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1 **The role of spectro-temporal fine structure cues**
2 **in lexical-tone discrimination for French and Mandarin adult listeners**

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26 Running title: weight of modulation cues in lexical tones

1 **Abstract**

2 The importance of spectro-temporal modulation cues in conveying tonal information for
3 lexical tones was assessed in native-Mandarin and native-French adult listeners using a
4 lexical-tone discrimination task. The fundamental frequency (F0) of Thai tones was either
5 degraded using an 8-band vocoder that reduced fine spectral details and frequency-modulation
6 cues, or extracted and used to modulate the F0 of click trains. Mandarin listeners scored lower
7 than French listeners in the discrimination of vocoded lexical tones. For click trains, Mandarin
8 listeners outperformed French listeners. These preliminary results suggest that the perceptual
9 weight of the fine spectro-temporal modulation cues conveying F0 information is enhanced
10 for adults speaking a tonal language. PACS numbers: 43.71 Rt, 43.71 Hw, 43.66 Mk

11

12 **I. INTRODUCTION**

13 Tonal variations at the syllable level distinguish word meaning in tonal languages
14 (*e.g.*, Liang, 1963). Native listeners rely mainly on fundamental-frequency (F0)—and thus,
15 voice-pitch cues—to discriminate lexical tones. However, other acoustic cues such as duration,
16 amplitude or voice quality may also play a secondary role (*e.g.*, Kuo *et al.*, 2008; Whalen and
17 Xu, 1992).

18 Over the last decades, psycholinguistic studies have investigated whether being native
19 (*i.e.*, expertise) in tonal language influences the relative weight of these acoustic cues in
20 lexical-tone perception (Gandour and Harshman, 1978). Burnham and Francis (1997) showed
21 that non-native (English-speaking) listeners are less accurate in discriminating lexical tones
22 than native (Thai-speaking) listeners (see also Burnham and Mattock, 2007). Their results
23 also suggested that non-native listeners rely more on mean F0 to perceive tones compared to
24 native listeners who are able to categorize F0 patterns in spite of phonetic and tonal variability
25 (*i.e.*, small variations in pitch within the same category). Lee *et al.* (2008) explored further the

1 influence of the native language on the identification of lexical tones by using degraded
2 speech sounds (*i.e.*, “fragmented” tones obtained by removing a variable number of F0
3 periods at the onset, center or final part of the syllables). Lexical tone identification
4 performance was affected by these degradations of F0 information for the non-native listeners
5 (English speakers learning Mandarin) only. These results confirm that non-native listeners
6 rely heavily on mean F0 whereas native listeners (Mandarin speakers) rely more on F0
7 direction (see also Huang and Johnson, 2010). Altogether, these studies are compatible with
8 the notion that expertise in tonal language influences the relative importance of the acoustic
9 cues involved in lexical-tone perception. From a wider perspective, they are consistent with
10 the idea that linguistic experience shapes the weight of acoustic cues in speech perception
11 (*e.g.*, Burnham and Mattock, 2007).

12 The search for the acoustic cues used in discriminating or identifying lexical tones has
13 been recently renewed by the use of “vocoders” that manipulate the spectral and temporal
14 modulation components of speech signals (see Shamma and Lorenzi, 2013 for a review). The
15 slowest amplitude-modulation cues (AM, corresponding to the relatively slow variations in
16 amplitude over time) play a major role in consonant recognition, whereas the fast AM cues,
17 frequency-modulation cues (FM, corresponding to the oscillations in instantaneous frequency
18 close to the center frequency of the frequency band), and fine spectral details are more
19 important in lexical-tone recognition. Chinese-speaking listeners have been shown to rely
20 more on the FM cues (*e.g.*, Wang *et al.*, 2011; Xu and Pfingst, 2003) cues compared to
21 English- or French-speaking listeners who hinge on AM cues to identify native speech sounds
22 (*e.g.*, Shannon *et al.*, 1995; Smith *et al.*, 2002). Fu *et al.* (1998) showed that for native
23 Mandarin speakers, lexical-tone recognition was more affected by a reduction of temporal
24 resolution (that is by the selective attenuation of the fast [F0-related] AM cues above 50 Hz)
25 than by a reduction of spectral resolution (tones were vocoded using a decreasing number [4,

1 3, 2, and 1] of broad frequency bands). In contrast, consonant and vowel recognition was
2 found to be mostly affected by a reduction of spectral resolution. In addition, Xu *et al.* (2002)
3 and Kong and Zeng (2006) showed a clear dependence of lexical tone recognition on spectral
4 resolution when the number of frequency bands varied from 1 to 32.

5 However, the vocoder-based studies cited above did not compare *directly* lexical-tone
6 recognition across listeners from different linguistic backgrounds using the same material and
7 procedure. Thus, it is still unclear whether the native language of adult speakers influences the
8 weight of the spectro-temporal modulation cues conveying F0 information in speech
9 perception. The goal of the present pilot study was to assess the effect of two different native
10 languages on the ability to use fine spectral details and FM cues in lexical-tone
11 discrimination. This comparison should reveal to what extent native language shapes the
12 perception of speech modulation cues. Three conditions were designed to: 1) preserve the
13 original speech modulation cues of lexical tones, 2) degrade the fine spectral details and FM
14 speech cues of lexical tones and thus the F0-related information and 3) generate sounds (click
15 trains) preserving only the F0-related FM cues of the original lexical tones. First, it was
16 hypothesized that native French-speaking listeners should be less accurate in lexical-tone
17 discrimination than native Mandarin-speaking listeners. Second, if Mandarin listeners rely
18 more on F0 direction than French listeners, they should be more affected by the degradation
19 of fine spectral and FM cues than the French ones. Third, if exposure to a tonal language
20 results in a higher perceptual weight of the fine spectral than temporal cues in perceiving F0
21 information for both speech and click-train sounds, Mandarin-speaking listeners should be
22 more accurate in the discrimination of F0 contours in the click-train condition than French-
23 speaking listeners (see Xu *et al.*, 2002). The present study used a same/different task to assess
24 the discrimination of lexical tones. Three Thai lexical tones were used in order to present non-
25 native stimuli for both French and Mandarin-speaking listeners and use similar stimuli than

1 those used in Burnham and Francis (1997): low, rising, and falling F0 patterns. We assumed
2 that the discrimination abilities of native Mandarin-speaking listeners should be facilitated by
3 their experience in lexical tone processing. Participants had to discriminate the following
4 three contrasts: rising/low, rising/falling, and low/falling using a same/different task. The
5 rising/low contrast would be the most difficult to discriminate for non-lexical users because of
6 the highly similar F0 trajectories until the mid-point of the tone. It is not the case for the rising
7 and falling tones that have totally different F0 trajectories and differ on other cues such as
8 duration, making them easier to distinguish (see Abramson, 1978). In addition, two different
9 inter-stimulus intervals (ISI) were used (500 and 1500 ms) in the present same/different task.
10 As suggested in previous studies (see Burnham and Francis, 1997; Clément *et al.*, 1999;
11 Werker and Tees, 1984) long ISI may affect information loss in the short-term memory
12 representation of the cues used to discriminate two sounds. We assumed that a long ISI (1500
13 ms) may affect the rate of information loss in the short-term memory representation of the
14 voice-pitch cues used to discriminate lexical tones compared to a short ISI (500 ms). This
15 effect may be greater for the French-speaking listeners than Mandarin-speaking listeners.

16 **II. METHOD**

17 **A. Participants**

18 One hundred and twenty young adult subjects, were split into 12 groups of 10 subjects.
19 No participant reported any history of speaking or hearing disorders. Sixty native French
20 speakers, born and raised in France, were tested in Paris, France (age range = [21-34 years];
21 mean = 24; standard deviation (SD) = 2.5 years; 24 females). They did not learn any tonal
22 language. The other 60 participants were native Mandarin speakers, born and raised in
23 Taiwan, and tested in Taipei, Taiwan (age range = [19-29]; mean = 23 years; SD = 2.5 years;
24 33 females). For each participant the musical experience was assessed and 52 native French-

1 speaking and 44 native Mandarin-speaking listeners reported to practice music. Table 1
2 summarizes the participants' characteristics.

3 -Table 1 about here-

4 **B. Stimuli**

5 Three Thai tones (rising, falling and low) were pronounced by a native female speaker
6 asked to speak clearly (F0 range=100-350 Hz, as estimated by YIN algorithm; de Cheveigné
7 and Kawahara, 2002) with the syllable /ba/ (see the Figure 1 for a representation of the F0
8 trajectories, the sound files also available online). All stimuli were recorded digitally via a 16-
9 bit A/D converter at a 44.1-kHz sampling frequency. In each lexical tone, eight different
10 tokens were chosen because of their higher clarity. The mean duration of the stimuli was
11 661.6 ms (SD=32.3 ms) for the rising tones, 509.9 ms (SD=36.8) for the falling tones, and
12 636 ms (SD=31.2) for the low tones.

13 -Figure 1 about here-

14 In the first condition ("Intact"), each digitized signal was passed through a bank of 32,
15 fourth-order gammatone filters (Gnansia *et al.*, 2009; Patterson, 1987) -also called "analysis
16 filters" hereafter, each 1-ERB_N-wide (average equivalent-rectangular-bandwidth of the
17 auditory filter as determined using young normally hearing listeners tested at moderate sound
18 levels; Moore, 2007) with CFs uniformly spaced along an ERB_N-number scale (one filter per
19 ERB_N) ranging from 80 to 8020 Hz. The Hilbert transform was then applied to each bandpass
20 filtered speech signal to extract the AM and FM components. The temporal envelope (AM
21 component) was lowpass filtered using a zero-phase Butterworth filter (36 dB/octave rolloff).
22 Cochlear filtering (modelled here by gammatone filtering) imposes limitations on the
23 maximum AM rate. As in Gnansia *et al.* (2009), we adjusted the cutoff frequency of the
24 lowpass filter (following gammatone filtering) to ERB_N/2; the ERB_N corresponded to that of
25 the (normal) cochlear filter tuned to the geometric center of the 1-ERB_N wide gammatone

1 filter. In each band, the FM carrier was then multiplied by the filtered AM function. Finally,
2 the narrowband speech signals were added up and the level of the resulting speech signal was
3 adjusted to have the same root-mean square (RMS) value as the input signal. In this condition,
4 speech processing resulted in near-perfect stimulus reconstruction.

5 In the second condition (“Vocoded”), the same signal processing scheme was used,
6 except that each digitized signal was passed through a bank of 8, fourth-order gammatone
7 filters, each 4- ERB_N -wide with CFs uniformly spaced along an ERB_N -number scale (one filter
8 per ERB_N) ranging from 80 to 8020 Hz. In this condition, the cut-off frequency of the low-
9 pass filter used to extract temporal envelopes was set to $ERB_N/2$; the ERB_N corresponded to
10 that of the (normal) cochlear filter tuned to the geometric center of the 4- ERB_N wide
11 gammatone filter. The original FM carriers were replaced by sine wave carriers with
12 frequencies at the center frequency of the gammatone filters, and with random starting phase
13 in each analysis band.

14 In a third condition (“F0-modulation”), the stimuli were generated by first extracting
15 the F0 trajectory of each original lexical tone using the YIN algorithm (de Cheveigné and
16 Kawahara, 2002; implemented in MATLAB, MathWorks, Natick, MA). Then, this F0
17 trajectory was used to modulate the F0 of a periodic click train (more precisely, the signal was
18 a periodic click train of 88- μ s square (*i.e.*, monophasic) pulses, which were repeated at a rate
19 equal to $1/F0$). A first order (butterworth) lowpass filter was used to limit the frequency range
20 below 22050 Hz. The “F0-modulation” signals have the same duration as the original lexical
21 tones (sound samples are provided on-line in the JASA supplementary material).

22 This study intended to measure lexical-tone discrimination on the sole basis on
23 temporal-envelope (AM) cues for lexical-tone users and non-users. Note that the stimuli were
24 not normalized in duration, because duration cues are considered to be an element of

1 temporal-envelope cues (Rosen, 1992). Thus, normalization in duration would degrade
2 envelope cues.

3 **C. Procedure**

4 A same/different task like Burnham and Francis (1997) was used to assess
5 discrimination using E-Prime 2.0 software (Psychology Software Tools). Two different ISIs
6 (500 and 1500 ms) were used. In each vocoder condition (Intact, Vocoded or F0-
7 modulations), eight practice trials, with feedback, were first presented with unrelated sounds
8 (unprocessed syllables /ko/ and /mi/) to train subjects with the task. This was followed by a
9 test phase composed of 48 test trials, without feedback. Half of the trials consisted of the
10 presentation of two stimuli of the same category, and the other half in the presentation of two
11 stimuli belonging to two different categories (8 trials per contrast: rising/low, rising/falling,
12 and low/falling). “Same” and “different” trials were presented in random order within two
13 blocks (of 24 trials). Each subject was randomly assigned to a given experimental condition
14 (Intact, Vocoded or F0-modulations) and a given ISI duration (500 or 1500 ms) in order to
15 reduce training effect between conditions and prevent recognition of the sounds in the
16 degraded conditions. Thus, six independent groups of ten adults from each language
17 background were tested in a soundproof booth in Paris or in Taipei using the same material
18 and by the same experimenter. All stimuli were presented in free field using a Fostex (model
19 PM0.5) speaker at a 70 dB SPL. Subjects sat in front of a computer controlling the experiment
20 and 50 cm from the speaker located on their right side (*i.e.*, at 40 deg azimuth and 0 deg
21 elevation). Subjects were instructed to listen carefully to the pairs of sounds and to respond as
22 fast and as accurately as possible by pressing two different keys (indicating same or different).
23 The subject’s accuracy was estimated by a d' score where $d' = Z[p(\text{hit}) - Z[p(\text{false alarms})]]$
24 (see Macmillan and Creelman, 1991). If the hit rate was 1.0 or the false alarm rate was 0, d'

1 was calculated after adjusting the hit rate or false alarm rate by the reciprocal of the number of
2 trials.

3 **III. RESULTS**

4 The d' scores of the native-Mandarin and native-French participants for each tone
5 contrast are represented in Figure 2 for the “Intact”, “Vocoded” and “F0-modulations”
6 conditions. A d' of 0 corresponds to chance, and a d' of 2.68 corresponds to perfect
7 discrimination. French and Mandarin speakers showed similar discrimination performance in
8 the “Intact” speech condition. In the “Vocoded” speech condition, the performance of both
9 groups decreased significantly but remained above chance level. Moreover, Mandarin
10 speakers scored lower than French speakers in this condition (when the fine spectro-temporal
11 modulation cues conveying voice-pitch information were severely degraded). In the “F0-
12 modulations” condition, Mandarin speakers showed slightly better discrimination of (F0)
13 pitch contours compared to French speakers.

14 -Figure 2 about here-

15 Even if native French-speaking listeners had more practice in music than native
16 Mandarin-speaking listeners [mean=6.30, sd=6.14, vs. mean=3.61, sd=3.8 for years of
17 musical practice], a preliminary analysis of variance (ANOVA) on the total d' score showed
18 no main effect of the factor Musician or interaction with Language. Thus, data were collapsed
19 across this variable in the main analyses. A repeated-measures ANOVA was performed with
20 Condition (Intact vs. Vocoded vs. F0-modulations), ISI (500 ms vs. 1500 ms) and Language
21 (French vs. Mandarin) as between-subject factors and Contrast (rising/low vs. rising/falling
22 vs. low/falling) as within-subject factor, to assess the role of Language and ISI in the three
23 experimental conditions on the d' scores. This analysis revealed a main effect of Condition
24 [$F(2,108)=125.54, p < .001$] and a *post-hoc* Tukey’s HSD test showed that the “Vocoded”
25 speech condition led to lower discrimination scores compared to “Intact” and “F0-

1 modulations” conditions (see Figure 2). No main effect of ISI or Language was found.
2 However, a main effect of Contrast was found [$F(2,216)=5.4, p=.005$]. *Post-hoc* comparisons
3 (Tukey’ HSD test) showed that as expected, the “rising-falling” contrast was easier to
4 discriminate than “rising-low”; no difference was observed between the other two contrasts.
5 Moreover, a significant Condition x Contrast interaction was observed [$F(4,216)=4.1, p=.003$]
6 indicating that the “rising-falling” contrast was easier to discriminate than the “rising-low”
7 contrast in the “Vocoded” speech condition. Furthermore, the significant interaction of
8 Condition x Contrast x Language [$F(4,216)=3.51, p=.008$] revealed that the higher scores
9 obtained for the “rising-falling” contrast were mainly obtained by Mandarin-speaking
10 listeners.

11 The significant interaction Contrast x ISI x Language [$F(2,216)=3.28, p = .04$]
12 indicated that the better d' scores for the “rising-falling” contrast were exhibited by the
13 French-speaking listeners with an ISI of 500 ms and by the Mandarin ones with an ISI of
14 1500 ms. Finally, a significant interaction between Condition x ISI x Language
15 [$F(2,108)=4.12, p = .02$] showed that French-speaking participants were better than Mandarin
16 ones with a short ISI in the “Vocoded” condition.

17 A significant interaction Condition x Language was also found [$F(2,108)=5.79, p$
18 $=.004$]. To explore further this interaction and to compare the discrimination performance of
19 Mandarin and French-speaking listeners in each condition, separated repeated-measures
20 ANOVAs were run with Language (French vs. Mandarin) and ISI (500 ms vs. 1500 ms) as
21 between-subject factors and Contrast (rising/low vs. rising/falling vs. low/falling) as within-
22 subject. In the “Intact” condition, no main effect or interaction with Language was observed.
23 A main effect of Contrast was observed [$F(2;72) = 3.75, p = .03$] indicating that the “falling-
24 low” contrast was more difficult to discriminate than the two other contrasts. In the
25 “Vocoded” speech condition, a main effect of Contrast was observed [$F(2;72) = 4.69, p = .01$]

1 but indicated that the “rising-falling” contrast was easier to discriminate than the “rising-low”.

2 A marginal effect of Language was observed [$F(1;36) = 3.83$; $p = .058$], showing that French

3 participants tended to be slightly better at discriminating the vocoded lexical tones than

4 Mandarin participants. Although the d' scores of both groups remained above chance level

5 (Student t test; all $p < .001$), a significant interaction between Contrast and Language

6 [$F(2,72)=3.4$, $p = .04$] was observed. *Post-hoc* comparisons (Tukey’s HSD test) indicated that

7 the d' scores varied between contrasts only for Mandarin-speaking listeners and that they

8 better discriminated the “rising-falling” than the “falling-low” contrast. A significant

9 interaction between ISI and Language was also found [$F(2,72)=4.39$, $p = .04$] indicating that

10 French speaking-listeners were better than the Mandarin ones with a ISI of 500 ms. In the

11 “F0-modulations” condition, a main effect of Language was observed [$F(1,36)=7.31$, $p = .01$]

12 and *post-hoc* comparisons revealed that Mandarin-speaking listeners obtained (slightly)

13 higher d' scores compared to French-speaking listeners.

14 **IV. DISCUSSION**

15 The present study aimed to investigate the role of native language on the processing of

16 spectro-temporal cues in lexical-tone discrimination. In apparent contrast with previously

17 published investigations on lexical-tone discrimination (*e.g.*, Burnham and Francis, 1997;

18 Hallé *et al.*, 2004; Sun and Huang, 2012), both French- and Mandarin-speaking listeners were

19 able to correctly perceive differences in pitch contours with the present lexical tones. The

20 absence of difference between language groups results from a ceiling effect (that is from the

21 high performance of both groups for the current discrimination task and for the present speech

22 stimuli that were carefully selected from a large set of clearly articulated utterances). As

23 expected in the “Vocoded” speech condition, results indicate an effect of native language on

24 the perception of F0 variations and suggest that lexical-tone users are more dependent on fine

25 spectral and FM cues than non-users when perceiving lexical tones. Moreover, French-

1 speaking listeners are better able to make use of the remaining (AM) information (conveying
2 duration and loudness information; *cf.* Rosen, 1992 (p. 74, lines 13-14)) than Mandarin-
3 speaking listeners in this condition. One possibility is that the experience with French prosody
4 and phonological categories makes French-speaking listeners more likely to focus on the AM
5 cues available (related to rhythm information) in the Vcoded stimuli and potentially relevant
6 for French language. Moreover, these results are consistent with previous studies showing that
7 native lexical-tone users rely more on the F0 direction than non-users (*e.g.*, Lee *et al.*, 2008,
8 2010). Furthermore, the duration of ISI influenced French and Mandarin participants’
9 performance differently in that Vcoded condition. As expected, better performance for the
10 “rising-falling” contrast was observed with a short ISI for French speakers and with a long ISI
11 for Mandarin speakers. This may reveal that native language affects the rate of information
12 decay in the short-term memory representation (and/or its use for further perceptual
13 processes) of the voice-pitch cues used to discriminate lexical tones (Mandarin speakers
14 showing less information decay than French speakers).

15 Finally, when the fine spectro-temporal modulations conveying the voice-pitch
16 information were presented for discrimination using “F0-modulations” sounds, Mandarin-
17 speaking listeners showed better discrimination of (F0) pitch contours compared to French-
18 speaking listeners. These results are in line with several studies showing an effect of native
19 language on the identification of pitch contours in non-linguistic signals such as sine waves,
20 harmonic complex tones, or iterated rippled noises (*e.g.*, Bent *et al.*, 2006; Swaminathan *et*
21 *al.*, 2008; Xu *et al.*, 2006).

22 Overall, the present results suggest that Mandarin-speaking listeners are more
23 dependent on F0 variations—and thus on FM and fine spectral cues—than French-speaking
24 listeners when discriminating lexical tones. The results of this pilot study are consistent with
25 the notion that native language shapes the weight of spectro-temporal fine structure cues in

1 processing speech sounds. Results obtained with click trains suggest that this influence of
2 native language could extend to non-linguistic sounds. Thus, temporal modulation processing
3 in the auditory system may be influenced by higher-level mechanisms fine-tuned by language
4 expertise. This influence is not incorporated in current models of modulation processing
5 (Jørgensen and Dau, 2013). However, our conclusions should be taken with caution because
6 several factors such as genetic and socio-cultural backgrounds and environmental factors were
7 not controlled in the present study. Further work investigating the development of lexical-tone
8 processing for infants learning tonal and non-tonal languages is required to address these
9 issues. Moreover, the perceptual strategies (*i.e.*, Bent *et al.*, 2006) used by native and non-
10 native lexical-tone listeners when listening to degraded lexical tones may be further explored
11 using a more cognitively demanding task such as an identification task.

12

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19

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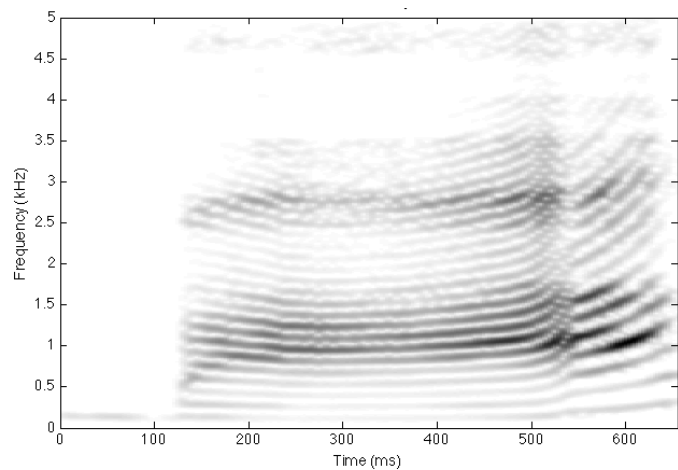
16 **Figure captions**

17 **Table 1.** Participants’ information

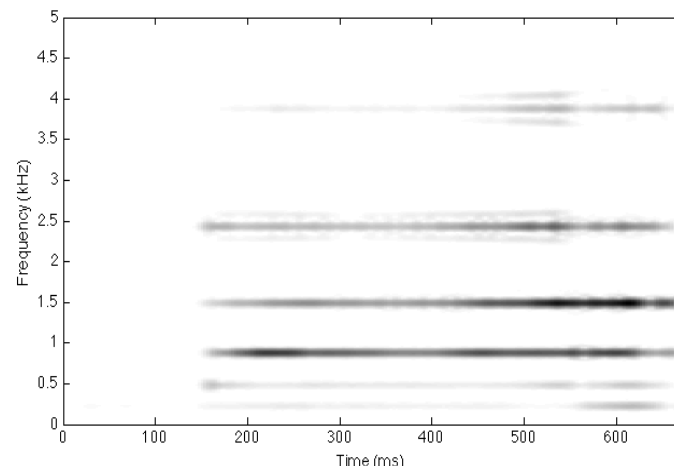
18 **Figure 1.** Spectrograms of the Intact (left panels), Vocoded (middle panels) and F0-
19 modulation (right panels) versions of a /ba/ rising (first row), /ba/ falling (second row) and
20 /ba/ low (third row) stimulus.

21 **Figure 2.** d' scores of the Mandarin-speaking and French-speaking listeners in the three
22 experimental conditions (Intact, Vocoded and F0-modulations) for each lexical-tone pair (RL:
23 Rising-Low; RF: Rising-Falling; FL: Falling- Low) presented in the two ISI (500 ms; 1500
24 ms). The bars represent the standard errors.

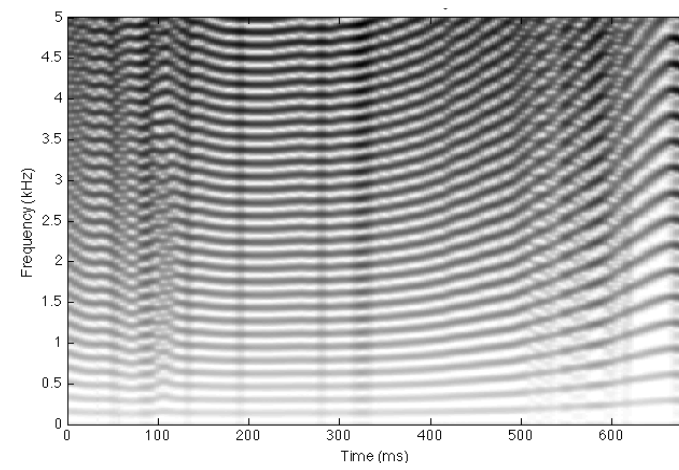
Condition	Isi	Language	mean age (years)	sd age (years)	age range (years)	number of females	number of musicians	mean musical practice (years)	sd of musical practice	range of musical practice (years)
Intact	1500	French	25	3.4	22-31	7	6	6.9	7.7	0-23
Intact	500	French	24	1.9	21-27	6	6	5.9	6	0-15
Intact	1500	Mandarin	24	2.4	22-29	7	5	3.4	4.1	0-14
Intact	500	Mandarin	23.6	2.5	20-27	6	6	4.9	2.9	0-10
Vocoded	1500	French	23.8	1.4	22-26	1	6	5	5.3	0-15
Vocoded	500	French	25.3	3.7	22-34	0	7	7.3	6.3	0-20
Vocoded	1500	Mandarin	22.1	1.7	19-24	4	4	4.5	4	0-12
Vocoded	500	Mandarin	23.2	2.9	20-29	6	6	3.8	4.1	0-13
F0-modulations	1500	French	24.9	1.97	22-29	7	6	5.4	6	0-16
F0-modulations	500	French	24.6	1.9	22-28	3	7	7.3	6.5	0-18
F0-modulations	1500	Mandarin	23.9	3.1	20-28	5	4	2	2.2	0-7
F0-modulations	500	Mandarin	21.7	1.9	20-26	6	5	3.4	4.7	0-15



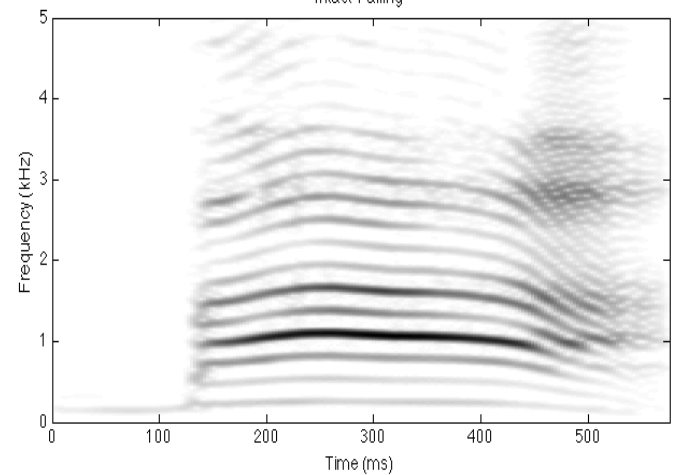
Intact-Falling



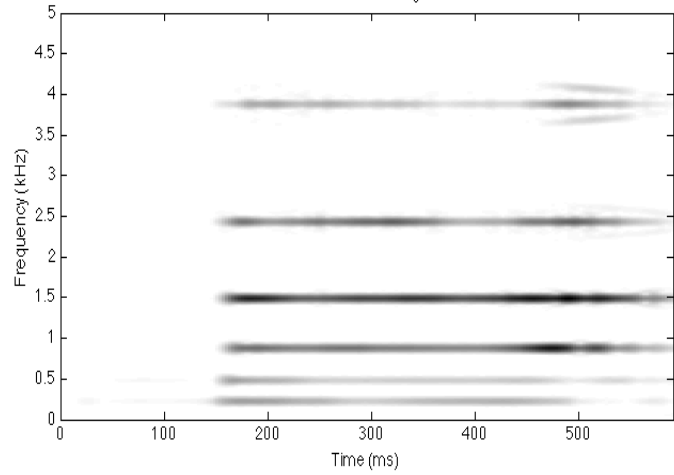
Vocoded-Falling



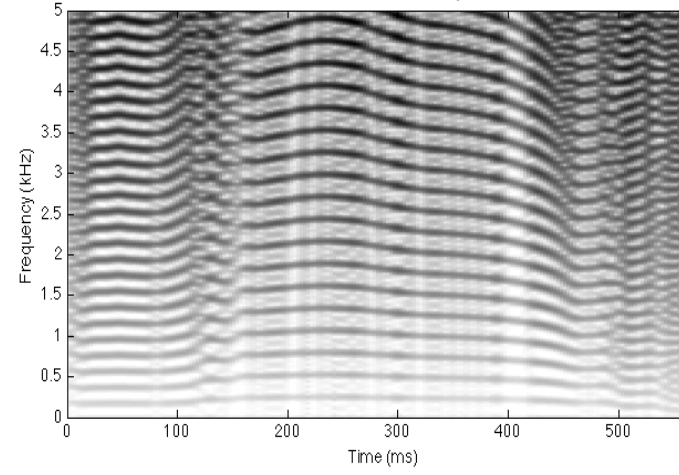
F0 modulations-Falling



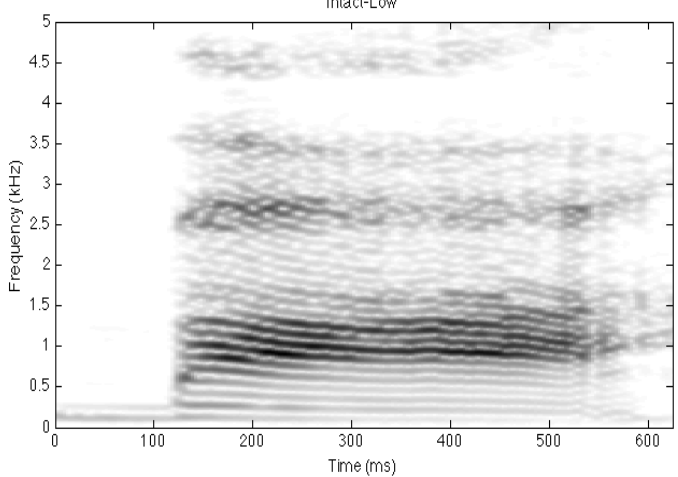
Intact-Low



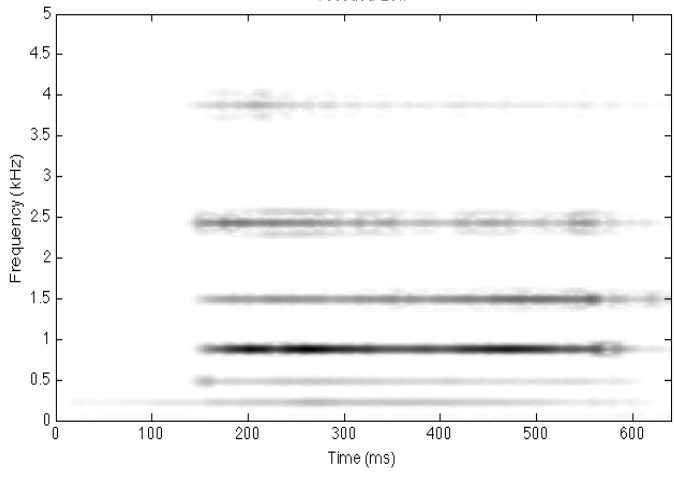
Vocoded-Low



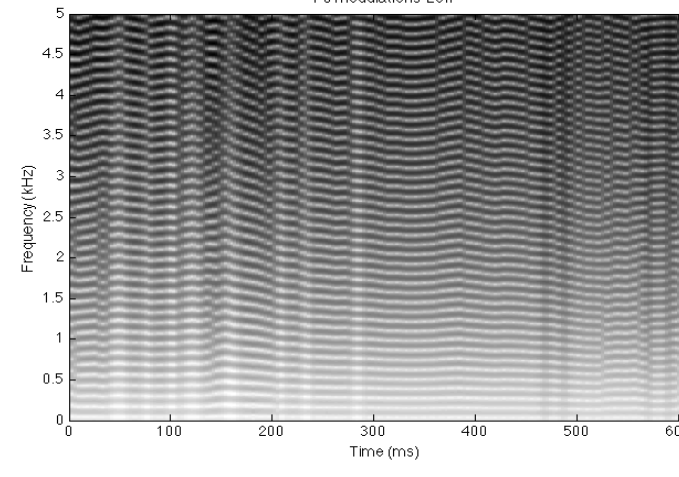
F0 modulations-Low



Intact-Falling



Vocoded-Falling



F0 modulations-Falling

