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VOICE ONSET TIME OF INITIAL STOPS IN MANDARIN AND HAKKA: EFFECT OF GENDER

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ABSTRACT

This paper examines the influence of gender upon voice onset time (VOT). VOT values of word-initial stops /p, t, k, p^h, t^h, k^h/ followed by three vowels /i, u, a/ in both Mandarin and Hakka revealed that male speakers produced longer VOTs in unaspirated stops than their female counterparts, but women produced longer VOTs in aspirated stops than male counterparts. In addition, VOT distinction in unaspirated and aspirated stops was greater in female speakers than in male speakers in both languages, perhaps because women tend to have a more careful manner of speech than men (Byrd 1992, 1994; Whiteside 1996). Gender has a statistically significant influence on VOTs in both Mandarin and Hakka. It is thus suggested that VOT data from different genders should be analyzed separately.

Keywords: voice onset time, Hakka stops, Mandarin stops, gender effect

1. INTRODUCTION

Lisker & Abramson (1964) defined Voice Onset Time (VOT) as the temporal interval from the release of an initial stop to the onset of glottal pulsing of a following vowel. VOT has been considered a reliable phonetic cue for categorizing stop consonants (i.e., voiced versus voiceless or unaspirated versus aspirated) in various languages (Cho & Ladefoged 1999; Gósy 2001; Keating, Linker & Huffman 1983; Lisker & Abramson 1964; Riney, Takagi, Ota & Uchida 2007; Rochet & Fei 1991; Zheng & Li 2005).

Various factors were found to influence VOT in previous studies. These factors include: speaking rate (Gósy 2001; Kessinger & Blumstein 1997, 1998; Magloire & Green 1999), age (Ryalls, Simon & Thomason 2004; Ryalls, Zipprer & Baldauff 1997; Whiteside & Marshall 2001), place of articulation (Cho & Ladefoged 1999; Lisker & Abramson 1964), vowel context (Chao, Khattab & Chen 2006; Chen, Chao & Peng 2007; Fant 1973; Gósy 2001; Lisker & Abramson 1964; Morris, McCrea & Herring 2008; Rochet & Fei 1991), and tone (Chao et al. 2006; Chen et al. 2007; Gu 2005; Liao 2005; Lisker & Abramson 1964; Rochet & Fei 1991; Liu, Ng, Wan, Wang & Zhang 2008; Peng, Chen & Lee 2009).

The current study investigates the possible influence of gender on VOT of the stops in Taiwan Mandarin and Hakka. Some researchers have claimed gender difference affects the VOTs of stops (Ryalls et al. 1997; Whiteside & Irving 1997; Whiteside & Marshall 2001). Others have reported no significant influences (Morris et al. 2008; Ryalls et al. 2004). This issue is worth examining because, if gender difference has an impact on voice onset time, VOT data from different genders should be analyzed separately in future studies.

Smith (1978a) claimed that male speakers produced significantly longer negative VOT values for English voiced initial stops. Swartz (1992) reported that female speakers produced significantly longer VOTs in English voiced and voiceless alveolar stops than their male counterparts. He further suggested that the differences between the speaking rates of men and women may account for this variation, but no significant correlation between gender and speaking rates was found. Whiteside & Irving (1997) found that female speakers have on average

longer mean VOT values than their male peers. Similar results were demonstrated in Whiteside, Henry & Dobbin (2004). Whiteside & Irving (1998) reported that female speakers produced longer mean VOTs in voiceless plosives and shorter mean VOTs in voiced plosives. Although the results in the production of English voiced and voiceless stops by male and female speakers were dissimilar in various studies, gender undoubtedly affects VOT values—even allowing the possibility that the variations noted, to some extent, may be caused by different methodologies in individual studies. For example, the speech materials and participants in both Whiteside & Irving's studies (1997, 1998) were the same, yet the results differed on examination of the speech materials embedded into phrases (1997) or in isolated words (1998).

The present study investigates male and female speakers' production of Mandarin and Hakka word-initial stops, which are mainly contrasted by aspiration (Cheng 1966; Cheng 1973; Chung 2004; Gu 2005; Liang 2004). If there are gender differences in stops, even for the same stops with different tones, it further verifies the result that gender is one of the factors affecting VOTs in Mandarin and Hakka. The discussion of tonal effect on VOTs was detailed in Peng et al. (2009).

2. METHODOLOGY

2.1 Participants

Mandarin and Hakka data are from different groups of speakers. The Mandarin participants included 14 male and 15 female college students and staff from an elementary school in Tainan City. All participants had grown up in Taiwan with no hearing or speech defects. Their ages ranged from 23 to 33 years (mean=27.2 years). As for Hakka, Sixian Hakka was chosen because it is the most extensively used Hakka dialect in Taiwan (Council of Hakka Affairs, 2010). The average age of the 21 participants—10 men and 10 women—was 51, with the oldest being 80 and the youngest 36. All of the participants in the Hakka group were also fluent speakers of Mandarin as Mandarin is the official language in

Taiwan. In the current study, the age range of the Mandarin participants is controlled within 10 years to avoid the effect of age difference. As for the Hakka participants, the age-range was quite wide because it is not easy to find fluent Hakka speakers.

2.2 Corpus

In both languages, the test items were generated by combining six stops /p, t, k, p^h, t^h, k^h/ and three vowels /i, u, a/, resulting in 18 combinations. With four contrasting lexical tones in Mandarin, a total of 72 monosyllabic words were created; among them, 18 of the combinations are not found in Mandarin. The six contrasting lexical tones in Sixian Hakka resulted in 108 monosyllabic words, 12 of which are not found in Hakka. Non-words in Mandarin and Hakka were presented using Mandarin phonetic symbols (zhuyin fuhao). Chen et al. (2007) claimed that disyllabic words can create a more natural-like context for participants. Therefore, in order to let speakers produce the words in a more natural manner, all of the real words were followed by another word in order to create meaningful disyllables. For example, the Mandarin word “*bi*” was followed by another word “*po*” to become the existing disyllable “*bi po*,” which means “force.” Non-words were also arranged in disyllabic forms to give them a more natural-like quality.

2.3 Procedure

The corpus was arranged randomly. Participants were asked to read the words out loud in a normal volume and at a comfortable rate. Except for mispronounced words, the VOTs of the words produced were all included for analysis. All speech was recorded using a Roland Edirol R-09 24 bit WAVE/MPS recorder, connected to an AKG head-mounted microphone positioned approximately 10 to 15 centimeters from the participant’s mouth in a quiet room.

2.4 Data Measurement

Although VOT is commonly used to study stops, there are slight differences in the measurement methods in various studies. Some obtained VOT values by measuring the interval between the beginning of the release burst and the onset of the first vowel formant (Chao et al. 2006; Chen et al. 2007) or the second formant (Cho & Keating 2001) visible in the spectrogram. Others obtained the VOT by measuring the temporal interval between the sudden spike that marks the release of the stop and the onset of the periodic wave, representing the start of the vowel (Riney et al. 2007; Whalen, Levitt & Goldstein 2007). Other researchers obtained VOT values from waveforms and verified the data with spectrograms (Kehoe, Lleó & Rakow 2004; Macleod & Stoel-Gammon 2005). Francis, Ciocca & Yu (2003) reported that the acoustic waveform, which shows the onset of the first clearly periodic pattern in the acoustic signal, provides the most accurate voicing onset and the most reliable measurements. Moreover, aspiration decreases the accuracy of spectrogram-based measurements. Therefore, VOT values were determined primarily by acoustic waveform in the present study. Moreover, although spectrogram-based measurements are affected by aspiration, they are still used herein as additional reference values for determining VOTs.

After recording, data were edited into individual files and analyzed using the Praat software (Boersma & Weenink 2009). VOT, measured in milliseconds, was obtained by measuring the temporal interval between the beginning of the release burst and the onset of the following vowel as shown in Figure 1. The values of both the waveform and spectrogram were recorded, but the VOTs were determined primarily through waveform analysis; the values in the spectrogram were provided as references. The burst of consonants and the onset of the first periodic pattern of vowels are clearer in the waveforms than in the spectrograms, so the exact transition from the burst to the onset of vowels can be measured. If the values in the waveform differed from the values in the spectrogram by more than five milliseconds, the data were re-measured to verify accuracy.

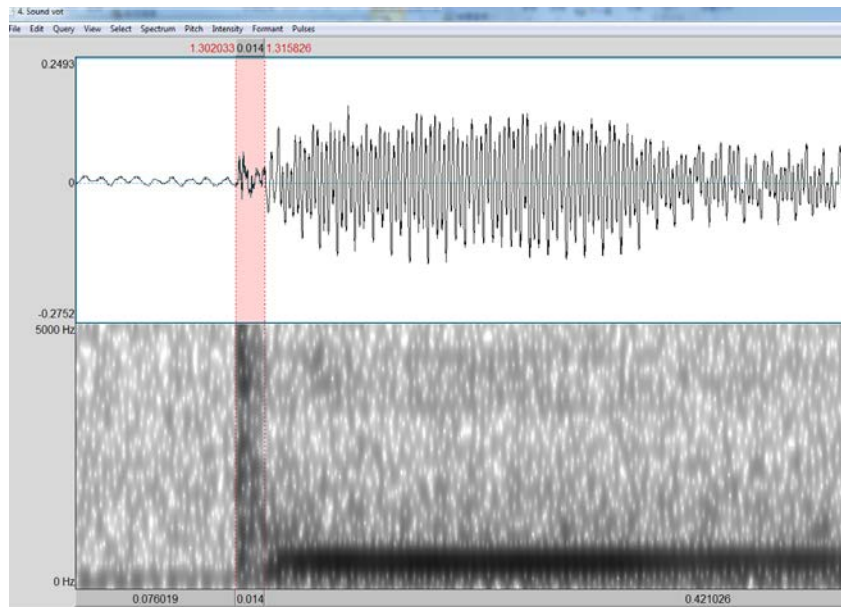


Figure 1. The spectrogram and waveform of the Mandarin word “*bu yao*” (don’t want). The marked area is the VOT value.

2.5 Data Analysis

The VOT values were measured by one investigator. Then, a number of items which comprised ten percent of the total read by a participant were randomly selected and re-measured by another investigator for each participant so as to verify the reliability of the results. Ultimately, seven Mandarin words and 11 Hakka words in each recording were re-measured. Pearson’s product-moment correlations (Gravetter & Wallnau 2008) indicated a high inter-rater agreement for both the Mandarin and Hakka data (Mandarin: $r = .995$, $p < .001$; Hakka: $r = .978$, $p < .001$).

The VOT values of the mispronounced words were excluded from the data analysis. Moreover, data in Hakka /pi/ in High-entering Tone were not analyzed due to incorrect word choices. Three-way repeated

measures ANOVA were used (gender x stop aspiration x place of articulation) to examine whether the variables significantly influenced stop VOT, in which the between-subject factor was gender and the within-subject factors were stop aspiration and place of articulation.

3. RESULTS

3.1 Mandarin

Repeated measures ANOVA were used to examine the influence of gender on VOTs of unaspirated and aspirated stops. There was no significant three-way interaction among place of articulation, gender, and stop aspiration ($F = 0.60$, $p = .542$). Next, three two-way interactions were examined. A significant two-way interaction between gender and stop aspiration was found ($F = 22.90$, $p < .001$). As illustrated in Table 1 and Figure 2, male speakers produced longer VOTs in unaspirated stops than female speakers ($p < .001$), but in aspirated stops female speakers produced longer VOTs than male speakers ($p < .001$). Furthermore, unaspirated and aspirated stops displayed significant VOT differences in both male and female speakers. These results indicate that gender had different significant effects on the VOTs of stop aspiration.

Table 1. Mean and standard deviation (SD) of VOTs of Mandarin stops produced by male and female speakers. All measurements are in milliseconds.

	Male ($n=14$)		Female ($n=15$)		Independent
	mean	SD	mean	SD	t -test
Unaspirated stops	22.01 (12.69)		18.41 (11.19)		$t = 4.85^{***}$
Aspirated stops	91.63 (28.24)		98.22 (26.78)		$t = -3.87^{***}$
Paired t -test	$t = -60.75^{***}$		$t = -71.86^{***}$		

*** $p < .001$

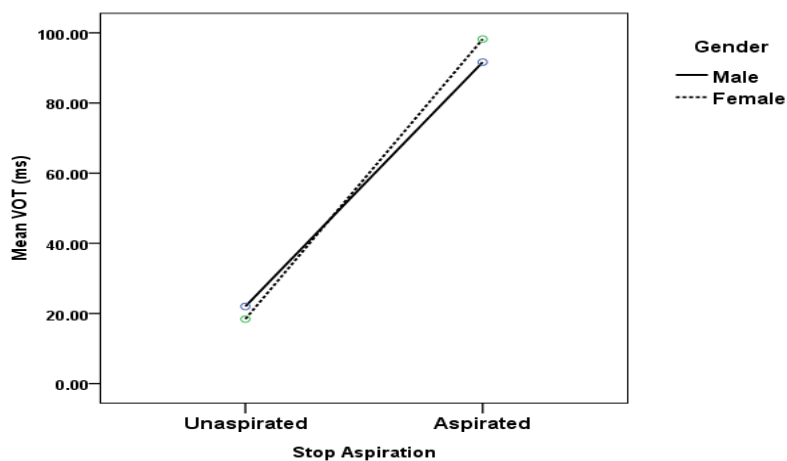


Figure 2. Mandarin unaspirated and aspirated stops produced by male and female speakers

A significant two-way interaction was found between place of articulation and gender ($F = 3.06, p < .05$). As shown in Table 2 and Figure 3, post hoc t-tests indicated that only labial stops showed a significant gender difference ($t = -2.28, p < .05$). Namely, gender only had a significant effect on the VOTs of labials, but no significant differences were found in the other two places of articulation. Moreover, three places of articulation displayed significant VOT differences in both male and female speakers (Male: $F = 190.74, p < .001$; Female: $F = 132.94, p < .001$).

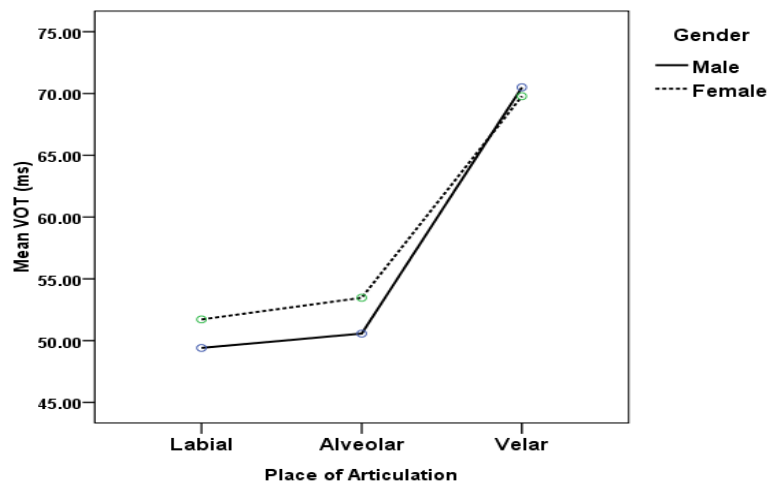


Figure 3. Mandarin stops of three places of articulation produced by male and female speakers

Table 2. Mean and standard deviation (SD) of VOT values of three places of articulation of Mandarin stops produced by male and female speakers. All measurements are in milliseconds.

	Male (<i>n</i> =14)		Female (<i>n</i> =15)		Independent
	mean	SD	mean	SD	<i>t</i> -test
Labial	50.61	(11.46)	53.37	(11.13)	<i>t</i> = -2.28**
Alveolar	49.36	(12.23)	51.80	(13.22)	<i>t</i> = -1.79
Velar	70.50	(19.52)	69.78	(16.39)	<i>t</i> = 0.374
Repeated Measure ANOVA <i>F</i> -test	<i>F</i> = 190.74***		<i>F</i> = 132.94***		

****p* < .001

***p* < .05

There was no significant interaction between places of articulation and stop aspiration ($F = 2.49$, $p = .107$). That is, place of articulation did not significantly influence the differences in VOT of unaspirated and aspirated stops.

3.2 Hakka

Repeated measures ANOVA were used to examine the influence of gender on the VOTs of unaspirated and aspirated stops. There was no significant three-way interaction among place of articulation, gender, and stop aspiration ($F = 0.39$, $p = .658$). Next, three two-way interactions were examined. As in Mandarin, a significant two-way interaction between gender and stop aspiration was found in Hakka ($F = 13.53$, $p < .001$). As illustrated in Table 3 and Figure 4, male speakers produced longer VOTs than female speakers in unaspirated stops ($p < .001$); meanwhile, female speakers produced longer VOTs than male speakers in aspirated stops ($p < .001$). Furthermore, unaspirated and aspirated stops displayed significant VOT differences in both male and female speakers. These results indicated that gender had different significant effects on VOTs of stop aspiration.

Table 3. Mean and standard deviation (SD) of VOTs of Hakka stops produced by male and female speakers. All measurements are in milliseconds.

	Male (n=10)		Female (n=10)		Independent
	mean	SD	mean	SD	t-test
Unaspirated stops	19.4 (9.9)		17 (10.4)		$t = 3.69^{***}$
Aspirated stops	74.6 (23.9)		83.3 (28.2)		$t = -5.00^{***}$
Paired t-test	$t = -52.22^{***}$		$t = -51.72^{***}$		

*** $p < .001$

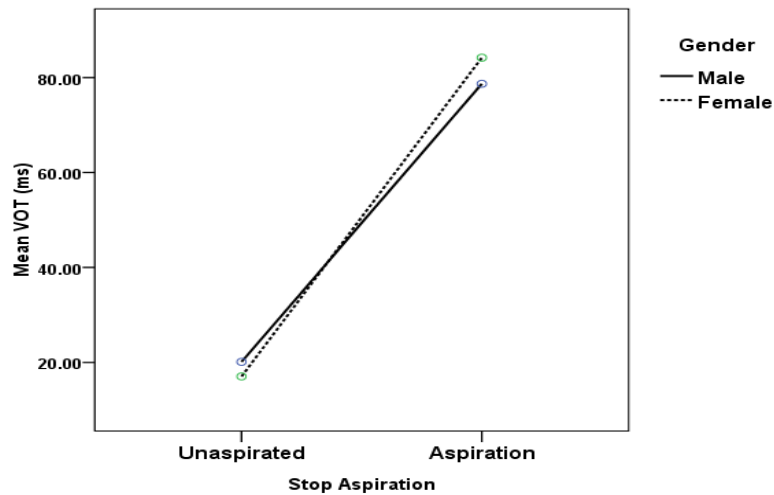


Figure 4. Hakka unaspirated and aspirated stops produced by male and female speakers

The two-way interaction between gender and place of articulation is non-significant ($F = 0.19$, $p = .809$). That is, place of articulation had no significant effects on gender differences of VOTs. As shown in Table 4, three places of articulation displayed VOT differences in both male and female speakers.

Table 4. Mean and standard deviation (SD) of VOT values of three places of articulation of Hakka stops produced by male and female speakers. All measurements are in milliseconds.

	Male ($n=10$)		Female ($n=10$)	
	mean	SD	mean	SD
Labial	40.44	(17.53)	44.57	(21.54)
Alveolar	42.64	(15.98)	44.02	(21.22)
Velar	50.29	(25.80)	51.97	(26.05)

There was no significant interaction between places of articulation and stop aspiration ($F = 0.83$, $p = .450$). That is, place of articulation did not significantly influence the differences in VOT of unaspirated stops and aspirated stops.

4. DISSUSSION AND CONCLUSION

The current study examined whether gender difference has an influence on the VOTs of stops. ANOVA tests revealed that gender has a different significant effect on VOTs in aspirated and unaspirated stops in both Mandarin and Hakka. In both languages, male speakers produced longer VOTs of unaspirated stops than female speakers did, while female speakers produced longer VOTs in aspirated stops. In addition, in both Mandarin and Hakka, the distinction of unaspirated and aspirated stops was greater in female speakers than in male speakers. Furthermore, gender only had a significant effect on the VOTs of labials in Mandarin, but not in Hakka. No significant differences were found in the other two places of articulation in either language. No consistent significant interaction between gender and place of articulation indicates that place of articulation does not influence the effects of gender on VOTs in either language. The insignificant role of place of articulation in the discussion of gender effects on VOTs was revealed in this current study although it was found in our previous studies (Peng et al., 2009) that the stop place of articulation (labial, alveolar, and velar), vowel context (/i/, /u/, /a/), lexical tones, and gender do create significant differences in VOT values of word-initial stops in both Mandarin and Hakka. The findings from the current study as well as previous studies indicate that male and female speakers produce unaspirated versus aspirated or voiced versus voiceless differently when speech materials are words (Smith 1978a; Whiteside & Irving 1998) or phrases and sentences (Peng et al. 2009; Swartz 1992; Whiteside & Irving 1997). The effect of gender may vary due to the variations in the speech materials (i.e. words, phrases, or sentences).

As for why men and women produced unaspirated and aspirated stops differently, researchers have suggested that, in spontaneous speech, men's speaking rate is faster than women's (Byrd 1992, 1994; Oh 2011; Swartz 1992;

Whiteside 1995, 1996). Moreover, supraglottal cavity, vocal fold length, air flow rate, and subglottal pressure differences between males and females (Smith 1978b; Swartz 1992), discourse topics, socioeconomic status, speaking styles, and so forth might be reasons for significant VOT differences. Whiteside & Irving (1997) suggested that physiological differences in different genders (e.g., vocal fold length, larynx) interact with the articulatory and aerodynamic conditions necessary for the production of unaspirated and aspirated stops. However, the nature of such interaction is quite complicated and needs to be further examined. The current study also determined that the distinction of unaspirated and aspirated stops was greater in female speakers perhaps because of the different speech styles of men and women, in that women tend to have a more careful speech manner than men (Byrd 1992, 1994; Whiteside 1996). However, this is just a conjecture as Oh (2011) reported that men exhibited more distinctive distributions for VOT values than women in Korean, suggesting that gender differences in the laryngeal anatomy and physiology are not enough to explain the variations. Socio-phonetic factors might be crucial and phonetic patterns can differ across languages or dialectal groups. In addition, inconsistent results in previous studies might be due to different methodologies employed as in Byrd (1992, 1994), Oh (2011), and Whiteside (1996). Further studies are thus needed to explore the possible factors.

There are some experimental defects in the current study. First, most of the speech materials in the current study were disyllabic words, while some in Hakka were trisyllables as no real disyllabic words have been found. Lisker & Abramson (1967) reported that the VOTs of stops vary when they occur in monosyllables and disyllables; therefore, the VOTs might also vary in disyllables or trisyllables. Consequently, speech materials should utilize the same number of syllables in future studies. Another source of potential experimental variation is that the age range of the Hakka participants was wide in the current study. In order to minimize the effect of linguistic differences between generations, such a wide age range would best be avoided. The results in this study indicate that males and females produced unaspirated and aspirated stops differently. Therefore, VOT measurements from different genders should be analyzed separately.

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國語及客語字首塞音嗓音起始時間：性別差異

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本研究檢視性別差異是否影響嗓音起始時間(voice onset time, VOT)。國語及客語字首塞音/p, t, k, p^h, t^h, k^h/，伴隨三種母音/i, u, a/的 VOT 值顯示性別差異對於 VOT 值有顯著影響。不送氣塞音方面，男性的平均 VOT 值比女性來的長，而女性的送氣塞音平均 VOT 值比男性長。此外，結果也指出，無論是客語還是國語，女性對於非送氣及送氣塞音分辨皆比男性清楚，也許是因為女性受試者比較小心注意自己的說話清晰度(Byrd 1992, 1994; Whiteside 1996)。本研究結果指出國語以及客語 VOT 值在性別上皆有顯著性差異。此結果建議爾後的研究，男性與女性受試者 VOT 資料應該分開處理。

關鍵字：嗓音起始時間、國語塞音、客語塞音、性別影響