The ups and downs of Vietnamese tones
A description of native speaker and adult learner tone systems for Northern and Southern Vietnamese

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The purpose of this study is to provide an empirical description of Northern and Southern Vietnamese lexical tones and to determine how successfully English-speaking adult learners of Vietnamese are able to produce native-like pronunciations. The primary methodology is a quantitative acoustic analysis of native speaker and adult learner speech with a focus on tone trajectory and duration. The native speaker results provide a comparative view of Northern and Southern Vietnamese tones, normalized for duration, which may aid future learners in understanding and reproducing the relative differences in tone trajectories within and across dialects. The adult learner results demonstrate that students have particular difficulty with the low falling-rising tone. Other common difficulties include the relative starting positions of tones and glottalization. The discussion raises the possibility that adult learners may benefit from concentrated training on tone discrimination and that there may be a role for screening students for tone deafness prior to language assignments.

INTRODUCTION

Vietnamese orthography reflects six lexical tones: ngang, huyén, sắc, nặng, hỏi, and ngã. Each tone name contains its corresponding diacritic (or, in the case of ngang, no diacritic). Whereas Northern Vietnamese is a six-tone system, Southern Vietnamese is a five-tone system in which hỏi and ngã have merged in pronunciation. In turn, the low falling-rising tone maps to hỏi in Northern, but maps to nặng in Southern. Figures 1 and 2 illustrate the tone systems of these two dialects.
Vietnamese tones are distinguished by pitch, voice quality, and duration (e.g., Brunelle, 2003; Michaud, 2004; Nguyen & Edmondson, 1998; Pham, 2003; Thompson, 1965; Vũ, 1981). Differences between the tones in pitch and voice quality are directly apparent in Figures 1 and 2. Pitch is represented by the vertical axis. Voice quality is represented by gaps in tone trajectories, specifically in Figure 1 for ngữ and nảng. These gaps occur whenever the voice quality of glottalization or creakiness, caused by irregular opening and closing of the vocal folds, makes it impossible to obtain reliable pitch measurements. Although the current analysis is unable to address other aspects of voice quality, such as breathiness or tenseness, a dedicated voice quality analysis is available as a separate technical report (Blodgett, Fox, Rytting, & Twist, 2009).

In terms of differences in duration, the gap at the end of nảng gives the appearance that this tone is shorter than the others. Duration measurements (discussed in a later section) do indicate that this tone is significantly shorter than the other tones in Northern Vietnamese, but duration is not a feature of these graphs. Pitch measurements were taken at regular intervals (represented by percentages) in order to normalize for variations in duration from token to token.

The current study provides a quantitative acoustic analysis of native speaker and adult learner tones with a focus on pitch and duration, and there are two goals for the native speaker analysis. The first is to provide an analysis of Northern and Southern Vietnamese tones in which tone trajectory is decoupled from variations in word duration and the pitch of speakers’ voices. We decouple trajectory from duration by sampling pitch measurements at evenly-spaced intervals in the tone region. We decouple trajectory from speakers’ pitch ranges by converting each speaker’s pitch measurements to a semitone scale that is anchored to his or her average pitch (Nolan, 2003). By aligning the subsequent tone contours as in Figures 1 and 2, we are able to provide learners with a visual representation that highlights the relative height and shape of tones independently of differences in word duration or speakers’ voices. As expected, we largely replicate the patterns reported in Vũ (1981). As with our figures, Vũ’s graphical representations were normalized for pitch, albeit using a different method; unlike ours, they displayed duration, rather than holding it constant.

The second goal of the native speaker analysis is to establish a generalization regarding the relative starting positions of tones. Here, the focus is on Northern Vietnamese as the bulk of existing research pertains to that dialect. Simply put, existing studies of Northern Vietnamese vary in their descriptions. For example, Brunelle (2003) refers to two starting points: middle of the pitch range for ngữ, hỏi, ngữ, and nảng, and a position lower than ngữ for sóc and huyễn. Nguyen and Edmondson (1998) describe a different pair of starting positions: middle of the pitch range for all tones except huyễn, which starts lower. Pham (2003) describes three positions: ngữ, hỏi, and nảng as higher than huyễn and ngữ, which, in turn, are higher than sóc. With respect to Vũ (1981), a figure summarizing the Northern data suggests that ngữ starts higher than sóc and ngữ, which starts higher than nảng, which starts higher than huyễn and hỏi. However, Vũ (1981) ultimately argues for two levels: ngữ, ngữ, and sóc, starting higher than nảng, huyễn, and hỏi.

The wide variation in description is not surprising given that these tone studies vary in their primary research questions, elicitation methods, speakers, and methods of analysis. However, one would expect generalizations to emerge about the trajectories of tones, including their relative starting and ending points. Based on our native speaker data (while excluding the two forms that appear in stop-final syllables), we argue that Vietnamese comprises a two-tier system in which ngữ (and, for at least one native speaker, sóc) starts higher than all other tones, whereas the relative starting positions of all remaining tones vary idiosyncratically.

The goal of the adult learner analysis is to identify common problems among otherwise idiosyncratic systems. In this analysis, the native speaker data provide a baseline against which to compare adult learners. The results demonstrate that students have particular difficulty with the low falling-rising tone. Other common difficulties include the relative starting positions of tones and glottalization. One adult learner appeared to have more difficulty than most at the time of recording, producing identical contours for all tones at least in the given speech task. This leads us to wonder more generally about the varying ability of students to perceive tonal distinctions accurately. For example, congenital amusia or tone deafness is thought to affect a small percentage of the population (e.g., Ayotte, Peretz, & Hyde, 2002). As such, auditory screening for tone deafness prior to language training assignments has the potential to identify learners who are more likely to succeed with non-tone languages than tone languages. For language programs that do not have the luxury of using pretest measures to assign students to different languages, there may be value in providing students with explicit training on tone discrimination (e.g., Lee, Perrachione, Dees, & Wong, 2007).

Table 1. Summary of previous descriptions of the relative starting points for Northern Vietnamese tones

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ngữ, hỏi</td>
<td>ngữ, hỏi, ngữ, nảng</td>
<td>ngữ, hỏi, nảng</td>
<td>ngữ</td>
</tr>
<tr>
<td>sóc</td>
<td>sóc, huyễn</td>
<td>huyễn, ngữ</td>
<td>sóc, huyễn, hỏi</td>
</tr>
</tbody>
</table>

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METHODOLOGY

Participants

Native speaker participants included four Northern dialect speakers (two female, two male) and two Southern dialect speakers (both female). All were originally from Vietnam and had been living in an English-speaking country for 3 to 26 years. They ranged in age from 32 to 73, and all had experience teaching Vietnamese as a foreign language to adults.

Non-native speaker participants included four Northern dialect learners (one female, three male) and six Southern dialect learners (two female, four male). They ranged in age from 26 to 50. All had been studying Vietnamese intensively (i.e., at least 5 hours a day), but for varying lengths of time. Their weeks of training ranged from 10 to 43. All participants resided in the Washington, DC, area at the time of recording.

Stimuli

The full set of targets comprised 160 monosyllabic words and included 11 vowels: i, ê, e, u, ū, ô, ō, o, a, â, ā. The vowels i, u, ū, ô, ō, and a appeared with all possible tones for each of three syllable types: open (e.g., ba, bà, bạ, bả, bã), stop-final (e.g., bạt, bát), and nasal-final (e.g., bang, bânh, bâng, bãng, vân). The vowels ê, e, and o appeared only in open syllables. Consistent with Vietnamese phonology, the vowels â and ā appeared in stop-final and nasal-final syllables only.

To the extent possible, targets were matched for initial and final segments within syllable type and within vowel. We attempted to maintain consistent consonant place and manner, but, when necessary, sacrificed one or both in the interest of ensuring that all target stimuli were real words.

Procedure

Speakers were recorded in a sound-dampened room using Sound Forge 7.0 (22 kHz, 16 bit, mono), a Yamaha 01V96 digital mixing console with no effects settings, and a Neumann TLM 103 microphone.

Participants produced three-word sentences in response to individual target words that appeared on a computer screen in red, blue, black, or purple. For example, if the target word bang appeared in blue, the speaker said Từ bang xanh (“the word bang is blue”). Participants had access to the written color names as they completed eight practice trials and then four lists of words. Lists 1 and 2 each contained 102 targets with the vowels i, u, ū, ô, ō, a, â, and a. Lists 3 and 4 each contained 58 targets with the vowels ê, e, o, a, â, and ā. Targets appeared in pseudo-random order such that the vowel, tone, and color of the word always changed from one trial to the next. Three additional targets occurred on Lists 1 and 2. Each was a non-adjacent repetition of an existing target, but in a narrow contrastive context (i.e., in the same color as the immediately preceding word). This added one token each of i, u, ū, ô, ō, and a. In addition, ma occurred in list-final position on every list. Targets that were paired with xanh and tím (purple) on List 1 and List 3 were paired with đen (black) and đỏ (red), respectively, on List 2 and List 4, and vice versa. Participants thus produced two repetitions of each target word, but novel utterances each time. In this self-paced task, participants could repeat any utterance before advancing to the next word. If the experimenters (who are not speakers of Vietnamese) thought they detected an error, e.g., a wrong color term, they directed the speaker to repeat that target utterance at the end of the given list. When speakers did repeat, we analyzed only the final repetition.

Table 2. Number of tone productions by syllable type based on whether participants completed Lists 1 and 2 or Lists 1 to 4

<table>
<thead>
<tr>
<th>Syllable Type</th>
<th>ngang</th>
<th>huyễn</th>
<th>sắc</th>
<th>năng</th>
<th>hồi</th>
<th>ngã</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lists 1 &amp; 2</td>
<td>Open</td>
<td>12</td>
<td>12</td>
<td>12</td>
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<td>12</td>
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<tr>
<td></td>
<td>Nasal-Final</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Stop-Final</td>
<td>18</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lists 1 to 4</td>
<td>Open</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Nasal-Final</td>
<td>32</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Stop-Final</td>
<td>50</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lists 3 and 4 were added partway through the study in order to increase the number of tokens for use in a separate vowel analysis (Winn, Twist, & Blodgett, 2009). Table 2 summarizes the number of tone productions by syllable type for participants who completed Lists 1 and 2 and for those who completed all four lists. In short, the 16 speakers participated over two cycles of recording and analysis. Speakers 1 – 10 participated in Cycle 1 and completed Lists 1 and 2. The Cycle
A full analysis was presented in technical reports E.4.1 and E.4.3. Speakers 11–16 (and Speaker 8) participated in Cycle 2 and completed all four lists. The current document provides a comprehensive analysis of all 16 speakers.

Analysis

Target syllables were annotated within their three-word utterances using Praat (Boersma & Weenink, 2008). Tone region onsets and offsets were marked based on auditory and visual inspection of each waveform and spectrogram. The beginning of the tone region coincided with vowel onset. The end of the tone region coincided with the end of vowel production in the open and stop-final syllables, and with the end of nasal production in the nasal-final syllables. Praat scripts automatically assigned nine evenly spaced points between each onset and offset to create time steps within the tone region in 10% increments. Scripts automatically returned the value in Hertz of the fundamental frequency (F0) or “pitch undefined” at all 11 points. We reviewed the output for possible pitch-tracking errors and replaced suspicious values with hand measurements or “pitch undefined” as appropriate. This resulted in modifications to 2% of the data over time steps 10–90%. We excluded the first time step (0%) from analysis to exclude effects of initial segments (all non-nasal obstruents) on the tone contour. We excluded the final time step (100%) from analysis to exclude segmental effects in stop-final syllables and because pitch was generally undefined late in the word in the open and nasal-final syllables.

Following the procedure in Nolan (2003), we converted Hertz to semitones using each speaker’s average pitch as his or her baseline and again reviewed the output for possible tracking errors, removing less than an additional 1% of the data. For each speaker, we calculated means for each tone at each time step separately for the three syllable types and graphed every time step at which approximately two thirds or more of data cells were defined. That is, gaps in the tone trajectories indicate points at which roughly one third or more of cells were undefined. The section for adult learner results describes additional exclusionary criteria for handling inconsistent tone production.

RESULTS: NATIVE SPEAKERS

Speakers 1, 8, 9, and 10 were recorded in Cycle 1; Speakers 15 and 16 were recorded in Cycle 2.

Northern Vietnamese

Figures 3–6 document the tone systems of the four native speakers of Northern Vietnamese in the study. Although each figure reflects data from open syllables only, similar patterns occur in the nasal-final data as shown in Appendix 1. In general, the figures are consistent with descriptions of ngang as high and level, and huyền as low and falling. In contrast to ngang, huyền is sometimes described as having a “relaxed” (e.g., Jorden, Sheehan, Nguyen, & Associates, 1967) or breathy quality (e.g., Pham, 2003; Thompson, 1965). Breathiness, which is not measured in the current acoustic analysis, corresponds to vocal folds that are farther apart, thus allowing greater airflow than during modal phonation. Modal phonation is typically reported for ngang or sắc.

Across these Northern speakers, sắc and ngã share a similar trajectory, and as expected, nga appears as a discontinuous or broken tone. Its glottalization or creakiness (caused by irregular opening and closing of the vocal folds) makes it impossible to obtain well defined pitch measurements at its midpoints. While this glottalization is audible in the recordings, native Northern speakers may not always produce a distinct gap in spontaneous speech (e.g., Dưng, Hưong, & Boulakia, 1998).

The trajectory of năng also shows evidence of its expected final glottalization. As mentioned in the introduction, the apparent shortness of năng is a by-product of its glottalization, as duration is not encoded directly in these figures. Duration is encoded in Figure 11, and when the duration of the tone region is measured directly, năng does demonstrate the shortest average duration (289 msec) across the vowel-final syllables displayed here. The average duration for all other tones in this syllable type is at least 370 msec (ngang, 400 msec; huyền, 403 msec; sắc, 379 msec; hỏi, 430 msec; nga, 376 msec). To investigate whether there is a significant difference in duration for the two low falling tones năng and huyền, we conducted a 2 (syllable type: vowel-final vs. nasal-final) x 2 (tone: năng vs. huyền) repeated measures Analysis of Variance (ANOVA). The results demonstrated a main effect of tone (F[1,3]=12.1, p<.05) and no effects of syllable type. Thus, năng is indeed significantly shorter than huyền, suggesting that duration may help capture the contrast between these two tones.

In terms of the hỏi tone, each Northern speaker demonstrates a mean falling-rising trajectory. However, there is variation in terms of how high these mean trajectories rise at the end, and the final rise has been reported to disappear in running speech (e.g., Brunelle, 2003; Thompson, 1965). This known falling variant appeared on a few individual utterances (e.g., from Speakers 8 and 9). In short, the rising tail that is particularly evident for Speakers 1, 8, and 15 may be somewhat misleading, and hỏi might be better described as a low falling tone that sometimes rises than as a low falling-rising tone.
Figure 3. Speaker 1 tone system (female, native speaker of Northern dialect, open syllables)

Figure 4. Speaker 8 tone system (male, native speaker of Northern dialect, open syllables)

Figure 5. Speaker 9 tone system (male, native speaker of Northern dialect, open syllables)

Figure 6. Speaker 15 tone system (female, native speaker of Northern dialect, open syllables)

Figure 7. Speaker 10 tone system (female, native speaker of Southern dialect, open syllables)

Figure 8. Speaker 16 tone system (female, native speaker of Southern dialect, open syllables)
The hỏi contour for Speaker 15 is remarkable in that the curve appears ill-formed. The perturbations in pitch that cause this effect around 40 – 60%, however, are consistent with reports of mid-tone breathiness (e.g., Pham, 2003) or creakiness (e.g., Brunelle, 2003) for hỏi. Speaker 15 shows two other patterns worthy of comment. First, her ngang tone sits slightly below her average pitch. In contrast, for each of the remaining native speakers, ngang sits either at that speaker’s average pitch (Speaker 10) or above it. This more common tone height matches that mentioned in the literature (e.g., Thompson, 1965) and is likely a key feature of the ngang tone. Second, there is a slightly rising tail on hỏi. This may be attributable to coarticulation with the following tone or to effects of breathiness on pitch measurements.

Southern Vietnamese

Figures 7 and 8 document the tone systems of the two native speakers of Southern Vietnamese in the study. Just as in the Northern dialect, ngang is high and level, and hỏi is low and falling (and possibly breathy). In the five-tone system of Southern Vietnamese, hỏi and ngã have merged. This merger separates the sắc trajectory from the hỏi/ngã trajectory (whereas sắc shares a trajectory with ngã in Northern). The merger also provides space for nặng to shift to Northern hỏi’s tone space and trajectory. The continuous lines for nặng are consistent with reports that in most Southern dialects (a local Da Nang dialect being the exception, Vũ, 1981), nặng lacks the distinct glottalization that truncates the tone trajectory in Northern nặng (Thompson, 1965). The continuous lines for hỏi/ngã are consistent with reports that changes in voice quality are not a consistent property of this contour (Thompson, 1965; Vũ, 1981). That said, on at least some hỏi/ngã tokens, Speakers 10 and 16 do produce audible changes in voice quality that resemble creakiness or vocal fold tenseness at the contour’s midsection.

These two native speakers seem to vary in their hỏi/ngã trajectories. In the case of Speaker 10, the onset of hỏi/ngã, hỏi and nặng (around 10 – 20%) share a similar tone space and trajectory. The hỏi/ngã trajectory begins to rise and separate from nặng most clearly at 40%. A similar pattern appears in the nasal-final syllables as well (see Appendix 1). In contrast, Speaker 16’s hỏi/ngã trajectory never overlaps with hỏi and is aligned with nặng from the outset. The trajectory begins to rise and separate from nặng later than for Speaker 10, with differentiation occurring most clearly at 70%. Speaker 16’s pattern also appears in her nasal-final syllables, although the hỏi/ngã trajectory separates from nặng one time step earlier at 60%. Similar variation in alignment of the Southern hỏi/ngã trajectory relative to hỏi and nặng is apparent in a comparison of Gsell (1980) and Vũ (1981). Whereas figures from Gsell suggest that the hỏi/ngã trajectory is intermediate between hỏi and nặng, the Southern graphic from Vũ suggests that the hỏi/ngã trajectory aligns more closely with nặng.

From a pedagogical perspective, students may benefit from learning to approximate Speaker 16’s tone system in which hỏi/ngã aligns more closely with nặng. Because all three tones fall below hỏi, not just nặng, this may reinforce production of this difficult feature. As we will discuss in the adult learner section, many students struggle to produce a low falling-rising contour (i.e., Northern hỏi or Southern nặng) that falls below hỏi.

The Relative Starting Positions of Tones

Figures 3 – 8 provide a visual representation of Northern and Southern Vietnamese tone systems that highlights the relative height and shape of tones independently of differences in word duration or individual speaker’s voices. As expected, these figures are generally consistent with the patterns reported in Vũ (1981), which reflect data aggregated across speakers from either the Northern or Southern dialect. By plotting each speaker’s tone system individually, we are able to look across speakers to develop a generalization regarding the relative starting positions of tones.

With respect to the six basic tones (i.e., setting aside sắc and nặng from stop-final syllables), a consistent pattern emerges across Northern and Southern Vietnamese: ngang has the highest initial starting point, and the relative starting positions of all remaining tones vary idiosyncratically. In the case of Speaker 15 (Northern dialect) and Speaker 16 (Southern dialect), and in the aggregate Southern data from Vũ (1981), this idiosyncratic variation happens to include a starting point for sắc that overlaps with ngang. There is simply no single rank order that covers the distribution of non-ngang tones across speakers. There is merely a general trend: rising tones (e.g., sắc, ngã) tend to originate higher than tones leading to the lowest midpoint (i.e., Northern hỏi, Southern nặng).
Tones in Stop-Final Syllables

Only two tones – sắc and nặng – occur in stop-final syllables, and Figure 9 (from Northern Vietnamese) and Figure 10 (from Southern Vietnamese) show the expected two-way contrast between a rising sắc and falling nặng. Note that even in Northern Vietnamese, nặng in this environment has a modal (non-creaky) voice quality.

Figure 9. Speaker 1 stop-final tones (female, native speaker of Northern dialect)

Figure 10. Speaker 10 stop-final tones (female, native speaker of Southern dialect)

Stop-final syllables are characteristically short in Vietnamese (Pham, 2003; Vũ, 1981). This property is not apparent in Figures 9 and 10 in which tones are normalized for duration. The shortness is apparent in Figures 11 and 12, which display the mean tone duration for each dialect by syllable type and tone. Because short vowels have the potential to shorten the duration of stop-final syllables even more, for this syllable type, only data from the long vowels a and ơ are included in these figures and the subsequent statistical analysis. Short vowels are not excluded from the nasal-final syllables because temporal compensation maintains a consistent duration in the tone region (Winn, Twist, & Blodgett, 2009), and in terms of the open syllables, they are simply phonologically disallowed. To investigate whether sắc and nặng are significantly shorter in stop-final syllables than in open or nasal-final syllables, we conducted two separate 2 (syllable type: stop-final vs. other) x 2 (tone: sắc vs. nặng) repeated measures Analyses of Variance (ANOVA) once for the open syllables and once for the nasal-final syllables. Both analyses demonstrated a significant main effect of syllable type (open syllable comparison: F[1,5]=114.2, p<.05; nasal-final syllable comparison: F[1,5]=110.1, p<.05) and no effects of tone. Thus, sắc and nặng are indeed significantly shorter when they occur in stop-final syllables.
RESULTS: ADULT LEARNERS

Speakers 2, 3, 4, 5, 6, and 7 were recorded in Cycle 1; Speakers 11, 12, 13, and 14 were recorded in Cycle 2.

Inclusion and Exclusion of Data

Our goal for the student data is to identify problems in tone pronunciation among adult learners in general as opposed to focusing on the performance of individual learners. We see this as an important approach given that the individual performances represent a snapshot in time. Each student has continued to study Vietnamese and to improve his or her pronunciation. Thus, the value of this analysis is not in identifying difficulties for each individual speaker, but in identifying difficulties that appear across multiple learners.

In graphing the adult learner tone systems, we focused on tone production that was consistent and that approximated native speaker targets. As a first step, we excluded obvious errors (e.g., a rising tone among otherwise level ngang tones). We then excluded forms that seemed inconsistent with the majority of productions. In some cases, the less frequent forms were the ones to approximate native speaker trajectories (Speaker 3 nasal-final syllables, Speaker 7 nasal-final syllables, Speaker 14 open and nasal-final syllables). In these cases, we plotted both the more frequent trajectory and the native-like trajectory. We also plotted two trajectories if they occurred with equal frequency (Speaker 4 open syllables, Speaker 14 nasal-final syllables). Because Speaker 14 contributed to both these situations, we also plotted a secondary trajectory for her nasal-final ngang and ngã even though these trajectories were not as frequent as the native speaker target.

Table 3 summarizes the number of tokens included for each tone by syllable type, and the legend in each figure indicates the number of tokens contributing to a given tone trajectory. Note that while Table 3 can convey consistency in tone production, it cannot convey accuracy. For example, Speaker 12 is highly consistent, but produces the same rising trajectory for every tone.

It is not surprising that language learners show some inconsistency in their tone production, and numbers flagged with an asterisk in Table 3 indicate points at which more than 1/3 of tokens have been excluded. Two speakers – Speaker 3 and Speaker 11 – contribute multiple asterisks. Speaker 3 appears to be struggling to produce tone contours consistently. His excluded nặng tones have a variety of shapes (e.g., rising, level, falling-rising-falling) across the three syllable types. His excluded ngang tones tend to fall, and the excluded huyền tones tend to be somewhat level. In contrast, Speaker 11’s exclusions correspond only to the nặng tone and tend to indicate cases in which pitch values were completely undefined as a result of glottalization or creakiness. Note that while this voice quality also helps explain the nặng exclusions for Speaker 6, it does not explain the nặng exclusions for Speaker 2 or 3. Both Speaker 2 and 3 produce excluded nặng tones with a variety of shapes that include rising and level contours.
Table 3. Number of tokens by syllable type and tone for adult learners (Speakers 2-14) of Northern (N) and Southern (S) Vietnamese. Pairs of numbers (n/n) indicate the native-like trajectory and a competing form, respectively. Numbers flagged with an asterisk (n*) indicate points at which more than 1/3 of tokens were excluded.

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Target Dialect</th>
<th>Max Number of Tokens</th>
<th>Open Syllables</th>
<th>Max Number of Tokens</th>
<th>Stop-Final Syllables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ngang</td>
<td>huyën</td>
<td>sáč</td>
</tr>
<tr>
<td>2</td>
<td>N</td>
<td>12</td>
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<td>12</td>
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<td>16</td>
<td>8*</td>
</tr>
<tr>
<td>4</td>
<td>S</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>S</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>S</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>N</td>
<td>16</td>
<td>7/9</td>
</tr>
<tr>
<td>11</td>
<td>S</td>
<td>32 others 16</td>
<td>32</td>
</tr>
<tr>
<td>12</td>
<td>S</td>
<td>32 others 16</td>
<td>32</td>
</tr>
<tr>
<td>13</td>
<td>S</td>
<td>32 others 16</td>
<td>32</td>
</tr>
<tr>
<td>14</td>
<td>N</td>
<td>32 others 16</td>
<td>18/10</td>
</tr>
</tbody>
</table>
Figure 13. Speaker 2 (male, adult learner of Northern dialect, open syllables)

Figure 14. Speaker 3 (male, adult learner of Northern dialect, open syllables)

Figure 15. Speaker 7 (male, adult learner of Northern dialect, open syllables)

Figure 16. Speaker 14 (female, adult learner of Northern dialect, open syllables)
Figure 17. Speaker 4 (female, adult learner of Southern dialect, open syllables)

Figure 18. Speaker 5 (male, adult learner of Southern dialect, open syllables)

Figure 19. Speaker 6 (female, adult learner of Southern dialect, open syllables)

Figure 20. Speaker 11 (male, adult learner of Southern dialect, open syllables)

Figure 21. Speaker 12 (male, adult learner of Southern dialect, open syllables)

Figure 22. Speaker 13 (male, adult learner of Southern dialect, open syllables)
Common Difficulty: Low Falling-Rising Tones

Figures 13 – 22 indicate that each of the adult learners produces a unique tone pattern. Despite these idiosyncratic systems, there are several common problems, the most frequent of which involves the low falling-rising tone. In previous technical reports (E.4.1, E.4.1), which reflected analyses of Speakers 1 – 10, we argued that none of the adult learners produces a native-like Northern hỏi or Southern nặng contour. While we maintain in the current report that this low falling-rising trajectory is still problematic for all but one student, the additional native speaker data has led us to revise our analysis of the critical properties of this contour. The original set of native speakers (Speakers 1, 8, 9, and 10) produced mean trajectories for Northern hỏi and Southern nặng that dipped below huyền and failed to rise past ngang, suggesting that both properties were intrinsic to the identity of this contour. However, data from two additional native speakers (Speakers 15 and 16) indicated mean trajectories that dipped below hỏi and clearly rose past nặng. Thus, the full set of native speaker data suggests that it is the dip below huyền that is an essential element of this contour. As such, one adult learner – Speaker 2 (Fig. 13) – produced a mean trajectory with this critical dip below huyền and a rise past nặng that is potentially comparable to the contour from Speakers 15 and 16.

The remaining students varied in their production of this contour. Several adult learners produced tone shapes that clearly rose past nặng, but failed to dip below huyền: Speakers 7 and 14 (Figs. 15 and 16) for Northern hỏi and Speaker 4 (Fig. 17) for Southern nặng. Among the Southern dialect learners, Speakers 5, 6, and 13 (Figs. 18, 19, and 22) produced contours that closely overlapped with huyền. For Speakers 3, 11, and 12 (Figs. 14, 20, and 21), the difficulty with this contour is tied to other problems in the tone system, i.e., starting huyền/nặng too high, producing Southern nặng with Northern glottalization, and producing the same contour for all tones.

Common Difficulty: Relative Starting Positions

A second area of difficulty – the approximation of native speaker starting points – involves at least four of the nine adult learners with differentiated tones: Speakers 3, 4, 5, and 11 (Figs. 14, 17, 18, and 20). Recall that native speakers from both dialects assign nặng the highest relative starting point, and that for some native speakers, sắc shares this position. In contrast, the relative starting positions of all remaining tones vary idiosyncratically. In giving nặng the highest relative starting point, native speakers tend to produce this tone at or above the speaker’s average pitch range.

Among the adult learners, Speakers 7, 6, and 13 (Figs. 15, 19, and 22) appear to produce native-like starting points. Speakers 2 and 14 (Figs. 13 and 16) might also be candidates for native-like systems given Thompson’s (1965) report that sắc can become nearly high and level in rapid speech. It is, however, an empirical question as to whether native speakers of Vietnamese are likely to confuse nặng and sắc when they are produced with high level parallel trajectories.

Among the students having difficulty with relative starting positions, two tone systems from Cycle 1 are of particular interest because they may reflect different strategies in tone production. Whereas Speaker 3 (Fig. 14) appears to start low for tones that rise, and high for tones that fall, Speaker 5 (Fig. 18) appears to start low for tones that fall, and high for tones that rise. Other difficulties include starting all tones from a central location (Speaker 4, Fig. 17) and producing nặng so low that it closely parallels huyền (Speaker 11, Fig. 20).

Common Difficulty: Glottalization

A third area of difficulty – native-like production of glottalization – is problematic for two of the adult learners with differentiated tones: Speakers 3 and 11 (Figs. 14 and 20). In addition, one adult learner (Speaker 6, Fig. 19) generally produces low pitch values with creaky voice, and another (Speaker 4, Fig. 17) might have benefited from using this voice quality to differentiate otherwise similar tone trajectories.

Recall that in Northern Vietnamese, ngã is broken in its midsection and nặng is truncated at its end by glottalization or creakiness. Two of the four adult learners of the Northern dialect successfully produced these voice quality changes. Speakers 2 and 14 (Figs. 13 and 16) produced native-like ngã and nặng tones that are audibly glottalized, and this glottalization is apparent in their tone contours.
Speaker 7 (Fig. 15) also produced native-like creakiness at the midsection of the ngã tone, and this voice quality is visible in the figure as a perturbation in pitch around 30 – 50%. While Speaker 7’s huyền and nặng trajectories both appear to be truncated, upon closer inspection of the utterances, this apparent shortness actually corresponds to a decrease in amplitude as opposed to strong glottalization or creakiness in either tone. Thus, Speaker 7 does not seem to use creakiness or a final glottal stop to differentiate huyền and nặng. Speaker 7 does, however, appear to differentiate these tones using duration. As shown in Figure 25, his nặng tones are shorter than his huyền tones in both vowel-final and nasal-final syllables. That said, the contrast in duration for Speaker 7 does not appear to be as great as for Speakers 2 and 14 (Figs. 23 and 26), who redundantly encode the contrast between these two tones with a contrast in voice quality. 2

In contrast to Speakers 2, 7, and 14, Speaker 3 produces nặng and huyền with similar durations and voice qualities (Fig. 24; Z’s < 1.4, p > .10). For this speaker, the apparent shortness in tone trajectories in Figure 14 corresponds to a decrease in amplitude for both tones and not to the use of glottalization or creakiness to differentiate nặng from huyền. In short, Speaker 3 fails to produce the voice quality that is characteristic of Northern nặng and ngã, and that might differentiate nặng from huyền or ngã from sắc.

For adult learners of Southern Vietnamese, we might expect to see continuous contours for every tone given that glottalization is not characteristic of this system. That said, the two native Southern speakers in this study do produce at

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1 In previous technical reports (E.4.1, E.4.3), we have plotted a gap at 30% for Speaker 7’s ngã tone in order to highlight the audible glottalization. In the process of incorporating data from 6 additional speakers (2 native, 2 students) for the current analysis, we have applied the criteria for plotting a gap more strictly across all speakers, resulting in a number of minor changes relative to earlier figures.

2 Figures 23 – 25 indicate two different bars for the stop-final syllables. The green bars, which reflect the long vowels a and ơ, provide a point of comparison to the native speaker durations in Figures 11 and 12. Recall that we excluded short vowels from the native speaker figures because they would have further shortened durations. Because adult learners produce long and short vowels with the same duration (Winn, Blodgett, & Twist, 2009), we also graphed all stop-final syllables regardless of vowel.
least some hỏi/ngã tokens with creakiness or vocal fold tenseness. For that reason, the broken hỏi/ngã contours and audible glottalization for Speakers 5 and 11 (Figs. 18 and 20) may still be consistent with native-like productions. Indeed, Speaker 4 (Fig. 17) might have benefited from producing a glottalized hỏi/ngã contour given the close alignment of her sắc and hỏi/ngã trajectories. There is no evidence of audible creakiness in her recordings.

Whereas Speaker 3 failed to produce a glottalized nặng or ngã for Northern Vietnamese, Speaker 11 (Fig. 20) did produce an audibly glottalized nặng, but for Southern Vietnamese. Although this voice quality is inconsistent with this tone in this dialect, Speaker 11 does differentiate nặng and huyền. In contrast, Speaker 6 (Fig. 19) tends to produce all low pitch values with a creaky voice, which is problematic for nặng and huyền, because they share a trajectory in her tone system.

DISCUSSION

The adult learner tone systems in the current study provide insight into some of the difficulties that native speakers of English encounter while acquiring Vietnamese tones as adults. One learner in particular, however, Speaker 12 (Fig. 21), appears to be having greater difficulty with tones than other learners. We can only speculate as to why this student produces the same contour for all tones at the time of recording, but one possibility is that the pattern is task dependent. Given a conversational task, this speaker may produce tones more successfully. Another possibility is that this student is having difficulty perceiving basic tone distinctions accurately. Indeed, a small percentage of the population, roughly no more than 4-5%, is thought to manifest congenital amusia, a disorder that can involve deficits in pitch discrimination or “tone deafness” (e.g., Ayotte, Peretz, & Hyde, 2002). While self-reported tone deafness is not a reliable indicator of difficulties with pitch discrimination (Cuddy, Balkwill, Peretz, & Holden, 2005), the Montreal Battery of Evaluation of Amusia (Peretz, Champod, & Hyde, 2003) has had some success differentiating false amusics from those likely to be true amusics, and language training programs that have the luxury of assigning students to particular languages based on pretest measures may wish to screen students for amusia. While we certainly do not wish to suggest that amusics will never be successful at learning tone languages, we do suspect that they will be more likely to reach higher levels of proficiency and to reach those levels more quickly with non-tone languages.

Each student produced a unique pattern of tones, but as a group, three common problems emerged. First, the majority of adult learners struggled to produce a native-like low falling-rising contour (i.e., Northern hỏi or Southern nặng). Only one student produced its key element – namely, a dip below huyền. We note that students learning Southern Vietnamese may be able to improve their production of this contour by adopting the tone patterns evident for Speaker 16. Because this native speaker aligned the hỏi/ngã contour with the low falling-rising nặng contour, multiple contours contain the critical dip below huyền, which may reinforce its production.

The second common problem involved producing the relative starting positions of tones. In two cases, the difficulty seemed to indicate particular learner strategies for producing tone contrasts (i.e., start low for rising tones and high for falling tones vs. start low for falling tones and high for rising tones). Unfortunately, such strategies tend to distort multiple tones in the system, which is likely to increase the odds that native listeners will have difficulty understanding a speaker.

The third common problem involved reproducing native-like patterns of glottalization, and the two most striking cases mapped to different dialects. Whereas one learner of Northern Vietnamese failed to produce any glottalized tones, which are characteristic of this dialect, one learner of Southern produced a robustly glottalized nặng tone, which is not characteristic of this dialect. Even the adult learners of Northern Vietnamese who do produce appropriately glottalized tones do not seem to use the glottalization to contrast pairs of tones as native speakers do. Whereas the native Northern speakers produce sắc and ngã with the same general trajectory, but glottalize ngã, none of the four adult learners follows this pattern. Similarly, two of them could use glottalization to contrast the same trajectory for huyền and nặng, but do not.

Two of our findings appear consistent with the one other study investigating the acquisition of Vietnamese tones by native speakers of English. As shown in Table 4, Nguyen and Macken (2008) found similarities among four American learners (two beginning level and two advanced) with respect to the frequency of their tone errors. In their analysis, hỏi, sắc, and nga nặng emerge as the most difficult tones. Although Nguyen and Macken do not specify the nature of student errors (native speakers simply evaluate tokens of each tone as “good” or “bad”), our finding that nearly all students struggled with the low falling-rising trajectory is consistent with the frequent “bad” ratings of hỏi tokens. Additionally, our finding that students struggle with the relative starting positions of tones and sometimes produce parallel trajectories for nga nặng and sắc could be consistent with the frequent “bad” ratings for these two tones.
Table 4. Error frequency patterns reported for four American learners of Vietnamese in Nguyen and Macken (2008)

<table>
<thead>
<tr>
<th>Learner</th>
<th>Error Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner 1</td>
<td>hỏi &gt; nằng &gt; sắc &gt; ngã &gt; huyền &gt; ngang</td>
</tr>
<tr>
<td>Learner 2</td>
<td>hỏi &gt; ngang &gt; sắc &gt; ngã &gt; nằng &gt; huyền</td>
</tr>
<tr>
<td>Learner 3</td>
<td>hỏi &gt; ngang &gt; sắc &gt; nằng &gt; huyền &gt; ngã</td>
</tr>
<tr>
<td>Learner 4</td>
<td>ngang &gt; sắc &gt; hỏi &gt; nằng &gt; ngã &gt; huyền</td>
</tr>
</tbody>
</table>

The pervasive nature of student difficulty with the low falling-rising tone that is evident in the current study and in Nguyen and Macken (2008) is consistent with Chen’s (1997, 2000) tone acquisition hierarchy for Mandarin. Based in part on his analysis of production data from adult learners, the hierarchy places the Mandarin falling-rising tone as the last tone to be acquired. This difficulty is also consistent with crosslinguistic tone perception studies (e.g., Gandour & Harshman, 1978; Huang, 2004), which demonstrate differences between native speakers of tone languages and non-tone languages. Whereas native speakers of tone languages are especially sensitive to tone shape or contour, native speakers of non-tone languages seem to focus on the less dynamic characteristics of tones, such as average pitch or endpoint.

New questions to answer

There is some suggestion in the literature that students who struggle to produce tone contrasts may benefit from periods of concentrated training on tone discrimination, particularly if the training materials are matched to their initial tone discrimination abilities. Results of Lee, Perrachione, Dees, and Wong (2007) suggest that individuals vary in their abilities to perceive differences in lexical tones. Furthermore, individuals who were unable to discriminate tones with at least 70% accuracy showed greater improvement when given training on a single speaker’s voice than training on tones from multiple speakers. In contrast, those who passed the 70% cut-off showed greater improvement when given training on multiple speakers than a single speaker. Although this finding needs to be replicated before being applied broadly to language learning environments, it raises the possibility that (1) all students are likely to improve their tone perception skills with focused ear training and (2) a particular type of training materials may maximize improvement among students experiencing the greatest difficulty.

Among the adult learners in the current study who do differentiate tones in production, Speaker 3 is representative of students who have difficulty producing target contours consistently. While all of the students made some mistakes, as expected among language learners, more than one third of Speaker 3’s ngang, huyền, and nằng tokens were excluded from analysis because of variations in tone shape. Other students, most notably Speaker 14, produced multiple competing trajectories, some of which were native-like and some of which were not. The current study examines a small cross-section of students who vary in their length of training. While it is tempting to compare the tone systems of those who are early in their training with those who are farther along, any apparent differences or lack thereof may be confounded with other factors, such as prior language learning experience. A longitudinal study, however, that recorded learners at multiple points throughout their training would be ideal for tracking improvements in consistency and tone development over time.

Finally, data from perception studies are needed to understand the ways in which adult learner errors affect their intelligibility. Whereas some errors may cause student speech to sound accented, other errors or combinations of errors may make student speech incomprehensible. Perception studies are currently underway to investigate how native speakers in Vietnam comprehend or fail to comprehend aspects of student speech.

CONCLUSIONS

The current study provides new native speaker and adult learner data on the production of Vietnamese tones. Analysis of the individual tone systems of four native Northern speakers and two native Southern speakers suggests that variation in the literature regarding the relative starting positions of tones can be resolved into a two-tier system in which ngang starts higher than all other tones and the relative starting positions of all remaining tones vary idiosyncratically. Analysis of 10 individual adult learner tone systems suggests that students have particular difficulty with the low falling-rising trajectory, the relative starting positions of tones, and glottalization. Language programs may find value in providing concentrated training on tone discrimination or screening students for their ability to discriminate contrasts in tone prior to assignment to a tone language.
APPENDIX 1: NATIVE SPEAKER NASAL-FINAL SYLLABLES

Figures 27 – 32 document the native speaker tone systems using nasal-final syllables. The patterns closely resemble those from open syllables provided in the main text.

Figure 27. Speaker 1 tone system (female, native speaker of Northern dialect, nasal-final syllables)

Figure 28. Speaker 8 tone system (male, native speaker of Northern dialect, nasal-final syllables)

Figure 29. Speaker 9 tone system (male, native speaker of Northern dialect, nasal-final syllables)

Figure 30. Speaker 15 tone system (female, native speaker of Northern dialect, nasal-final syllables)

Figure 31. Speaker 10 tone system (female, native speaker of Southern dialect, nasal-final syllables)

Figure 32. Speaker 16 tone system (female, native speaker of Southern dialect, nasal-final syllables)
APPENDIX 2: NATIVE SPEAKER STOP-FINAL SYLLABLES

Figures 33 – 38 document the native speaker tone systems for stop-final syllables. The patterns closely resemble the representative figures provided in the main text.

Figure 33. Speaker 1 stop-final tones (female, native speaker of Northern dialect)

Figure 34. Speaker 8 stop-final tones (male, native speaker of Northern dialect)

Figure 35. Speaker 9 stop-final tones (male, native speaker of Northern dialect)

Figure 36. Speaker 15 stop-final tones (female, native speaker of Northern dialect)

Figure 37. Speaker 10 stop-final tones (female, native speaker of Southern dialect)

Figure 38. Speaker 16 stop-final tones (female, native speaker of Southern dialect)
APPENDIX 3: ADULT LEARNER NASAL-FINAL SYLLABLES

Figures 39 – 48 document the adult learner tone systems using nasal-final syllables. The patterns closely resemble those from open syllables provided in the main text.

Figure 39. Speaker 2 tone system (male, adult learner of Northern dialect, nasal-final syllables)

Figure 40. Speaker 3 tone system (male, adult learner of Northern dialect, nasal-final syllables)

Figure 41. Speaker 7 tone system (male, adult learner of Northern dialect, nasal-final syllables)

Figure 42. Speaker 14 tone system (female, adult learner of Northern dialect, nasal-final syllables)
Figure 43. Speaker 4 tone system (female, adult learner of Southern dialect, nasal-final syllables)

Figure 44. Speaker 5 tone system (male, adult learner of Southern dialect, nasal-final syllables)

Figure 45. Speaker 6 tone system (female, adult learner of Southern dialect, nasal-final syllables)

Figure 46. Speaker 11 tone system (male, adult learner of Southern dialect, nasal-final syllables)

Figure 47. Speaker 12 tone system (male, adult learner of Southern dialect, nasal-final syllables)

Figure 48. Speaker 13 tone system (male, adult learner of Southern dialect, nasal-final syllables)
APPENDIX 4: ADULT LEARNER STOP-FINAL SYLLABLES

Figures 49 – 58 document the adult learner tone systems for stop-final syllables. Pham (2003) has argued that the important feature of stop-final syllables is not their tones, but the fact that they are short syllables that end in stops. As a result, we might expect adult learner deviations from native-like patterns to matter less to intelligibility than deviations in open or nasal-final syllables. Speaker 3’s tone patterns (Fig. 50) are consistent with his apparent strategy to start rising tones low (and falling tones high). Speakers 4 and 12 (Fig. 53 and 57) produced a compressed pitch range and a single contour for all tones, respectively, in the open syllable and nasal-final syllable conditions.

Figure 49. Speaker 2 stop-final tones (male, adult learner of Northern dialect)

Figure 50. Speaker 3 stop-final tones (male, adult learner of Northern dialect)

Figure 51. Speaker 7 stop-final tones (male, adult learner of Northern dialect)

Figure 52. Speaker 14 stop-final tones (female, adult learner of Northern dialect)
Figure 53. Speaker 4 stop-final tones (female, adult learner of Southern dialect)

Figure 54. Speaker 5 stop-final tones (male, adult learner of Southern dialect)

Figure 55. Speaker 6 stop-final tones (female, adult learner of Southern dialect)

Figure 56. Speaker 11 stop-final tones (male, adult learner of Southern dialect)

Figure 57. Speaker 12 stop-final tones (male, adult learner of Southern dialect)

Figure 58. Speaker 13 stop-final tones (male, adult learner of Southern dialect)
APPENDIX 5: TONE DURATIONS FOR ADULT LEARNERS OF SOUTHERN VIETNAMESE

Figures 59 – 64 document the average tone durations by syllable type for adult learners of Southern Vietnamese.

Figure 59. Speaker 4 mean tone durations by syllable type (female, adult learner of Southern dialect)

Figure 60. Speaker 5 mean tone durations by syllable type (male, adult learner of Southern dialect)

Figure 61. Speaker 6 mean tone durations by syllable type (female, adult learner of Southern dialect)

Figure 62. Speaker 11 mean tone durations by syllable type (male, adult learner of Southern dialect)

Figure 63. Speaker 12 mean tone durations by syllable type (male, adult learner of Southern dialect)

Figure 64. Speaker 13 mean tone durations by syllable type (male, adult learner of Southern dialect)
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