Internal and contextual cues to tone perception in Medumba

Kathryn H. Franich

Department of Linguistics, University of Chicago, 1115 E. 58th St., Room 224, Chicago, IL 60637

Running title: Cues to tone perception in Medumba
Abstract

This study presents results of an identification experiment with speakers of Medumba, a Grassfields Bantu language, aimed at evaluating the relative effects of $f_0$ and duration in cuing tonal identification, as well as the role of lexical vs. non-speech pitch contexts in biasing tonal perception. Results show that duration is a cue for tone perception, with the influence of duration strongest where target $f_0$ values were lower. Lexical tone perception is also sensitive to the identity of a preceding lexical tone, but not to the presence of a preceding non-speech pure tone.

© 2015 Acoustical Society of America

Keywords: tone, speech perception, $f_0$, duration, context
1 Introduction

This work investigates the role of target-internal and contextual factors in tone perception in Medumba, a Grassfields Bantu language spoken in Cameroon. Despite the large body of work examining perceptual properties of tone languages (Abramson, 1979; Gandour, 1981; Xu, 1994; Brunelle, 2009), little work has examined such properties in African languages. Omozuwa (1991) found that $f_0$ level and direction of $f_0$ change were the most important cues for tone perception of disyllabic nouns in Edo, a Volta-Niger language. Connell (2000) found that speakers of Mambila, a Benue-Congo language with four lexical tones, showed much clearer categorical boundaries for High (H) and Low (L) tones than for the two Mid (M) tones in the language. Mixdorff et al. (2011) examined perception of tones in Sesotho, a Southern Bantu language, finding that $f_0$ can outweigh vowel quality as a cue in lexical identification.

Besides $f_0$ and vowel quality, duration has been shown to be an important cue associated with both the perception and production of lexical tone cross-linguistically. Specifically, while L tones have been found to be produced with longer duration (Gandour, 1977), listeners tend to hear L tones as shorter than H tones when duration is held constant (Yu, 2011; Gussenhoven & Zhou, 2013). This effect is thought to arise from a compensatory mechanism on the part of speakers to normalize for $f_0$-related perceptual or articulatory biases (Yu, 2011; Gussenhoven & Zhou, 2013). While the phenomenon has been documented for English and Chinese languages, it has yet to be explored in an African tone language.

Tone perception has also been found to be influenced by the pitch of words in the surrounding context. Such contextual effects have been found to have a strong influence in studies on talker
normalization in tone perception (Leather, 1983; Wong & Diehl, 2003; Francis et al., 2003, 2006); however, it is unclear whether such effects were specific to linguistic stimuli, or whether they represent a more general auditory effect of $f_0$. Huang & Holt (2009, 2011) found, for example, that contextual non-speech pure tones which mimic the $f_0$ of a real talker can elicit perceptual biases in tone categorization, suggesting tone perception may rely on domain-general auditory processing mechanisms.

Manipulations for talker normalization studies either involved different talkers saying a carrier sentence, or synthetically altered stimuli meant to create the impression of different talkers. An additional question thus concerns how much intra-speaker effects of pitch context can influence tone perception. Two early studies aimed to examine such effects by looking at Mandarin tone identification in paired syllables. Lin & Wang (1985) found that raising the onset $f_0$ of the second syllable (which bore a falling tone) made subjects more likely to hear a rising tone on the first syllable, even though the $f_0$ of the first syllable was unchanged throughout the experiment. However, a later study by Fox and Qi (1990) using a similar methodology found little effect of context. A potential issue with both of these studies was that they directly compared perception of level and contour tones in context, though more recent work has found contextual effects to be stronger for level tones than for contours (Francis et al., 2003).

The current study examines tone perception in Medumba, which contrasts only H and L level tones (Voorhoeve, 1971). In particular, I focus on two questions, including: (1) the role of duration in tonal perception in Medumba; and (2) the effect of $f_0$ of the preceding sound on tonal perception of a target syllable. If speakers are indeed sensitive to pitch cues from the surrounding context, a related question concerns the types of stimuli which can exert such an influence. Specifically, I investigate whether speakers are sensitive only to the pitch of surrounding speech sounds, or
whether the pitch of contextual non-speech sounds can also bias tonal perception.

2 Methods

2.1 Participants

Nineteen Medumba speakers (9 female) aged 18-47 participated in a word identification task. Speakers were paid the equivalent of $10 US and none reported any speech or hearing problems.

2.2 Stimuli

Stimuli consisted of 6 syllable types and two contrastive tones (Table 1). A female native speaker (who did not participate in the experiment) produced the syllables, which were then resynthesized in Praat using PSOLA. A 7-step $f_0$ continuum was created for each syllable which ranged from 185 Hz to 275 Hz, increasing at each step by 15 Hz; $f_0$ remained constant throughout the syllable. The highest and lowest values on the continuum were based on the average $f_0$ values of the model speaker’s H and L tones, as assessed from production data collected in a separate experiment. A 3-step duration continuum was then created from the resynthesized syllables with values of 100ms, 175ms and 250ms. The original syllables from the model talker were produced with durations of around 175ms, on average. To achieve the three target durations, stimuli were either trimmed or lengthened by splicing in copies of vowel wavelets taken from within the target syllable. In addition, pure tones consisting of a single sine wave with a frequency corresponding to either the highest or lowest points on the $f_0$ continuum were generated as ‘context pure tones’ to be played 40 ms before the target syllables. Manipulations resulted in the creation of 42 total stimuli per
syllable (7 $f_0$ values $\times$ 3 durations $\times$ 2 context pure tones), for a total of 252 trials (42 stimuli $\times$ 6 blocks) per subject. All stimuli were normalized for intensity.

2.3 Procedure

All data was collected by the author in Bangangté, Cameroon in September of 2015. The experiment was run in a quiet room using Praat version 5.3.84 on a 10" Macbook Pro. Participants listened to stimuli through headphones and used the computer’s trackpad to click on one of two buttons on the screen, corresponding to the word they heard; they could not listen to a stimulus more than once. Stimuli were presented in blocks according to syllable, with stimulus order randomized within each block and block order randomized by subject. Subjects were given a brief tutorial on how to use the trackpad (as many had not had previous experience with a computer) and were given one full block of training (responses were not recorded) before the actual experiment began. The study was self-paced, and took around 25 minutes to complete on average, including short breaks between blocks.

3 Results

H tone responses was modeled using mixed effects logistic regression with the lme4 package for R. The model included five predictors, TARGET_F0 ($f_0$ of the target syllable), DURATION (duration of the target syllable), PREC_F0 ($f_0$ of the target syllable in the preceding trial), PREC_RESPONSE (response to the target syllable in the preceding trial, H or L) and PURE TONE (level of context pure tone, H or L). The first three continuous variables were centered to avoid collinearity effects and the last two categorical variables were sum-coded. Random intercepts for SUBJECT and SYLLABLE
(segmental content of the syllable, ignoring tone) were included in the model, and random slopes were included for all aforementioned variables. Model selection proceeded with likelihood ratio tests.

As expected, there was a strong main effect of TARGET_F0 ($\beta = 1.3801$, $p < 0.0001$) with H responses correlated positively with $f_0$ of the target syllable. There was also a strong effect of DURATION ($\beta = -0.2936$, $p < 0.001$), with fewer H tone responses at longer durations. This finding is in line with previous work, and is possibly attributable to a compensatory process (Yu, 2011; Gussenhoven & Zhou, 2013). There was also a strong interaction between TARGET_F0 and DURATION ($\beta = 0.1569$, $p < 0.0001$). As can be seen in Figure 1, the identification curve becomes steeper at longer durations, suggesting that tone categories were better-defined at longer durations.

As mentioned, there was a bias toward H tone responses at shorter durations, but H tone response rates converged as $f_0$ of the target syllable increased.

Figure 1: Proportion of H Tone Responses on Target by F0 and Duration

For contextual effects, there was no effect of PURETONE ($p > 0.8$), indicating that perception was not subject to the frequency of non-speech information. However, there was a strong effect of...
both $\text{PREC}_F_0$ ($\beta = -0.4115, p < 0.0001$) and $\text{PRECRPONSE}_F_0$ ($\beta = 0.3204 p < 0.0001$), indicating that both the actual $f_0$ of the syllable in the preceding trial and the perceived tone of that syllable were good predictors of listeners’ perception of the target. A positive correlation between H tone responses and preceding response indicates that participants tended to hear more H tones when they had judged the previous tone as H, and more L tones when they had judged the previous tone as L. As can be seen in Figure 2, there was an inverse relationship between H tone responses for the target and $f_0$ of the preceding trial, showing that lower $f_0$ values of the preceding syllable encouraged more H tone responses, and vice versa.

Figure 2: Proportion of H Tone Responses on Target by F0 of Preceding Trial

There was also a significant three-way interaction between $\text{TARGET}_F_0$, $\text{PREC}_F_0$ and $\text{PRECRPONSE}_F_0$ ($\beta = 0.5765, p < 0.0001$). As can be seen in Figure 3, the proportion of H tone responses increased as the $f_0$ of the target syllable increased, but only in those cases where participant judgments of the preceding tone were the most congruent, or consistent with the actual $f_0$ of the previous syllable; conversely, where participant responses were incongruent with the preceding syllable’s $f_0$, the relationship between target $f_0$ and target response was much less consistent. 

October 30, 2015
Interestingly, where the preceding syllable was in the middle of the \( f_0 \) continuum (230 Hz), \( f_0 \) of the target syllable was a good predictor of participant response regardless of whether subjects rated the preceding syllable as H or L. This is likely the result of perceptual assimilation, such that subjects could interpret these preceding 230 Hz syllables as either H or L reference points in perception of the target tone. On trials where the preceding syllable was 230 Hz, judgments of target tones occurring in the middle of the \( f_0 \) continuum were heavily biased by judgments on the preceding syllable. Specifically, more H tone responses were recorded where the preceding response was H, and vice versa. However, responses converged at either end of the target continuum (185 Hz and 275 Hz), presumably because target \( f_0 \) values at these points were extreme enough that subjects relied less on the preceding context.

Figure 3: Proportion of H Tone Responses on Target by \( f_0 \), Preceding Response and \( f_0 \) of Preceding Trial (individual windows represent \( f_0 \) of preceding target syllable within block)
4 Discussion

This study examined two types of cues to tone perception in Medumba, including the relative weighting of target-internal phonetic properties of duration and $f_0$, and the contextual influence of preceding speech and non-speech tones. Findings indicate that $f_0$ and duration are both cues to tone perception in the language, with duration being an especially salient cue for tonal differences where the target syllable carries a lower $f_0$ value. In particular, lower $f_0$ syllables with short durations were perceived as H tones more often than their longer counterparts. This result could be due to a compensatory effect as proposed by Yu (2011) or Gussenhoven & Zhou (2013), though the nature of such an effect remains unclear in the absence of corroborating production data.

The $f_0$ of the target syllable within a preceding experimental block had a strong effect on perception of the target tone, suggesting that contextual pitch information does have an influence on tone perception. In general, preceding $f_0$ had a ‘contrastive’ effect, with lower $f_0$ values leading to more H tone responses on the target syllable, and vice versa. Subjects’ tone identification on the target was also positively correlated with their preceding response. The importance of contextual information was made especially clear from the 3-way interaction between target syllable $f_0$, preceding syllable $f_0$, and perceived tone of the preceding syllable. Specifically, conflicts between category assessment and actual $f_0$ value of the preceding syllable influenced listeners’ tone identification on the target, making it less predictable from target $f_0$ values.

Interestingly, H and L non-speech tones had no effect on subjects’ perception of tone. This is somewhat unexpected given findings by Huang & Holt (2009, 2011) which indicate that contextual non-speech stimuli can elicit similar perceptual effects as speech stimuli. Non-speech stimuli used
in the present study consisted of a single tone, in contrast to previous studies where it consisted of several tones of different frequencies whose overall frequency/\(f_0\) was raised or lowered to create the surrounding context. It is possible that the complexity of processing both speech and non-speech stimuli in rapid succession effectively ruled out any potential effects of the non-speech stimuli, as subjects were likely attending much more directly to the speech stimuli. Future work should investigate whether providing a longer non-speech context leads to larger effects in target tone perception.

5 Conclusions

This study has shown that Medumba speakers are sensitive to both internal and contextual tonal cues in perceiving tonal categories. An important finding was that duration, in addition to \(f_0\), influences tone perception; such effects have not been widely described for African tone languages. Also of interest was that the pitch of preceding speech sounds had a strong effect on tone perception of the target syllable, but pitch of non-speech sounds did not.

Acknowledgments

This work was supported by National Science Foundation Linguistics Program Grant No. BCS-1423865 (co-PIs: Kathryn Franich and Alan C.L. Yu). The National Science Foundation does not necessarily endorse the ideas and claims in this paper.
Notes

1 All stimuli can be accessed at http://home.uchicago.edu/kfranich/Perception_Study_Sound_Files.html

References and links


October 30, 2015


October 30, 2015


Table 1: Translations of Medumba words

<table>
<thead>
<tr>
<th>Syllable</th>
<th>H Tone</th>
<th>L Tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) fə</td>
<td>‘sheet of paper’</td>
<td>‘cadaver’</td>
</tr>
<tr>
<td>2) tsə</td>
<td>‘season of famine’</td>
<td>‘in-laws’</td>
</tr>
<tr>
<td>3) ia</td>
<td>‘pomade’</td>
<td>‘pineapple’</td>
</tr>
<tr>
<td>4) sa</td>
<td>‘dance’/‘game’</td>
<td>‘star’</td>
</tr>
<tr>
<td>5) to</td>
<td>‘hole’</td>
<td>‘belly button’</td>
</tr>
<tr>
<td>6) ko</td>
<td>‘summit’</td>
<td>‘lance’</td>
</tr>
</tbody>
</table>
Figure 1: Proportion of H Tone Responses on Target by F0 and Duration

Figure 2: Proportion of H Tone Responses on Target by F0 of Preceding Trial

Figure 3: Proportion of H Tone Responses on Target by F0, Preceding Response and F0 of Preceding Trial (individual windows represent F0 of preceding target syllable within block)