The Effect of L1 Pitch Status and Extralinguistic Factors on L2 Tone Learning

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Abstract

Some adult L2 learners perceive and acquire lexical tone more easily than others. Such inter-learner variability in tone learning facility has been attributed to individual L1-specific factors (such as the lexical status of pitch in the L1 and the shapes of L1 intonational and tonal types) [1] and extralinguistic factors (such as pitch perception aptitude, musical experience, and working memory) [2]. However, the relative importance of each of these factors when taken together is not well understood. Therefore, this study investigated non-native tone word learning by native speakers of languages on a spectrum of lexical pitch usage: Dutch (stress), Japanese and Swedish (pitch accent), and Thai (tonal). Participants were matched for their musical experience and working memory capacity. They completed a tone categorization task to measure pre-lexical pitch perception aptitude. They were then trained to memorize nine pseudolanguage words with a three-way segmental (/lala/ /lele/ /lili/) and a three-way tonal contrast (level, falling, peak), and were tested on their tone word learning ability in a word identification task.

Results from Bayesian inference suggest that tone word learning was primarily facilitated by individual pitch perception aptitude, which was in turn facilitated by musical experience. The findings of this study are discussed in the light of the "Functional Pitch Hypothesis" of L2 tone perception [1], and highlight the importance to account for extralinguistic individual aptitudes in speech learning in addition to L1-specific factors.

Index Terms: tone, musical experience, individual variability, L2 acquisition

1. Introduction

1.1. Individual differences in tone learning facility

Lexical tones are known to be a relatively challenging aspect of speech to acquire for adult L2 learners. In particular, whereas learners may overcome difficulties in perceiving tones pre-lexically (*tone perception*) [3], linking tone to lexical meaning (*tone word learning*) appears to present more persistent difficulty, even in advanced learners [4]. Yet, some learners appear to perform relatively well at early stages of tone learning, and show greater learning facility than others [2, pp. 774–775], [5]. To account for individual differences in tone learning facility, previous studies have identified both L1-specific and extralinguistic factors that may modulate the ease with which tones are perceived and learned.

1.1.1. L1-specific factors affecting tone learning facility: L1 pitch status and tone types

It may seem intuitively plausible that a learner who has L1 familiarity with the use of pitch for lexical distinctions can benefit from this familiarity in L2 tone learning, and some studies suggest that *L1 pitch status* (i.e., the functional load of pitch in the L1) positively predicts L2 tone processing accuracy [6]–[8]. Moreover, it has been suggested that L1 pitch status modulates L2 tone processing in an incremental fashion. For instance, in a study on Thai tone discrimination accuracy [1], L1 speakers of Mandarin Chinese (maximal pitch status) outperformed speakers of Japanese (intermediate pitch status), who in turn outperformed English speakers (low pitch status). These findings have given rise to the "Functional Pitch Hypothesis" of non-native tone perception.

It is important to note that while there is evidence supporting the notion that mere L1 pitch status facilitates L2 tone perception, there exist many cross-linguistic studies that fail to find such an effect [9]–[12]. One reason why L1 pitch status alone may not explain individual differences in L2 tone perception is because the effect of *tone type* needs to be considered. Tone type here refers to the specific shape of non-native target tones and their similarity to L1 tone types (either tonal or intonational). Tone type modulates non-native tone processing because learners from different L1 backgrounds differ in the degree to which they pay attention to acoustic-phonetic properties of tones, such as pitch height or pitch contour [10], [13], [14]. Additionally, learners may assimilate non-native tonal contrasts phonologically to similar-sounding L1 contrasts, which may affect perception accuracy as predicted by speech perception models such as the Perceptual Assimilation Model [15]–[17]. In other words, whether or not L1 pitch status facilitates L2 tone processing may depend on the specific tone types to be perceived and acquired.

1.1.2. Extralinguistic factors affecting tone learning facility

In recent years, the tone perception and acquisition literature has shifted attention to examining the effects of factors that are independent of a learner's L1 to account for individual variability in tone learning facility. One of the most investigated factors is musicianship, which can be either defined as musicality, as measured by standardized tests [9], [18], or musical experience, as measured by years of musical practice [19], [20]. Musical experience has been found to facilitate pre-lexical tone perception [20], [21] and tone word learning [19]. Other extralinguistic factors that may facilitate tone learning are cognitive capacities such as working memory (WM) [2], [22]. Finally, studies that investigate the link between pre-lexical and lexical tone processing suggest that the ability to perceive tones devoid of lexical meaning in perception, which has been referred to as "pitch perception aptitude" [2], [23] may be a strong indicator of how learners perform in tone word learning.

Crucially, whereas previous studies have separately investigated the effects of L1-specific (L1 pitch status and tone type) and extralinguistic factors (musical experience, WM, and pitch perception aptitude) , there are only a handful studies that look at both L1-specific and extralinguistic factors, and most of these only address L1 pitch status and musicianship [9], [24], [25]. To the best of the author's knowledge, there are no previous studies that have investigated an array of extralinguistic factors with participants on a spectrum of L1 pitch status to examine the relative weighting of L1-specific and extralinguistic facilitative factors on tone learning. The present study aims to address this gap in the literature and provide a more complete account of the factors that explain individual variability in tone learning facility.

2. The present study

2.1. Overview

This study is inspired by [1], who found that L1 pitch status facilitated Thai tone perception in an incremental fashion. Similar to [1], the present study included participants whose L1s represent a spectrum of L1 pitch statuses (Dutch, Swedish, Japanese, and Central Thai). It differs in that the target language is not Thai, but a tonal pseudolanguage with a three-way tonal contrast (level, fall, peak, Fig. 1). As described in section 2.2., the choice for a pseudolanguage system was motivated by the fact that this allowed to design a tone system that is hypothetically equally easy or difficult to acquire for all participants, thereby mitigating the potential effects of interference between L1 and L2 tone types. A second novelty of this study is that it investigated tone processing not only at the pre-lexical level in perception, but also at the lexical level in word learning. Third, this study considers both the effect of L1 pitch status and that of extralinguistic factors (musical experience, WM, and pitch perception aptitude) on tone learning facility. Finally, the sample size of the present study is roughly twice that of [1]. This will allow to revisit the "Functional Pitch Hypothesis" that postulates that non-native tone processing is shaped by the functional prosodic domain at which pitch variations are realized in an L1 [1]. As such, this study's aim is to contribute to a deeper understanding of the factors that modulate non-native tone learning facility.

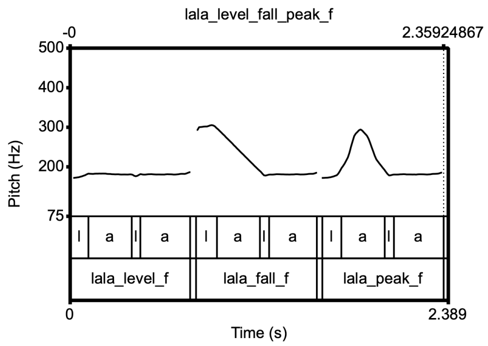

Figure 1: *F0 curves showing the level, fall and peak tonal contrasts. In terms of Chao numerals, the contrasts can be described as [11], [51], and [141].*

2.2. Predictions

Based on the Functional Pitch Hypothesis, it is predicted that L1 pitch status will have an incrementally facilitative effect on non-native tone processing. As such, Thai speakers are expected to outperform Japanese and Swedish speakers, who in turn are expected to outperform Dutch speakers.

To mitigate the effect of tone type and to focus on whether L1 pitch status in and of itself facilitates non-native tone processing, the present study examined perception and production in a tonal pseudolanguage system with tone types that are hypothesized to be equally challenging for all speakers. This tonal system consisted of a low-level, a falling, and a peaking tone. The static low-level tone contrasts with the dynamic falling and peaking tones in both height and direction, and such "static-dynamic" contrasts are expected to be inherently easy to perceive. The fall-peak contrast constitutes a "dynamic-dynamic" contrast, which may be inherently difficult to perceive, regardless of L1 background [1], [26]. Although it cannot be excluded that the intonational or tonal systems of the learners' L1s will affect the processing of the pseudolanguage tones in different ways, it is predicted that, following [1], the effect of tone types from stress and pitch accent languages (Dutch, Swedish, Japanese, here) on non-native tone processing is limited. There may be a more direct effect from Thai tone types on the processing of the pseudolanguage tones, but it is still expected that the static-dynamic contrast will be relatively easy, and the dynamic-dynamic contrast will be relatively difficult. Namely, it is possible that the falling and peaking tones assimilate in a many-to-one fashion onto the Thai falling tone, which is sometimes described as a rising-falling, i.e., peaking tone [15, p. 6]. This may make the fall-peak contrast relatively difficult to process. The presence of static-dynamic contrasts in Thai would imply that Thai speakers can process the static-dynamic contrasts in the pseudolanguage with relative ease.

Finally, musical experience, WM, and pitch perception aptitude are all expected to facilitate tonal pseudolanguage word learning, although there may be a differential in relevance of these factors depending on the L1 [9]. In the absence of cross-linguistic studies that have assessed an array of extralinguistic factors in non-native tone learning, no specific predictions are formulated about the relative weighting of each of the abovementioned factors.

2.3. Participants

A total of 114 participants took part. Participants were recruited through university networks and social media. All were native speakers of Dutch (NL), Swedish, Japanese, or Central Thai, and had grown up in the respective countries of origin but were resident in the UK as students or young professionals at the time of the study. Participants first filled out a questionnaire regarding their linguistic and musical background before being included in the main study. Following [1], speakers of Dutch, Swedish or Japanese who had knowledge of another pitch accent or tone language were excluded. Because of an imbalance in the number of musicians and non-musicians across groups in the original participant pool, the data presented here focus on a subset of 80 participants (22 Dutch, 15 Swedish, 23 Japanese, and 20 Thai participants) who were matched for their degree of musical experience, measured in years of formal training. Equivalence tests [27] revealed no significant difference between the groups in terms of their musical experience or WM.

2.4. Stimuli

The audio stimuli consisted of set of meaningless vowels (/a/ /e/ /i/), which were used in a tone categorization task (tone perception), and a set of pseudolanguage words (/lala/ /lele/ /lili/), which were used in a word identification task (tone word learning). Each of these stimuli carried either a low-level, a falling , or a peaking tone (Fig. 1), resulting in nine vowel and nine pseudolanguage word stimuli for each task. Stimuli were recorded in a sound-attenuated booth and produced by two native speakers of Italian (one male, one female). The baseline stimuli were produced with a flat (low-level) tone. Stimuli with the falling and peaking tones, of which the contours were based on natural productions, were synthesized using Pitch Synchronous Overlap (PSOLA) in *Praat* [28]. This ensured that tone minimal triplets only differed in F0 and not in other acoustic cues. For the pseudolanguage words, the tone contrasts occurred on the first syllable of the word. Visual stimuli in the tone categorization task consisted of arrows representing the level, falling, and peaking contours. In the word identification task, each pseudolanguage word (which was only presented aurally) was linked to an image representing its meaning [29].

2.5. Procedure

The study was carried out on *Gorilla Experiment Builder* [30]. Written instructions were in the participants' respective L1s. Headphone screening ensured that participants were in a silent room and were using headphones [31]. The study consisted of two 25-minute sessions with a 24-hour gap in between both sessions. On day 1, participants completed a tone categorization task, which served to measure pre-lexical tone processing, also known as pitch perception aptitude [19], [23]. Participants heard one of the vowels with a level, a falling, or a peaking tone, and were instructed to categorize the tone by clicking on an arrow representing the pitch contour. The tone categorization task was followed by tone word training. In the first part of the word training, participants were presented aurally with the pseudolanguage tone word and simultaneously saw its meaning represented by an image. They were encouraged to repeat the word out loud as accurately as possible. Each word was presented twice. A debrief revealed that 87% of the time, participants repeated out loud "all of the words" and 11% of the time "about half of all the words". After the listen-and-repeat session, participants completed word identification training, in which they heard a pseudolanguage word and had to indicate its meaning by selecting the corresponding image from a 9-way answer board. Feedback was given after each presentation. In the word identification training, each word was presented four times. After the training session, participants completed a tone word identification task, which was identical to the word identification training, only that no feedback was given and that each word was presented six times.

On day two, participants first completed a working memory pre-test, which consisted of a backwards digit span task. They then proceeded with the same word training sessions as on day 1. After the training session, participants took a word identification task, which had the same format as the word identification task on day 1, but the crucial difference was that the audio stimuli were spoken by a new speaker (female), in order to test participants' generalization ability.

2.6. Analysis

Performance was measured by accuracy in the tone categorization and word generalization tasks. Null responses and responses with unnaturally fast reaction times (<250 ms) were removed, excluding 0.62% and 0.45% of data points from each task, respectively. Bayesian models were constructed using weakly informative priors with the mean centered around zero and a standard deviation of 10 for all population- and group-level regression coefficients and LKJ(2) for correlation priors. Four sampling chains were run with 3000 iterations and 1500 warm-up iterations. The model for tone categorization (dependent variable: correct/incorrect) contained fixed effects for *L1* (Dutch, Swedish, Japanese, Thai; contrast-coded), *Tone* (Level, Fall, Peak; contrast-coded), *Musical Experience* (Years of formal practice, centered and scaled), and *Working Memory* (Digit span score; centered and scaled), and a two-way interaction with *L1* and each of the fixed effects. The random effects structure contained a by-subject random slope for *Tone* and a random intercept for item. The model for word identification had the same structure, but in addition contained a fixed effect of *Pitch Aptitude* (accuracy in the tone categorization task, centered and scaled), and an *L1*Pitch Aptitude* interaction to investigate the effect of pre-lexical tone processing on lexical tone processing. For brevity, only the results of the word generalization task on day 2 are reported. In the reporting of results, "compelling evidence" is assumed for an effect of which the 95% credible interval lies entirely above or below zero [32, p. 1079].

3. Results

3.1. Tone categorization task (tone perception)

Based on the priors, the data, and the model, there was compelling evidence that musical experience facilitated tone perception for all participants (0.74 [0.37, 1.12]). There was compelling evidence for an *L1*Tone* interaction. Planned comparisons between tones revealed that participants were more likely to accurately categorize level tones than falling or peaking tones (i.e., level>fall=peak Fig. 2), except Thai participants, who were more likely to accurately categorize level and peaking tones than falling tones (i.e., peak>level=fall). Comparisons between L1s revealed compelling evidence that Japanese speakers were more likely than Dutch or Thai speakers to correctly categorize level tones, although this should be interpreted with caution given the ceiling performance. There was compelling evidence for an *L1*WM* interaction. Post-hoc analyses revealed that WM only facilitated tone perception for Japanese speakers (1.06 [0.45; 1.69]).

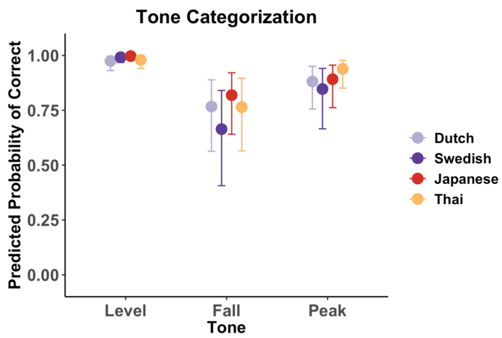

Figure 2: *Predicted probabilities of correct tone categorization per tone and per L1.*

3.2. Word identification task (tone word learning)

There was considerable individual variability in performance in the word identification task (Fig. 3). It is worth noting that in each group, between 70-80% of all word identification errors were "Tone-Only Errors" (TOEs), indicating that participants had acquired the words' segmental, but not tonal properties (i.e., misidentifying /la51.la/ as /la141.la/). An analysis of the TOE patterns revealed that participants predominantly misidentified falling tone words as peaking tone words and vice versa (Fig. 3).

There as compelling evidence that pitch aptitude facilitated word learning for all participants (0.91 [0.44, 1.36]; Fig. 5). There was compelling evidence for an *L1*Tone* interaction. Planned comparisons between tones per L1 revealed similar results as in the tone categorization task (Fig. 6). Namely, there was weak to compelling evidence that participants were more likely to accurately identify words with level tones than words with falling or peaking tones. Planned comparisons between L1s revealed compelling evidence that Thai speakers were more likely to identify level tone words than Swedish speakers, and that Dutch speakers were more likely to identify falling tone words than Japanese speakers. There was compelling evidence for an *L1*Musical Experience* interaction. and post hoc analyses revealed that musical experience only facilitated tone perception for Swedish participants (0.72 [0.08; 1.43]).

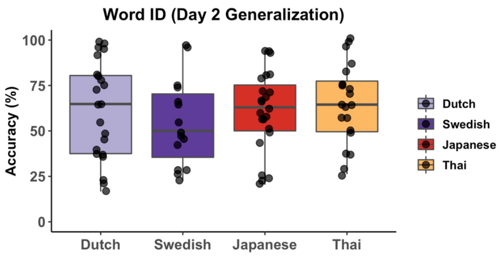

Figure 3: *Accuracy in the word identification task.*

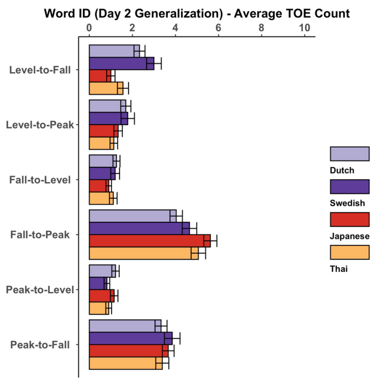

Figure 4: *Overview of Tone-Only Error patterns.*

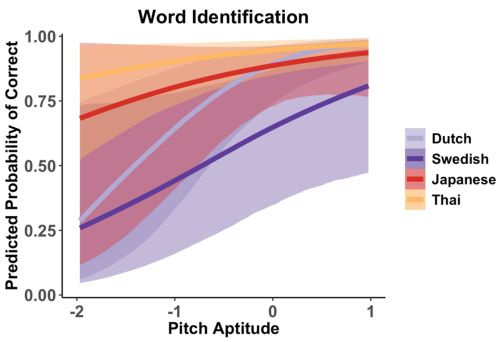

Figure 5: *Predicted probabilities of correct word identification based on pitch aptitude.*

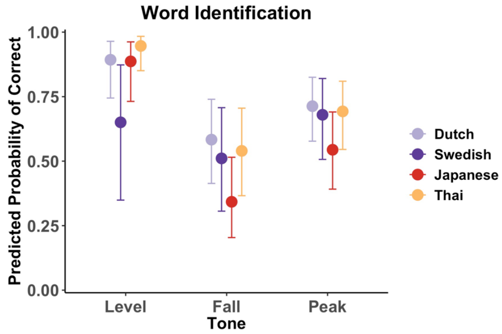

Figure 6: *Predicted probabilities of correct word identification per tone and per L1.*

4. Conclusion

The present study aimed to provide an overall account of the L1-specific and extralinguistic factors that facilitate non-native tone learning. Against the predictions and previous findings by [1], there was no evidence for an incrementally facilitative effect of L1 pitch status on tone perception. L1 pitch status neither facilitated tone word learning: there were no noticeable differences between groups in terms of overall accuracy, nor in the proportion of tone-only errors. This suggests that lexical tones are indeed a relatively challenging aspects of speech to acquire regardless of L1 background. As for the effect of tone type, it was found that dynamic-dynamic contrasts (i.e. fall vs. peak) were more challenging than static-dynamic contrasts (i.e., level vs. fall and peak), and the error patterns were largely similar across groups (Fig. 4). However, the fact that Thai speakers were better than Swedish speakers at identifying level tone words, and Dutch speakers better than Japanese speakers at identifying falling tone words may suggest that the ease to acquire certain tones was modulated by L1-specific factors.

Overall, musical experience most reliably predicted individual performance in tone perception. In turn, tone perception performance most reliably predicted individual performance in tone word learning. It remains puzzling why WM only facilitated Japanese speakers in tone perception, and musical experience only facilitated Swedish speakers in word learning, although this may be indicative of a differential in relevance of extralinguistic factors depending on the L1 [9] .

In sum, the results suggest that L1 pitch status only partially shapes non-native tone learning at both the pre-lexical and at the lexical level. Instead of a theory based on the functional load of pitch in the L1, it appears that a feature-specific approach based on individual pitch aptitude (either derived from musical experience or from the ability to process tones devoid of lexical meaning) best predicts early-stage L2 tone learning across learners from various backgrounds. This falls in line with previous tone word learning studies that have investigated an array of extralinguistic factors but in speakers of the same L1 [2]. The findings from this cross-linguistic study show that, when accounting for an array of factors, pitch perception aptitude best predicts early-stage L2 tone learning.

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