Predictive Modelling of perceptual strategies: exploring the perception of ironic tone of voice by L2 learners of French

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Abstract

The use of acoustic correlates in the production of ironic tone of voice has been well-documented. However, how L2 learners employ these acoustic cues to decode ironic speech has been comparatively underexplored. This study aims to investigate the perceptual strategies utilized by native Mandarin speakers with advanced French proficiency to interpret the ironic tone of voice in French. 42 native Mandarin speakers participated in an irony identification task, during which they listened to utterances from a separate production task designed to elicit ironic and non-ironic utterances. A predictive modelling approach was employed. Firstly, the results were subjected to Generalized Linear Mixed Models (GLMM), from which we calculated the Irony Score (I-score) to estimate the predicted probability that a specific utterance would be perceived as ironic. Subsequently, through a Random Forest regression analysis, we explored the relationship between the calculated I-scores and eight acoustic cues, recognized as essential correlates for ironic speech, as suggested by previous literature. Our findings suggested that F0 span is the most salient cue for native Mandarin speakers learning French as L2 in perceiving irony in French. In addition, jitter, speech rate, and intensity span carried relatively more weight than other acoustic cues for irony detection.

Index Terms: perceptual strategies, second language acquisition, irony, acoustic cues, predictive modelling, French

1. Introduction

In spoken language communication, the prosody employed by speakers stands out as one of the pivotal factors that significantly shapes the interpretation of attitude and emotion [1]. Previous studies investigating the production of irony by native speakers across various languages consistently observe that ironic speech features a reduced speech rate (e.g., [2], [3], [4] for English; [5] for Mandarin; [6], [7], [8] for French; [9] for Dutch; [10] for Italian; [11] for Cantonese; [12] for German and [13] for Japanese).

However, additional acoustic properties essential for encoding irony, such as pitch, intensity, and voice quality, show language-specific variations. Studies on English ironic speech (e.g., [2], [3], [4]) reported that ironic tone of voice is characterised by a reduced pitch and a narrowed pitch range compared to sincere speech, aligning with findings in Mandarin [5] and German [12]. Conversely, studies in French [6], [7], [8], Italian [10] and Cantonese [11] found the opposite result.

Regarding intensity, ironic speech in Mandarin [5], French [6], [7], Dutch [9], Cantonese [11] and Japanese [13] is marked by a lower intensity, whereas in English [2], [3], [4] and Italian [10] by an increased intensity. To assess voice quality, the harmonics-to-noise ratio (HNR) is commonly employed. Experimental results further indicate lesser noise (i.e., higher HNR values) in the ironic speech of Dutch [9], Cantonese [11] and Mandarin [14], but more noise in English [3]. Studies on the production of ironic speech suggest that the ironic tone of voice is unique to each language. Therefore, we have reasons to suspect that when it comes to the perception of irony, L2 (second language) learners may encounter certain difficulties. Studies focusing on non-native speakers' perception of irony validated that L2 learners perform at a disadvantage compared to native speakers (e.g., [15], [16], [17]).

Previous studies on ironic speech perception have demonstrated that prosodic cues alone are adequate for native speakers to identify ironic utterances (e.g., [4], [15], [18]). In contrast, concerning non-native speakers, [15] discovered that listeners are unable to identify ironic utterances solely based on prosodic information in an unfamiliar language with no prior language exposure. Additionally, [14], [15], focusing on intermediate or advanced L2 learners, found that L2 learners face challenges in utilizing prosodic cues to identify irony and tend to depend more on context or facial expressions. Furthermore, certain studies (e.g., [19], [20]) have confirmed that L2 learners do exhibit the ability to recognize verbal irony in the target language and their accuracy in identifying irony tends to improve with increased language proficiency and greater experience in the target language.

While the aforementioned studies have extensively explored the perception of ironic speech by L2 learners in the target language, there remains a gap in specific research on the perceptual strategies employed by these speakers. This paper aims to fill this gap by investigating which acoustic correlates best explain the perceptual judgments of Mandarin speakers learning French as L2 in the perception of ironic speech. The hypothesis is that only highly proficient L2 speakers can successfully perceive ironic speech in the target language by relying exclusively on acoustic information, with reduced speech rate and lower intensity as the main predictors of learners' responses based on predictions from previous literature on both Mandarin and French (e.g., [5], [6], [7]). Pitch modulation might not be an efficient cue, as previous studies (e.g., [5], [6], [7], [8]) found differences in its use by native speakers of Mandarin and French to mark irony.

Adopting the statistical methodology described in [21], data from an irony identification experiment was firstly analysed using Generalized Linear Mixed Models (GLMM). Subsequently, the Irony Score (hereafter I-score) was computed to estimate the predicted probability of an utterance being perceived as ironic. This was followed by a Random Forest regression analysis to explore the relationship between the

calculated I-scores and acoustic cues, recognized as essential correlates for ironic speech based on previous literature.

2. Method

2.1. Stimuli collection

2.1.1. Speakers

20 participants were recruited, with 10 native French speakers (mean age 23.7; SD 3.3; range 18-30; 5 female) and 10 native Mandarin speakers (mean age 25.6; SD 2.6; range 22-30; 5 female).

2.1.2. Materials and procedures

The experiment utilized a "story-framework" comprising 12 scenarios adapted from [7], [22]. Each scenario assigned participants the role of one of the interlocutors in a simulated daily conversation between two acquaintances. Following the definition of irony (see [23], [24]), the script is designed to elicit a hostile or derogatory judgment or feeling, thereby inducing a dissociative attitude among participants. Two types of conditions were created: ironic criticism (hereafter IC) and its counterpart, literal praise (hereafter LP). The first two lines of the scenario provide a general context related to the characters and situation. The third line is the only line that differs between the two conditions, containing critical contextual information that could lead the target sentence to an ironic or literal meaning. Two types of sentences were designed for the target sentence: declarative and exclamative.

Recordings were captured using a Shure WH20XLR headset microphone connected to a USB sound device (Komplete Audio 2) and digitized at a sampling rate of 44 kHz, in mono channel, and 16-bits quantization. A total of 480 utterances (20 participants × 2 types of scenes × 12 stories). were recorded. After removing the mispronounced utterances (19 out of 480), 228 French speech (IC = 116, LP = 112) and 233 Mandarin speech (IC = 116, LP = 117) were used for subsequent analyses.

2.1.3. Stimuli validation

To ensure the selection of appropriate stimuli for the perception experiment, we conducted a validation task with the assistance of native French and Mandarin speakers. One native French speaker (19 years old, female) and one native Mandarin speaker (26 years old, male) were recruited to listen to all the utterances in their respective languages without any contextual information and determine whether the heard sentence was ironic or sincere speech. For the French utterances, the participant correctly identified 88 IC utterances (accuracy rate = 75.9%) and 102 LP utterances (accuracy rate = 91.0%). Regarding the Mandarin utterances, participant correctly identified 90 IC utterances (accuracy rate = 77.6%) and 100 LP utterances (accuracy rate = 85.5%). Based on the validation results, a total of 80 French sentences (40 IC and corresponding 40 LP) and 80 Mandarin sentences (40 IC and corresponding 40 LP) were selected as stimuli for the subsequent acoustic measurements and perception experiment.

2.2. Acoustic measurements

Words and phonemes were automatically segmented and aligned using the Montreal Forced Aligner [25]. All word boundaries were manually verified and corrected when necessary. Annotation and acoustic analysis were conducted using Praat (version 6.3.10) [26].

The acoustic correlates of ironic speech were eight in total across five dimensions. Pitch measures included the mean F0 and F0 span. Speech rate was calculated by dividing the total duration of an utterance by the total number of syllables. Intensity measures included mean intensity and intensity span. These dimension were obtained via ProsodyPro [27]. Voice quality measures included jitter (ddb) and shimmer (local in dB). Additionally, Harmonics-to-Noise Ratio (HNR) was used as a noise measure. Voice quality was measured using a Praat script adapted from [28].

2.3. Perception experiment

2.3.1. Participants and procedures

A total of 42 native Mandarin participants were involved in the study. Based on their answers on a pre-experiment questionnaire assessing language proficiency and exposure, they were categorized into two groups: the High Proficiency group (mean age 24.9; SD 5.1; range 19-36; 13 females) comprised 21 university students in France with a French test level higher than C1, aligned with the Common European Framework of Reference for Languages (CEFR). They had lived in France for an average of 24.2 months. The Non-native group (mean age 25.1; SD 5.2; range 19-35; 7 females) included 21 university students in China without any knowledge of French, who had never lived in French-speaking countries or regions.

The online experiment, implemented using PsychoPy (version 2021.2.3) [29] on platform *Pavlovia*, was designed to instruct participants to listen to fully randomized utterances in French and Mandarin and to identify whether the utterances are ironic or sincere. During each trial, an utterance was automatically played. Participants were instructed to press the corresponding keys on the computer keyboard to make their choice. They had five seconds to decide after the sentence finished playing. Once the five seconds elapsed, the next trial started automatically. Regardless of their proficiency in French, all participants were exposed to both French and Mandarin sentences. A total of 6720 observations (160 trials x 42 participants) were collected for statistical analyses.

2.4. Statistical analyses

After excluding empty rows resulting from missing responses (14 cases out of 6720), our dataset with 6706 observations (3349 for French utterances and 3357 for Mandarin) was analysed using RStudio, (version 2023.03.1.446), [30] in R language, (version 4.1.2) [31].

2.4.1. GLMM

With *glmer()* function from the *lme4* R package [32], separate GLMMs were constructed for French and Mandarin utterances. In each model, binary-coded perceptual judgments (0 for LP and 1 for IC) were treated as the outcome variable. Dummy coding was applied to categorical predictors: Attitude (LP = 0, IC = 1) and Language Proficiency (Non-native Group = 0, High French Proficiency = 1). Speaker Gender was centred with a value of -0.5 for females and 0.5 for males, while Sentence Type was centred with -0.5 for declarative and 0.5 for exclamative sentences. To account for random effects, a crossed random structure included speakers, listeners, and items, incorporating both by-speaker and by-item random

slopes using a maximal specification model [33], [34]. The optimal model is represented by the following formula:

Perceptual judgement ~ Attitude + Gender + Sentence Type + (Attitude|Listener) + (1|Speaker) + (Gender|Item)

2.4.2. I-score and Random Forest regression

We then calculated the I-score for each utterance in both French and Mandarin to represent the proportion of participants who perceived the respective utterance as ironic following [21]. A new dataset was created, including the utterances judged as ironic by each participant, irrespective of correctness. Next, the perceptual judgments from participants in the High Proficiency group were used. GLMMs were constructed to estimate the predicted probability (ranging from 0 to 1) as the majority vote for an utterance to be perceived as ironic: higher I-scores indicated a consensus in detecting ironic speech, while lower I-scores indicated a consensus in detecting sincere speech.

A Random Forests regression analysis was then used to explore the relationship between the I-scores and the various acoustic correlates, allowing the assessment of each parameter's relative importance in predicting irony perception by L2 French learners. We used the ranger package (version 0.14.1) [35], with each Random Forest being grown with 2000 trees, with the number of random variables per tree being the rounded square root of the total predictors, set to 3 in our case with eight acoustic parameters. The dataset was split into a training set (70%) to grow the Random Forest and a test set (30%) to assess its predictive performance. Following [21] and [37], permutation variable importance was computed to assess the relative impact of each acoustic correlate in predicting the perceptual judgments of ironic speech of L2 French learners.

3. Results

3.1.1. GLMM

Figure 1 and Figure 2 show the predicted probability curve as obtained from the GLMM. The performance in identifying Mandarin ironic utterances serves as the baseline. Mandarin listeners were successful at distinguishing IC and LP (with rising curves). The performance in the two groups does not show any differences.
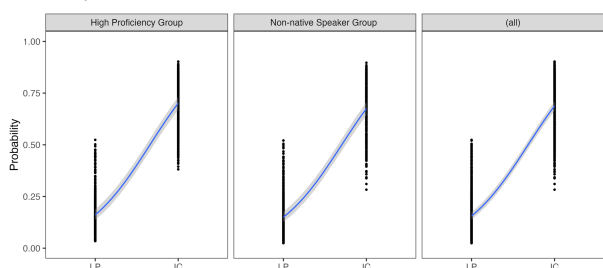

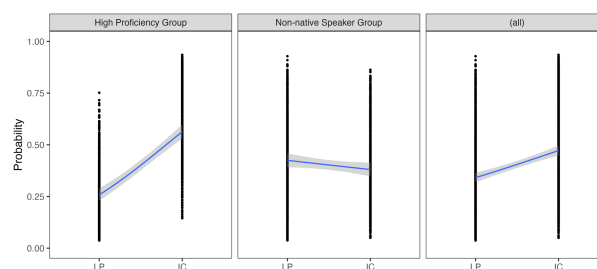Figure 1: *Predicted probability curves for categorical predictor Attitude: LP and IC in Mandarin.*

Figure 2: *Predicted probability curves for categorical predictor Attitude: LP and IC in French.*

Participants' ability to distinguish French ironic utterances did not match their performance in their native language, as illustrated by the rightmost curve in Figure 2. Additionally, differences in performance emerged between the two groups. While the High Proficiency group's performance did not reach the level of native ironic utterance recognition, the upward trend suggests that this group can identify ironic utterances through acoustic cues. Conversely, the Non-native group struggled to differentiate between ironic and literal speech in French based on acoustic information alone

3.1.2. Random Forest regression

The Random Forest regression aimed to identify which prosodic correlates predicted L2 learners' perceptual judgments of French ironic speech. The results demonstrated a robust correlation with the actual data, showing an r-squared value of 0.96 (p < 0.0001). This suggests that the selected set of eight acoustic predictors can explain over 95% of the variation in perceptual judgments of irony in French. The variable importance score of each acoustic parameter was assessed using the *varimp* function, and the results are depicted in Figure 3.

F0 span emerges as the most predictive cue in predicting the perceptual judgments made by learners of French with high French proficiency. This is followed by the jitter, speech rate, and intensity span. These prosodic correlates provide additional valuable information for listeners in differentiating between the two types of utterances.

Our second Random Forests regression on Mandarin utterances correlated well with the actual data (r^2 = 0.93, p < 0.0001). Figure 4 shows the variable importance scores, with the mean intensity being the most predictive for native Mandarin participants to detect ironic speech in their native language. Similar to the perceptual strategies adopted for French, jitter, speech rate, and intensity span are secondary cues that contribute to identifying ironic utterances.
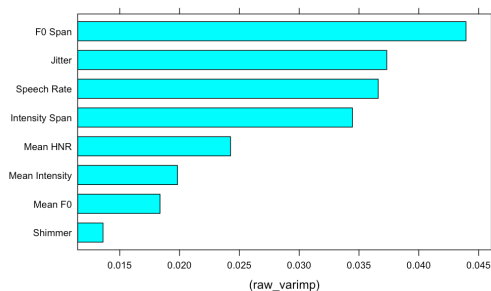

Figure 3: *The relative importance scores of eight acoustic parameters to identification of attitudes (IC*

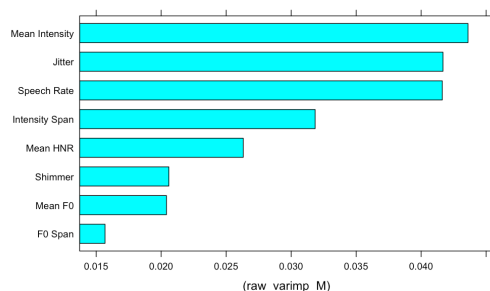*vs. LP) in French by participants with high French proficiency.*

Figure 4: *The relative importance scores of eight acoustic parameters to identification of attitudes (IC vs. LP) in Mandarin by participants with high French proficiency.*

4. Discussion and Conclusions

Our results of GLMM, aligning with [15], supported the hypothesis that only highly proficient L2 listeners can successfully perceive ironic speech in the target language even when relying solely on acoustic information. Regarding the perceptual strategies, we hypothesized that speech rate and intensity are two main cues that listeners use to identify French ironic speech. However, our Random Forest regression analysis demonstrated that F0 span is the most predictive acoustic cue to identify ironic speech, while jitter, speech rate, and intensity span serve as secondary cues.

In comparing the results in Figure 3 and Figure 4, we found similarities and differences between the perceptual strategies used to identify irony in French and Mandarin. The secondary cues that contribute to identifying ironic utterances in French, such as jitter, speech rate, and intensity span, also carried more weight than other acoustic cues to perceive ironic speech in Mandarin. However, pitch measures weigh differently. When native Mandarin listeners distinguish ironic speech from sincere speech in French, F0 span was the most important cue. Mean F0 was relatively less important (see Figure 3). However, as shown in Figure 4, mean F0 and F0 span were the two least important cues to identify Mandarin ironic speech. Instead, Mean Intensity is the most powerful cue for Mandarin ironic speech.

Previous studies on production of ironic tone of voice suggest that French ironic speech is marked by a higher pitch and wider pitch range [6], [7], whereas in Mandarin, a gender difference is found [5]. Only females were found to produce ironic speech with higher pitch and wider pitch range. The observed gender difference may play a role in Mandarin listeners not relying on pitch when evaluating ironic statements in Mandarin.

Another plausible explanation is that, as a tonal language, Mandarin's four lexical tones impose more constraints on the realisation of intonation compared to non-tonal languages [37], [38], [39]. Therefore, while previous research suggests that native Mandarin speakers use pitch when encoding ironic speech [5], the limited extent of pitch change may not offer sufficient information for Mandarin native listeners to make accurate judgments. Consequently, for listeners whose native language is Mandarin, other acoustic cues, such as intensity and

changes in voice quality, may be more emphasized compared to pitch.

In comparison, [5] and [6] reported that French ironic speech exhibits a distinct intonational contour at the sentence-final position. The perception task conducted with native French speakers also confirmed that when judging ironic speech, native French listeners depend more on pitch and intonational cues than other acoustic correlates [7]. In our study, native Mandarin listeners with advanced French proficiency adopted a similar perceptual strategy as native French speakers, with F0 span being more powerful than other acoustic cues. However, it remains a question why mean F0 bears relatively less weight than other acoustic cues such as speech rate, voice quality, and intensity. Further studies should take the specific sentence-final intonation contour into account and add it to our model predictions to explore the relative weight of intonational cues. Additionally, a perception task on native French speakers with the same experimental materials is being prepared, which will allow us to compare the perceptual strategies used by native Mandarin speakers with advanced French proficiency.

In summary, our study reaffirmed prior observations that listeners lacking familiarity with the target language face challenges in identifying ironic utterances based solely on prosodic cues, whereas L2 learners with high proficiency in the target language exhibit success in this task. Moreover, our results provide novel cross-language evidence, highlighting the language-specific nature of the ironic tone of voice. Lastly, our findings offer insights into the perceptual strategies employed by L2 learners when discerning ironic speech in the target language.

5. Acknowledgements

6. References

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