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Identifying the acoustic features in tonal phonemes in Chinese[1]

ABSTRACT. The current paper refers to the particular phonetic and phonological substance of the Chinese language. The key topics include the acoustic features of tonal languages, speech sound and audio-perception, as well as some issues of acquisition of Chinese language skills and reception conditions. The difficulties in tonal phonemes identification in hearing-impaired native Chinese and in non-tonal language users learning Chinese as a foreign language inspire the scientists to research the register of tones, acoustic features of tonal languages, the fundamental frequency (F0), tone contour and duration, and the speech signal – natural and subjected to filtration.

KEYWORDS: Chinese; tonal languages; tones; tonal phonemes; Chinese language acquisition.

1. THE CHINESE SYLLABLE

Chinese is a tonal language, thus the difference in the tone is directly linked to the word meaning. Tones in Mandarin Chinese, like in other languages in Central, East and South-East Asia, such as Thai or Burmese (Fromkin et al. 2003), share the same typological feature alien to non-tonal language users, i.e. the sound pitch which is as distinctive as the components of segmental phonemes of the syllabic structure. The syllable cannot miss the tone, as it is an inherent part of the monosyllabic morpheme structure of Chinese. This also means that different words in Chinese written with the same or with a different character can be pronounced alike with a difference in the tone (Wu 1993: 179-181; Jeng 1995: 257-276; Guo et al. 2010: 78).

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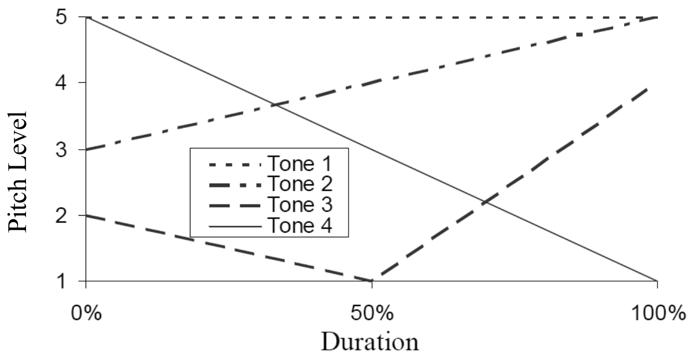
The Chinese language is relatively poor in syllables. There are only about 404 (Jeng 1995) simple structure syllables in the Chinese language, all constructed in accordance with (C)V(C) limits as a combination of optional consonants (C) and obligatory vowels (V). A comparison with the estimated at ca. 42 thousand syllables in the Polish language gives an idea of the need to differentiate the limited in number syllables in Chinese (Śledziński 2008: 231). Lee et al. call the (C)V(C) sound sequence *base syllables* and count them to as many as 408. This results in a huge number of homophones and syllables forming confusing sets (Lee Y. et al. 1997: 75). "Tones in Chinese are defined in terms of the rhythmic rise and fall of pitch or the pitch counter of the voiced part of the character" (Leong 2006: 74).

2. TONE AS A DISTINCTIVE PROPERTY

Tone is a linguistic term. In phonological categories it means a suprasegmental feature which distinguishes two words with the same segmental structure of the syllable. It is due to tonal phonemes in Chinese that, according to Chao (1968), there are about 1,297 syllables, or 1300, as Lee et al. (1997) quoted. With regard to monosyllabic morphemes and the relatively high rate of recurrence of mono- and bi-syllabic vocabulary, there is a clear distinction between syllables, which determines verbal communication. Tones have always been an integral part of the sound in the Chinese language. Three out of the four original traditional Chinese tones are distributed into four tones of the Modern Mandarin Chinese (Xie 1994: 32-37) in all the standards: Continental Standard Chinese, Taiwan Standard Chinese, Hong Kong Standard Chinese and Singapore Standard Chinese (Künstler 2000: 18,270–271; Kratochvil 1968: 24). The relative position in pitch frequency of the four Chinese isolated tones is scaled in a five-point scale (time-pitch grasp) introduced by Chao (1968) to show the pitch contours of the tones.



The sequences of the numbers represent the tones, the level tone (55), the rising tone (35), the falling-rising tone (214) and the falling tone (51). Two more sandhi tones related to the morphological structure of Chinese words should be added, with contours 53 (when 51 is preceding 51, as in 看見 *kàn-jiàn* 'see' or 大陸 *dàlù* 'continent') and 21 (when 214 is preceding tones 55, 35 or 51, as in 老大*lǎodà* 'the eldest son') (Chao 1968: 25-29; Kratochvil 1968: 38-39, 41). However, since the falling-rising tone 214 is also changing into the rising tone 35 (as in老早*lǎozǎo* 'dawno temu' *lǎo* changes into *láo*), it correlates with the original rising tone and thus does not add one more contour to the Mandarin Chinese tones.

3. ACOUSTIC FEATURES OF THE TONE

The tone duration depends on the vowel/vowels of the syllable rather than on the contour changes. However, two pairs (T1 and T3 vs. T2 and T4) of long and short time pronunciation are sometimes suggested. It is important to stress that the modern Chinese, similarly to other languages or dialects in the region, does not have the phonological opposition of length (short : long) (Künstler 2000: 227). Though the syllabic structure of Chinese is simple, the vocality essential for the tones is common for Mandarin languages. Künstler (2000: 272) writes "The vocalism of Mandarin languages (…) is relatively rich: apart from vowels, there are large inventories of diphthongs and triphthongs, with tendencies to diphthongize simple vowels and to triphthongize diphthongs dominating" (translated by prof. Majewicz A.F.).

The F0 is the lowest frequency in the sound spectrum. In Chinese, the tones' F0 range is relative and subjected to a personal voice scope and changes within the tone contour. Therefore, it varies from one person to another, lower for a male and higher for a female and a child. Following the reports, a female f0 operates between 180 Hz and 270 Hz when pronouncing the syllable *ma* in four Chinese tones (Jongman et al. 2006: 211). The average means of f0 from another study carried out by Xu (1997: 67) run from about 90 Hz to slightly above 140 Hz. Given the fact that a loss of the speech sound spectrum below 350 Hz in Polish results in a loss of only 2% speech clarity, it can be concluded that the Polish recipient with no hearing problems does not attach particular importance to the reception of low frequency sounds in speech. In some way high exposure to speech frequency within the 400 Hz – 4000 Hz spectrum, relevant to comprehend the Polish language, does not endow the recipient with sufficient sensitivity to bass and treble sounds (Hojan & Skrodzka 2005: 104-105).

4. FROM THE PHONE TO THE PHONEME

The physiological frequency range of phonation provides a register in which vocal functions of the native speakers of Mandarin Chinese allow exceeding the maximum range of non-tonal language speakers (Chen Sheng Hwa 1996: 79-86). Phonation is mutually related to hearing ability, its range being greater in Chinese native speakers compared to non-tonal language users. The pitch range of native Chinese and English speakers tested on both, English and Chinese language utterance, differs in favor of the Chinese with a 1.5 times wider range when compared to the English speaking English, and a slightly wider range in the case of the English speaking Chinese (Wang et al. 2006: 250).

This is a perfect starting point to turn from the acoustic sound features to the meaning. Effective hearing of the sound's pitch and contour distinction are prior to processing the speech signal into meaning. According to the related papers, there are some acoustic features of speech sound in Mandarin Chinese which strongly condition tone processing and identification. In order to understand the mechanisms responsible for the native hearing-impaired and non-native speakers' problems with tone identification, the acoustic features of tones were extracted in syllables using new technology tools and subjected to identification tasks. Syllables naturally produced by native speakers, both in isolation and context, normalized, synthesized, extended and/or transmitted through low-pass acoustic filters preserve the feature expected to play the main role in sound processing. The rates of proper tones identification compared to one another give an answer to which acoustic cue is more distinctive to the other.

The sequence Chinese children acquire tones highly correlates with non-native users learning to identify tones. Basically, research provides us with evidence that the first and fourth tones are easier to be grasped, while the second and third tones are acquired later, yet mutually confused for the longtime acquisition process in L1 (Li & Thompson 1977: 185; Chang et al. 2004: 225, 237-238; Tseng C.-C.et al. 2007: 43-69). The mistaking of T2 and T3 seems to be a common problem for both, hearing-impaired children – users of Mandarin, and foreign learners (Guo et al. 2010: 80). Mandarin speaking hearing-impaired children experience inefficiency of auditory perception and tone recognition due to processing the lexical tones in a limited scope of register. At that very point they show similar difficulties in tone judgment to users of non-tonal languages, when learning Chinese.

The experiments on a flattened pitch contour (a monotone speech) of Chinese syllables were preceded with stimuli prepared as synthesized speech. The tasks of lexical identification, tone restoration of monotone disyllabic stimuli in Chinese (meaningful words, meaningless non-syllables and non-words) and transcribed F0 flattened and F0 intact re-synthesized sentences, allowed to evaluate intelligibility of monotone syllabic words to native speakers of Mandarin. The results of the experiments revealed differentiation in the reaction time and intelligibility scores, depending on the kind of stimulus, as well as great difficulty to restore the original tone and grasp the information conveyed in stimuli data (Jeng 1994: 175-196). It becomes clear in auditory lexical decision tasks that, in a tonal language, the pitch contour as a lexical tone is a factor of fundamental frequency which is responsible for encoding information. Those learning Chinese as a foreign language have to face difficulty to recognize the pitch contour within the register not present in their non-tonal L1.

Chang (2007: 101) recalling different studies arranges the tone identification difficulty degree as T1, T3, T4 and T2 for English speakers (after: Wang et al. 1999) and T1, T4, T2, T3 for, generally, non-tonal language speakers (after: Petrushin 2000). Although the difference in the position of T2 in tones' order may come from a number of objects in an experiment, numerous research studies point to T2 as the tone most easily confused with the three other tones. This is the case for native speakers of Mandarin, considering both normal-hearing and hearing impaired children according to the experiment carried out in a significant group of primary school students. An additional result of Chang's tone discrimination study states the tone's difficulty degree as following: T2, T3, T1 and T4 (Chang 2007b: 101, 115)

The acoustic features of tones are unfamiliar to native users of non-tonal languages. Chen Gwang-tsai (1975: 25-27) draws attention to the pairs of tones when teaching foreigners Chinese, i.e. high and low, rising and falling. There is a discussion among researchers as to the tone duration, especially with regard to the third tone as the longest one. The third tone is longer than the other tones, while the fourth tone is the shortest. However, the third tone may be regarded as the shortest when the pitch contour 214 becomes 21 (Chao 1968; Jeng 1995; Xu 1997). The differences in data are probably caused by differences in preparing the sound samples. Guo et al. (2010) further specify three parameters of the contour: the initial frequency of F0 contour, the moment of the contour turning point in the tone duration and the initial falling shape. According to this explanation, the contour and the time of turning point in the course of change in fundamental frequency seem to be crucial for the discrimination between the second and third tones. The fundamental frequency contour of the second tone decreases to 25%-30% of the time period, then rises. Xu (1997) points out that the turning point of the second tone is observed in the onset of the syllable. The frequency falling down period is too short to be easily identified by human ear, so it is somehow ignored and the frequency rising period within 75% of time plays a significant role. The fundamental frequency contour of the third tone decreases in the 75% of the time, to rise again in the ending 25% of time. The two tones also differ in the degree of the initial fall. These two factors, i.e. the degree of initial fall and its duration before the turning point, making the switch point perceivable (for T3) or hardly perceivable (for T2), seem to be crucial for native speakers in identifying tones. Therefore, the pitch contour regarding the differences in fall and rise within sound duration contributes to the differences in tone and sound discrimination (Guo et al. 2010: 79; Chang 2007b: 99-100). These, as Xu says, canonical form of tones "will be distorted by various factors, including the adjacent onset and offset values of the neighboring tones" (Xu 1997: 67). Yet, Chang (2007b: 100) refers to Garding et al. (1989) and compares T3 and T4 regarding contour falling in terms of timing and diapason. When discussed as half-third tone omitting the tone's rising, these features differentiate the falling contours of the two tones.

5. CONCLUSION

Concluding, the tonal phonemes present in the Chinese language lack a counterpart in non-tonal first languages of learners. Limited natural feedback determines auditory perceptual sensitivity. In order to understand the nature of challenge faced by an adult learner of Mandarin Chinese, the basis of neuro-processing needs to be taken into consideration. According to Wang et al. (2006: 250) tones along with segmental properties, in the case of native users, are naturally, predominantly but not exclusively, processed in the left hemisphere. Being decoded as a non-linguistic feature – tones operate in the right hemisphere region, at least at the beginning of learning Chinese as a foreign language. There is, however a competition for both, native and non-native users, between the auditory (initial) and linguistic (effective for the meaning) processing of tones. The functional contribution of the F0 contour to the segmental structure draws attention to psychoacoustics (2006: 50). A wide range of studies contribute significantly to the understanding of acoustic parameters of the speech signal in Mandarin. When applied to the Chinese language teaching to Polish students, the broad knowledge of tones requires confronting with the studies on audio-perception and decoding by users of Polish as L1.

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