

# Effects of stimulus variability on pitch discrimination: Lexical tones and musical intervals

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## Background

### Pitch in Language and Music

- Language and music both use pitch (frequency) in the form of lexical tones (Figure 1) and intervals (Figure 2).<sup>1</sup>
- Lexical tone is unfamiliar and hard to learn for speakers of English and other non-tonal languages.<sup>1</sup>
- Musicians are better than non-musicians at many perceptual tasks involving pitch, including perceiving lexical tones.<sup>2</sup>

Fig 1. Mandarin<sup>3</sup>

- 1) ma1 'mother'
- 2) ma2 'hemp'
- 3) ma3 'horse'
- 4) ma4 'scold'

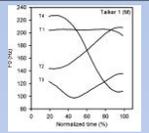


Fig 2. Melodic Intervals

- 1) major second (2 semitones)
- 2) minor third (3 semitones)
- 3) major third (4 semitones)
- 4) perfect fourth (5 semitones)



### Speaker Normalization

- Phonetic variation between and within talkers means even the same word can sound rather different, depending on context.<sup>4,5</sup>
- Listeners need to compensate for (normalize) this variability, and normalization ability improves with language proficiency.<sup>4,5</sup>
- Stimulus variability plays a role in the learning of tone systems.<sup>6</sup>
  - English speakers with better pitch perception learned Mandarin tones best with high variability training sets.<sup>6</sup>
  - English speakers with poorer pitch perception learned best with low variability training sets.<sup>6</sup>
- Learners with poorer pitch perception may not yet perceive pitch well enough to recognize tones spoken by different speakers.<sup>3</sup>
- Music perception requires normalization processes similar to those found in language.<sup>7</sup>
  - Musical elements maintain their musical identity across different instruments or keys.<sup>7</sup>

## Hypotheses

We explored the ability of a group of participants to perceive lexical tones and musical intervals at different levels of stimulus variability.

1. We expected that, for non-native listeners, lexical tone discrimination ability decreases with increasing variability.
2. If music is subject to similar normalization demands, interval discrimination should also decrease with greater variability.

## References

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2. Patel (2011). *FPSYG* 2(142).
3. Chandrasekaran (2010). *JASA* 128(1).
4. Johnson (2005).
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## Tone Test

- Stimuli recorded from 4 Native Mandarin speakers from China (3 female, 1 male).
- **Words:** monosyllables ('ka', 'ma', 'di') spoken with each of four tones (Figure 1).
  - Some were real Mandarin words, some were not.
- **Trials:** two words with the same syllable (e.g., 'ka').
  - Same tone (40%) or different tones (60%).
  - Inter-onset interval 1500ms.
- **Blocks:** differing in variability: four variability levels:
  - 1: same speaker
  - 2: two speakers of the same gender
  - 2.5: two speakers of different genders
  - 3: all four speakers (3 female, 1 male)
- Participants heard examples of the four tones and were informed that pitch was an important part of word meaning in this language.
- Participants were instructed to decide whether the two words were the same (whether they meant the same thing, even if spoken by different people).
- 12 Blocks (3 at each variability level) of 10 trials each (120 trials).

## Interval Test

- Stimuli synthesized using *Aria Maestosa* software.
- **Intervals:** major 2<sup>nd</sup>, minor 3<sup>rd</sup>, major 3<sup>rd</sup>, perfect 4<sup>th</sup>; ascending & descending.
- **Instruments:** piano and saxophone.
  - Played in one of two octaves (below middle C or above middle C).
- **Trials:** two intervals with different starting notes.
  - 40% same interval; 60% different intervals.
  - Direction was always the same.
  - Inter-onset interval 1000ms.
- **Blocks:** differing in variability: levels for this test were,
  - 1: same instrument, same octave, different start note up and down
  - 2: different instrument, same octave, different start note up and down
  - 2.5: same instrument, different octave, different start note up and down
  - 3: different instrument, different octave, different start note up and down.
- Participants were to mark whether the intervals were the same or different, even if played on different instruments or in different ranges.
- 12 Blocks (3 at each variability level) of 10 trials each (120 trials).

## Procedure

- Procedure administered to 30 Penn State students.
  - Participants completed language and music history questionnaire.
  - Participants varied in linguistic and musical backgrounds.
- Tone and Interval Tests administered in a single 30-minute session.
  - Counterbalanced for order.
  - Audio presented via speakers or headphones.
  - Responses made on paper form

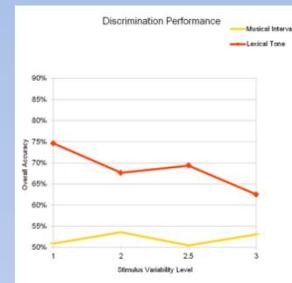
## Findings

### Tone Test

- As variability increased, tone discrimination decreased.
- Confirms hypothesis 1.

### Interval Test

- As variability increased, interval discrimination was not affected.
- Discrimination was near chance for all variability levels.
- The results of the interval test did not confirm our second hypothesis.



Separate mixed-effects ANOVA  
DV: accuracy  
within subject factor: variability  
tone  $F(1,28)=18.813, p<.001$   
interval  $F=(1,28)=0.1669, p>.6$

## Discussion

- Stimulus variability had the predicted effects on lexical tone, but not interval discrimination.
- It was less difficult to differentiate between words and lexical tones than it was to differentiate between intervals.
- The interval test may have been too hard, and the percentage of correct responses (50%) confirms this.
- To reassess hypothesis 2, we will:
  - Make interval test easier (easier intervals, less variability).
  - Analyze by participant musical/linguistic backgrounds.

## Summary

- We tested whether the ability to adapt to stimulus variability is correlated across musical and linguistic pitch tasks.
- The number of speakers per block led to decreased discrimination of foreign lexical tones.
- The interval test was too difficult, even at low variability levels to assess the influence of variability in a musical task.
- What remains for us is to better match the test for difficulty, and to compare participants by musicality and language to determine how this background affects normalization ability.

## Notes

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\* These authors contributed equally to the work

