Cross-linguistic perception of Mandarin intonation

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Abstract

This study investigated how phonological knowledge and psychoacoustic mechanism interact in intonation perception. In the experiment, Mandarin and Cantonese listeners identified Mandarin statement and question in both unfiltered and low-pass filtered contexts. The results show that the importance of different perceptual factors varies depending on the perception materials. Language background plays an important role even in processing low-level psychoacoustic materials.

Index Terms: cross-linguistic perception, intonation, Mandarin, the Frequency Code

1. Introduction

1.1. Intonation and the Frequency Code

This study investigates the interaction between psychoacoustic mechanism and phonological knowledge in intonation perception. The most relevant psychoacoustic mechanism to the perception of statement and question is the Frequency Code proposed by Ohala [1]. It explains the cross-linguistic correspondence between intonation contour and (para-)linguistic meaning, stemming from a biological basis [2]. Since the organ that produces a lower sound is usually larger, low-pitched individuals are associated with being dominant and aggressive, whereas individuals that produce a higher pitch are associated with being subordinate and submissive. As a result, the informational interpretations of the Frequency Code relate high or rising contour to "uncertainty", and thus questioning, and relate low or falling contour to "certainty", and thus being assertive, i.e., statements [1], [2].

1.2. Tone and intonation of Mandarin

1.2.1. Lexical tones in Mandarin

There are four lexical tones in Mandarin [3] (Table 1), all differ in pitch shape. There is a tone sandhi rule in Mandarin. In a T3-T3 sequence, the first T3 is produced as a high rising tone [4], perceptually indistinguishable from T2 [5] [6].

Table 1. *Lexical tones in Mandarin.*

	T1	T2	T3	T4
Tone Shape	Level	Rising	Dipping	Falling
Tone Letter	55	35	21/214	51

1.2.2. Production of Mandarin question intonation

While some studies suggested that questioning in Mandarin could be a local event at the final tone [5]–[8], other studies showed that the tone shape of the final tone remains very similar to the citation form acoustically [11]-[13]. Many studies have demonstrated that Mandarin questions were signaled by modification of the F0 contour of the whole utterance [14]-[21]. Yuan [13] showed that the global F0 of a question was raised and the whole sentence had a smaller declination slope compared with that of a statement. The final T2 of a question had a steeper rising and a higher ending, and the final T4 of a question had a higher beginning and a higher ending than those of a statement, and hence had a flattened falling contour. He concluded that a boundary tone is not necessary to model the distinction between statement and question in Mandarin. The essential mechanism of Mandarin questioning is its raised F0 contour over the scope of the whole utterance.

1.2.3. Perception of Mandarin question intonation

Studies on intonation perception of Mandarin revealed several asymmetries in their perception results. First of all, statements are easier to identify than questions. This bias towards statement shows that statement would be an unmarked sentence type [13], [22]. Second, the sentence-final lexical tone does not affect the identification of statements, but influences the identification of intonational questions (yes-no questions that are signaled by intonation only, without any sentence final particles). Questions with a sentence-final falling tone (T4) are easiest to be identified, and a question ending with a final rising tone (T2) is the most difficult to identify [9]. Yuan [13],[23] explained that this was due to the flattening of the falling tone at the end of a question. This is a language/tone specific perceptual pattern; and intonation perception was sensitive to the phonological tone identity at the end of an utterance. Third, question-final lexical tones are rarely affected by intonation perceptually. Each tone in statements or in questions can be easily recognized by listeners [23]. Jiang and Chen [24] showed that cutting off the final tone does not significantly influence perception. What is important to questioning is the last prosodic word of the utterance.

1.3. Intonation of Cantonese

This study includes Cantonese listeners because Cantonese intonation patterns are different from Mandarin. Cantonese yes-no questions are signaled by a final rising that change the canonical tone shape of any tone at the end of the questions [25]-[27]. In addition, global F0 contour does not play an important part in questioning [27], [28]. As a result, Cantonese listeners may have different interpretation of Mandarin intonation patterns from native listeners.

1.4. Cross-linguistic perception of prosodic features

An important theme in cross-linguistic perception is how phonetic forms are shaped in the perception with different language backgrounds [29], [30]. Huang and Johnson [31] showed that language experience was impactful in the perception of tonal contrasts even in low-level psychoacoustic processing. Burnham et al. [32] showed that tonal contrasts in musical sounds were better discriminated than in low-pass filtered speech, which in turn was better discriminated than in

normal speech, indicating that listeners were more sensitive to acoustic differences in non-speech signal than in speech.

While some studies showed that language background played an important role in perceiving intonation [33], [34], Gussenhoven and Chen [35] showed that listeners with different native languages associated question intonation with a later or a higher F0 peak and higher end pitch in a made-up speech, concurring with the Frequency Code that a high or rising pitch contour is associated with questioning. Grabe et al. [29] suggested that experience with a native language was added to the universal auditory mechanism in shaping listeners' perception of intonation.

1.5. Summary

Previous studies have shown that the Frequency Code plays an important part in intonation perception [35], but intonation perception is also shaped by listeners' first language intonation phonology[33], [34]. However, no previous studies have systematically demonstrated the interactions between these factors. This study aims to fill in this research gap.

2. Method

2.1. Materials

Nine-syllable sentences in Mandarin shown in Table 2 were designed for the experiment. The final two syllables of each sentence share the same lexical tone. With the final syllable cut off, the utterances still remained meaningful, and the ending tone remained the same (with the exception of T3 because of unavoidable tone sandhi).

Table 2. *Mandarin utterances used in the experiment*

Finals	Sentences (Chinese, pinyin and English translation)
T1	妈妈今晚炖的是鸡(汤)。 ma1 ma jin1 wan3 dun4 de shi4 ji1 (tang1). 'Mommy cooked chicken (soup) for tonight'
T2	亚马逊是最长的河(流)。 ya3 ma3 xun4 shi4 zui4 chang2 de he2 (liu2). 'Amazon is the longest river.'
T3	他最大的缺点是懒(散)。 ta1 zui4 da4 de que1 dian3 shi4 lan3 (san3). 'His biggest shortcoming is laziness.'
T4	工人在修公园的路(面)。 gong1 ren2 zai4 xiu1 gong1 yuan2 de lu4 (mian4). 'The workers are repairing the road in the park.'

Two native speakers, both professional Mandarin teachers, (male aged 30 from Shaanxi, female aged 26 from Hubei) were recorded reading the sentences for the experiment. The recording took place in a sound-treated room. The speakers were instructed to read the sentences focus-neutrally.

After screening the naturalness of the recordings, four presentation sentence conditions (complete statement and question, statement and question with the final syllable cut-off) were prepared for the perception test for two experiment contexts (normal speech and low-pass filtered speech). All cutting points were at zero crossing following the offset of the penultimate syllables of the utterances. The average amplitude of all the utterances was also normalized. Low-pass filters were applied with 100 Hz bandsmoothing. The cutoff frequency was determined by the highest pitch each speaker produced in their T2 questions, being 250 and 400

Hz for the male and female speakers respectively. Informal tests showed that native speakers of both languages could not understand the content of the low-pass filtered sentences They reported only hearing some low frequency humming.

2.2. Listeners and procedure

20 Cantonese and 20 Mandarin listeners participated in the perception experiment. All the Cantonese listeners were native Hong Kong Cantonese speakers, speaking Mandarin with varying proficiency. All the Mandarin listeners came from Northern China. They all spoke English as a foreign language. None of them have received any systematic training in linguistics when they participated in the experiment. None had a reported history of speech or hearing disorder.

The perception experiment was carried out in a sound-attenuated room. The materials were presented to them using the software E-Prime. After a practice session, the listeners finished the section with low-pass filtered speech before the section with normal speech, to prevent them from guessing the content of the filtered materials. In the filtered section, two blocks of filtered Cantonese utterances were used as fillers to conceal the identity of language the listeners heard. The blocks and the tokens within each block were randomized. Each of the 64 stimuli (4 sentence conditions × 2 contexts × 2 genders × 4 tones) was repeated twice. Listeners listened to each trial only once before they decided whether the utterance they just heard was a statement or a question by pressing a button on the keyboard.

2.3. Data analysis

Average identification accuracy (IA) were calculated. Three-way (Intonation type × Condition × Final tone) repeated measures ANOVAs were conducted on the identification scores. Corrections for violations of sphericity were made, where appropriate, using the Greenhouse–Geisser estimates of sphericity. Bonferroni correction was applied for pairwise comparisons.

3. Results

3.1. Mandarin listeners: Normal speech

Figure 1 shows the identification accuracy for Mandarin listeners listening to normal utterances. The main effects of Intonation type [$F(1,19)=23.02$, $p<0.001$], Condition [$F(1,19)=148.52$, $p<0.001$] and Final tone [$F(3,57)=18.65$, $p<0.001$] are all significant. In the complete utterance condition, statements were well identified across different tones. T3 (M=78%, SD=0.26) complete question has the lowest IA, significantly lower than T2 and T4 ($p<0.05$ in each comparison). In the cut-off condition, while T1, T2 and T4 statements remain well identified, T3 statement has the lowest IA (M=74%, SD=0.29), probably due to the penultimate high rising pitch contour induced by tone sandhi. The IA of T3 cut-off statement is significantly lower than T2 and T4 statements ($p<0.05$ in each comparison). Among the cut-off questions, T4 question remains almost unaffected by the elimination of the last syllable, while the IA for T1 and T2 questions become much lower than their complete counterparts. The identification accuracy for T4 is significantly higher than all the other tones ($p<0.05$ in every comparison). The results suggest that T3 is a difficult tone to identity in Mandarin

questions in the compete condition. In contrast, T4 may be the easiest ending tone for Mandarin questions. Cutting off the final syllable influences the perception of intonation, but the exact influence depends on different tones.
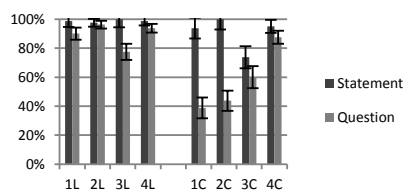

Figure 1: *IA of normal utterances by Mandarin listeners.*
(L: complete utterances; C: cut-off utterances)

3.2. Cantonese listeners: Normal speech

Figure 2 shows that Cantonese listeners had lower IA than native Mandarin listeners, especially for questions. The main effect of Intonation type [$F_{(1,19)}$=71.31, $p<0.05$], Condition [$F_{(1,19)}$=55.50, $p<0.05$] and Final tones [$F_{(3,57)}$=13.10, $p<0.05$] are all significant. For the complete utterances, listeners performed well for statements with all ending tones. This is not the case for questions, as T3 complete question is poorly identified (M=43%, SD=0.20, below chance level). The IA is significantly lower than complete questions with the other tones ($p<0.05$ in every comparison). For the cut-off statements, T3 statements is the worst identified (M=71%, SD=0.34), with IA significantly lower than the other tones ($p<0.05$ in every comparison). For the cut-off questions, T1 and T2 questions (both identified below chance level) are identified significantly more poorly than T3 and T4 questions ($p>0.05$ in every comparison). There are no significant differences between the IAs of T1 and T2 ($p>0.05$) or between those of T3 and T4 ($p>0.05$). The result shows that Cantonese listeners also found T3 to be a difficult ending tone. They also found questions ending with T1 and T2 in the cut-off condition confusing.
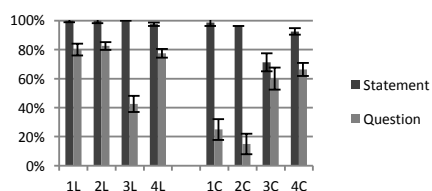

Figure 2: *IA of normal utterances by Cantonese listeners.*

3.3. Mandarin listeners: Filtered speech

Figure 3 shows the identification accuracy for Mandarin listeners listening to low-pass filtered utterances. The main effect of Intonation type [$F_{(1,19)}$=57.39, $p<0.001$], Condition [$F_{(1,19)}$=173.57, $p<0.001$] are significant. Although the main effect of Final tone is not significant [$F_{(3,57)}$=1.73, $p>0.05$], the significant interactions Final tone × Intonation type [$F_{(2.29,43.59)}$=15.94, $p<0.001$] and Final tone × Condition [$F_{(3,57)}$=6.74, $p<0.01$] suggest that tones affect listeners' identification depending on the intonation type and condition. For example, complete question ending with T3 (M=76%, SD=0.23) is the least well identified by listeners among the

complete questions, significantly poorer than T1 (M=93%, SD=0.14, $p<0.05$). Among the cut-off utterances, T3 statement is significantly more poorly identified than statements in all other tones, whereas T3 question is significantly better identified than the other tones ($p<0.05$ in all comparisons), both owing to the rising penultimate tone due to tone sandhi. Besides, within the cut-off condition, T4 question (M=51%, SD=0.37) is significantly better identified than T1 question (M=25%, SD=0.26, $p<0.05$), suggesting that for Mandarin listeners, questions ending with T4 are still easier to identify than some other tones, even though the original final tone is cut off.
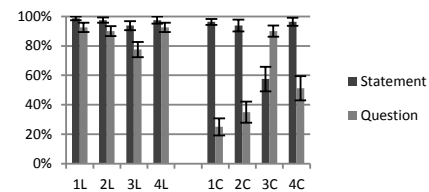

Figure 3: *IA of filtered utterances by Mandarin listeners.*
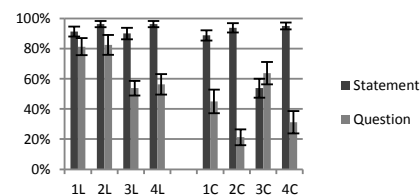
3.4. Cantonese listeners: Filtered speech

Figure 4: *IA of filtered utterances by Cantonese listeners.*

Figure 4 shows the patterns of Cantonese listeners' identification accuracy for filtered Mandarin utterances. The main effect of Intonation type [$F_{(1,19)}$=40.69, $p<0.001$], Condition [$F_{(1,19)}$=69.82, $p<0.001$], and Final tone [$F_{(3,57)}$=5.28, $p<0.005$] are all significant. In the complete condition, the identification accuracy of T3 (M=54%, SD=0.22) question is significantly lower than T1 (M=81%, SD=0.25) and T2 (M=83%, SD=0.29) questions ($p<0.05$ in each comparison). In the cut-off condition, the T3 utterances end with the sandhi-ed T3 with a rising contour. As a result, the T3 cut-off question (M=64%, SD=0.33) was better identified than the other tones (comparisons with T2 (M=21%, SD=0.23) and T4 (M=31%, SD=0.33) questions were significant, $p<0.05$). The T3 cut-off statement (M=54%, SD=0.28) was identified most poorly among all the tones (significant compared with every other tone, $p<0.05$). Furthermore, unlike the patterns of Mandarin listeners, the T4 complete question (M=56%, SD=0.30) was poorly identified by Cantonese listeners, with the accuracy significantly lower than that of T1 and T2 questions ($p<0.05$ in each comparison). The identification of T2 cut-off question (M=21%, SD=0.23) was also not successful, significantly poorer than T1 and T3 ($p<0.05$ in each comparison). The perceptual patterns suggest that Cantonese speakers mainly use the final tone in their judgment, much like the way they identify intonation type in their own language. Final high level and high rising pitch contours (in the case of complete T1, T2 utterances and cut-off

sandhi-ed T3 utterances) seem to be a strong indicator for question, while a dipping tone and a falling tone (complete T3 and T4 utterances) were associated with statements.

4. Discussion

This study examined the perception of three kinds of materials: native speech as a baseline, non-native speech, and filtered-speech. In general, the listeners from both groups performed well in the complete utterance condition. There is no significant difference in IA among different tones in complete utterances, except that the IA of T3 complete question was significantly lower than the other tones. On the other hand, eliminating the last syllable affects listeners' judgment of questions, but not so much of that of statements. With the exception of sandhi-ed T3, the IA of the cut-off questions is lower than that of complete questions across listener groups and experiment contexts.

Our data show that perception of intonation is influenced by phonological knowledge. For example, Mandarin final T4 benefits question identification because native listeners are sensitive to the identity of final tone in questions [13] (Cantonese listeners also have experiences in speaking Mandarin). This seems to be the case in the normal speech context. In the cut-off condition, T4 question was hardly influenced by the loss of the final tone, and was significantly better identified than questions with all the other tones. However, when the identity of language and lexical tone were concealed from the listeners by the low-pass filter, listeners were unable to use the knowledge of tone-intonation interaction to identify questions. Therefore, the IA of T4 questions decreased for both groups of listeners, especially in the cut-off condition, suggesting that the absence of phonological knowledge affects the identification of questions.

When perceiving non-native speech, Cantonese listeners' identification of Mandarin intonation was facilitated by different tools that interacted with each other. In most cases, they used the phonological knowledge of intonation in Cantonese by locating the perceptual cue for question at the end of the utterances, as this is where the cue for their native language is placed. Then they made use of the Frequency Code to associate a high rising tone with questions and a low tone with statements. For example, they performed well in T3 cut-off questions but performed poorly for T3 complete questions. Finally, the experience in knowing Mandarin also helped them to identify questions with T4.

In the low-pass filtered speech, segmental information was eliminated and F0 became the main resource of information left in the stimuli. Therefore, the use of native phonological knowledge was restricted and the Frequency Code might have become the most, if not the only, available and useful tool for intonation perception. The listeners performed generally quite well in perceiving the low-pass filtered speech, indicating that F0 provided most information for intonation perception. The role of the Frequency Code can be observed from the results. On the one hand, the canonical T3 (low tone) is associated with a statement. On the other hand, the cut-off T3 statement ending with a rising tone was identified significantly less successfully than the other tones; and the cut-off T3 question was identified more accurately than the other tones, especially in the low-pass filtered speech, where the Frequency Code dominated the process of the perception.

To sum up, listeners process different materials differently. When listening to native speech, they primarily use their phonological knowledge of the language. For non-native speech, both the Frequency Code and some phonological knowledge were used. For filtered-speech (or non-speech), the Frequency Code becomes the most useful tool. In other words, the biologically-based universal Frequency Code lays the foundation for perception, while phonological knowledge comes into play when native speech materials are used. When phonological knowledge and the Frequency Code contradicted with each other, the former takes advantage in the perception of native language.

However, although the Frequency Code is shown to have dominated the perception of intonation in the filtered context, the perceptual patterns of the two groups of listeners were not identical. For example, the IA of T1 cut-off question is not significantly different from T3 question for Cantonese listeners, but is significantly lower than T3 questions for Mandarin listeners. T4 complete question was well identified by Mandarin listeners but not so by Cantonese listeners. These differences stem from the different language backgrounds the two groups of listeners have, suggesting that language experience shapes prosodic perception even in the low-level processing of unintelligible filtered speech. This finding echoes previous study in cross-linguistic perception of lexical tone by Huang and Johnson [31].

Finally, the results further the insights into question-statement bias previously observed in individual languages [13]. For both groups of listeners, the IA of questions was constantly lower than that of statements, especially in cut-off utterances. The fact that both groups of listeners showed the same preference towards statements suggests that the bias towards statement being an unmarked sentence type may be universal.

5. Conclusions

In conclusion, the results demonstrate that two interactions in intonation perception. One of them is the interaction between tone and intonation: no matter how intonation modifies F0 contour, at the final tone or on a sentential level, listeners are sensitive to the identity of lexical tone at the end of the utterance. Therefore, the processing of tone and intonation in tone languages is interdependent. More importantly, phonological knowledge and the Frequency Code co-direct listeners' perception of intonation, especially when listeners are given a less familiar language or filtered speech. Listeners follow the Frequency Code when phonological knowledge is not applicable. When the linguistic resources are rich in the speech signal, and when phonological knowledge and the Frequency Code conflict with each other, phonological knowledge would override the Frequency Code. As a result, listeners could perceive intonation patterns that seemingly contradict the Frequency Code in their native/familiar language. Furthermore, language background is an important and robust factor in intonation perception even with filtered speech materials, as different patterns arose from the two groups of listeners because of their language background. The results also confirm that statements are generally identified better than questions. This tendency applies to intonation perception cross-linguistically.

6. References

[1] Ohala, J. J. "Cross-language use of pitch: an ethological view", *Phonetica*, 40, 1–18, 1983.

[2] Gussenhoven, C. *The Phonology of Tone and Intonation*, Cambridge University Press, 2004.

[3] Chao, Y. R. "Tone and intonation in Chinese", *Bull. Inst. Hist. Philos.*, 4, 121–134, 1933.

[4] Shih, C. "The Prosodic Domain of Tone Sandhi in Chinese", Ph.D dissertation, University of California, San Diego, 1986.

[5] Wang, W. S.-Y., and Li, K. "Tone 3 in Pekinese", *J. Speech Hear. Res.*, 10(3), 629–636, 1967.

[6] Peng, S. "Lexical versus 'phonological' representations of Mandarin sandhi tones", in M. B. Broe and J. Pierrehumbert [ED], *Acquisition and the lexicon: Papers in Laboratory Phonology V*, 152–167, Cambridge: Cambridge University Press, 2000.

[7] Ho, A. T. "Intonation variation in a Mandarin sentence for three expressions interrogative, exclamatory and declarative", *Phonetica*, vol. 34, pp. 446–457, 1977.

[8] Wu, Z. "Variation of lexical tones in Mandarin intonation", *Studies of The Chinese Language*, vol. 6, pp. 439–449, 1982.

[9] Lin, M. "On Production and Perception of Boundary Tone in Chinese Intonation", in *Proceedings of the International Symposium on Tonal Aspects of Languages*, 2004.

[10] Peng, S., Chan, M. K. M., Tseng, C., Huang, T., Lee, O. J., and Beckman, M. E. "Towards a Pan-Mandarin system for prosodic transcription", in S.-A. Jun [ED], *The Phonology of Intonation and Phrasing*, 1-63. 2006.

[11] He, Y. and Jin, S. "Experimental investigation of intonation in Beijing Mandarin." *Language Teaching and Research*, 2, 71–96, 1992.

[12] Yuan, J., Shih, C. and Kochanski, G. P. "Comparison of declarative and interrogative intonation in Chinese", in *Proceedings of Speech Prosody*, 711–714, 2002.

[13] Yuan, J. "Intonation in Mandarin Chinese: Acoustics, perception, and computational modeling", PhD Dissertation, Cornell University, 2004.

[14] Shi, P. "Intonation variations in four types of Mandarin sentences", *Language Teaching and Research*, 2, 71–81, 1980.

[15] Gårding, E. "Chinese and Swedish in a Generative Model of Intonation", in C.-C. Elert and I. Johansson, [ED], *Nordic Prosody III*, Stockholm: University of Umeå, 79– 91, 1984.

[16] Gårding, E. "Speech act and tonal pattern in Standard Chinese: constancy and variation", *Phonetica* 44 13-29, vol. 44, pp. 13–29, 1987.

[17] Shen, J. "The tone range and intonation of Beijing Mandarin", in T. Lin and L. Wang, [ED], *Exprimental Phonetic Studies of Beijing Mandarin*, 73–130, 1985.

[18] Shen, J. "Construction and types of Chinese intonation", *Dialect*, 3, 221–228, 1994.

[19] Shen, X. S, *The prosody of Mandarin Chinese*, University of California Press, 1990.

[20] Yuan, J. "Mechanisms of question intonation in Mandarin", in, Q. Huo, B. Q. Ma, E.-S. Cheng, and H. Li [ED], *Chinese Spoken Language Processing*, Springer, 19–30, 2006.

[21] Lee, O. J. "The prosody of questions in Beijing Mandarin", PhD dissertation, The Ohio State University, 2005.

[22] Yuan, J. "Perception of intonation in Mandarin Chinese", *J. Acoust. Soc. Am.*, 130(6), 4063–4069, 2011.

[23] Connell, B. A., Hogan, J. T., and Rozsypal, A. J., "Experimental evidence of interaction between tone and intonation in Mandarin Chinese", *J. Phon.*, 11, 337–351, 1983.

[24] Jiang, P., and Chen, A., "Representation of Mandarin intonations: Boundary tone revisited", in *Proceedings of the North American Conference on Chinese Linguistics*, 1, 97–109, 2011.

[25] Ma, J. K.-Y., Ciocca, V., and Whitehill, T. L., "Effect of intonation on Cantonese lexical tones", *J. Acoust. Soc. Am.*, 120(6), 3978–3987, 2006.

[26] Gu, W., Hirose, K., and Fujisaki, H., "Modeling the Effects of Emphasis and Question on Fundamental Frequency Contours of Cantonese Utterances", *IEEE Trans. audio, speech Lang. Process.*, 14(4), 1155–1170, 2006.

[27] Lee, H.-Y. D., "The Intonation of Cantonese Declarative Questions", MPhil dissertation, Cambridge, 2008.

[28] Xu, B. R., and Mok, P., "Final rising and global raising in Cantonese intonation", in *Proceedings of International Congress of Phonetic Sciences*, 2173–2176, 2011.

[29] Grabe, E., Rosner, B. S., and Garcia-Albea J. E., "Perception of English Intonation by English, Spanish, and Chinese Listeners", *Lang. Speech*, 46(4), 375–401, 2003.

[30] Vaissiere, J., "Perception of intonation", in D. B. Pisoni and R. E. Remez [ED], *The Handbook of Speech Perception*, Blackwell Publishing, 236–263, 2005.

[31] Huang, T., Johnson, K., "Language specificity in speech perception: perception of Mandarin tones by native and nonnative listeners", *Phonetica*, 67(4), 243–67, 2010.

[32] Burnham D., Francis, E., Di, W., Sudaporn L., Chayada A., Lacerda, L. F. and Peter K., "Perception of lexical tone across languages: Evidence for alinguistic mode of processing", in *Proceedings of the International Conference on Spoken Language processing*, 2514–2517,1996.

[33] Handding-Koch, K. and Studdert-Kennedy, M., "An experimental study of some intonation contour", *Phonetica*, 11, 175–185, 1964.

[34] Jiang, P. and A. Chen, "Tonal effect on Mandarin intonation perception : A comparative study of listeners with different L1 backgrounds Research questions", in *International Symposium on Bilingualism and Comparative Linguistics*, 2012.

[35] Gussenhoven, C. and Chen A., "Universal and language-specific effects in the perception of question intonation", in *Proceedings of International Conference on Spoken Language Processing*, 2000.

[36] Grabe, E., Rosner, B. S., and Garcia-Albea, J. E., "Perception of English Intonation by English, Spanish, and Chinese Listeners", *Lang. Speech*, 46(4), 375–401, 2003.