



Perceptual assimilation of non-native prosodic cues: Cross-linguistic effects of lexical F0 learning

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Abstract

This preliminary study examines how first (L1) and second language (L2) experience with lexical fundamental frequency (F0) variations affect the perception of Japanese pitch accent. Japanese-L1 speakers and English-L1 speakers performed an ABX discrimination task and a 3-alternative-forced-choice (3-AFC) categorization task with instructions given in participants' native language. Results support previous findings on non-native perception: Japanese-L1 speakers' were more accurate at both tasks than English-L1 speakers. The English-L1 group then completed a 15-week university level introductory Mandarin Chinese language course in which learners were taught the lexical role of F0, i.e., tone. At the end of their L2 language training, the English-L1 group was retested using the same ABX and 3-AFC tasks and stimuli. Participants' accuracy equaled that of Japanese-L1 listeners in both tasks. Analyses of listeners' sensitivity (*d'*) revealed a statistical improvement in the ABX task but not in the 3-AFC task. These preliminary results suggest that learning lexical F0 variations in an L2 can influence the perception of an additional non-native language that utilizes lexical F0 cues (i.e., at the phonological level) as well as the discrimination of prosodic categories that share overlapping F0 contours (i.e., at the phonetic level). These findings are compatible with models of perceptual assimilation of suprasegmentals.

Index Terms: pitch accent, second language acquisition, perception, lexical tone, fundamental frequency

1. Introduction

First language (L1) linguistic experience is at the core of established theories and models of second language (L2) speech perception, e.g., [1, 2, 3]. For example, the Perceptual Assimilation Model (PAM) and its extension to L2 learning (PAM-L2), posit that L2 speech perception of segments is guided by listeners' implicit or explicit knowledge of L1 phonological equivalence classes [4, 5]. Similarly, the Perceptual Assimilation Model for Suprasegmentals (PAM-S) states that listeners' perception of non-native prosodic categories (e.g., tone, pitch accent, and intonation) is guided by L1 prosodic categories [6, 7]. These perceptual assimilation models state that non-native speech perception is constrained by general L1 phonological properties (i.e., contrastive and categorical details), as well as phonetic proprieties (i.e., non-contrastive, and within-category details) of speech. Importantly, the PAM framework proposes that general linguistic experience with a broad set of L1 speech cues does not necessarily affect the perception of L2 cues; the important factors are the phonemic status and phonetic features between the L2 categories and listeners' L1 categories.

Previous research in this area has primarily used lexical tone as the speech cue of interest. For example, Mandarin Chinese (hereafter 'Mandarin') as spoken in Beijing China consists of four lexical tones primarily characterized by their fundamental frequency (F0) contours [8]. The four F0 contours can be summarized as high-level (tone 1), rising (tone 2), low-dipping (tone 3) and falling (tone 4). In [6], native Cantonese, Japanese, and English listeners were asked to categorize the four Mandarin tones. The authors argued that the pattern of tonal sensitivities and errors observed could not solely be attributed to Cantonese listeners' greater linguistic experience with lexical tone or to the Japanese and English listeners' lack of experience with lexical tone; language-specific perceptual assimilation between listeners' L1 and L2 categories were observed. For instance, if a non-native Mandarin tone was perceptually similar to an L1 category, (e.g., sharing a similar F0 contour with a Cantonese tone), it was perceptually assimilated as an exemplar of that L1 category. If the tone overlapped with two or more L1 categories, it was considered perceptually dissimilar and therefore not assimilated.

Research on how L1 experience shapes the perception of non-native prosody, however, is inconclusive. Other studies support the claim that linguistic experience with a broad prosodic category does, in fact, facilitate perception of non-native prosodic categories, e.g., [9, 10]. One source of evidence for this claim comes from [10] in which native Mandarin listeners outperformed native English listeners in a Cantonese tone identification task with speaker normalization cues controlled. These results suggest that general experience with tone as a lexical cue can facilitate the perception of non-native tones regardless of the similarity (or dissimilarity) between L1 and L2 categories. Since previous studies have primarily examined non-native lexical tone perception, these conflicting results leave open the possibility that previous findings may have been partially attributable to the short-term tone training and testing paradigms used, e.g., [11].

The present study evaluates the claim that L1 and L2 linguistic experience with a broad set of prosodic cues does not necessarily affect the perception of non-native prosodic cues. We expand on previous non-native prosodic perception research by examining native English listeners' perception of Japanese pitch accent before and after extended L2 training on Mandarin tones. This allows us to first establish how L1 experience shapes non-native lexical F0 perception by comparing native English listeners' discrimination and categorization of pitch accent to that of native Japanese listeners e.g., [12]. We then examine how the same group of native English listeners discriminate and categorize Japanese pitch accent patterns after undergoing a 15-week Mandarin as a second language course. This allows us to test whether Mandarin L2 training facilitates overall pitch accent

perception as a result of general linguistic experience with lexical F0 cues or whether Mandarin L2 training facilitates only the perception of specific pitch accent categories that share overlapping F0 contours with Mandarin tone categories.

1.1. Japanese Pitch Accent

Japanese (as spoken in Tokyo-type accent regions) is a pitch-accent language that uses F0 as the primary cue to mark accented syllables. A sharp fall from a relatively high pitch to a relatively low pitch indicates the accented syllable [13]. There is also a large class of unaccented words that do not contain a pitch fall [14]. Including the unaccented pattern, the number of possible lexical accent patterns at a word length of n syllables is $n+1$ [15]. In the present study, we examine the perception of three pitch patterns: HLL (initial accent), LHL (medial accent), and LHH (unaccented).

Although only an estimated 14% of spoken Japanese homophones are distinguished by pitch accent [16], native Japanese speakers make use of pitch information during the processing of words and larger prosodic units [17, 18]. As a result, acquisition of pitch accent contrasts is important for L2 learners of Japanese at both the word and phrase level. Discrimination and categorization of pitch accent by English-L1 speakers, however, is typically poor, with L2 learners demonstrating a large degree of individual variation in their perception abilities [19, 20]. English-L1 speakers' difficulty acquiring pitch accent categories is partially due to their limited experience with lexical F0 cues at the word and phrase level. As a stress-accent language [21], English typically uses vowel quality and length differences rather than F0 cues to distinguish between homophones [17]. At the phrasal level, English intonation can convey pragmatics, such as a rising pitch for a yes/no question or a falling pitch for a statement. Though unlike tone or pitch accent, English pitch patterns are not consistently fixed to a pragmatic function or an individual word or phrase; the same word/phrase can be produced with rising or falling pitch patterns [22]. Therefore, while English-L1 listeners are familiar with F0 rise and fall in intonation patterns of English [21, 22], this F0 information is not lexically contrastive. To correctly discriminate and categorize Japanese-L2 pitch accent patterns, English-L1 listeners must recognize F0 peak and fall cues as lexically contrastive information.

Previous research has established that English-L1 learners of Japanese can improve their perceptual abilities either through short auditory training or instructed L2 acquisition [12, 20]. In the following experiment, we test to what degree naïve listeners' perception of pitch accent improves when trained on a different language that makes use of lexical F0 cues. Specifically we test English-L1 listeners before and after a 15-week Mandarin-L2 course. This allows for an examination of how Japanese pitch accent discrimination and categorization changes as a result of L2 lexical F0 training. If listeners' perception of F0 cues improves as a function of linguistic experience, Mandarin-L2 lexical tone training should facilitate pitch accent perception for all three pitch accent categories. If, however, listeners' perception of F0 cues improves only the perception of specific pitch accent categories, then LHH should improve given its pitch pattern is similar to that of Mandarin tone 2 (rising F0), and HLL should improve given its pitch pattern is similar to that of Mandarin tone 4 (falling F0). LHL should not improve since this pitch pattern does not map onto a Mandarin tone category.

2. Experiment

2.1. Participants

Two groups of participants took part in the experiment. The Japanese-L1 group consisted of 8 university students (4 female; 4 male) studying in the U.S. All participants spoke English as a second language, and had not studied Mandarin or any other tone language. The mean length of residence in the U.S. was 3.4 years at testing. All participants were native to a Tokyo-dialect region of Japan. The English-L1 group consisted of 8 university students (4 female; 4 male). All participants spoke American English as their native language. Due to secondary school language requirements, all participants had studied a European L2 previously, but no participant had ever studied Japanese or any tone language, and no participant self-rated as a fluent speaker of their L2 (Likert scale: 1=beginner, 5=fluent; mean: 2.1). All English-L1 participants were enrolled in a first-year Mandarin Chinese as a foreign language course. For both groups, an adaptive pitch test [23] was used to assess hearing and to control for nonlinguistic pitch perception abilities. At 500 Hz, all participants in both groups were able to reliably differentiate two tones 16 Hz or lower apart.

2.2. Materials

10 nonwords were created with a segmental structure of CVCVCV. Each of these trisyllabic stimuli were recorded by a female native speaker of Tokyo Japanese at 16 bits/44,100 Hz with three existent pitch accent patterns: HLL (initial accent), LHL (medial accent), and LHH (unaccented). For example, the nonword *makana* was produced with the accent patterns *MAkana* (HLL), *maKAna* (LHL), and *maKANA* (LHH). Acoustic analysis of mean F0 fall from the accent-bearing H to L mora aligned with the accent patterns used in [12, 17]. This resulted in 30 target nonwords (10 nonwords \times 3 accent patterns).

2.3. Procedure

All participants were tested individually in a quiet room using headphones. Participants first filled out a language background questionnaire before receiving oral and printed instructions in their native language. Participants performed two listening tasks, the order of which was counterbalanced: ABX discrimination and 3-alternative-forced-choice (3-AFC) categorization. The ABX stimuli consisted of three consecutive multisyllabic sounds with a 750 ms inter stimulus interval. The first two sounds, A and B, only differed in pitch accent. Participants were asked to decide whether the third sound, X, matched the pitch accent of the first (A) or second (B) as quickly and as accurately as possible by button press. If the participant failed to respond within 5 seconds then the next trial would proceed automatically. AB ordering was counterbalanced across all trials. The interval between trials was 1 second. Participants performed 120 trials with 2 practice trials.

For the 3-AFC task, participants were first given oral and printed instructions explaining the difference in pitch accent. Images taken from [24], which visually represented the three possible pitch patterns, were displayed on a computer monitor at all times. In each trial, participants heard a multisyllabic nonword over headphones and were asked to categorize the sound into one of three accent categories (corresponding to the

onscreen pattern) as quickly and as accurately as possible through button press. If the participant failed to respond within 5 seconds then the next trial would proceed automatically. The interval between trials was 1 second. Participants performed 30 trials with 3 practice trials. Both the ABX and 3-AFC tasks were presented using Superlab 5.

Since it was assumed the Japanese-L1 group's perception of pitch accent would not change, these participants were only tested once. The English-L1 group was tested twice: once during the first week of their Mandarin-L2 language course and again approximately 15 weeks later after the completion of the Mandarin course. The procedures and stimuli were the same for the two tests. During the 15-week Mandarin-L2 course, learners were explicitly instructed in pitch contours and the lexical role of tone. Participants' Mandarin textbook included visualizations of F0 contours similar to the images used in the 3-AFC experiment.

2.4. Predictions

Because F0 information is not a consistent lexical cue in English, Japanese-L1 listeners should overall be more accurate and more sensitive than English-L1 listeners in the first test, e.g., [12, 20]. If English-L1 listeners demonstrate an initial difference across pitch accent categories, listeners may demonstrate the highest accuracy for the LHH pattern as it is typically easier than other accented patterns for naïve listeners to identify [25] and relatively similar to English rising intonation e.g., [6, 7]. The other two pitch accents (HLL and LHL) should be responded to with lower accuracy at comparable levels. After English-L1 participants complete the 15-week Mandarin course, in which they receive extensive training in tone production and perception, participants should exhibit an accuracy increase for the second test (English-L1+Mandarin-L2). Because an estimated 71% of Mandarin homophones are distinguished by tone, the functional load or informativeness of tone is higher than that of pitch accent [16]. As a result, English-L1+Mandarin-L2 participants may demonstrate overall 3-AFC and ABX accuracy equal to or even greater than that of Japanese-L1 participants. If improvement is observed for all three pitch accents, this will suggest a general facilitatory effect of F0 training. Alternatively, if only specific pitch accent categories improve, this will suggest perceptual assimilation between L2 tone categories and Japanese pitch accent categories; accuracy improvement should primarily be driven by the HLL (initial accent) given its similarity to Mandarin tone 4 and by LHH (unaccented pattern) given its similarity to Mandarin tone 2. Perception of the LHL pattern, which is dissimilar to any Mandarin tone, should not improve with training.

3. Results

3.1. ABX Discrimination

As expected, the Japanese-L1 group was more accurate at ABX discrimination than the English-L1 group at the first test: 95% CIs [.81, .94] and [.65, .84], respectively. At the second test, the English-L1+Mandarin-L2 group demonstrated a large accuracy improvement: 95% CI [.84, .97]. To test whether ABX discrimination accuracy differed between groups and tests, a mixed effects logistic regression model was built in R version 3.3.3 using the *lme4* package. The model contained group as a fixed effect with the Japanese-L1 group as the reference level and random subject and item intercepts.

Pairwise comparisons were calculated from least-squares means using the *lsmeans* package. The Japanese-L1 group was more accurate than the English-L1 group at the first test ($\beta = -1.03$, $SE = 0.32$, $Z = -3.15$, $p < .01$). At the second test, the English-L1+Mandarin-L2 group did not differ from the Japanese-L1 group ($\beta = -0.34$, $SE = 0.34$, $Z = -1.01$, $p = .57$). For the English-L1 group, this represented a significant accuracy improvement from test 1 to test 2 ($\beta = -1.37$, $SE = 0.36$, $Z = -3.85$, $p < .001$).

To examine whether this improvement was due to a general increase in sensitivity to F0 cues or an increase to specific pitch-accent categories, participants' sensitivity index (d') was calculated for each pitch-accent pattern using the differencing model strategy [26]. Figure 1 plots mean sensitivity results (error bars indicate one standard error) by group and pitch accent. Listeners' mean d' scores were analyzed using a two-way ANOVA with group as a between-subjects factor and pitch accent as a within-subject factor. A test for a two-way interaction between group and pitch accent revealed a significant effect $F(8, 51) = 3.63$, $p < .01$. A post-hoc Tukey's test confirmed that for the English-L1 group, sensitivity to the HLL pitch accent was significantly lower than that of the Japanese-L1 group at test 1 ($p = .04$) but not after Mandarin-L2 training at test 2 ($p > .05$); this was a significant improvement between tests ($p = .01$). Learners' sensitivity to the LHL and LHH accents did not significantly change between tests ($ps > .05$) and did not differ from that of the Japanese-L1 group ($ps > .05$). No sensitivity difference was found among the three pitch accent patterns within each group ($ps > .05$).

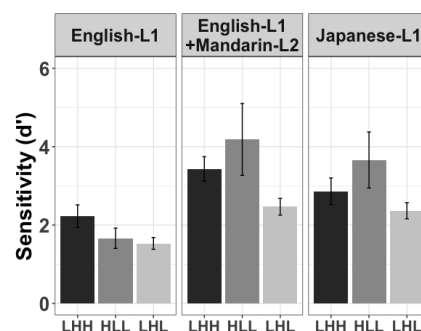


Figure 1: Mean sensitivity results for ABX task.

3.2. 3-AFC Categorization

Similar to the discrimination results, the 3-AFC categorization results revealed that the Japanese-L1 group was more accurate than the English-L1 group at the first test: 95% CIs [.68, .97] and [.47, .72], respectively. At the second test, the English-L1+Mandarin-L2 group demonstrated a large accuracy improvement: 95% CI [.58, .94]. Mixed effects logistic regression models testing categorization accuracy were built using the same parameters as the first model. The Japanese-L1 group was more accurate than the English-L1 group at the first test ($\beta = 1.54$, $SE = 0.55$, $Z = 2.76$, $p = .01$). At the second test, the English-L1+Mandarin-L2 group did not differ from the Japanese-L1 group ($\beta = 0.62$, $SE = 0.57$, $Z = 1.11$, $p = .51$). However, for the English-L1 group, this improvement from test one to test two was not significant ($\beta = -0.91$, $SE = 0.57$, $Z = -1.59$, $p = .25$).

To further examine how the English-L1 group differed from the Japanese-L1 group, each participant's sensitivity

index (d') was calculated for each pitch pattern (Figure 2). Means were tested using a two-way ANOVA. A test for a two-way interaction between group and pitch accent confirmed a significant effect $F(8, 51) = 2.86, p = .01$. A post-hoc Tukey's test, however, revealed that for the English-L1 group, sensitivity to the LHH pitch accent was only marginally lower than that of the Japanese-L1 group at test 1 ($p = .09$); no difference was found after Mandarin-L2 training at test 2 ($p > .05$). The changes in sensitivity between tests for the HLL and LHL accents were not significant nor did they differ from those of the Japanese-L1 group ($ps > .05$). No sensitivity difference was found among the three pitch accent patterns within each group ($ps > .05$).

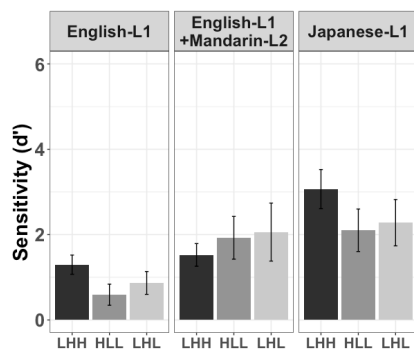


Figure 2: Mean sensitivity results for 3-AFC task.

4. Discussion

This preliminary study set out to examine how English-L1 listeners' perception of Japanese pitch accent changes after undergoing a 15-week Mandarin-L2 course. This served as a more robust test of PAM-S' predictions of non-native prosodic discrimination and categorization by examining how learning a lexically distinctive function of F0 in an L2 affects F0 perception in a new language, i.e., a third language. Results from the first test indicated that the Japanese-L1 group was more accurate at discriminating and categorizing pitch accent than the English-L1 group. The English-L1 participants' poor discrimination and categorization performance was ostensibly due to their limited experience with lexically contrastive F0 information. This finding corroborates previous studies that demonstrated an influence of listeners' L1 prosodic categories on the perception of non-native prosodic categories, e.g., [6, 7, 12, 20].

At the second test, however, the Japanese-L1 group's accuracy advantage was no longer observed; after Mandarin-L2 training, the English-L1 group's accuracy for both tasks was statistically similar to that of the Japanese-L1 group. These results suggest an overall improvement in perception as a result of the 15-week Mandarin-L2 training. Linguistic experience with F0 as a lexical cue through Mandarin tone learning improved learners' overall discrimination and categorization of Japanese pitch accent.

We next carried out analyses of the English-L1 listeners' sensitivity index (d') for each pitch accent pattern. The d' results revealed that learners only improved in their discrimination ability. After Mandarin-L2 training, the English-L1+Mandarin-L2 group's ABX results resembled that of Japanese-L1 speakers (Figure 1). This change to more native-like sensitivity was driven primarily by the improvement of the HLL pitch accent. No other pitch accent

discrimination or categorization d' improvement was statistically significant between the two tests.

One interpretation of these results is that learners perceptually assimilated the HLL pitch accent as an exemplar of the Mandarin tone 4 (falling F0) category. This perceptual assimilation account is analogous to [6] in which native Cantonese listeners assimilated non-native Mandarin tones into L1 Cantonese tonal categories given the tones' overlapping F0 contours. These preliminary results suggest that early-stage L2 learners may assimilate non-native or L3 prosody into newly learned L2 prosodic categories on the basis of overlapping phonetic features, such as F0 fall, e.g., [6, 7, 27].

Yet, under this perceptual assimilation account, learners should have also improved their discrimination of LHH pitch patterns since LHH stimuli could be treated as exemplars of the Mandarin tone 2 (rising F0) category. Figure 1 shows that English-L1 listeners' sensitivity to LHH pitch patterns was already at a native-like level at test 1. After Mandarin-L2 training, learners' sensitivity to LHH improved to become, on average, higher than that of Japanese-L1 listeners. Similarly, sensitivity to LHL patterns was statistically already at a native-like level at test 1. Thus, only sensitivity to the HLL pitch pattern could statistically improve between tests. We are in the process of collecting a larger sample of data in order to capture finer sensitivity differences between groups and pitch accent patterns. Additional data may also allow for sensitivity patterns to emerge in the 3-AFC categorization task.

We note that the proposed perceptual assimilation account cannot falsify whether English-L1 listeners' familiarity with F0 fall (through experience with English intonation patterns) affected the HLL sensitivity improvement, e.g., [5, 7]. Under this L1 transfer account, English-L1 rising F0 question intonation should have similarly affected LHH sensitivity. Given that English-L1 listeners' LHH sensitivity was statistically no different from that of the Japanese-L1 listeners at test 1, this claim requires additional data in order to be adequately evaluated.

With respect to the perception of non-native pitch accent, previous research has reported an inconsistent pattern of perceptual accuracy, with HLL more accurate in some studies [20], and LHH in others [19, 25]. The present results suggest that observed variability may not be solely attributable to L1 category fit – even limited L2 experience such as a short 15-week training in a tone language may affect the discrimination and categorization of pitch accent. The present research expands the scope of non-native pitch perception research to include variability due to L2 tone experience and supports the claim that experience with tone helps perceive pitch accent, e.g., [28, 29].

In conclusion, this preliminary study demonstrated that the phonological and phonetic properties of listeners' L1 and L2 prosodic systems affect their perception of non-native pitch accent in a third language. English-L1 listeners' discrimination and categorization accuracy of Japanese pitch accent improved as a result of Mandarin-L2 training. A sensitivity improvement in the HLL pitch accent pattern was found only in the ABX discrimination data. This d' improvement may have been due to the similarity of the HLL F0 fall to that of the F0 fall of Mandarin tone 4, or to that of English F0 falling intonation. Additional data is being collected to clarify these results.

5. References

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