did not vary correspondingly with the size of intervals between priming tone and the test tone, for example, the distance of minor second was generally larger than other intervals: the VII degree kept larger distance with the I degree;

- and the same interval size did not have the equal distance, for instance, the distances of tones in minor thirds – as in II-IV, VII-II were generally larger than the distances of tones in other minor thirds – as in III-V, VI-I;

- but the I degree was not so close to IV and V in both conditions.

Although these results were different from the chord MDS, they also implied that German participants depended more on harmonic relationship in their judgment, the tones in tonic, dominant and subdominant triads were in relative stable and closer relations; and the tones in minor second as rare interval in major mode might be activated by each other not so easily.

However, the distances between some two degrees were different in conditions with the “lower degree priming” and “higher degree priming”. For instance, some intervals benefited from “lower degree priming”: the interval between I-III was closer when the priming tone served as the I degree, and the test tone was the III degree in the context, so did the same between I-V, II-VI, III-IV; some intervals benefited from “higher degree priming”: the interval between IV-VII was closer when the priming tone had the function of the VII degree, and the test tone was IV in the context, so did intervals VI-I, VII-III. From this point, there was some tendency on tonic, dominant, mediant and subdominant, which were anchored to “higher degree priming” tones; while “lower degree priming” led to less stable degrees.

For Chinese participants, the multidimensional scales in the two conditions were quite similar, but different from German MDSs. Here were some common features:

- There was large distance between III and VII;

- the distance did not correspond to the size of intervals between priming tone and the test tone, for example, the distance of major second was generally as similar to the distance of perfect fourth, or even larger;

- the distance of interval perfect fourth was relatively equal and stable than other intervals in the two conditions;

- the I degree was closer to the IV degree than to the V degree in both conditions.

These results implied the “rare” perfect fifth between the III and VII degrees, and also the importance of interval perfect fourth.

However, it seemed that the distances between some degrees depended more on the “lower degree priming” or “higher degree priming”. For instance, some intervals benefited from “lower degree priming”: the interval between IV-VI was closer when the priming tone served as IV, and the test tone was VI in the context, so did the same as intervals I-VI, VI-VII, III-IV, III-V; some intervals benefited from “higher degree priming”: the interval III-II was closer when priming tone had the function of the III degree, and test tone was II in the context, so did II-I, VI-II, VI-III, VII-V. From this point, there were some tendencies on degrees tonic, dominant, mediant and supertonic that were anchored by “higher degree priming” tones. Furthermore, in Chinese heptatonic mode, the IV (*fa*) is usually solved to submediant (*la*), but not mediant (*mi*); and the VII (*si*) is usually solved to dominant (*sol*), but not to tonic (*do*) (Zhang, 2002). The MDS reflected the distance of ascending IV-VI was shorter than the distance of its descending interval, and the distance of descending IV-III was longer than the distance of its ascending; and the distances of descending VII-V also was shorter than the distance of its ascending interval, the distance of ascending VII-I was a little shorter than the distance of its descending interval. These are similar to the description in the theory.

So, in the major multidimensional scales, Chinese and German participants had different presentations of major scale degrees. German listeners presented more about harmonic relationships in major, intervals as in minor or major third and perfect fifth were important to them; while Chinese listeners presented less harmonic relationships, like the larger distance between the III and VII degrees and the preference to perfect fourth, reflecting some pentatonic features. Besides, both groups showed more free degree tendency with “lower degree priming” tones, but more cadential tendency to I, V in “higher degree priming”. These results from “indirect priming” were consistent with the results from “direct priming”.

2) Pentatonic MDS

There was no Chinese pentatonic tonal hierarchy depicted in charts in the former studies, so the present study was an attempt to present the perceived pentatonic relationship in multidimensional scales. In the present study, the same as major mode, the in-key tone MDSs were drawn in two conditions: one was with the priming tone on a higher degree and the test tone on a lower degree, the other was with the priming tone on a lower degree and the test tone on a higher degree. The distance between each two tones in the multidimensional scales indicated some musical relationship between the two tones.

For Chinese participants, the multidimensional scales were quite similar in the two conditions. Here are some features: the I, II and V degrees were in one dimension, the III and VI degrees were in the other dimension. The distance did not correspond with the size of intervals between priming tone and the test tone: the distance of minor third was shorter than the distance of other intervals, even shorter than the distance of major second. However, the distances depended on the conditions. The distance of perfect fourth and major third varied in the two conditions. For instance, perfect fourth II-V had closer distance when priming tone served as V, and test tone was II in the context. While major second II-I, major third III-I benefited from “lower degree priming”: they had a closer distance when priming tone served as I, and test tone was II or III in the context. So in the Chinese pentatonic mode, the degrees in minor third relation were easily activated, but the degrees in perfect fifth were hardly activated.

For German participants, though the multidimensional scales in two conditions were not quite the same, there were still some common points: the distances of the intervals I-II, I-III, I-V were equal in the two conditions, among which the distance of interval I-III was slightly closer than the other two intervals; the distance between II and VI was large in both conditions; the same interval size did not have the equal distance, for instance, the distance of minor third between III-V was closer than I-VI in both conditions, and the distance of perfect fifth between I-V was slightly closer than II-VI. However, in “higher degree priming”, the I degree kept nearly equal distance with other four degrees in the pentatonics; the distance between III and V was much shorter than any other intervals, but the V degree kept larger distance with II and VI; the distance between I-VI was shorter. In “lower degree priming”, the V degree kept nearly equal distance with other four degrees in the pentatonics; the I and III degrees were near to each other, but both of them were far from the II and VI degrees; the distances of perfect fourths II-V, III-VI were shorter. These results presented, that the I degree was the “center” in “higher degree priming”, and the V degree was the “center” in “lower degree priming”, and the relations among I, III, V were much closer than other relations that reflected Western tonal knowledge.

Thus, Chinese participants and German participants reflected different relations among degrees, which implied their tonal knowledge based on their own musical cultures.

45. Intervals

The indirect method shows listeners preference of in-key intervals' direction and starting scale degrees. The experiment with priming intervals only involved four intervals: perfect fourth and perfect fifth – as inversed intervals within octave, minor second and tritone – as rare intervals in major mode. The three-tone row within perfect fourth plays an important role in Chinese pentatonic music; perfect fifth is a common interval with limitations; and neither minor second nor tritone is involved in Chinese pentatonic structure. So it was expected that Chinese participants could respond faster to interval perfect fourth, slower to perfect fifth, but faster to minor second and tritone, if there was the inverted U-shape relations between popularity and reaction time.

As expected, Chinese participants responded significantly faster to perfect fourth and minor second than to perfect fifth. Furthermore, the response to tritone was also faster than to perfect fifth, though not significant. It seemed that Chinese participants' judgment depended on popularities of interval in pentatonics.

But German participants responded faster to perfect fifth, then to perfect fourth, but slower to minor second and tritone, though the differences were not significant. It implied that common intervals in major could facilitate recognition of tones from the priming interval in the post context, but rare intervals had less such advantage.

Summary

Here are the main points discussed above:

1) The profiles of the test tone in the middle of the context were different from the profiles of the test tone at the end of the context, so there could be different schemata for simple frequency of occurrence for scale degrees in keys and for simple frequency of occurrence for scale degrees as final tones, as Aarden (2003) and Huron (2007) supposed;

2) Chinese listeners' key profiles were different from German listeners' key profiles, in the three modes: major, minor and Chinese pentatonics;

3) Chinese participants perceived major and minor materials with assistance of their

tonal knowledge, which presented that the III degree (*mi*) and perfect fifth on the III degree (*mi*) was not easier processed than perfect fifths on other degrees; two out-of-pentatonic the IV (*fa*) and VII (*si*) degrees were processed differently;

4) Chinese tonal hierarchy may involve a mid-layer between the pitch layer and the key layer, the fourth frame layer, which is a flexible frame interacting back and forth with other two layers in the perceptive processing;

5) There might be a selection mechanism of tonal knowledge for “bi-musical” Chinese listeners; but tonal indications in major had little effect on their judgment making;

6) German non-musicians depended on more tonal indications for making judgment; and they perceived minor mode with major clues;

7) German listeners also showed their tonal knowledge with pentatonic materials: tones in tonic triad are important. So, chord layer is important in their tonal schema and connects both pitch layer and key layer.

General Discussion and Conclusion

The final part discusses the similarity and difference of methods and results in the experiment series 1 and 2. The tonal processing is discussed in relation to memory, top-down and bottom-up cognitive strategies, as well as learning and cultural aspects, which take part in the priming paradigm to activate implicit tonal knowledge.

46. Experiment series 1 & 2

46.1 Methods in experiment series 1 & 2

In the experiment series 1, a "stem-completion"-like task was used. Students of music were asked to complete the scale (major or minor scale) with association in their minds and then to give judgments on whether the priming tone belonged to the scale or not. This method was used, because in psychological studies "word-stem" completion task is a method to activate schema in the implicit memory.

Participants (even amnesic patients, e.g. Warrington & Weiskrantz, 1970) can have better performances in the word-stem completion task than in the recall or recognition task after they have learned unconsciously or have seen the words before the task. It proves the function of the implicit memory in the word-stem completion task, because participants are not told that the priming words should be remembered or relate to the task.

The "scale-completion" task is quite similar to word-stem completion. Before dealing with the scale completion, participants were asked to hear a priming tone, which was the same as the priming word in the word-stem completion task. Then the scale should be completed in a certain mode – major or minor scale (according to the colorful square signal shown on the screen), starting from a given tonic. The scale is like a schema which is already learned and stored in their musical knowledge and can be activated by the priming tone. It was supposed that when the priming tone and the given tonic were in the same scale, the scale schema could be more easily activated; that is, the scale-completion could be faster, and this led to faster judgment of the priming tone. Given that the participants were music students, the task was set as an explicit task for judging the belonging of the priming tone to the latter scale context, which referred to their musical knowledge. Unlike the word-stem completion task which is applicable for studying implicit memory, the explicit memory also plays an important role in this task. Most of the participants reported after the experiment that they tried to remember the pitch of the priming tone, while few of them responded intuitively.

This method contains some disadvantages. First of all, processing of a final judgment is complex. There are at least two steps: one is to complete the scale, and the other is to make the judgment. As a result, the response time is longer than former studies with probe-tone technique or priming paradigm. In former studies, the response time was usually about 2 seconds; in this study, however, participants were too cautious to make their decision, and some of them spent even more than 10 seconds for a reply. Secondly, the strategies used by participants can be hardly controlled, because the scale completion was no obligatory oral report. Thus, it was unknown whether the completion was done freely or done by scale completion in a step-wise ascending or descending way. Whether the scale completion was in a step-wise or arpeggiated way, it would bring the sequence effect of association that the degrees around the tonic induced faster responses. As a result, there was a bow-shape profile of tone hierarchy. Thirdly, theoretically there are two possible alternative explanations for the processing. One is the importance of degrees in the scale, and the other is the proximity. Both causes could not be clearly separated from each other in the experiments, thus the results were not so consistent with the conclusions from former studies; that is, the validity of this method may not be so high. However, tonal sense develops with unfolded music, so a relatively unclear profile of the opening tones can also be acceptable.

In order to avoid the problems in the experiment series 1 and to involved non-musical participants, an implicit task was used in the experiment series 2. The implicit task is an indirect way to test the unconsciously learned knowledge, and it is popularly applied in studies with children and non-experts in the priming paradigm. In Western music studies, the implicit knowledge of tonal stabilities are usually studied via harmonic priming paradigm (e.g. Bharucha & Stoeckig, 1987; Bigand & Pineau, 1997; Bigand, Poulin, Tillmann, Madurell, & D' Adamn, 2003; Marmel, & Tillmann, 2009), in which the implicit task can be timbre discrimination (e.g. Schellenberg, Bigand, Poulin-Charronnat, Garnier, & Stevens, 2005; Marmel & Tillmann, 2009), intonation discrimination (e.g. Bharucha & Stoedckig, 1987; Tekman & Bharucha, 1992, 1998), consonant and dissonant discrimination (e.g. Schellenberg, et,al, 2005), and phoneme discrimination (e.g. Schellenberg, et,al, 2005; Tillmann, Bigand, Escoffioer, & Lalitte, 2006). These priming paradigms with implicit tasks prove that tonal stabilities determine the processing speed of tasks. So the experiment series 2 involved the timbre discrimination task.

Comparing with the task in the experiment series 1, the timbre discrimination task was a single-task. Participants were asked to make judgment on whether a tone in trumpet timbre appeared in its context. This task did not cost much resource and time. However, participants had to pay more attention to distinguish the test tone of trumpet timbre in the context background of piano timbre. Participants were told neither to remember the pitch of the priming tone, nor that the trumpet tone would appear in the latter context. So in each trial, non-musical participants were unaware of the identical pitches of the priming tone and the test tone in the context – although some participants noticed the pitch height identity or difference, they knew little about the relationship of which scale degree the priming tone would be given in the latter context. What they should attend to the response was only the appearance of the test tone in trumpet timbre. Thus, it was an implicit single-task.

Concerning two possible reasons in the experiment series 1, the proximity aspect was controlled in the experiment 2. The test tone was set in two positions: in the middle and at the end of the context, but not at the beginning. One reason for not setting the test tone at the beginning of the context was to avoid the "implicit clue" – the implicit interval between the priming tone and the first tone of the latter context. According to the participants' reports after the experiment series 1, some of them relied on the "starting" interval as a reference for the judgment. In the experiment series 2, the timbres of priming tone and the test tone were in trumpet sound. When the test tone was at the beginning of the context, such timbre “gestalt” might elicit the “starting” interval. Therefore, the test tone was set in the middle or at the end of the context. In addition, the implicit “starting” interval (the priming tone and the first tone of the context were presented in two timbres) was relatively standardized. They were set in either fourth or seventh: perfect fourth or tritone could induce clear sense of tonality (e.g. Butler, 1989, 1992; Vos, 1999; Parncutt, & Bregmann, 2000), major and minor seventh could reduce proximity of the two tones. The other reason was that the context was presented in a rapid-string, which was also used by Huovinen (2002). He suggested that rapid-string could make participants perceive the tones as “chunk” and “promote structural properties of the intervals” (Huovinen, 2002, p.102). When the test tone was set in the middle or at the end of the context, it could be perceived in the scale-context “chunk” of the context, but not in the timbre “chunk”. Each tone in the context lasted about 200ms, so when the test tone is at the beginning of the context, it might be neglected without prepared attention or easily interrupted by following tones.

Setting the test tone in the middle or at the end of the context makes it possible to compare the “melodic” hierarchy with the “cadence” hierarchy. According to Huron (2007), he mentioned five different expectable schemata (the schema for scale degrees in major and minor key contexts, the schema for scale degrees as major and minor phrase-final tones, and the schema for degrees as initiate tones), the test tone in the two positions could activate two schemata: the profile for scale degrees in the key contexts and the profile for scale degrees at the cadence. As a result, the two profiles from the experiment series 2 are not quite the same.

Compared to the methods used in the former studies, there are two differences in this study from probe-tone technique and harmonic priming paradigm. In the former studies with probe-tone technique, the context always appeared before the probe tone. This method has been criticized for the musical cadence effect and cognitive recency effect. To avoid these two questionable points, the context was set after the “probe tone” in the present study; so the probe tone became the priming tone. Then the experiment followed the priming paradigm. However, the materials used in the priming paradigm were nearly all harmonic materials, either two successive chords – making judgment on some characters of the second chord (e.g. Tekman & Bharucha, 1992, 1998), or a chord sequence (usually 6-8 chords, see studies of Bigand et.al) as the post-context. However, the melodic material was seldom used as a context in the priming paradigm. With harmonic materials, the relationship between chord level and key level in the network MUSACT was verified, but the direct or indirect relationship between pitch level and chord level and between pitch level and key level was still unclear. To make an attempt, this study used melodic context to explore the indirect or direct relationship among the three layers in MUSACT model.

46.2 Results in experiment series 1 & 2

Although the methods used in the two experiment series were different, the aims were quite similar. The two experiment series aimed to verify whether subjective tonal schemata affect tonal perception of opening tones, and whether there are different tonal profiles between Chinese listeners and Western listeners. Generally, there was a consistent result from the two experiments, but some differences were also observed.

1) Similarity in the two experiment series

An expected point in the results of two experiment series was the slow response on the III degree. In the experiment series 1, the III degree showed nearly the slowest and the most incorrect response in both major and minor keys. In the experiment series 2, the III degree showed also a slower response among Chinese participants (though not always the slowest); while German participants' responses to the III degree were more similar to the results from earlier studies that they were just slower than the responses to the tonic and the dominant. Thus, the III degree marks the typical difference between Chinese listeners and German (or Western) listeners.

According to Chinese music theory, tonic is important on the pitch level. Instead of Western harmonic relationship or the chord level, the "perfect fourth" frame can be the middle level connecting the pitch level and the key level. The "perfect fourth" is formed either by a major third and a minor second, or by a minor third and a major second, and its sequence is relatively free. Unlike Western key level, which has only two equally important modes distributed on twelve chromas, the Chinese key level includes five modes which vary in importance or popularity. According to statistical distribution of the five modes in Chinese folk songs, it was found that *Zhi* mode is the most popular mode, while *Jue* mode is the least popular mode (Zhou, 2009). If we take into account of the Western scale order: *do, re, mi, fa, sol, la, si,* the Chinese *Zhi* mode starts from *sol* (consists of *sol la do re mi*), and *Jue* mode starts from *mi* (consists of *mi sol la do re*). Although the two modes consist of the same five tones, the essential difference derives from the lack of dominant in *Jue* mode. That is why *Jue* mode is less popular. So in the Chinese tonal hierarchy, *mi* is a relatively less important in-key tone in the pentatonic system. The perceptive result from this study is coincidental with Chinese music theory that III or *mi* arouses a slower response in Chinese listeners. The slower response corresponds with the less important mode. So it can be further inferred that a tone can directly arouse the key level.

Another result is that "tonal indication" in the context prompts the responses, and the response profiles are more similar to the profiles attained in former studies. The context was either supplied with a tonic-triad-tone at the beginning or at the end, or with both kinds of tonal indications, or with a short motive from real music, especially with a "cadence indication". In the experiment series 1, it was shown that the congruence of starting and cadence on tonic or dominant got faster responses; in the experiment series 2, the responses in context with tonal indication were faster than in context without tonal indication, and the profiles of context with tonal indication were more similar to the profiles in former studies. These results indicate that such tonal indications are more efficient clues for tonal "comprehension" than the clues as in perfect fourth or tritone at the beginning. The tonal indication in the context offers background support for the activation of the implicit tonal knowledge or tonal hierarchy by the priming tone. Such a process combines both bottom-up and top-down strategies. Priming tone(s) can activate the implicit tonal knowledge or tonal hierarchy to some degree; the activation effect is verified, and it is either strengthened or weakened by the coming context with clear tonal indication or not.

2) Difference in the two experiment series

There is a difference in the pitch level and "frame level", which may be caused by the experiment method or by the musical training.

For the pitch level, in the experiment series 1, the tonic in major responded usually faster in Chinese music students. However, with the limitation of the method, the profile of response time was bow-shaped. So it was difficult to say whether it resulted from the primacy effect in the association task, or it derived from a result of the tonal knowledge. In the experiment series 2, it was interesting to see that the tonic in the major context showed no fast response among Chinese listeners. And an unexpected result was that the subdominant (*fa*) showed faster responses, because *fa* is a non-pentatonic tone in Chinese music theory. It may be unfamiliar to Chinese ears, so it was sensitively picked out by Chinese listeners. While the other non-pentatonic tone in Chinese music, *si* got medial response time. It may be because of its tendency to the tonic. The responses to *fa* and *si* may show a mixed utilization of Chinese schema and Western schema in Chinese listeners. There was no frame preference showed in the experiment series 1, while in the experiment series 2, Chinese listeners displayed a relatively stable relationship of the "perfect fourth frame", independent from the tonal context. This may be caused by experimental methods, so the "perfect fourth frame" effect in Chinese musicians can be further studied.

Another difference among Chinese listeners was that in the experiment series 1, the "implied" perfect fifth and perfect fourth (between the priming tone and the given tonic) showed more accurate responses than other intervals, and perfect fifth as priming interval also showed relative accurate responses. It can attribute to the importance of primed tonal function, and also due to the consonance between the two remembered pitches. While in the experiment series 2, the priming interval perfect fifth and perfect fourth showed significant difference in response time: the responses to perfect fifth were much slower than the responses to perfect fourth. This difference may be caused by the two methods, or by different musical training. Music students are more familiar with music theory and they are more influenced by Western music, so when they were tested with major and minor materials, their Western tonal schema was activated. But non-music students depended more on their Chinese tonal schema with different musical materials.

Concerning the response profiles, no bow-shape profile was presented in the experiment series 2. This probably results from different methods. The correlation between accuracy profiles of Chinese musicians and K-K profiles (Krumhansl & Keil, 1982), however, was higher than the correlation between response time profiles of Chinese non-musicians and K-K profiles. This indicates the difference in musical training between two groups, the Chinese students of music are not so "Chinese" because they all have learned Western music theory and history, while Chinese music-naive listeners were more "Chinese", because they have less access to "real" Western music.

47. Processing & memory

During the tasks in the experiments, memory plays an important role in the processing. Generally speaking, there are three types of memory according to the memory duration: the sensory memory, the short term memory and the long term memory. The sensory memory for auditory processing deals more with of physical sonority (e.g. Huron & Parncutt, 1993), and it lasts only a few hundred milliseconds, and no more than 2s (Massaro, 1970; Cowan, 1984; Huron, & Parncutt, 1993). The short term memory "organizes" or integrates the materials of stimuli, encoding and making tonal sense into perceptual events (Cowan, 1997), and it can be held only for a few seconds and then disrupted easily by the following events. The long term memory preserves music-cultural explicit and implicit knowledge that is learned consciously or unconsciously and is grouped under the schemata. The sensory memory and short-term memory take part in perceiving and integrating the stimuli, and interact with the knowledge in long-term memory either in bottom-up or top-down ways (Parncutt, & Bregman, 2000). The performance of memory is affected by tonal features of stimuli (e.g. Steinke, Cuddy, & Holden, 1997), and participants with different musical trainings (musician or non-musician) present different "habits" in their memory strategies (e.g. Williamson, Baddeley, & Hitch, 2006, 2010). Musicians are more sensitive to “local” changes (Huron, & Parncutt, 1993), but are not restrained from proximate pitch in the serial recall task (Williamson, Baddeley & Hitch, 2010); while non-musicians are not sensitive to specific changes (Huron, & Parncutt, 1993), and do not do well in recalling or recognizing tasks of proximate melodic series recall (Williamson, Baddeley & Hitch, 2010). These findings demonstrate an effective connection between lower level (foreground) and higher level (background) among the musicians, but non-musicians do not have such an advantage.

Although there was no explicit instruction to ask participants to remember the priming tone, or to do the recall or recognition tasks, both tasks referred to short term memory. In the association task of experiment series 1, the pitch of priming tone should be remembered, which made it possible to “meet” the pitch again in the scale completion or to take the reference of the implicit “starting interval” between the priming tone and the given “tonic” of the latter context, which formed a virtual consonant or dissonant sonic feature in the mind and listeners showed more preference towards consonant sounds. Musical participants were aware of this “memory task” and tried to remember the pitch of priming tone by rehearsing silently or humming softly.

If the response strategy was scale completion, as it was instructed, then the memory of the priming tone might be disturbed. Participants should activate the corresponding scale schema in the long-term memory and then complete the scale, which might be regarded as an easy task of serial recall. During or after the completion, when the same pitch as the pitch of priming tone stored in the short-term memory appeared, the response could be made. This strategy is a recognition process, or say, a top-down process; that is, the priming tone is found in the recalled scale. The recognition of the priming tone as an in-scale tone depended on how long and how well the priming tone was kept. The studies about the short-term memory for musical sequences have indicated that pitch memory was easily disturbed by proximal pitch other than distal pitch, especially in the same octave (e.g. Deutsch, 1972, 1973, 1974). According to Deutsch’s opinion, there might be a lateral inhibition in the scale-completion process, which interfered with the recall of the priming tone's pitch; while based on working-memory (or short-memory) model proposed by Baddeley (1986), there could be sub-systems for preserving the incoming perceived information for the engaging task, such as the articulatory loop playing an important role in speech processing for storing phonological code and refreshing the articulatory process (Baddeley, 2007). In relation to music processing, the articulatory loop is "a kind of 'tonal' loop" which depends on musical training (Pechmann & Mohr, 1992). It would not work automatically as verbal articulatory loop, but demands more attention effort. Although it is already verified that musicians possess a better working memory (e.g. Pechmann & Mohr, 1992; Micheyl, Delhommeau, Perrot, & Oxenham, 2006; Besson, Schön, Moreno, Santos, & Magne, 2007), the interference of tonal information in pitch memory is also encountered among musicians. The only difference between musicians and non-musicians is that non-musicians have more difficulties to avoid the proximal disturbance, whereas musicians are immune to proximal pitches (Williamson, Baddeley, & Hitch, 2010). Thus, it is reasonable to assume that the memory of priming pitch of musical participants in the experiment series 1, was not disturbed too much by pitches in the completion task, and they made attentional effort to rehearse the priming pitch in the "tonal" loop.

As it was made known by the bow-shaped profile of response time, the fifth and the fourth degree showed slower responses than other degrees, because they marked the distal pitches from the tonic, either ascending or descending. This may also reflect that participants could have selected an economical way to complete the scale; that is, they tried to find the priming tone's location in the scale, either ascending or descending from the tonic, but not always in one direction. So, the greater the distance from the tonic was, the slower came the response. However, the profile of response accuracy was not influenced by the completion sequence. If we compare the Deutsch's studies (1975) on pitch memory with the recent studies, there are some interesting incoherent phenomena. Besides studies on auditory lateral inhibition, Deutsch also conducted series studies on pitch memory consolidation. Two important conclusions were drawn from her paradigm, in which 4 or 6 intervening tones were interpolated between a standard tone and a comparison tone: the first conclusion clarified that when the same pitch of the standard tone appeared early in the serial position of the intervening sequence, the judgment of the standard tone and the comparison tone would be more correct; the other conclusion explained that in reality the memory consolidation was brought about by the pitch repetition. But in the present study, if taking the tones in the scale-completion as intervening items between the priming tone and its reappearance, the “intervening items” between the first tone of the context and the IV and V degrees were more than the “intervening items” between the first tone the II, III, VI and VII degrees (except for I with immediate repetition) without repetition, but they (IV and V) got more accurate responses. This may be due to the tonal importance of scale degrees, because in Deutsch’s study, it was not mentioned the tonal relationship between the intervening tones and the two test tones, even in some conditions the intervening tones were randomly selected. In the scale-completion task, the “intervening tones”, however, started with the tonic which was a very strong tonal signal. Therefore, it is reasonable to assume that hierarchical importance did play an important role in the processing, and the profile of response accuracy reflected the hierarchical importance of scale degrees, which charged with hierarchical importance on the tonic, the dominant, the subdominant and the supertonic. This was not quite the same as former results from Western listeners, who preferred the tonic, the dominant and the mediant at the pitch level.

If the response strategy depended on “starting interval”, the interference in the memory of the priming tone would not be strong, because in this case, the judgment turned to be a discrimination of in-key or out-of-key interval. Because the in-key interval starting from or ending with the tonic includes only major second, major third, perfect fourth, perfect fifth, major sixth, minor seventh (ascending from the tonic) and their complementary intervals in an octave (descending from the tonic), other kinds of intervals are out-of-key interval. In other words, the implicit starting interval would be further compared with the associated scale, which is kept in the long-term memory as schema. Such a strategy is a bottom-up process. This process would be probably influenced by either functional importance of intervals, or the frequency of intervals (as in tritone and perfect fifth), or the span of intervals. But there is no in-key tone forming a tritone with the tonic, so the descending minor second from the tonic would be the "rare" interval in the available intervals from the tonic. Considering the bow-shaped profiles of response time in both major and minor mode, as well as the interval size and frequency, it can be assumed that the response time speeds up with smaller interval; as the profiles of correct responses in both major and minor mode show, it assumes that the accuracy gets better with popularity of interval. Thus, intervallic size determined the response time, whereas interval popularity determined the response accuracy. The "best" performances in both speed and accuracy were associated with perfect unison and with major second; perfect fifth and perfect fourth followed in this ranking of performance; the "worst" performances in both speed and accuracy were intervals major third, minor third and minor second. If this argument is convincing, a further conclusion can be made that there are some preferences of intervals among Chinese listeners. But it is hard to explain the tonal hierarchy in a scale based on this "implicit starting interval" strategy. The preferred intervals perfect unison, major second, perfect fifth and perfect fourth are the basic and common intervals in Chinese modes, while minor second, minor third and major third are less popular.

In the experiment series 2, a timbre judgment task was applied. The timbre of the priming tone and the test tone in the context was presented in the trumpet timbre and the other tones in the context were in the piano timbre. Participants were asked to assure whether the trumpet tone appeared in the context or not, and whether they had the same pitch or not, though some participants inquired about pitch similarity during the experiment or reported they noticed pitch similarity of the priming tone and the test tone after the experiment. Thus, it can be seen that this task referred mainly to the timbre memory, and the pitch memory came along in the processing. The retaining of timbre memory and little disturbance between memory of timbre and pitch were the key factors for faster response.

For the memory of timbre, it works similar to the memory of pitch that it is easily interfered by similar stimuli (e.g. Deutsch, 1970; Starr, & Pitt, 1997). The timbres of trumpet and piano used in this experiment are easily discriminated because of their different spectral distribution and amplitude envelopes, so they are frequently used in the timbre judgment task (e.g. Krumhansl, & Iverson, 1992; Schellenberg, et al., 2005). The interference of the two timbres would be at a low level; that is, the piano timbre cannot or can hardly disturb the memory of the trumpet timbre and vice versa.

Concerning the disturbance between memory of timbre and pitch, it is already verified in the former studies that the memory for timbre and the memory for pitch are two separate memory systems (e.g. Deutsch, 1970; Semal, & Demany, 1991). However, the interaction between the perception and memory of the pitch and timbre is still an open question. Some studies have dealt with this issue, and their results are contradictory: some studies showed the interaction between the perception of timbre and pitch, which often happened in isolated tones (e.g. Krumhansl, & Iverson, 1992, experiment 1); while the other studies demonstrated that such interaction in the tonal context was found among musicians (Warrier, & Zatorre, 2002) and non-musicians (Semal, & Demany, 1991, 1993). In addition, non-musicians were more sensitive to timbre (e.g. Gaab, & Schlaug, 2003; Halpern, & Müllensiefen, 2007), and there was interference of timbre in pitch perception or memory among non-musicians (Pitt, 1994); or maybe there was no disturbance at all for both groups (Radvansky, Fleming, & Simmons, 1995). According to these results, it is hard to state whether non-musicians in the experiment series 2, experienced a perceptual conflict between timbre and pitch, maybe these participants who were aware of pitch relations of two test trumpet tones were a little bit confused in the task. When they were told to neglect the pitch, it seemed that they were released from the confusion.

Although the problem was not completely solved, in Warrier and Zatorre's (2002) study, there was also another result about the disturbance of timbre and pitch relating to tonal context. The scholars found that tonal context could promote pitch perception, and reduce the impact from timbre. If this conclusion is acceptable, reviewing the experiment series 2 again, the response profiles of the context with tonal indication by both Chinese and German participants are more similar to K-K profiles. So the former results are supported. But the profile of the context without tonal indication cannot be simply due to the interference between timbre and pitch, because if the interference existed, it companied along with all trials, then it was not the determinant factor for the judgment. The important factor still rested on tonal importance of scale degrees, reflected in profiles.

At the end of this discussion we can sum up that memory did play an important role in both tasks of experiment series 1 and 2. After the analysis about the processing of the two tasks, the effect of memory did not determine the final response, but the tonal importance of scale degrees. The discrepancy between the results of the present study and former studies is mainly caused by methods or problem solving strategies; and the difference among participants relies on music training as well as their musical culture background.

48. Cross-cultural differences

The main differences between Chinese and German participants observed in the two experiment series consist of the response to the III degree in major mode or *mi* and the "perfect fourth frame". Besides, there is an unexpected result among Chinese participants that the IV degree in major mode or *fa* got a faster response.

Here it will be discussed the scale degree *mi* only in major mode, which corresponds to Chinese pentatonic *Gong* mode (with *do* as the tonic). In relation to the III degree or *mi*, no matter what kind of strategy participants use, it results that the III degree is a "weak" or less stable degree in Chinese music, because it does not have a simple ratio in frequency with *do* (64:81), so it causes a dissonance that has to be solved to other degrees (e.g. Zhao, 1964). At the mode level, there are fewer musical examples based on the mode with *mi* as the tonic, because there is no dominant above it; "rare" intervals are build on it, like major third - only once in pentatonics, minor third (frequency ratio of *mi* and *sol* is 32: 27) - twice in pentatonics, and even minor second - none in pentatonics, but twice in heptatonics (thus stressing the pentatonic relationship) - which are also considered as dissonant intervals in Chinese music theory (e.g. Zhao, 1964). So *mi* is perceived by Chinese listeners as relatively less important, not only in major context but also in pentatonic context. Whereas in

Western music, the III degree is the mediant in major scale, a component of tonic triad. Thus it is usually perceived by Western listeners with a melodic tendency from the IV degree, and with a harmonic function of tonic, but with a weak relation to the key level. The difference in the relationships among pitch, chord and key in Chinese and Western music theory causes music-cultural perceptual difference.

Before going to the discussion about the "perfect fourth frame", we would like to note here that the IV degree or *fa* showed faster response. Although *fa* is apparently not included in the pentatonic scales, it maintains perfect fourth with the I degree. In Chinese music theory, perfect fifth and perfect fourth are the basic relations among the tones and keys. Zhao (1964) argued that an important way to stabilize the tonic is stressing the tones in perfect fifth and perfect fourth around it, the so-called dominant and subdominant in Western music theory. The function of dominant and subdominant pitches is to stabilize the tonic, whether tonic appears in a context or not. *Fa* does not appear in *Gong* mode (*do* as the tonic), but it comes out in *Zhi* mode (*fa* as the tonic), in which *do* is the dominant. Thus, IV *fa* is a perfect fourth over *do* or a perfect fifth below *do*, and Chinese listeners are sensitive to such tonal functions, but not fixed in a certain mode.

While the "perfect fourth frame" is generated by four perfect fourths in a pentatonic scale: two frame tones are usually functional tones, tonic, subdominant and dominant; a tone in the middle separates the perfect fourth into either a major second or a minor third, no matter which interval is found at the lower part. Such divisions manifest the functional tendency of dominant (when the major second is in the lower part), or of subdominant (when the minor third comes first in the lower part). This means that the mid-tone in the frame has a tonal tendency either to dominant or to subdominant function (Zhao, 1964; Tong, 2004; Liu, 2007). They are the basic melodic progressions in Chinese music and also appear in cadence (Liu, 2007). Such theoretical rules encountered in Chinese perceptual results that perfect fourth and minor second yielded faster responses than perfect fifth; while German participants did not show such tendency.

The relation between Western minor mode and the corresponding Chinese modes has been subjected to debate in Chinese music theory: whether *Yu* mode should be viewed similar to Western minor mode because of the common tonic on the VI degree of major mode or *la.* Some agree with the statement about the common tonic, but the others disagree with it, judging from a deeper perspective in Chinese music. Minor mode is named “minor” because its tonic triad is a minor triad: the third is a minor third over the tonic which marks also an “opposite” term for major. In *Yu* (pentatonic) mode, the second degree is *do*, which is a minor third above *la.* If we compare it with *Gong* mode, the interval between the first two degrees in *Yu* mode is larger than in *Gong* mode (major second); in this case, *Yu* mode is relative “major”, while *Gong* mode is a relative “minor” (Zhao, 1964). The most important point between Western minor mode and *Yu* mode is that the minor third, which is consonant in Western music theory, is regarded as dissonant in Chinese music (frequency ratio is 81:96, more dissonant than major second 8:9), therefore it has to be solved to tonic or subdominant. The perceptual results partly supported the latter theoretical hypothesis that the III degree yielded a slower response and accompanied with more errors among the Chinese music students in the experiment series 1; and it also responded slower among the Chinese non-musicians in the experiment series 2, especially in a context without tonal indication – no matter the test tone was in the middle or at the end of the context. Such an effect was weakened or disappeared in context with tonal indications because participants tended to perceive the minor context in “major” ways, that is, they still took *do* as a tonic, but not *la.* So a non-tonal indication condition arouses a cultural implicit knowledge.

As noticed, the difference between Chinese and Western musical cultures is caused by temperament or tuning. This fact arouses a practical question: what is the tuning system of Chinese instruments? Do they still use Chinese traditional tuning systems (as same as Pythagorean tuning), or a well-tempered system, or natural temperament (just intonation)? Are dissonant major third and minor third to Chinese ears influenced by tuning? Although the theory of the equal temperament appeared in China (by Zhu Zaiyu) and in Europe (by G. Zarlino) around 1600, it was gradually widely used in Western instruments manufacture, while it stayed in the theory but not well used in the practice in China (Miao, 2005). The plucked instruments as Pipa were tuned similarly to the equal tuning system (Miao, 2005; Li, 2008). In the development of Chinese instruments (since 1950s), most Chinese instruments now have adapted the well-tempered system in order to meet the requirement of ensembles composed of Western instruments; though sometimes the fourth degree and the seventh degree are especially tuned to suit the Chinese traditional music (Miao, 1996/2002, p.298; Xia, 2007). Furthermore, a recent study on the pitch measurement (Chen, 2009) found that the pitch, either in single tone test or in performance test, had about 10 cents difference from the corresponding tuning system of a certain instrument. This fact indicates that tuning determines the tonal hierarchy in the development of music culture, during which people emphasized the perceived consonance and neglected the dissonance in their tuning system (e.g. Chinese minor third and major third). But tuning can not work efficiently or can be perceived in a short time, so it is not the most important aspect which affects the features of tonality, but the relationship among tones in the scale or out-of the scale is more essential.

In summary, the III degree or *mi* is the typical distinction between Chinese music theory and Western music theory, and it is perceived differently by both groups of listeners. While perfect fourth and perfect fifth relationship, or the subdominant and dominant, are important in both musical cultures; but on the perceptual level, Chinese listeners can perceive such tonal functions at the pitch level or melodic level; while Western listener perceive them at the chord or harmonic level. In addition, Chinese participants had a special preference for the "perfect fourth frame".

49. Musicians & non-musicians (statistical learning & perceptive learning)

Many studies compared perceptual features between musicians and non-musicians. It is widely verified that musicians and non-musicians do process musical information in different ways, and with different brain electrical activities. In tonality perception, musicians are more sensitive to local musical information, which is effectively connected with tonal knowledge in the background; while non-musicians cannot consciously figure out tonal relationship, though they can detect proximal pitches (e.g. Parncutt, & Bregman, 2000; Williamson, Baddeley, & Hitch, 2006, 2010) .

In this study, the experiment series 1 was conducted with Chinese students in music, and the experiment series 2 was done mainly with Chinese and German non-music students. Both similarity and difference between Chinese music students and non-music students were observed, but the difference may be caused by different methods. The similarity was that both groups perceived the III degree in major and minor modes as less important as a consequence of more errors and slower responses. The different aspect resulted from the fact that music students perceived minor mode in a "minor" way; that is, they responded faster to tonic than other degrees; but non-music students perceived minor mode in a "major" way in the context with indications at both the start and the end.

While tonal profiles of German non-music students, compared with former studies, their tonal profiles depended more on the tonal condition. In the context with tonal indication at both the start and the end, their major profile was similar to K-K profile; their minor profile also presented a "major tendency" as in Chinese non-music students, and they responded faster to *do, mi, sol* (the tonic triad in the major mode). In other contexts with less tonal indication, their profiles varied according to different conditions.

Therefore, non-musicians depend more on context, and clearer tonal contexts can arouse their implicit tonal knowledge more effectively.

50. Conclusion

Different cultures have different musical patterns and music theories, and as a consequence, they shape different tonal schemata and knowledge among native listeners. Tonality is compared in several theoretical and perceptual aspects within a specific musical culture or ethnic group as well as between various cultures and nations.

This study is an attempt to highlight tonal perception among and between Chinese and German listeners. As a cross-cultural approach, it juxtaposes the tonality concepts in both Chinese and Western music theory, and the perceptive features of Chinese and German listeners. Theoretically, Chinese music differs from Western music in terms of non-harmonic features and different key or mode relationships, which affect their perceptual results of the involved listeners. Like in other cross-cultural studies, even here participants reflect their native music theory embodied in their tonal knowledge. The priming paradigm is used to explore the relationship between foreground and background, tone level and key level. It is verified that the importance of tonal function can affect perception of an opening tone or interval, and a context with "clearer tonal sense" is more helpful for tonal perception; this result supports the bottom-up and top-down processing in tonal perception. In addition, it is believed that the "MUSACT" model of Chinese listeners is different from that of Western listeners. The "perfect fourth frame" in Chinese tonal knowledge replaces the chord level in Western "MUSACT". The relationships between perfect fourth and perfect fifth are perceived as important at tone level, and they may be also connected with key or mode level; the "neglected" III degree is the most conspicuous distinction between Chinese and Western perceived tonal hierarchy.

Concerning further studies, there are five points that can be noted. First, the validity of method needs to be further examined. The methods in the two experiment series are revised from former studies, and are directly used with Chinese listeners and some non-musical Western listeners. Although the results are compared with "classic" K-K profiles, it is still difficult to infer whether the revised methods work efficiently on Western musical listeners. Second, the materials can involve more real music. In this study, music excerpts are used, but they are not the focus of the whole study and are not discussed enough. Third, the Chinese music theory can be further examined by cognitive experiments. The perceptual results can be regarded as a reference for some controversial points in Chinese music theory, as well as to fulfill the development of the Chinese music theory. Fourth, although the tonal perception is not sensitive to features in tuning which contributes to the formation of tonal hierarchy, it is necessary to test tonal perception among Chinese infants and children in order to figure out whether the Chinese tonal schema is inherited or learned. And lastly, the relationship between absolute pitch sense and tonality perception is open to further studies in the future.

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Appendices:

Appendix 1: Score of Molihua (from Jiangsu Province)

Appendix 2: Score of Yuangguansandie

Appendix 3: CD files

Grieg

1) Grieg: *Piano Concerto*; Liszt: *Piano Concerto No.2* (2002)
   Leif Ove Andsnes (Artist), EMI Records (Ltd 7243 5 61996 2 0)
2) Grieg: *Lyric Pieces* (2002)
   Leif Ove Andsnes (Artist), EMI Classics (7243 5 57296 2 0)

Haydn

1) Joseph Haydn: *11 Klaviersonaten* (1986)
   Alfred Brendel (Artist), Philips (Universal) (stereo 416 643-2)
2) Joseph Haydn: *3 Piano Sonatas: Klaviersonaten Hob. XVI: 32, 34 & 42*, *Fantasia, Adagio* (1984)
   Alfred Brendel (Artist), Philips (Universal) (stereo 412 228-2)

Mozart

1) Mozart: *Piano Sonatas: Klaviersonaten KV340&457* (1990)
   Alfred Brendel (Artist), Philips (Universal) (stereo 412 525-2)
2) Mozart: *Piano Variations, Rondo, Etc.* (1991)
   Unknown (Artist), Philips (Universal) (stereo 422 726-2, stereo 422 727-2)

Schubert:

1) Schubert: *Sonaten* (2007)
   Martin Stadtfeld (Artist), Sony Classical (Sony Music) (88697135902)
2) Schubert: *Klaviersonate: D 960*, *Moments musicaux D 780* (1968)
   Daniel Barenboim (Artist) , Deutsche Grammophon (stereo 453 674-2)
3) Schubert: *Fantasie C-dur "Wanderer-Fantasie" D 760*, *Impromptus D899 & D 935* (1978)
   Wilhelm Kempff (Artist), Deutsche Grammophon (stereo 453 672-2)

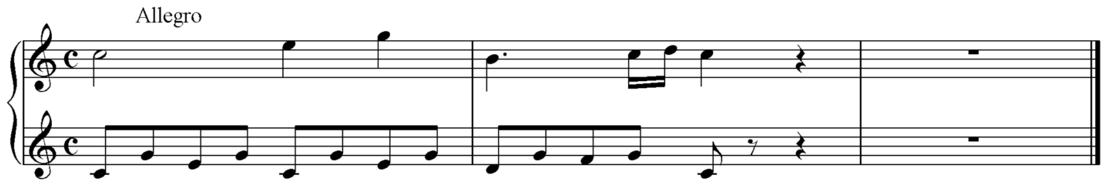
Schumann

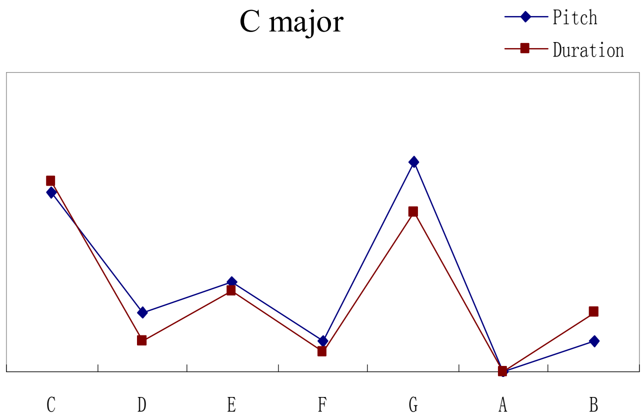
1) Schumann: *Klaviersonate/Humoreske: Sonata in F sharp minor* [Hybrid SACD] (2007)
   Angela Hewitt (Artist), Hyperion Records (SACDA67618)
2) Schumann: *Davidsbündlertänze / Klaviersonate 2, Piano Sonata op.22, Toccata op.7* (1998)
   Boris Berezovsky (Artist), Teldec (Warner) (9031-77476-2)

Appendix 4: Excerpts in experiment series 1

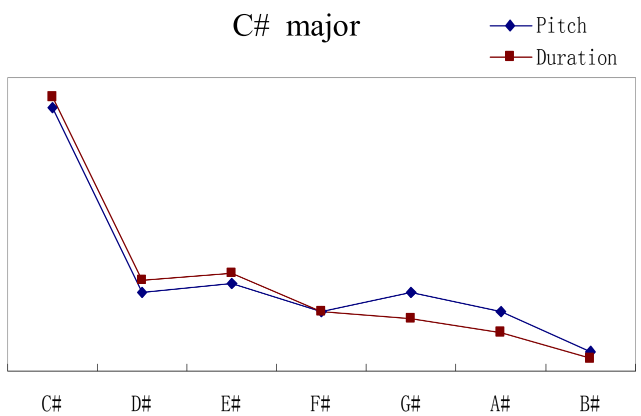
Major:

1. Mozart: Sonata No.16 K. 545 in C major

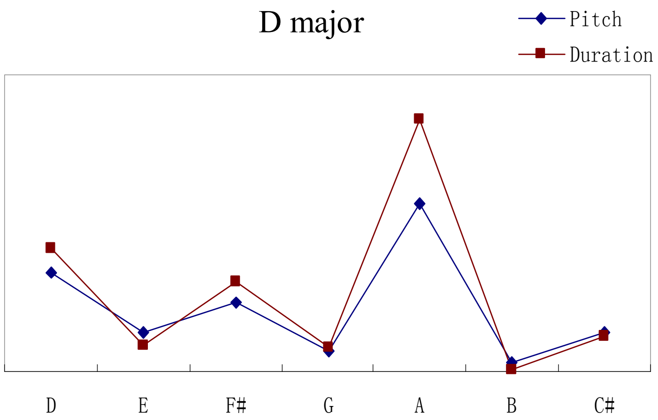




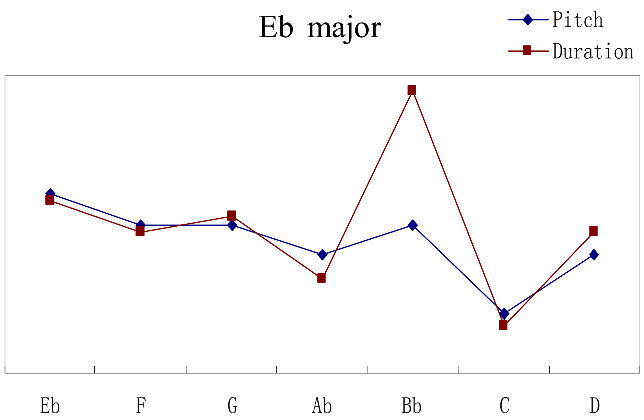
2. Bach: Prelude No. 3 in C sharp major



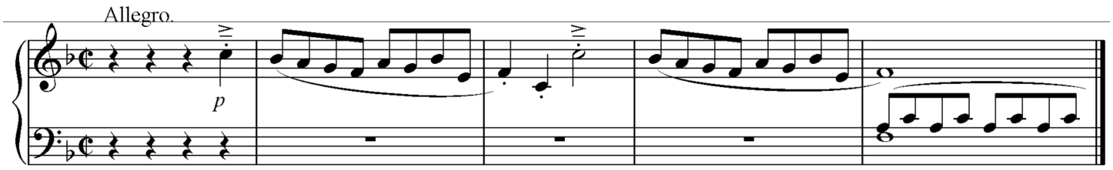
3. Mozart: Sonata No. 18 K. 576 in D major

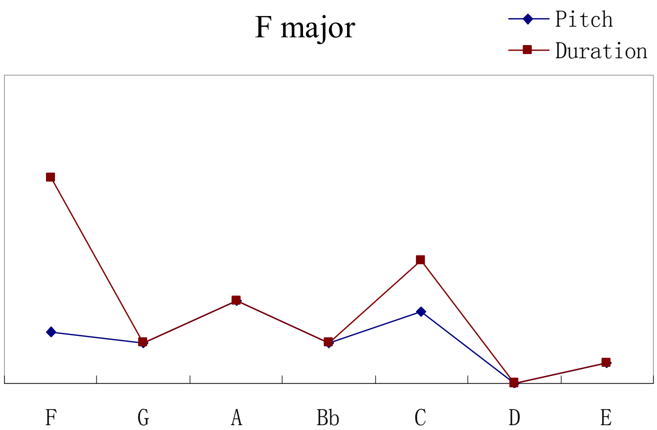


4. Mozart: Sonata No.4 K. 282 in E flat major

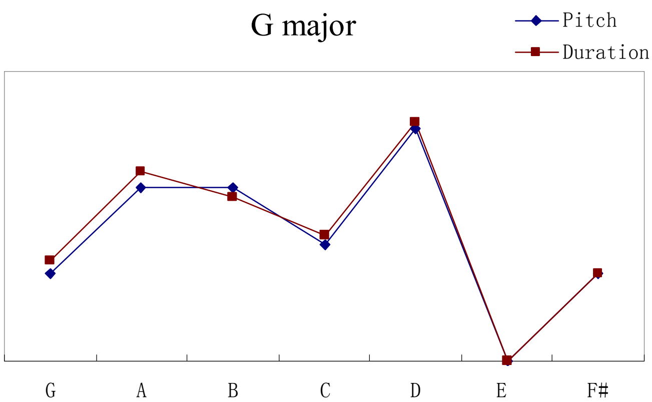


5. Mozart: Sonata No. 15 K. 533 in F major

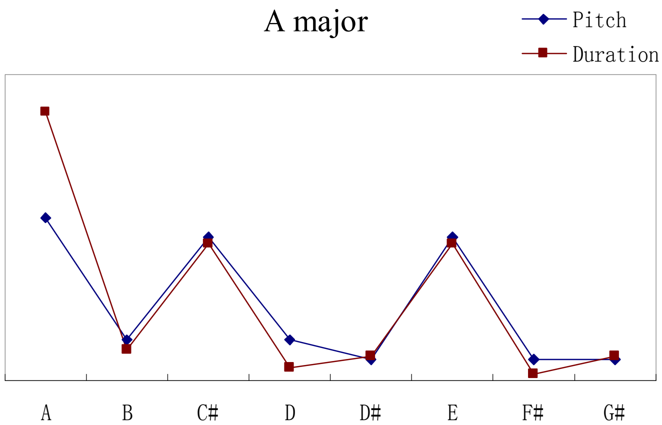




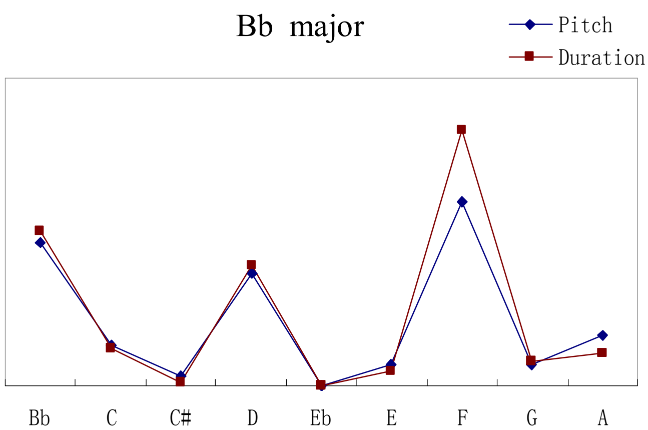
6. Mozart: Sonata No.5 K. 283 in G major



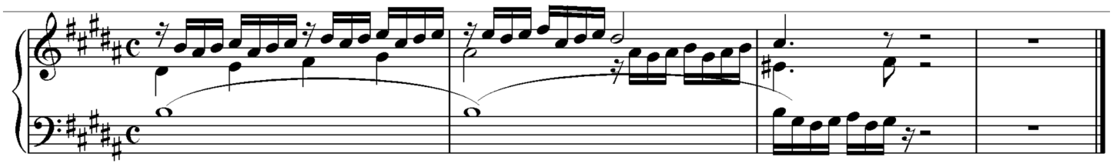
7. Mozart: Sonata No. 11 K. 311in A major

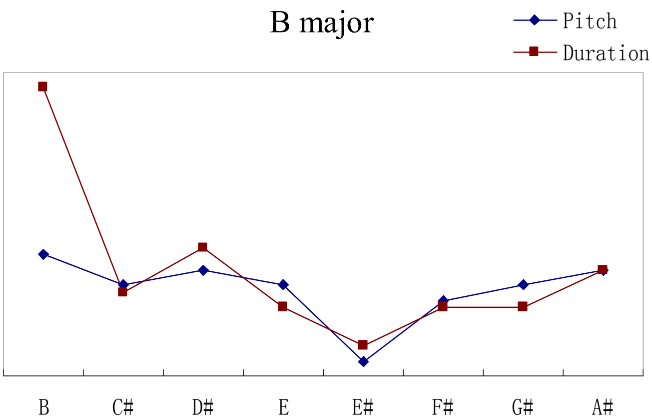


8. Mozart: Variation KV 500 in B flat major



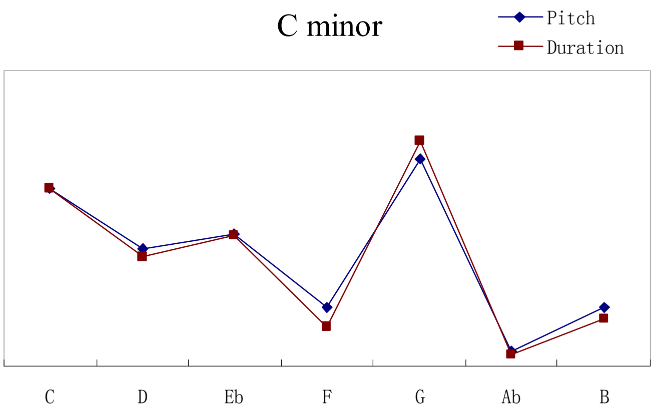
9. Bach: Prelude No. 23 in B major



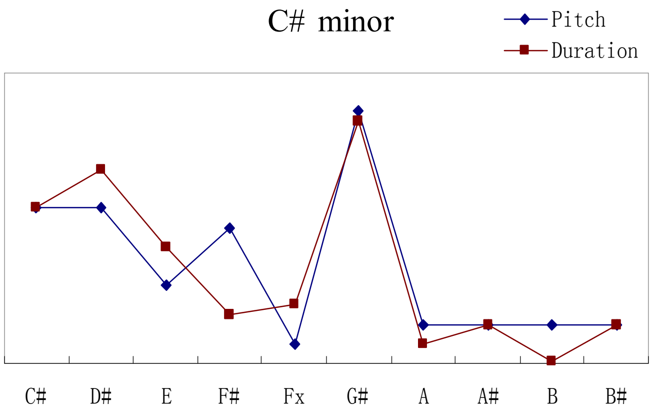


Minor:

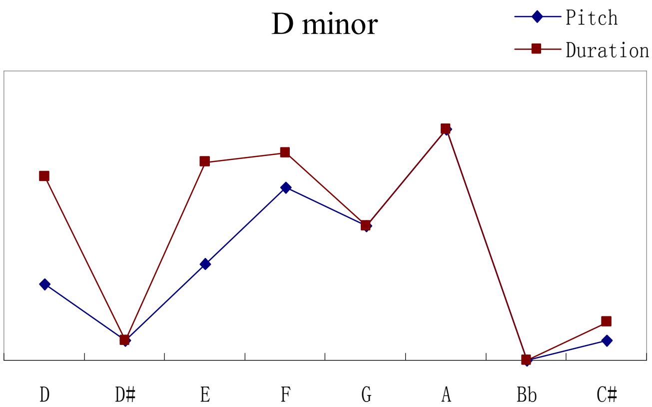
1. Beethoven: Sonata No.8 Op. 13 (Rondo) in C minor



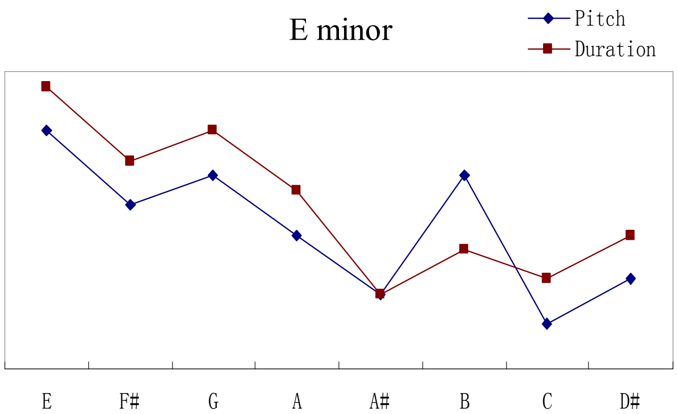
2. Chopin: Walzer Op. 64 No.2 in C sharp minor



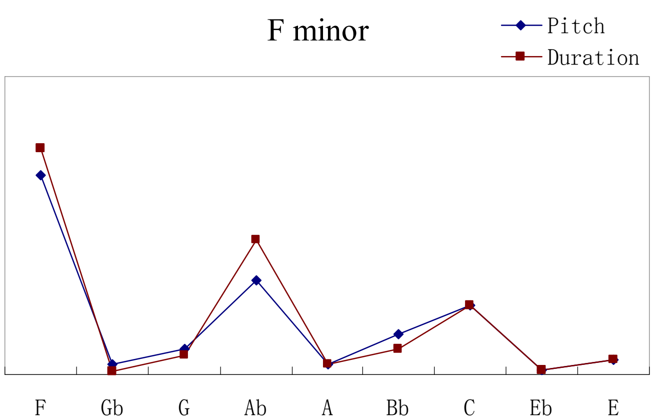
3. Mozart: Fantasia K. 397 in D minor



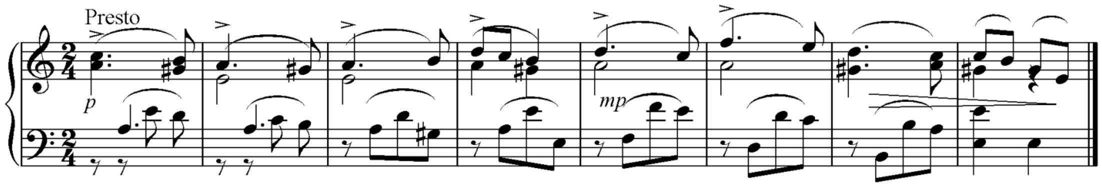
4. Haydn: Sonata No. 53 in E minor

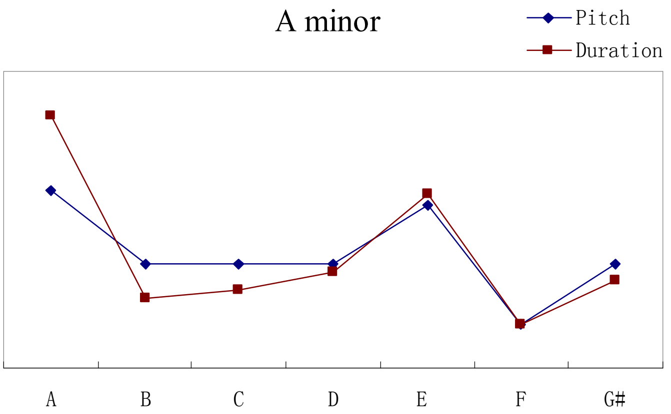


5. Schubert: Moments Musicaux D. 780 in F minor

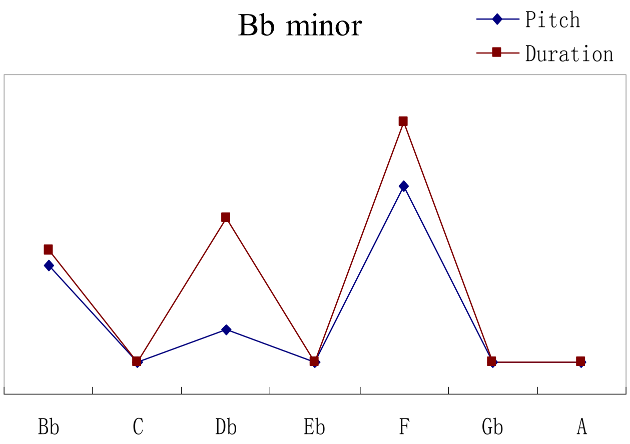


6. Mozart: Sonata No.8 K.310 in A minor

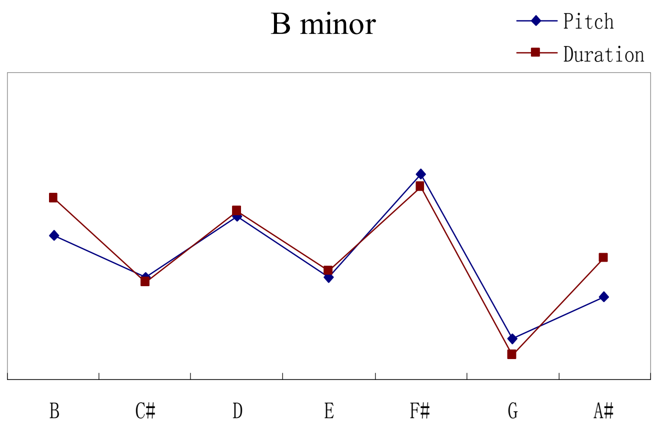




7. Chopin: Nocturnes Op. 9/1 in B flat minor



8. Chopin: Walzer Op. 69 No.2 in B minor

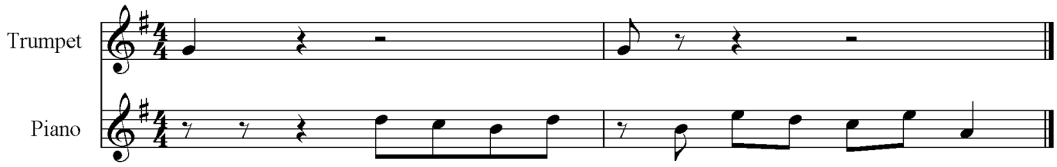


Appendix 5: Excerpts in experiment series 2

The excerpts are not original, but edited.

Major:

1. From Alexander Dargomyzhsky



2. From Mozart

3. From Bach

4. From Händel

5. From Reinhold Moritzevich Glière

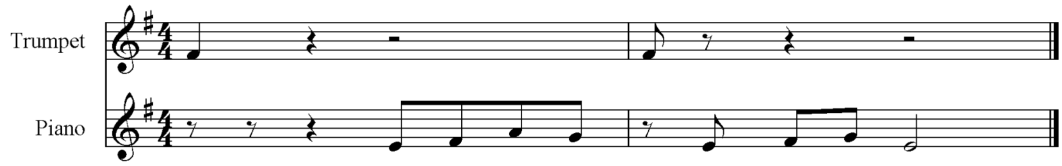
6. From Jean-François Dandrieu

7. From Mozart

Minor:

1. From Schumann

2. From Grieg



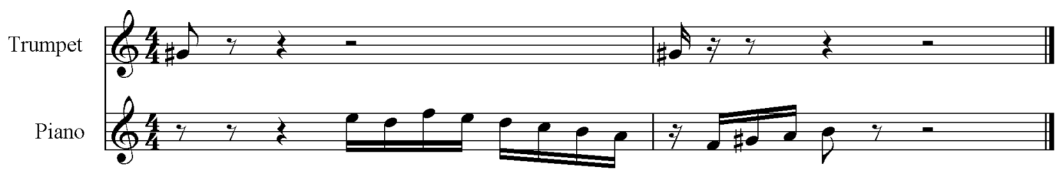
3. From Heinrich Lichner

4. From Jean-philippe Rameau

5. From Tchaikovsky

6. From Chopin

7. From Heinrich Lichner



Pentatonics:

1. From a folk song of Northeast China

2. From Bartók Béla Viktor János

3. From a folk song of Dong minority

4. From a folk song in Jiangsu Province

5. From a folk song in Yunnan Province

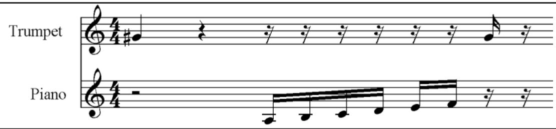
Appendix 6: Artificial materials in experiment series 2 (direct trials in major and minor)

No tonal indication

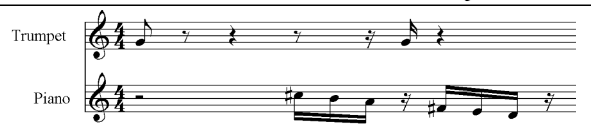
Major/degree	Test tone in the middle
Middle: G/I	
Middle: E^b/II	
Middle: C/III	
Middle:D/IV	
Middle: D/V	
Middle:D/VI	
Middle:A/VII	
Major/degree	Test tone at the end
End: G/I	
End: E^b/II	
End: F/III	
End: D/IV	
End: E^b/V	

End: C/VI	
End: A/VII	

Minor/degree	Test tone in the middle
Middle: G/I	
Middle: E^b/II	
Middle: C#/III	
Middle:D/IV	
Middle: D/V	
Middle: D#/VI	
Middle: A/VII	
Minor/degree	Test tone at the end
End: G/I	
End: E^b/II	
End: F#/III	
End: D/IV	

End: E^b/V	
End: C#/VI	
End: A/VII	

Cadence or starting indication

Major/degree	Test tone in the middle
Middle: G/I	
Middle: E^b/II	
Middle: C/III	
Middle:D/IV	
Middle: D/V	
Middle:D/VI	
Middle:A/VII	
Major/degree	Test tone at the end
End: G/I	
End: E^b/II	

End: F/III	
End: D/IV	
End: E^b/V	
End: C/VI	
End: A/VII	

Minor/degree	Test tone in the middle
Middle: G/I	
Middle: E^b/II	
Middle: C#/III	
Middle:D/IV	
Middle: D/V	
Middle: D#/VI	
Middle: A/VII	

Minor/degree	Test tone at the end
End: G/I	
End: E^b/II	
End: F#/III	
End: D/IV	
End: E^b/V	
End: C#/VI	
End: A/VII	

Bi-tonal indication

Major/degree	Major
Middle: G/I	
Middle: E^b/II	
Middle: C/III	
Middle:D/IV	

<table>
<tr><td>Middle: D/V</td><td>
</td></tr>
<tr><td>Middle:D/VI</td><td>
</td></tr>
<tr><td>Middle:A/VII</td><td>
</td></tr>
<tr><td>Major/degree</td><td>Minor</td></tr>
<tr><td>End: G/I</td><td>
</td></tr>
<tr><td>End: E^{b}/II</td><td>
</td></tr>
<tr><td>End: F/III</td><td>
</td></tr>
<tr><td>End: D/IV</td><td>
</td></tr>
<tr><td>End: E^{b}/V</td><td>
</td></tr>
<tr><td>End: D#/VI</td><td>
</td></tr>
<tr><td>End: A/VII</td><td>
</td></tr>
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