Meaning in Melody

The correlation between lexical tone and musical pitch in Mandarin Chinese

BA-thesis General Linguistics

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Introduction

During the time I studied the acquisition of Mandarin Chinese as a second language[1], I repeatedly wondered whether in Mandarin a correlation exists between the lexical tones of words in a lyric and the melody of the song. Does the melody of a song influence the way Chinese listeners interpret the words in a Mandarin song, or are there any other, possibly unknown, elements that help listeners identify those words? Does a composer create a musical environment that matches the lexical tones, or the other way around? Or does he abandon the rules concerning music/tone correspondence? My Chinese teachers and friends thought these questions irrelevant and could not help me answer them.

Around that time I happened to come across an article that answered the very same question, with the only difference of Cantonese being the questioned language. In this article the authors[2] argue that native speakers of Cantonese Chinese use the relative pitch differences to help them identify the meaning of words in a sung environment. Fascinated by this phenomenon, that Wong and Diehl call "ordinal mapping", I decided to adopt their research and find out whether the same conclusions can be drawn for Mandarin Chinese. For the purpose of this thesis, I repeated both their contemporary song analysis and the perceptual experiment. Based on these two elements I expected to find roughly the same results as Wong and Diehl did, as Mandarin Chinese, just like Cantonese, relies heavily on tonal features to facilitate semantic intelligibility.

Wong and Diehl's conclusions were drawn after presenting two sets of stimulus melodies to Cantonese Chinese listeners. The musical environment of these melodies was created in such a way[3] that it enabled the researchers to investigate the correlation of change in direction of melodic pitch with the choice of Chinese character, that is to say lexical tone, chosen by the participants. The same principle was used in my own research. However, Mandarin being a language with a whole different character than Cantonese, the stimulus melodies were not of much use in their original form.

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[1] September 2005 - May 2006, University of Edinburgh.

[2] Patrick Wong and Randy Diehl (2002). How Can The Lyrics Of A Song In A Tone Language Be Understood? *Psychology of Music* **30**, 202-209.

[3] For a description of Wong and Diehl's used methods and research, see Chapter 3.

By adapting their stimuli, which were used in the experiment with Cantonese Chinese listeners, I was able to create a set of melodies ready for use in my own research. With these adapted melodies I approached Mandarin Chinese informants in order to find data that I expected to support my theory. The ways in which I needed to adapt these stimulus melodies will be described more extensively in Chapter 4 of this thesis.

Wong and Diehl had two reasons for conducting an analysis on contemporary songs in a tone language. Firstly, they wanted to see whether they would find any consistency with the outcomes of their perceptual experiment. Secondly, previous studies in this area have only examined non-contemporary songs, with the exception of Chao (1956), who claims associations between tone and melody are abandoned in modern Mandarin song composition. As Wong and Diehl put it themselves, they found a contemporary song analysis necessary because they were interested in "whether the evolution of music composition involved an abandonment or relaxation of rules governing melody-tone relations"[4].

For the purposes of my own research, I have two additional reasons. However useful for the purpose of my own research, Chao's article, mentioned above, does not provide any examples or statistics to support his assumption about the relaxation of rules concerning melody-tone relations in modern Mandarin songs. Neither does Levis (1936 & 1963) when he claims that "composers of more recent times have confessedly omitted them [choice of words containing a similar melodic form as the corresponding melody]."[5] By conducting an analysis of contemporary Mandarin songs I will provide accurate examples that might support their point of views.

Secondly, it will be interesting to see in what ways Mandarin song composers use a different strategy than their Cantonese colleagues. Based on assumptions on the differences I may find, I will be able to explain any possible outcome of the perceptual experiment. After all, participants in the experiment, all native speaking Mandarin Chinese, must have listened to these kinds of songs extensively throughout their lives and will probably use this knowledge during the identification task of the perceptual experiment.

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[4] Wong and Diehl (2002), p. 203.
[5] Levis (1936), p. 32.

But before I discuss the methods used for the contemporary song analysis and the perceptual experiment, we will first delve deeper into the matter of tone languages. Also, I will examine different strategies used by composers that help them cope with the dilemma they face while writing new songs.

Chapter 1 describes several opinions concerning tone languages, whereas Chapter 2 examines various strategies composers have found to preserve the intelligibility of a song. Chapter 3 provides a brief description of Wong and Diehl's research, after which in Chapter 4 I discuss the theoretical part on the matter of used methods in my own research. In Chapter 5 and Chapter 6 I discuss respectively the results of an analysis of three contemporary Mandarin songs and those of the perceptual experiment, after which I will be able to draw my conclusions in Chapter 7. This chapter also contains relevant discussion points regarding the results of the research and its conclusions.

Chapter 1 Tone languages

In most European languages phonemic distinctions are made by the difference in the placement of articulation and the alternation of vowels and consonants. Prosodic features like tonal contour and pitch accents are mostly used to distinguish relationships between syntactic constituents[6] and/ or semantic distinctions at the phrase or sentence level[7]. For example, by raising the pitch level at the end of a sentence, one can produce a question phrase.

In more than half of the world's languages, however, change in pitch does more than indicate emotional state or constituent relationships. In such a tone language, variation in pitch, fundamental frequency (F_0), is used to create contrast in word meaning. That is to say, in addition to its consonants and vowels, listeners are required to extract the pitch patterns from an utterance in order to understand what is being said. As it is put by Chao (1956): "The phonemic burden, or phonological load, of this element of pitch pattern, or tone, is of the same magnitude as that of vowels."[8] But he also adds that, thanks to the amount of redundancy that is usually present in all languages, without tones [a tone language] is also intelligible, provided that its pronunciation, construction and use of words are perfect[9].

McCawley (1978) discusses the dichotomy of the world's tonal languages. The first type he mentions is the so-called pitch-accent system. The only distinctive melodic characteristic of a sentence or a word in a pitch-accent language is where the pitch-accent lies. According to him Japanese is a prototype of a pitch-pattern language: "In standard Japanese, the only distinctive melodic characteristics of a phrase is the location of the syllable where the pitch drops."[10]

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[6] Siertsema (1962), p. 15.
[7] Gandour (1978), p. 41.
[8] Chao (1956), p. 52.
[9] Chao (1956), p. 53.
[10] McCawley (1978), p. 113.

Ka'kiga	-	oyster
Kaki'ga	-	fence
Kakiga	-	persimmon

Figure 1. Example of minimal pitch-accent pairs in Japanese[11]

The second type he says to be a true tonal language in which melodic *contours* make semantic differences. Mandarin Chinese is said to be a text-book case of a true tonal language, for difference in pitch is important for understanding what is being said. Chao (1930) first introduced a systematic method of numerically describing the phonetic pitch of tones, which is shown in figure 1 and 2. Anderson said about this system: "A systematic method of numerically describing the pitch of tones. Five-level system in which a tone 55 begins i the highest level/register and remains level, 35 begins in the middle of the scale and rises to high, and so on. But the actual range of phonetically distinguishable tones is not limited to 5 values."[12]

Tonal categories[13]	Tonal values
Yin ping	55
Yang ping	35
Shang	214
Qu	51

Figure 2. Mandarin tones[16]

Tonal categories[14]	Tonal values
High-level[15]	55
High-rising	35
Mid-level	33
Low-falling	21
Low-rising	23
Low-level	22

Figure 3. Cantonese tones.

[11] These and more minimal pairs can be found in McCawley (1978), p.113.
[12] Anderson (1978), p. 141.
[13] For a classification of the traditional classification of tones, see for example Mei (1970) p. 104, Yip(1980) and Bao (1999) p. 10.
[14] This classification of Cantonese tones is directly taken from Wong and Diehl (2002), p. 203. Other classifications have been made by different authors, for example Yung (1983), who tells us that Cantonese uses nine lexical tones.
[15] Because a traditional classification categories for the Cantonese tones is not to be found, I used Wong and Diehl's classification system.
[16] See Howie (1976) for detailed description nature Mandarin tones.

Abramson uses a system that dichotomizes lexical tones used by true tonal languages into dynamic or contour tones and static or level tones. In his article he discusses the usefulness of this dichotomy when he states that “it is conventional to classify phonemic tones into dynamic or contour tones and static or level tones […] although imprecise, the typological dichotomy is useful.”[17] Looking at figures 2 and 3, it can indeed be used to roughly identify those lexical tones shown above. As we can see in figures 2 and 3, so-called true tonal languages can have tones of a whole different quality: half of the Cantonese tones has a dynamic shape and the other half stays on the same pitch, whereas in Mandarin only one tone out of four is static.

One must not make the mistake to think that fundamental frequency is the only feature that speakers and listeners use to distinguish between lexical tones. Although it is known that tones are primarily indicated by pitch, other elements are also recognized. When describing the lexical tones in Cantonese, Yung distinguishes duration next to F_o.[18] According to Chao, elements like duration and vocal constriction play a role in tone recognition in Mandarin Chinese. Although considered secondary, they may become important under special conditions, such as whispered speech.[19]

[17] Abramson (1978), p. 319.
[18] Yung (1983), p. 29.
[19] Chao (1956), p. 53.

Chapter 2 Tone languages and composing strategies

For speakers of a non-tonal language it is often hard to imagine how fundamental frequency can play a role in understanding the words, just as important as the vowels and consonants in that language. This notion becomes even more complicated if we try to imagine in what way these tonal elements are intertwined with the music created by in a scociety in which a tonal language is spoken. However, the intertwinement of linguistic prosodic features with musical composition is not an exotic phenomenon solely limited to tone languages. Elements like rhythm and stress turn out to play an unexpected role even in languages as familiar as English and French.

Patel and Daniele (2003) performed a quantative analysis to investigate whether the stress patterns of one's native language influence a composer's style. They found that "(...) English and French musical themes are significantly different in this measure of rhythm, which also differentiates the rhythm of spoken English and French. Thus, there is an empirical basis for the claim that spoken prosody leaves an imprint on the music of a culture."[20]

Considering the influence that *rhythmic* prosody of a language has on its music, it is reasonable to believe that the *intonational* prosody of a tone language equally influences the way music is composed by its speakers. Researchers have found that composers from various parts of the world use different strategies to cope with this dilemma. After discussing these strategies used in different language communities, I will explore whether similar strategies can be found for Mandarin Chinese.

One can imagine the difficulties a composer faces when creating a song melody based on lyrics in a true tonal language. When creating a new melody, a composer faces the dilemma whether he should preserve the lexical melody for the sake of intelligibility, or whether he should abandon linguistic pitch and indulge in musical creativity. One can imagine that, in order to sustain a certain level of semantic intelligibility, poetical creativity must be reduced.

[20] Patel and Daniele (2002), p. B 35.

Various ways of dealing with this problem have been found in song composition in tone languages. Song writers can keep to an absolute correlation between lexical tone and musical tone, they can abandon all correlation, or they can use relative pitch scale differences to musically imitate the tonal contours of the words in the text.

List (1961) examined the relation between lexical tone and tone used in recitings and chants in Thai. He found that Thai songwriters find no need to develop new tunes, but instead draw from a common pool of pre-existing material. While creating a new song, the composer simply applies those syllables whose tones match the contour of the corresponding place in the melody.

In Cantonese opera, composers also rely on a stock of already existing melodies. Unlike Thai, however, they do not just try to keep to the tonal contour of the syllables of the lyrics, instead they must assign an absolute tone-melody relation. Yung found evidence for this absolute matching for linguistic tones of the text and the melodic contour. "The specific pitches and the melodic contour of the aria type are to a great extend determined by the linguistic tones of the text."[21] Although he admits that, in certain situations the singer is to some extend allowed to depart from absolute matching. Modern Cantonese song composition however, keeps only direction of linguistic tones.[22]

In traditional Mandarin Chinese singing there was great dependence on lexical tones, which resulted in somewhat stereotyped forms of melodies. Although a singer was bound to the tones of the words, he was allowed and expected to introduce grace notes to the melody, with the effect of a clearer diction.[23] However, most of contemporary Mandarin songwriters pay no attention to tone. Levis says about this matter that "composers of more recent times have confessedly omitted them."[24] According to Chao this has to do with the low prestige of Mandarin tones in old-style drama, for "only very recently do composers, when they compose by tone at all, use Mandarin tones and then only occasionally."[25]

[21] Yung (1978), p. 39.
[22] Investigated by Wong and Diehl (2002), whose research is described in Chapter 3.
[23] Chao (1956), p. 57.
[24] Levis (1936), p. 32
[25] Chao (1956), p. 58.

In short, composers often rely on already existing melodies from which they can choose a tune to match with their texts. Linguistic tones play a large role while matching words to melody, either in an absolute fashion, in which case poeticality must be reduced, or in a relative fashion, that offers much more poetic freedom. In the case of modern Mandarin song composition, all relationship is said to be abandoned. In the next chapter I will discuss composing strategies and listening strategies of Cantonese.

Chapter 3 Wong and Diehl and ordinal mapping

Each of the studies previously described in chapter two questioned the way composers (of traditional songs in tone languages) solve the problematic linguistic and musical role of F_0 words in…

In their article *How Can the Lyrics of a Song in a Tone Language Be Understood?*[26] Wong and Diehl were not as interested in what strategies composers use to solve the intelligibility dilemma and the tension between musical creativity and keeping to the meaning and tones of the words. Instead they investigated how native listeners of a tone language extract the lexical meaning of a sung text in a non-contextual and therefore tonal ambiguous environment. They were especially interested in the Cantonese language, since it is "one of only 15% of the world's tone languages having six or more tones" (Hombert, 1977) and " reliance on F_0 is probably greater in tone languages with more tonal distinctions" (Wong and Diehl, 2002).

As I mentioned in the Introduction, Wong and Diehl conducted an analysis for these two reasons: out of curiosity in the evolution of Cantonese music composition, and to find consistencies with the outcomes of the perceptual experiment. They chose four contemporary Cantonese songs for analysis. They found that "whereas in carefully spoken Cantonese utterances, tone sequences have a characteristic F_0 ratio (i.e. constant percentage of F_0 change), in contemporary Cantonese songs, corresponding tone sequences preserve only the *direction* of pitch change." (p.204) The analysis resulted in an outcome that showed that an ordinal mapping between musical and tonal sequences occurred 91.81% of the time.[27] Abandonment of the ratio scale of F_0 difference from speech in music is also demonstrated by the fact that in 77 instances the interval between two succeeding musical notes was larger than two whole notes.

In order to conduct the perceptual experiment, Wong and Diehl created two different sets of three melodies, in which only the tone of the last syllable is subject to change. As the distances between the penultimate and the target tone changes by 2, 5 or 9 semitones, participants are expected to choose a different answer, the tones of which

[26] Appeared in *Psychology of Music* (2002), p.202-209
[27] For the results of their song analysis, see Wong and Diehl (2002), table 2 on p. 205

correlating with the relative pitch differences in the melody. These melodies were all sung with the neutral sentence “ha6 yat1 go3 zi6 hai6 si3[28]” (“the next word is to try”).

The responses of the eight participants show that over 95% of the cases were as predicted by an ordinal mapping rule. Moreover. “listeners’ tone assignments are most generally characterized by an ordinal mapping rule similar to that used by composers of contemporary Cantonese songs.

Having discussed research methods and results of Wong and Diehl’s research, in the next chapter I will give a detailed description of methods used for my own research.

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[28] The numbers after each syllable correspond with the Cantonese lexical tones as shown in figure 2, p. 5.

Chapter 4 Song Analysis

As I discussed the methodological basis and changes for this research in the previous chapter and Wong and Diehl's article, which forms the basis of this thesis, in Chapter 3, I am now ready to present the first portion of the actual research bit of my thesis. This chapter will be dedicated to an analysis of contemporary Mandarin Chinese songs. Apart from sheer curiosity to the musical evolution of Chinese song composition, I have several other reasons I already mentioned in the Introduction, why an analysis of Mandarin pop songs is necessary.

Firstly, such an analysis has so far been discussed only by Chao (1956), who claims that songwriters of modern times have abandoned traditional rules that govern the relationship between melody and lexical tone. Even though his opinion is supported by others, no examples are shown to found this observation. Secondly, the outcome of this song analysis provides a useful tool that will help me explain the results of the perceptual experiment (Chapter 6). The songs were popular during the last five years[29] and well known by seven of nine of the participants in my research. Assuming that these three songs represent the general fashion in the song writing business, it may well be that the results are influenced by the listeners' knowledge of modern Chinese music.

There is another matter to be considered. Before Wong and Diehl started their song analysis, they observed that "whereas in carefully spoken Cantonese utterances, tone sequences have a characteristic F_0 ratio (i.e. constant percentage of F_0 change), in contemporary Cantonese songs, corresponding tone sequences preserve only the *direction* of pitch change."[30] Mandarin Chinese tone sequences, however, do not appear to have such a constant percentage of F_0 change. Levis observes that the nature of Mandarin Chinese tone pronunciation is not associated with absolute pitch levels: "To think that the differences of meaning under different tonal treatment are brought about by repeating this vocable with different specific musical tones (...) is wrongly to conceive as the basis of

[29] This is only an indication; since no data on the years of production of the three songs could be found, I depend on the memory of my informants.
[30] Wong and Diehl (2002), p. 204.

tonal elements in Chinese words."[31] In addition, Xiao-nan states that Mandarin Chinese utterances do not even keep a constant percentage of pitch change, like in Cantonese, when she says that in speech "tone value is a directional value. Absolute pitch interval is not pertinent to tonal composition [in speech]."[32] I therefore was not able to compare the interval levels of the songs with relative pitch change in Mandarin tones in speech, neither could I create melodies that would imitate these relative pitch changes, because they seem to be non-existent.

Three contemporary Mandarin songs were chosen for analysis: "Qing1cang2 gao1yuan2[33]" ("Tibet"), composed by Li Tianyi and performed by Han Hong; "Bai2 hua4lin2" ("The forest of the white birch"), composed and performed by Pu Shu; and "Ning2xia4" ("Peaceful summer"), produced by Liang Jingru and composed by Li Zhengfan[34]. As in Wong and Diehl's song analysis, my goal was to investigate whether any overlap, or mapping, can be found between the direction of movement of the musical melody and the corresponding lexical tones in the lyrics. This mapping was expected to be a relative, ordinal one. However, in addition to the elements Wong and Diehl analyzed, I also expected to find a correlation of pitch movement on lexical contour with succeeding notes in the melody. Prosodic cues are usually not limited to a reference to preceding notes to a syllable, instead, utterances in a tone language have a constant flow of changing tone. The analysis will show if an equal percentage of mapping can be found for the preceding and succeeding pitch movements.

The tone of the target syllable is expected to be determined by the relative difference in pitch between the note of the target and both its preceding note and its succeeding note. Expectedly, the prosodic contour of the lyrics is to be reflected by the corresponding musical contour. A syllable that is pronounced with the first Mandarin tone is be expected to be either higher than both the preceding and succeeding syllable, or on the same level. A second tone syllable is expected to be higher than the preceding or lower than the succeeding syllable. A third tone syllable will lower than both preceding

[31] Levis (1936), p. 19.
[32] Xiao-nan (1989), p. 67.
[33] In Pinyin, the transcription of Chinese syllables in Latin script, the pronunciation of the Mandarin tones is shown by the following accents: - stands for a high-level tone, ′ for a rising tone, ˋ
[34] The musical scores, including lyrics, are provided in appendix?, p?.

and succeeding syllables. Finally, a fourth tone syllable needs an environment with a descending contour, that is to say, preceded by a higher note or followed by a lower note.

A total of 414 syllables has been analyzed throughout the three songs. Not included were syllables with a neutral tone[35], an overall amount of 36 syllables. I also excluded three syllables of which, according to the dictionaries used[36] for translating the lyrics, the characters had ambiguous meanings and were pronounced with a different lexical Mandarin tone.

		Preceding musical sequence			
Tone sequence		Up	Down	Same	
Tone 1	same	13.5	9.4	3.6	*26.6*
Tone 2	up	7.0	11.8	3.6	*22.5*
Tone 3	down-up	5.1	8.7	2.2	*15.9*
Tone 4	down	13.5	17.4	4.1	*35.0*
		39.1	*47.3*	*13.5*	**100%**

Table 1. Preceding melodic contour in song analysis.
The highlighted cells are results as expected.

		Succeeding musical sequence			
Tone sequence		Up	Down	Same	
Tone 1	same	10.6	11.3	5.1	*27*
Tone 2	up	8	12.6	3.6	*24.2*
Tone 3	down-up	6.8	6.5	2.4	*15.7*
Tone 4	down	13.5	16.2	3.4	*33.1*
		38.9	*46.6*	*14.5*	**100%**

Table 2. Succeeding melodic contour in song analysis.
The highlighted cells are results as expected.

Tables 1 and 2 on page 17 respectively show preceding and succeeding musical sequences. While formulating the expectations in the analysis of the three Mandarin popular songs, I kept to Chao's indication of Mandarin tones as shown in Figure 2 on page 7. According to Chao, a first tone stays on the same (high) pitch, a second tone rises from a mid-level pitch, a third tone has a falling and rising contour and a fourth tone has

[35] The New Practical Chinese Reader says about the matter of neutral tones: "In the common speech of Modern Chinese, there are a number of syllables which are unstressed and are pronounced in a 'weak' tone. This is known as the neutral tone and is indicated by the absence of a tone mark [in Pinyin]", p. 20.
[36] Refer to Chinese dictionaries in Reference List.

a radically falling pitch. Only 36.7 % of the preceding tonal contours keep to the predicted pattern. Of the succeeding contours, the result is an even lower percentage: only 36.1 % acts as expected.

It seems that the composers of these three contemporary songs did not apply an ordinal mapping rule as described by Wong and Diehl (2002), as there does not seem to be a strong correlation between the pitch contours of the syllables in the lyrics and the melodic contour. However, certain tone/melody combinations appear to have a slight preference. In the case of a first tone, the melody tends to have a rising contour, followed by either an even higher note or a falling note. These tone sequences result in a musical environment that does not imitate the "sameness" of the tone, instead it emphasizes the highth of it. Also, when I came across a third tone throughout the three songs they seem to prefer a contrary musical environment: first a falling tonal contour, followed by a rising contour. Finally, one must note that the songs were written in such a way that fourth tone syllables were somewhat more often placed within a descending musical sequence.

The lack of a strong correlation in Mandarin contemporary song composition as in Cantonese songs may imply two things. Firstly it may indicate that contemporary songwriters do not pay as much attention to traditional rules governing tone-melody relation as traditional songwriters. The phenomenon of relaxation of these rules was earlier described by Chao (1956) and Levis (1936). By analyzing these three contemporary Mandarin songs, I was able to acquire statistical data that seem to support their theory.

In the second place, if, as I assumed earlier, these results form a fair representation of a general fashion in the song writing business, the outcomes of the analysis may mirror the Mandarin Chinese listeners' knowledge of contemporary music. After all, participants in the experiment, all native speaking Mandarin Chinese, must have listened to this kind of songs extensively throughout their lives and will probably use this knowledge during the identification task of the perceptual experiment. The contemporary habits in composing songs, thus the participants' knowledge, may very well influence the choices that are made during the identification task of the perceptual experiment.

Chapter 5 Perceptual experiment

After having discussed the analysis of the relationship between the lexical tones in the lyrics and the direction of pitch change in the melodies of three modern Chinese songs, I have arrived at the meat of this thesis: the perceptual experiment. With this experiment I investigated whether relative changes in musical pitch in the stimulus melodies caused native Mandarin Chinese listeners to hear a different lexical tone on the target syllable.

In an attempt to repeat Wong and Diehl's experiment as accurately as possible, I first needed to adapt their stimuli to the Mandarin Chinese language and tone system. This did not only imply that the target sentence had to be translated, but it also asked for a different melodic approach. As figure 2 and 3 on page 3 of this paper show, the Mandarin Chinese language has only four lexical tones instead of six and they have a different quality than those in Cantonese. As pointed out in the first chapter of this paper, Abramson uses a typological dichotomy that devises true tonal phonemes into dynamic tones and static tones. Since three out of four of the Mandarin tones have a dynamic quality, I needed an approach that would enable me not just to investigate the correlations between melody and tone on the level tone, but also on the moving tones.

As in Wong and Diehl's experiment I investigated whether there is a correlation between relative key difference of the target syllable and the relative difference in key with its previous syllable. However I also expected to find a correlation of the same kind with regard to the following syllable. I tried to find these correlations by investigating three levels of tone. By combining tones on a high, middle and low key on the three places in the melody as mentioned in Chapter 4, I created a musical environment that imitated the level, rising and falling character of the Mandarin tones.[37] I asked a Dutch conductor, who is a qualified musician, to compose three sets of nine melodies which consisted of slight pitch changes. Each of these differed, just like in Wong and Diehl's experiment, on the target syllable, but also on those directly adjacent to the target syllable.

The composer obeyed the harmonic rules of the pentatonic Asian music scale, while at the same time taking into account the relative pitch pattern of the lexical tones of

[37] See appendix for an overview of all the melodies and their tonal variations.

the syllables as they would be pronounced in a carefully spoken utterance. The semantic and contextual neutral target sentence was /xia4 yi2 ge ci2 shi4 yu#[38], zhe4 ge ci2 hen2 hao3/ ("The next word is language, that is a correct word") in which "yu#" is the target syllable. The lack of context in the stimulus melodies causes lexical ambiguity of the target syllable. It was expected that listeners used the relative pitch differences of both preceding and succeeding notes in order to solve this ambiguity and identify the meaning of the target word. That is to say, depending on the contour of the melody, the participants were expected to hear /yu1/ (迂 roundabout), /yu2/ (魚 fish), /yu3/ (雨 rain) or /yu4/ (浴 bath). Figure 4 shows the identification task the participants were presented with.

下一个词是 … ，这个词很好。 A. 鱼 B. 浴 C. 迂 D. 雨

Figure 4. Identification task presented to the participants in the experiment.
While listening to the stimulus melodies, the subjects were asked to fill in the gap with one of the presented characters.

As an amateur singer with several years of singing experience and former student of the Chinese language, I considered myself competent to do the recordings of the stimulus melodies personally. The recordings were done in a nearly sound proof chamber, using an Olympus DSS Digital Voice Recorder, type DM 10; they were stored on a Macintosh computer and prepared for the perceptual experiment with Praat[39]. As a trained musician, the composer of the musical stimuli verified that the melodies were sung in pitch. After the recordings were completed, I asked a language professor in the Asian Studies Department of the University of Leiden to verify whether my pronunciation was correct.

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[38] The # sign indicates the tonal ambiguity of the target word /yu/.
[39] P. Boersma & D. Weenink (1992-2007), version 4.5.19.

	1	2	3	4	
HHH	11	4	6	6	*27*
HHM	11	7	4	5	*27*
HHL	12	9	1	5	*27*
HMH	5	10	9	3	*27*
HMM	10	7	7	3	*27*
HML	8	8	10	1	*27*
HLH	1	6	17	3	*27*
HLM	4	2	19	2	*27*
HLL	4	4	16	3	*27*
MHH	14	7	1	5	*27*
MHM	11	5	4	7	*27*
MHL	14	6	1	6	*27*
MMH	11	6	8	2	*27*
MMM	14	4	7	2	*27*
MML	9	5	7	6	*27*
MLH	6	7	13	1	*27*
MLM	8	4	14	1	*27*
MLL	6	8	12	1	*27*
LHH	13	6	2	6	*27*
LHM	13	8	1	5	*27*
LHL	8	8	3	8	*27*
LMH	20	3	1	3	*27*
LMM	17	2	4	4	*27*
LML	19	3	2	3	*27*
LLH	2	3	19	3	*27*
LLM	4	5	13	5	*27*
LLL	7	4	12	4	*27*
Total	*262*	*151*	*213*	*103*	**729**

Table 3. Subject responses per melody. Highlighted cells contain expected results.

Participants to the perceptual experiment were two male and seven female native Mandarin Chinese from various parts of China[40]. All but two were students of the Universiteit van Amsterdam or Universiteit Leiden, and none of them had had any professional musical background. In exchange for their time, they were offered free entrance to the Botanical Garden of Amsterdam and a nice cup of coffee.

The stimulus melodies were presented three times in random order to each participant. The total amount of stimuli is 729 (27 melodies x 3 repetitions x 9 participants). Table 1 shows the number of times a response was chosen after presenting

[40] A description of each of the participants can be found on page ? of the Appendix, table ?.

a stimulus melody. The melodies are named after the level of musical pitch of respectively the preceding syllable, the target syllable and the succeeding syllable. For instance, the code HHL indicates that the preceding syllable as well as the target syllable have a high pitch, and the succeeding syllable is sung on a low pitch.

If the listeners were not to apply an ordinal mapping rule to help them identify the meaning of the target word –in spite of the created contextual ambiguity-, then each response would be equally distributed among the melodies. Table 3 shows that this is not the case. In the cases that more than one response is expected (i.e. more than one cell in a row is highlighted), the responses would to be equally distributed. In my hypothesis I assumed that listeners in the experiment would choose a character to fill in the gap, in such a way that the lexical tone of the syllable matched the direction of pitch of two consecutive notes in the melody. This means that in case of a high or level musical contour a first tone is heard, that a rising contour triggers a second tone response, that a third tone is a preferred answer to a falling-rising contour, and a fourth tone is chosen when the melody descends. As said before, this is described as the ordinal mapping rule[41]. Almost half of the subjects' responses, 47.1% or 343 of a total of 729, was as predicted by this ordinal mapping rule. In these instances a correlation between the direction of the musical pitch and that of the lexical tone could indeed be found. This correlation, however, is by no means as strong as the 91.8% correlation found by Wong and Diehl in their research on Cantonese.

One can observe that some of the patterns found in the perceptual experiment can also be found in the song analysis described in the previous chapter, for example the fact that a first tone often is chosen in a musical environment that has a rising-falling contour. Also, a third tone is accepted as an appropriate outcome when the melody has a low pitch contour.

Tables 4 and 5 respectively display the differences in pitch in semitones preceding and succeeding the target. Again, the highlighted cells contain the expected results and when more than one response is expected, two cells in a row are highlighted. There appears to be a slightly higher percentage of overlap between the direction of the musical pitch of the preceding note and the lexical tone of the target (table 4) than that of the

[41] See Chapter 3 for Wong and Diehl's definition of the ordinal mapping rule.

succeeding note (table 5): respectively a total of 363 responses (49.8%) in table 4 against 302 responses (41.4%) in table 5.

Preceding note	Musical semitones difference target	迁 Tone 1	鱼 Tone 2	雨 Tone 3	浴 Tone 4	
High	0	34	20	11	16	*81*
	-5	23	25	26	7	*81*
	-9	9	12	52	8	*81*
Middle	+5	39	18	6	18	*81*
	0	34	15	22	10	*81*
	-2	20	19	39	3	*81*
Low	+7	34	22	6	19	*81*
	+2	56	8	7	10	*81*
	-1	13	12	44	12	*81*
Total		*262*	*151*	*213*	*103*	***729***

Table 4. Subject responses to preceding tonal pitch differences.
The difference between the target musical note and its preceding musical note is shown in the second column; -9 means that the target note is nine semitones lower than its preceding note.

Target note	Musical semitones difference succeeding note	迁 1	鱼 2	雨 3	浴 4	
High	0	38	17	10	16	*81*
	-5	35	20	9	17	*81*
	-9	34	23	4	20	*81*
Middle	+5	36	19	18	8	*81*
	0	41	13	18	9	*81*
	-6	36	16	19	10	*81*
Low	+9	9	16	49	7	*81*
	+4	16	11	46	8	*81*
	0	17	16	40	8	*81*
Total		*262*	*151*	*213*	*103*	***729***

Table 5. Subject responses to succeeding tonal pitch differences.
The difference between the target musical note and its succeeding musical note is shown in the second column; -9 means that the succeeding note is nine semitones lower than the target note.

These assumptions on correlation are supported after a χ^2 analysis. In the case the participants had not listened to the musical pitch in order to identify the meaning of the target word, in other words their responses would depend on sheer coincidence, the results would have been equally distributed across the melodies. To exclude coincidental results, I adopted this 0-hypothesis, which I will call H_0. And indeed, the value of χ^2_{Obs} exceeds the χ^2_{Crit}[42] for both preceding and succeeding tonal movements, even with an α-level of 0.001, as shown in table 6. This obviously leads me to reject the hypothesis that the results are coincidental, like expected. However, my original hypothesis in which I assumed that the subject responses are influenced by the relative differences in musical pitch in the stimulus melodies (H_1), must also be rejected. The χ^2_{Obs} values of the preceding and succeeding outcomes exceed the χ^2_{Exp} even more extremely than those of H_0.

		Preceding[43] χ^2_{Obs}	Succeeding[44] χ^2_{Obs}
$df = 24$ $\alpha = 0.001$ $\chi^2_{\mathrm{Crit}} = 51.179$	H_0 (responses are coincidental)	311.259	260.716
	H_1 (responses are as expected)	7182.950	9708.348

Table 6. Critical and Observed χ^2 values for both H_0 and H_1. All $\chi^2_{\mathrm{Obs}} > \chi^2_{\mathrm{Crit}}$.

Having observed these numbers, one must notice two important facts. First, these numbers are, just like those obtained during the song analysis in the previous chapter, not as high as in Wong and Diehl's research. In their experiment over 95% of the subject responses[45] were as predicted by the ordinal mapping rule, whereas in my research the results are nearing 50%. In the second place, the expected results from the perceptual experiment, though a little bit higher, are quite comparable to those of the song analysis: 36.7% and 36.1% overlap between tonal direction of melody and syllable in the song analysis, to 49.8% and 41.4% in the perceptual experiment.

[42] The values used are derived from Brown (2002), Table 12.3, p. 192.
[43] See Table 4, p. 20, for subject responses to preceding tonal differences.
[44] See Table 5, p. 21, for subject responses to succeeding tonal differences.
[45] Page 12 of this paper, or see for exact figures Wong and Diehl, 2002, p. 208.

On the one hand, as I suggested in Chapter 5, page 16, the results of the perceptual experiment seem to mirror the participants' knowledge of contemporary song writing. Seven out of nine participants to this research were students familiar with the three pop songs that I used for analysis. The other two participants knew only one or two of the songs. This assumption is also supported by the matching patterns found in both the song analysis and the experiment, like the choice of a first tone on a rising-falling contour and a third tone in a low pitch environment.

On the other hand, these results seem to suggest that Mandarin Chinese tones may not be as important for the identification of word meanings in a musical environment as in Cantonese. As mentioned on page 11 of this thesis, Wong and Diehl thought it probable that reliance on F_0 to resolve word meaning becomes greater as a language allows more tonal distinctions. This implies that other elements, such as context, could play a larger role than expected. This intuition is supported by the obtained χ^2 values. The outcomes of the experiment do not seem to be a complete coincidence, but neither do they support the expectations in my hypothesis. Although it does not necessarily mean that the participants in my experiment did not map lexical tone to musical tone in the melodies presented to them, it is reasonable to assume that tone alone does not play the largest role. Or it may indicate that the ordinal mapping follows a different pattern than I assumed in the first place. After all, I based the expectations of this research on the somewhat simplified representation of Mandarin tones, displayed on page 7. These are only a representation of isolated syllables as carefully pronounced without the influence of tonal and other features of surrounding syllables. Further research is needed to investigate which necessary adjustments need to be made.

Chapter 6 Conclusion and Discussion

Whereas Wong and Diehl showed that in Cantonese Chinese a strong correlation can be found between the pitch of the linguistic tone and the direction of the melody of a song, I was not able to support the theory that a similar correlation can be found in Mandarin Chinese. Even though during Mandarin speech successfully understanding an utterance depends largely on the identification of the tonal features of the words, in a musical environment understanding the lyrics seems to depend on other elements.

In Chapter 5 I performed an analysis of three contemporary Mandarin songs. The results showed that not even 40% of the preceding and succeeding tonal movements in the three songs had the same direction as the lexical tones in the lyrics. Furthermore, to see whether an ordinal mapping strategy could be found for native Mandarin Chinese listeners, I presented a set of 27 stimulus melodies to the participants to my experiment. Because the lyrics lacked any context, I expected them to make use of the musical pitch change to help them in the identification task of the experiment. Just like in the song analysis, the outcomes of the perceptual experiment were much lower than expected. Interestingly enough, in both the song analysis and the experiment a more or less equal correlation was found between the preceding musical sequence and the target syllable, and the succeeding musical sequence and the target syllable, and also the results from the perceptual experiment were quite comparable with those of the song analysis.

These somewhat disappointing research results of the perceptual experiment may have been caused by several factors. Firstly, I suspect that native Mandarin listeners may not anymore be used to listening to songs that are composed according to rules that guard melody-tone relations. Even though the traditional musical composition of China consisted of a rich system of rules governing the relationship between linguistic tone and melody, the results of the song analysis suggest that these rules have mostly been abandoned. This relaxation of the traditional Chinese art of song composition has earlier been proposed by Levis (1936) and Chao (1956). The compatibility of the outcomes of the experiment with those of the analysis seem to support this observation.

In the second place, as Wong and Diehl mention in their article, dependence on F_0 is probably greater in a tone language with a larger amount of lexical tones. As Mandarin Chinese has not as many tones as Cantonese, it is probably not surprising that participants to my version of Wong and Diehl's experiment showed less eagerness to map their responses to the expected musical contours. This also may explain why it is possible why for contemporary Mandarin songwriters it is easier to release the traditional way of composing songs.

As a third reason I must consider that my singing, since I am obviously not a native Mandarin Chinese, may have been un-Chinese and therefore might have confused the participants in my research. Apart from my having an accent, some elements could have been missing. As I mentioned in Chapter 1, page 8, Chao considers other prosodic features like duration of vowels and vocal constriction of further importance for word intelligibility. In addition, in Chapter 2, the introduction of grace notes is said to result in a clearer diction. For obvious reasons I was not able to involve these factors in the stimulus recordings.

Finally, as a discussion point, I would like to propose another possible explanation of the lack of an ordinal mapping in Mandarin Chinese. Considering the differences between Cantonese and Mandarin on the prosodic level, Cantonese having absolute pitch intervals and Mandarin having relative pitch intervals, I believe that a hierarchical system exists, which may be the underlying basis for the way the linguistic prosody of different languages influences musical composition in different ways. If in musical composition a tonal language will take one step back when it comes to lexical intelligibility, then it would explain why in my research on Mandarin Chinese ordinal mapping between lexical tone and melody there is a lower correlation than in Wong and Diehl's research on Cantonese.

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Appendix Perceptual Experiment

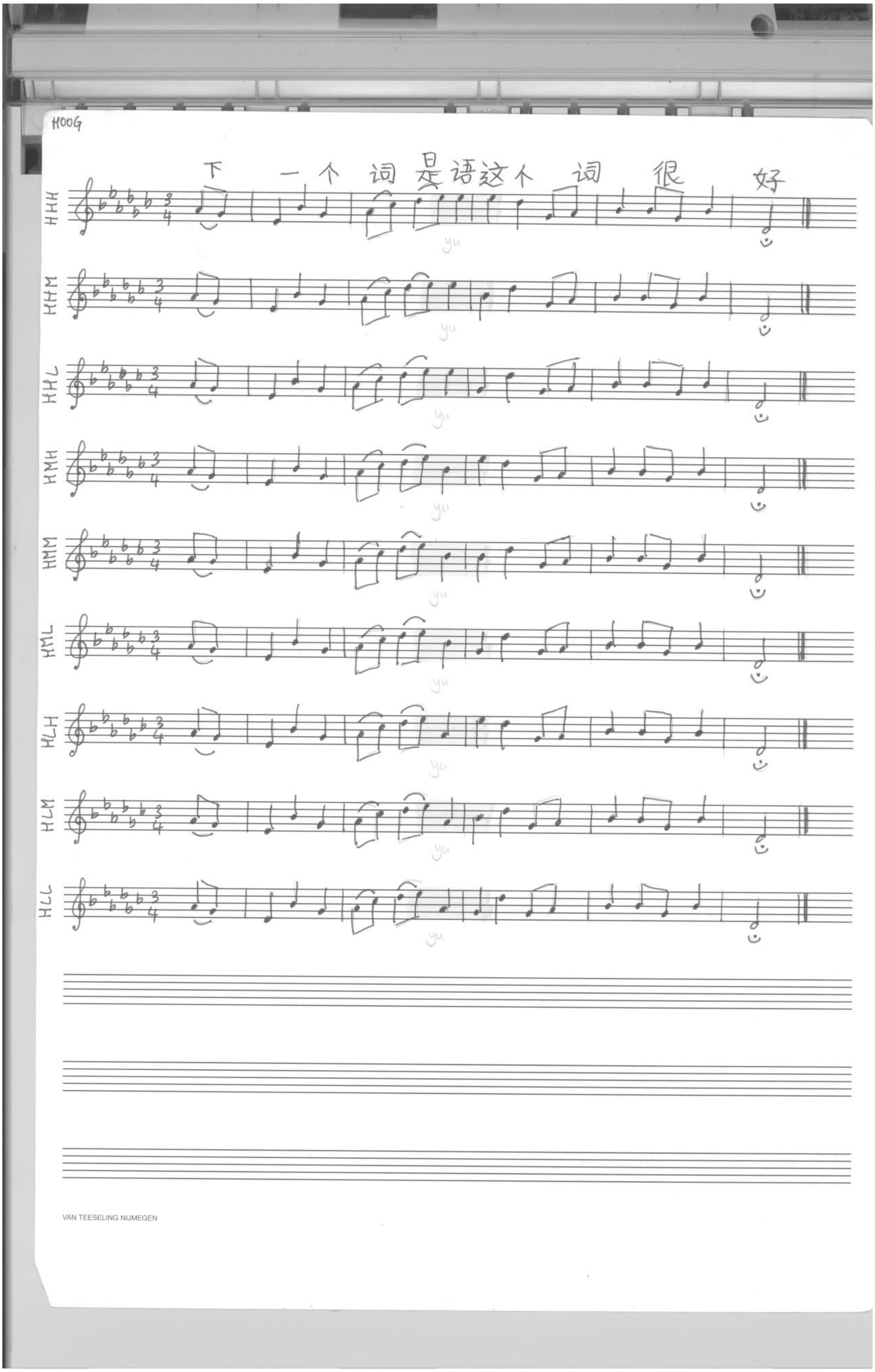
Participants:

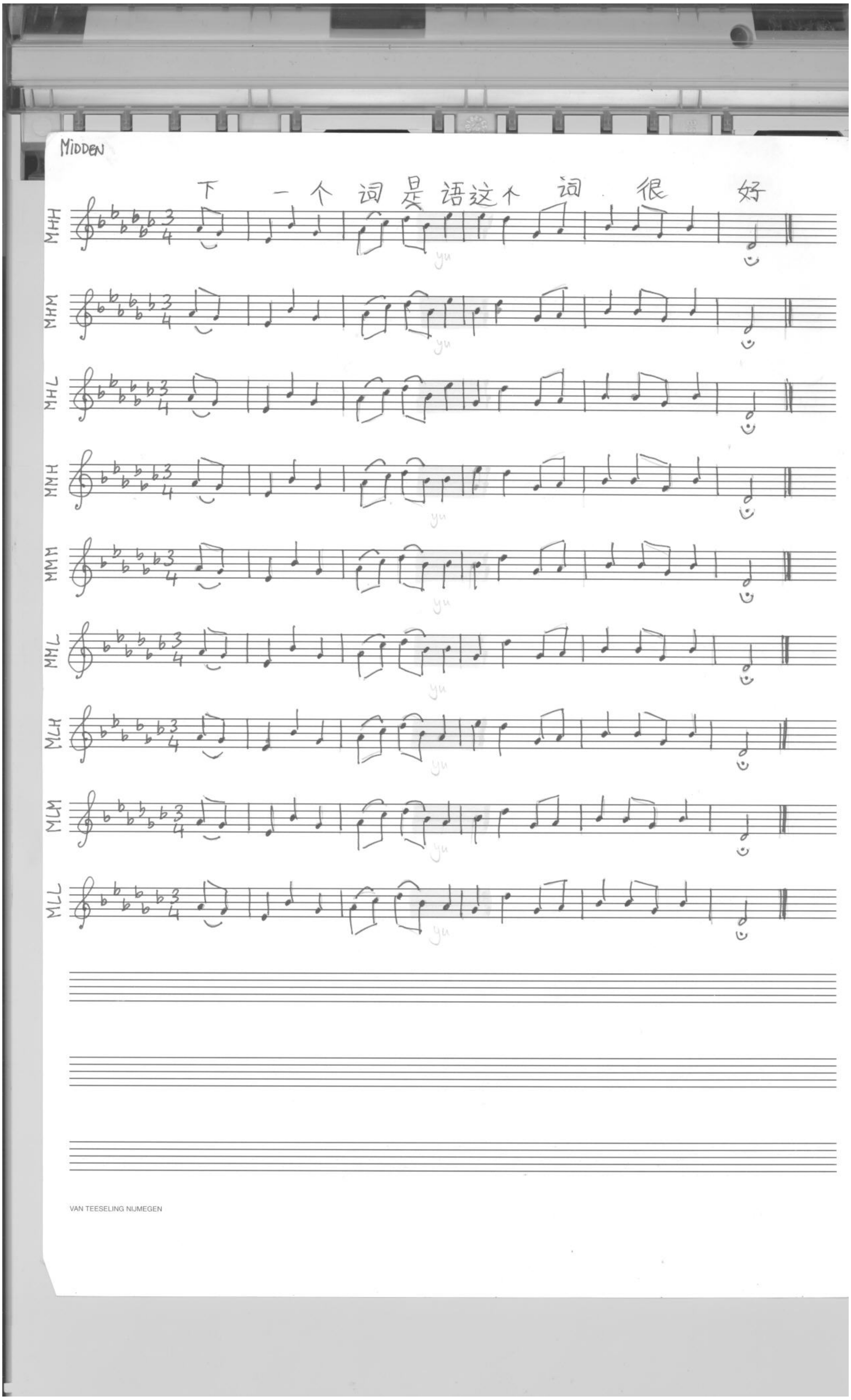
	A	B	C	D	E
Province	Liaoning	Inner Mongolia	Beijing	Beijing	Shanghai
Date of birth	june 30 1981	May 12 1981	Unknown	June 11 1984	May 13 1976
Study/ profession	Student Economics and Business	Student Economics	Chinese Teacher	Student Economics	Intercultural consultant
Musical background	Piano lessons	None	Singing lessons	Singing lessons	None
Gender	Female	Male	Female	Female	Female

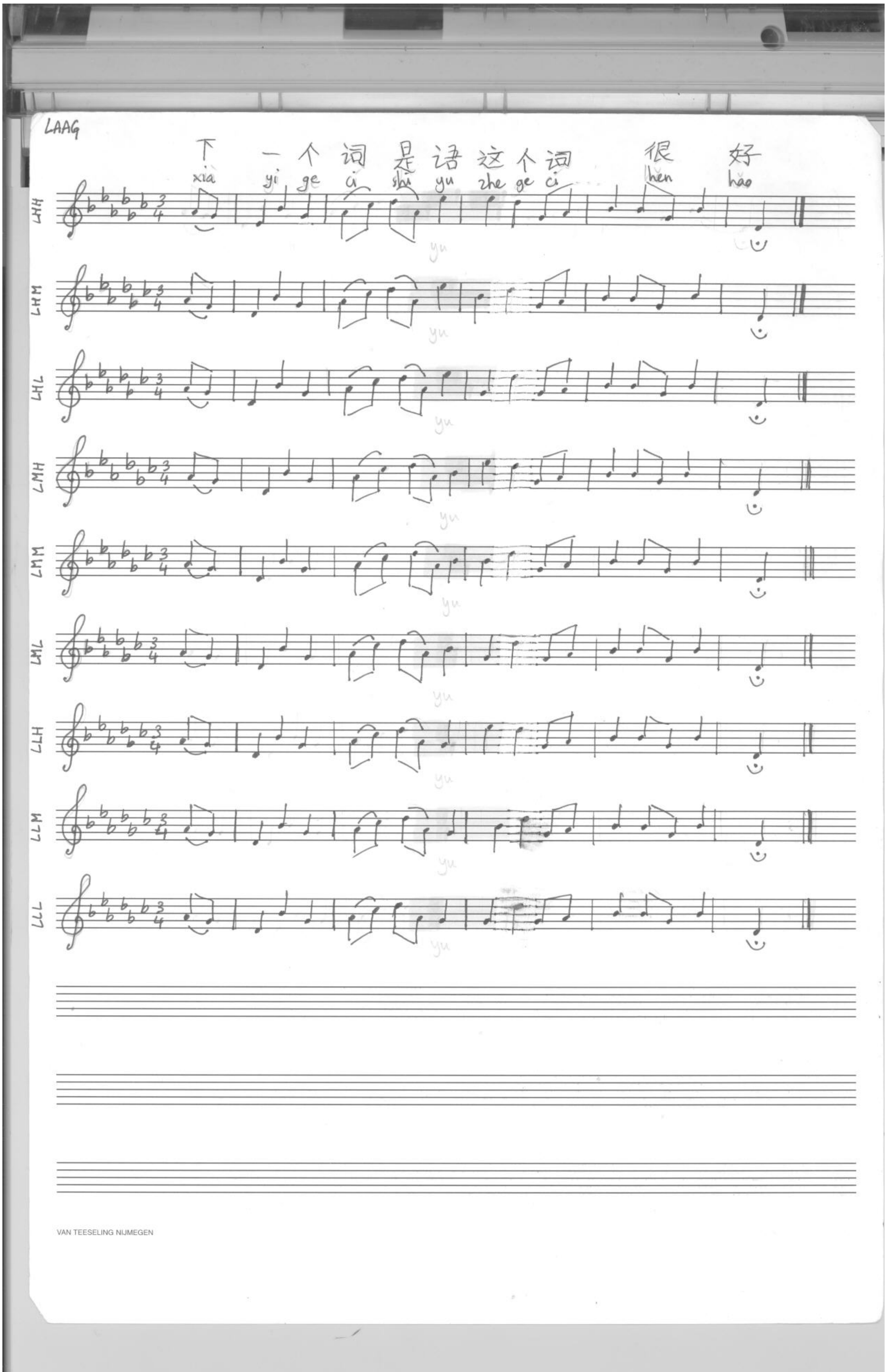
	F	G	H	I
Province	Beijing	Hunan	Tianjin	Jiangsu
Date of birth	January 9 1980	December 20 1981	February 6 1983	April 22 1980
Study/ profession	PhD Media and Arte Studies	Student Linguistics	Student European Business Law	Student ICT Business
Musical background	None	Accordeon lessons	Singing	Singing
Gender	Female	Female	Female	Male

Table 1. Description of participants. Corresponding results to the actual experiment can be found on page ? of the appendix.

Stimulus melodies




MIDDEN
下 一个 词 是 语 这个 词 很 好
MHH
MHM
MHL
MMH
MMM
MML
MLH
MLM
MLL
yu
VAN TEESELING NIJMEGEN


LAAG
下 一个词是语这个词 很 好
xia yi ge ci shi yu zhe ge ci hen hao
LHH
LHM
LHL
LMH
LMM
LML
LLH
LLM
LLL
VAN TEESELING NIJMEGEN

Question form

You will now repeatedly hear a sung melody. For this melody, you'll find the lyrics below. Which character do you think goes best with the empty space within these lyrics? There is no right or wrong answer.

下一个词是 … ，这个词很好。

These are the characters you may choose from to fill in the gap.

A. 鱼
B. 浴
C. 迂
D. 雨

Please write down the track number you're hearing in the first and the answer you think is appropriate in the second cell. The other three rows of cells remain empty.

Track number	Answer			

Thank you very much for kindly participating in this experiment.

Results

Participant **A**

Preceding pitch contour	Up	Down	Same	
Tone 1	8	3	9	*20*
Tone 2	11	4	4	*19*
Tone 3	1	16	10	*27*
Tone 4	7	4	4	*15*
	27	*27*	*27*	**81** N

%	Up	Down	Same	
Tone 1	9.9	3.7	11.1	*24.7*
Tone 2	13.6	4.9	4.9	*23.5*
Tone 3	1.2	19.8	12.3	*33.3*
Tone 4	8.6	4.9	4.9	*18.5*
	33.3	*33.3*	*33.3*	**100** %

Succeeding pitch contour	Up	Down	Same	
Tone 1	9	5	6	*20*
Tone 2	1	10	8	*19*
Tone 3	14	4	9	*27*
Tone 4	3	8	4	*15*
	27	*27*	*27*	**81** N

%	Up	Down	Same	
Tone 1	11.1	6.2	7.4	24.7
Tone 2	1.2	12.3	9.9	23.5
Tone 3	17.3	4.9	11.1	33.3
Tone 4	3.7	9.9	4.9	18.5
	33.3	33.3	33.3	**100** %

Participant B

Preceding pitch contour	Up	Down	Same		
Tone 1	18	10	12	*40*	
Tone 2	9	8	4	*21*	
Tone 3	0	9	11	*20*	
Tone 4	0	0	0	*0*	
	27	*27*	*27*	**81**	N

	Up	Down	Same		
Tone 1	22.2	12.3	14.8	*49.4*	
Tone 2	11.1	9.9	4.9	*25.9*	
Tone 3	0.0	11.1	13.6	*24.7*	
Tone 4	0.0	0.0	0.0	*0.0*	
	33.3	*33.3*	*33.3*	**100**	%

Succeeding pitch contour	Up	Down	Same		
Tone 1	11	14	15	*40*	
Tone 2	2	11	8	*21*	
Tone 3	14	2	4	*20*	
Tone 4	0	0	0	*0*	
	27	*27*	*27*	**81**	N

%	Up	Down	Same		
Tone 1	13.6	17.3	18.5	*49.4*	
Tone 2	2.5	13.6	9.9	*25.9*	
Tone 3	17.3	2.5	4.9	*24.7*	
Tone 4	0.0	0.0	0.0	*0.0*	
	33.3	*33.3*	*33.3*	**100**	%

Participant C

Preceding pitch contour	Up	Down	Same		
Tone 1	11	5	6	*22*	
Tone 2	9	9	8	*26*	
Tone 3	2	9	7	*18*	
Tone 4	5	4	6	*15*	
	27	*27*	*27*	**81**	N

%	Up	Down	Same		
Tone 1	13.6	6.2	7.4	*27.2*	
Tone 2	11.1	11.1	9.9	*32.1*	
Tone 3	2.5	11.1	8.6	*22.2*	
Tone 4	6.2	4.9	7.4	*18.5*	
	33.3	*33.3*	*33.3*	**100**	%

Succeeding pitch contour	Up	Down	Same		
Tone 1	2	9	10	*21*	
Tone 2	11	9	7	*27*	
Tone 3	8	4	7	*19*	
Tone 4	6	5	3	*14*	
	27	*27*	*27*	**81**	N

%	Up	Down	Same		
Tone 1	2.5	11.1	12.3	25.9	
Tone 2	13.6	11.1	8.6	33.3	
Tone 3	9.9	4.9	8.6	23.5	
Tone 4	7.4	6.2	3.7	17.3	
	33.3	33.3	33.3	**100**	%

Participant D

Preceding pitch contour	Up	Down	Same		
Tone 1	5	10	9	*24*	
Tone 2	3	8	7	*18*	
Tone 3	2	8	5	*15*	
Tone 4	17	1	6	*24*	
	27	*27*	*27*	**81**	N

%	Up	Down	Same		
Tone 1	6.2	12.3	11.1	*29.6*	
Tone 2	3.7	9.9	8.6	*22.2*	
Tone 3	2.5	9.9	6.2	*18.5*	
Tone 4	21.0	1.2	7.4	*29.6*	
	33.3	*33.3*	*33.3*	**100**	%

Succeeding pitch contour	Up	Down	Same		
Tone 1	10	5	9	*24*	
Tone 2	7	6	5	*18*	
Tone 3	9	2	4	*15*	
Tone 4	1	14	9	*24*	
	27	*27*	*27*	**81**	N

%	Up	Down	Same		
Tone 1	12.3	6.2	11.1	*29.6*	
Tone 2	8.6	7.4	6.2	*22.2*	
Tone 3	11.1	2.5	4.9	*18.5*	
Tone 4	1.2	17.3	11.1	*29.6*	
	33.3	33.3	33.3	**100**	%

Participant E

Preceding pitch contour	Up	Down	Same		
Tone 1	17	0	1	*18*	
Tone 2	3	7	7	*17*	
Tone 3	6	17	12	*35*	
Tone 4	1	3	7	*11*	
	27	*27*	*27*	**81**	N

%	Up	Down	Same		
Tone 1	21.0	0.0	1.2	*22.2*	
Tone 2	3.7	8.6	8.6	*21.0*	
Tone 3	7.4	21.0	14.8	*43.2*	
Tone 4	1.2	3.7	8.6	*13.6*	
	33.3	*33.3*	*33.3*	**100**	%

Succeeding pitch contour	Up	Down	Same		
Tone 1	1	11	6	*18*	
Tone 2	9	4	5	*18*	
Tone 3	17	6	12	*35*	
Tone 4	0	6	4	*10*	
	27	*27*	*27*	**81**	N

%	Up	Down	Same		
Tone 1	1.2	13.6	7.4	22.2	
Tone 2	11.1	4.9	6.2	22.2	
Tone 3	21.0	7.4	14.8	43.2	
Tone 4	0.0	7.4	4.9	12.3	
	33.3	33.3	33.3	**100**	%

Participant F

Preceding pitch contour		Up	Down	Same		
	Tone 1	14	2	10	*26*	
	Tone 2	1	11	6	*18*	
	Tone 3	1	14	9	*24*	
	Tone 4	11	0	2	*13*	
		27	*27*	*27*	**81**	N

	%	Up	Down	Same		
	Tone 1	17.3	2.5	12.3	*32.1*	
	Tone 2	1.2	13.6	7.4	*22.2*	
	Tone 3	1.2	17.3	11.1	*29.6*	
	Tone 4	13.6	0.0	2.5	*16.0*	
		33.3	*33.3*	*33.3*	**100**	%

Succeeding pitch contour		Up	Down	Same		
	Tone 1	1	15	11	*27*	
	Tone 2	11	2	4	*17*	
	Tone 3	15	1	8	*24*	
	Tone 4	0	9	4	*13*	
		27	*27*	*27*	**81**	N

	%	Up	Down	Same		
	Tone 1	1.2	18.5	13.6	*33.3*	
	Tone 2	13.6	2.5	4.9	*21.0*	
	Tone 3	18.5	1.2	9.9	*29.6*	
	Tone 4	0.0	11.1	4.9	*16.0*	
		33.3	*33.3*	*33.3*	**100**	%

Participant G

Preceding pitch contour

	Up	Down	Same		
Tone 1	11	5	8	*24*	
Tone 2	4	2	6	*12*	
Tone 3	8	16	10	*34*	
Tone 4	4	4	3	*11*	
	27	*27*	*27*	**81**	N

%	Up	Down	Same		
Tone 1	13.6	6.2	9.9	*29.6*	
Tone 2	4.9	2.5	7.4	*14.8*	
Tone 3	9.9	19.8	12.3	*42.0*	
Tone 4	4.9	4.9	3.7	*13.6*	
	33.3	*33.3*	*33.3*	**100**	%

Succeeding pitch contour

	Up	Down	Same		
Tone 1	6	7	11	*24*	
Tone 2	4	6	2	*12*	
Tone 3	13	11	10	*34*	
Tone 4	4	3	4	*11*	
	27	*27*	*27*	**81**	N

%	Up	Down	Same		
Tone 1	7.4	8.6	13.6	*29.6*	
Tone 2	4.9	7.4	2.5	*14.8*	
Tone 3	16.0	13.6	12.3	*42.0*	
Tone 4	4.9	3.7	4.9	*13.6*	
	33.3	*33.3*	*33.3*	**100**	%

Participant H

Preceding pitch contour	Up	Down	Same		
Tone 1	18	16	15	*49*	
Tone 2	9	0	4	*13*	
Tone 3	0	6	4	*10*	
Tone 4	0	5	4	*9*	
	27	*27*	*27*	**81**	N

%	Up	Down	Same		
Tone 1	22.2	19.8	18.5	*60.5*	
Tone 2	11.1	0.0	4.9	*16.0*	
Tone 3	0.0	7.4	4.9	*12.3*	
Tone 4	0.0	6.2	4.9	*11.1*	
	33.3	*33.3*	*33.3*	**100**	%

Succeeding pitch contour	Up	Down	Same		
Tone 1	14	17	18	*49*	
Tone 2	0	9	4	*13*	
Tone 3	8	0	2	*10*	
Tone 4	5	1	3	*9*	
	27	*27*	*27*	**81**	N

%	Up	Down			
Tone 1	17.3	21.0	22.2	*60.5*	
Tone 2	0.0	11.1	4.9	*16.0*	
Tone 3	9.9	0.0	2.5	*12.3*	
Tone 4	6.2	1.2	3.7	*11.1*	
	33.3	*33.3*	*33.3*	**100**	%

Participant I

Preceding pitch contour

	Up	Down	Same		
Tone 1	25	0	12	*37*	
Tone 2	0	5	3	*8*	
Tone 3	0	22	8	*30*	
Tone 4	2	0	4	*6*	
	27	*27*	*27*	**81**	N

%	Up	Down	Same		
Tone 1	30.9	0.0	14.8	*45.7*	
Tone 2	0.0	6.2	3.7	*9.9*	
Tone 3	0.0	27.2	9.9	*37.0*	
Tone 4	2.5	0.0	4.9	*7.4*	
	33.3	*33.3*	*33.3*	**100**	%

Succeeding pitch contour

	Up	Down	Same		
Tone 1	5	20	12	*37*	
Tone 2	5	3	2	*10*	
Tone 3	16	2	10	*28*	
Tone 4	1	2	3	*6*	
	27	*27*	*27*	**81**	N

%	Up	Down	Same		
Tone 1	6.2	24.7	14.8	*45.7*	
Tone 2	6.2	3.7	2.5	*12.3*	
Tone 3	19.8	2.5	12.3	*34.6*	
Tone 4	1.2	2.5	3.7	*7.4*	
	33.3	*33.3*	*33.3*	**100**	%