The phonetics of prosody in Yoloxóchitl Mixtec

Christian DiCanio
ccdicanio@buffalo.edu
Joshua Benn
jbenn@buffalo.edu
Rey Castillo García
reyyoloxochitl@gmail.com

Departament of Linguistics
University at Buffalo
Secretaria de Educación Pública (Guerrero)

11/17/17
How do both instances of /yaa₁⁴/ ‘ash’ differ?
Research questions

Prosody can influence the production of tones in tonal languages.

1. The influence of information structure on tone.
Research questions

Prosody can influence the production of tones in tonal languages.

1. The influence of information structure on tone.

2. Tone production in pre-pausal/connected speech contexts.
Research questions

Prosody can influence the production of tones in tonal languages.

1. The influence of information structure on tone.

2. Tone production in pre-pausal/connected speech contexts.

3. Tone production and utterance-level intonational patterns.
How is prosodic prominence marked in tone languages?

1. **Phonological**
   Intonational pitch accents or boundary tones can influence tonal contour shapes.
   e.g. Kipare (Herman, 1996), Shekgalagari (Hyman and Monaka, 2011), Thai (Luksaneeyanawin, 1998)

2. **Phonetic**
   Prosodic prominence is marked via phonetic lengthening, register shift, or pitch range expansion.
   e.g. Mandarin (Xu, 1999), Akan (Kügler and Genzel, 2011)
Register shift

High tones in Mandarin undergo raising and F₀ range expansion when in focus (Xu, 1999).

![Graph showing tone variations in Mandarin with high tones underlined and F₀ range expansion marked.](image-url)
Phonetic marking of domains

Prominent positions in the prosodic hierarchy undergo processes of phonetic enhancement

- domain-initial strengthening (Fougeron and Keating, 1997; Keating et al., 2000)
- focal F0 range expansion (Xu, 1999) and gestural hyperarticulation (Mücke and Grice, 2014)
- stress-related hyperarticulation (Byrd and Choi, 2010; de Jong, 1995; Krivokapić and Byrd, 2012)
Prosodic lengthening and strengthening

- Stressed syllables undergo greater prosodic lengthening under focus than unstressed syllables do.
  
  English (Turk and Sawusch, 1997; Turk and White, 1999), Dutch (Cambier-Langeveld and Turk, 1999), Swedish (Heldner and Strangert, 2001)

- Intonational pitch accents are aligned with stressed syllables in non-tonal languages (Gussenhoven, 1983). Is focus aligned with stress in tone languages?
Dynamical parameters (Cho, 2006)

(a) Change in Stiffness

(b) Change in Target

(c) Change in Intergestural Timing

(d) Change by shrinking

Figure 2. Hypothetical movement trajectories that correspond to a change in each parameter. (a) show change in stiffness; (b) change in target; (c) change in intergestural timing; and (d) change by shrinking. Empty circles indicate the timepoint of the peak velocity attainment.

(1) Stiffness. Variation in articulatory movement duration is thought to be controlled by the stiffness parameter: the stiffer the spring (the articulator), the faster the movement. An idealized pattern in a pure change in stiffness is visualized in Figure 2a, and its corresponding kinematic relationships in Figures 3a-b. If stiffness is the only parameter underlying kinematic differences, there should be a change in peak velocity (i.e., the maximum velocity that the articulator attains during the gesture), but not in displacement (i.e., the amount of spatial distance that the articulator travels), therefore showing vertical distribution of the datapoints (Figure 3a). In addition, (with a change only in stiffness)
1. How do tones change in prosodically weak/strong environments? at boundaries?

2. Is this phonological or phonetic?
Yoloxóchitl Mixtec (YM)

- Otomanguean, spoken in Guerrero, Mexico (≈4000 speakers).
- Phonological/phonetic fieldwork (Castillo García (2007), DiCanio et al. (2014), DiCanio (submitted a, b), Palancar et al. (2016)).
Yoloxóchitl, Guerrero
All roots are minimally composed of bimoraic feet, consisting of either monosyllabic stems with long vowels (CVV) or disyllabic stems with shorter vowels (CVCV) (Castillo García, 2007).

No codas.

Glottalization is contrastive: /yaʔ⁴a¹/ ‘grey’, /saʔ³ma⁴/ ‘cloth to wrap tortillas’

Final syllables are prominent.
  - Nasal vowels only occur on stem-final syllables.
  - Restricted vowel contrasts on non-final syllables.
  - 9 tones on stem-final syllables, but only 5 on non-final syllables.
  - Final syllable lengthening
### Tone is lexical and morphological

Twenty-six tonal melodies are possible on a disyllabic word.

<table>
<thead>
<tr>
<th>Melody</th>
<th>Word</th>
<th>Gloss</th>
<th>Melody</th>
<th>Word</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>ta¹ma¹</td>
<td>without appetite</td>
<td>4.13</td>
<td>na⁴ma¹³</td>
<td>is changing</td>
</tr>
<tr>
<td>1.3</td>
<td>na¹ma³</td>
<td>to change (intr)</td>
<td>4.14</td>
<td>nda⁴ta¹⁴</td>
<td>is splitting up</td>
</tr>
<tr>
<td>1.4</td>
<td>na¹ma⁴</td>
<td>soap</td>
<td>4.24</td>
<td>ya⁴ma²⁴</td>
<td>Amuzgo person</td>
</tr>
<tr>
<td>1.32</td>
<td>na¹ma³²</td>
<td>I will change myself</td>
<td>4.42</td>
<td>na⁴ma⁴²</td>
<td>I often pile rocks</td>
</tr>
<tr>
<td>1.42</td>
<td>na¹ma⁴²</td>
<td>my soap</td>
<td>13.2</td>
<td>hi¹³ni²</td>
<td>has seen</td>
</tr>
<tr>
<td>3.2</td>
<td>na³ma²</td>
<td>wall</td>
<td>13.3</td>
<td>na¹³na³</td>
<td>has photographed (self)</td>
</tr>
<tr>
<td>3.3</td>
<td>na³ma³</td>
<td>to change (tr)</td>
<td>13.4</td>
<td>na¹³ma⁴</td>
<td>has piled rocks</td>
</tr>
<tr>
<td>3.4</td>
<td>na³ma⁴</td>
<td>sprout</td>
<td>14.2</td>
<td>na¹⁴ma²</td>
<td>I will not change</td>
</tr>
<tr>
<td>3.42</td>
<td>na³ma⁴²</td>
<td>I will pile rocks</td>
<td>14.3</td>
<td>na¹⁴ma³</td>
<td>to not change</td>
</tr>
<tr>
<td>4.1</td>
<td>ka⁴nda¹</td>
<td>is moving (intr)</td>
<td>14.4</td>
<td>na¹⁴ma⁴</td>
<td>to not pile rocks</td>
</tr>
<tr>
<td>4.2</td>
<td>na⁴ma²</td>
<td>I am changing</td>
<td>14.13</td>
<td>na¹⁴ma¹³</td>
<td>to not change oneself</td>
</tr>
<tr>
<td>4.3</td>
<td>na⁴ma³</td>
<td>it is changing</td>
<td>14.14</td>
<td>nda¹⁴ta¹⁴</td>
<td>to not split up</td>
</tr>
<tr>
<td>4.4</td>
<td>na⁴ma⁴</td>
<td>is piling rocks</td>
<td>14.42</td>
<td>na¹⁴ma⁴²</td>
<td>I will not pile rocks</td>
</tr>
</tbody>
</table>
# Morphological tone

<table>
<thead>
<tr>
<th>Morphology</th>
<th>‘to break’ (tr)</th>
<th>‘hang’ (tr)</th>
<th>‘to change’ (intr)</th>
<th>‘to peel’ (tr)</th>
<th>‘to get wet’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem</td>
<td>$ta^3?\beta i^4$</td>
<td>$t\bar{i}^3k\bar{u}^2$</td>
<td>$na^1ma^3$</td>
<td>$kw\bar{i}^4$</td>
<td>$t\bar{i}^3i^3$</td>
</tr>
<tr>
<td>NEG</td>
<td>$ta^{14}?\beta i^4$</td>
<td>$t\bar{i}^{14}k\bar{u}^2$</td>
<td>$na^{14}ma^3$</td>
<td>$kw\bar{i}^{14}i^{14}$</td>
<td>$t\bar{i}^{14}i^3$</td>
</tr>
<tr>
<td>COMP</td>
<td>$ta^{13}?\beta i^4$</td>
<td>$t\bar{i}^{13}k\bar{u}^2$</td>
<td>$na^{13}ma^3$</td>
<td>$kw\bar{i}^i^4$</td>
<td>$t\bar{i}^{13}i^3$</td>
</tr>
<tr>
<td>INCOMP</td>
<td>$ta^{4}?\beta i^4$</td>
<td>$t\bar{i}^4k\bar{u}^2$</td>
<td>$na^{4}ma^{13}$</td>
<td>$kw\bar{i}^{4}i^{14}$</td>
<td>$t\bar{i}^{4}i^4$</td>
</tr>
<tr>
<td>1S</td>
<td>$ta^{3}?\beta i^{42}$</td>
<td>$t\bar{i}^{3}k\bar{u}^2=ju^1$</td>
<td>$na^{1}ma^{32}$</td>
<td>$kw\bar{i}^{1}i^{42}$</td>
<td>$t\bar{i}^{3}i^2$</td>
</tr>
</tbody>
</table>
How do we elicit information structure differences in YM?
Methodological issues I

Most work on information structure involves reading.

e.g. in Mandarin (Chen and Gussenhoven, 2008; Xu, 1999), Guaraní (Clopper and Tonhauser, 2013), Arabic (de Jong and Zawaydeh, 2002), German (Mücke and Grice, 2014), Dutch (Peters et al., 2014), etc.

There is no native literacy in YM and many speakers are not functionally literate in Spanish.
Solution I

Corpus linguist/Syntactian’s solution: Just mine a corpus for natural examples!

Issue: You are not controlling for tone or word structure.
Methodological issues II

A Q&A paradigm following a short story can naturally elicit NPs of different types (narrow, broad, contrastive focus).

e.g. in Akan (Kügler and Genzel, 2011), Guaraní (Clopper and Tonhauser, 2013)

This works well for contexts of narrow or contrastive focus, but not so well for broad focus.
Why?

1. YM (and other Mixtecan languages) use pronominal clitics for animate entities that have been backgrounded.

2. Mixtecan languages are object-dropping.

3. “Describe what happened.” is an odd demand after listening to a text. Speakers attempt to answer it by speculating about the actors’ intents in the text.
Solution II

Use a repetition task?

Issue: Speakers might mimic the prompt and this is less natural than a Q&A paradigm.
Stimuli elicitation for focus - a mixed design

- **Argument focus (after story)**
  Rey: Who arrived?
  Speaker: John arrived.

- **Contrastive focus (after story)**
  Rey: Did Marcus arrive?
  Speaker: John arrived.

- **Sentential focus (repetition)**
  Rey: John arrived.
  Speaker: John arrived.
Focus in Yoloxóchitl Mixtec

(1)  ni₁-ta³jι³  yu³βa⁴=о⁴  kwa⁴yu²  nda³ʔa⁴=о⁴
PERF-give father=2S  horse  hand=2S
‘Your father gave you a horse.’

(2)  yu³βa⁴=о⁴  ni₁-ta³jι³=ɾi⁴  kwa⁴yu²  nda³ʔa⁴=о⁴
father=2S  PERF-give=3S  horse  hand=2S
‘Your father gave you a horse.’

(3)  yu³βa⁴=о⁴  ni₁-ta³jι³=ɾi⁴  kwa⁴yu²  nda³ʔa⁴=о⁴
father=2S  PERF-give=3S  horse  hand=2S
‘Your father gave you a horse.’
Methods

- Each answer/response was repeated six times by each respondent across two separate recording sessions (3 reps/session).
- Recording took place in San Luis Acatlán, a town near Yoloxóchitl.
- Each condition contained the same 28 target words which possessed nine tonal melodies: 1.1, 1.3, 1.4, 1.42, 3.2, 3.3, 3.4, 4.2, 4.4.
- Ten native speakers participated; a total of 5,040 utterances were analyzed (504/speaker).
- Target words segmented and analyzed using a script written in Praat (Boersma and Weenink, 2016).
- Normalized F0 trajectories extracted over 5 time points and converted to log-normal values. Onset and vowel duration also extracted.
- Results analyzed using LMMs with lmertest (Kuznetsova et al., 2013). All reported results are significant.
Since we have a mixed design, we will present the contrastive-argument focus comparison first and then compare them both to the sentential focus condition.
Results: Duration I

Onset duration by stress and focus type

Vowel duration by stress and focus type

Word position
- unstressed
- stressed

Focus
- argument
- contrastive

Onset consonant duration (ms)

Vowel duration (ms)
Results: Duration - comparative

Onset duration by stress and focus type

Vowel duration by stress and focus type

Word position
- unstressed
- stressed
Table: Durational patterns across focus types. Except for ratios and percentages, all numbers are in milliseconds.

<table>
<thead>
<tr>
<th>Focus Type</th>
<th>C1</th>
<th>V1</th>
<th>C2</th>
<th>V2</th>
<th>σ₁</th>
<th>σ₂</th>
<th>σ-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sentential focus</td>
<td>70</td>
<td>77</td>
<td>95</td>
<td>90</td>
<td>141</td>
<td>185</td>
<td>1:1.31</td>
</tr>
<tr>
<td>Contrastive focus</td>
<td>77</td>
<td>92</td>
<td>120</td>
<td>99</td>
<td>169</td>
<td>219</td>
<td>1:1.30</td>
</tr>
<tr>
<td>Argument focus</td>
<td>76</td>
<td>94</td>
<td>136</td>
<td>107</td>
<td>170</td>
<td>242</td>
<td>1:1.42</td>
</tr>
<tr>
<td>Maximum Lengthening under focus</td>
<td>10%</td>
<td>22%</td>
<td>43%</td>
<td>19%</td>
<td>21%</td>
<td>31%</td>
<td></td>
</tr>
</tbody>
</table>
Globally, contrastive focus undergoes raising relative to argument focus.

Effect of focus type on level tonal melodies

Effect of focus type on rising tonal melodies
Results: Falling and complex melodies

Effect of focus type on falling tonal melodies

- Non-final
- Final

Effect of focus type on complex tonal melody /1.42/

- Non-final
- Final

DiCanio et al (UB/SEP)
Results: Tone - comparative

For most melodies, tone is lower in sentential focus than argument focus.

Effect of focus type on level tonal melodies
- Non-final: Tonal melody 4.4, Focus: argument
- Final: Tonal melody 3.3, Focus: contrastive

Effect of focus type on rising tonal melodies
- Non-final: Tonal melody 1.4, Focus: argument
- Final: Tonal melody 3.4, Focus: contrastive
Discussion: duration and focus

- Focus lengthens the stressed syllable in YM, but more on the onset than on the vowel. Why?

- In Swedish onsets are lengthened when a syllable contains a phonologically short vowel (Heldner and Strangert, 2001).

Given that all vowels in the CVCV disyllables were short, vowel length may have influenced the domain of prosodic lengthening in YM.
Discussion: tone and focus

- Contrastive focus is distinguished from narrow focus by increased $F_0$ range and raising of tonal melodies.

- Tones in fronted, focal NPs undergo $F_0$ range expansion and raising relative to tones in sentential focus.

Tonal hyperarticulation, $F_0$ raising, and range expansion mark focus.
**Positional effects**

<table>
<thead>
<tr>
<th>Effect</th>
<th>Tones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong focus x position interaction</td>
<td>T1.3, T1.4, T1.42</td>
</tr>
<tr>
<td>Weak focus x position interaction</td>
<td>T1.1, T4.4, T4.2, T3.2</td>
</tr>
<tr>
<td>No focus x position interaction</td>
<td>T3.3, T3.4</td>
</tr>
</tbody>
</table>

**Why initial tone /1/?**
• Maintaining the level of /1/ enhances the syntagmatic contrast between it and the following tone.

• The distance between tones in a /1.4/ melody is 2.5x as large under contrastive focus as under sentential focus.

• Focus induces processes of tonal hyperarticulation that enhance syntagmatic contrast on the word.
Asymmetrical expansion occurs because low tones are near the $F_0$ floor. High vowel displacement functions in a parallel way under different focus conditions (Cho, 2006; Mücke and Grice, 2014).
Phrase-final position is a domain of articulatory strengthening (Barnes, 2006; Cho, 2006) and where articulatory gestures may reduce their velocity (Krivokapić and Byrd, 2012).

Declination is a universal phonetic process (Gussenhoven, 2004) but phrase-final tonal alternations may be phonological.

How does one separate domain-final effects from global effects in speech production?
Three possibilities

Impressionistic descriptions of Mixtecan languages mention phrase-final tonal alternations (Pike and Small, 1974; Pike and Wistrand, 1974), but such descriptions do not specify the origin of such effects.

- **Declination**

- **Final lowering**

- **Final allotony**
Tone production is sensitive to word and phrasal position.

High > Falling in Diuxi Mixtec (Pike and Oram, 1976)
Low > Low falling in Ayutla Mixtec (Pankratz and Pike, 1967)

In a more complex tonal system, like YM, one anticipates less sensitivity of tone to phrasal position (Connell, 2017).
Declination is a universal process in declarative utterances (Gussenhoven, 2004), but there are exceptions in tone languages:

1. It does not occur in a sequence of high tones, e.g. Mandarin (Xu, 1999), Taiwanese (Peng, 1997).
2. It only occurs in a sequence of low tones, e.g. Mambila (Connell, 2017), Yoruba (Laniran and Clements, 2003).
3. It does not occur, e.g. Choguita Rarámuri (Garellek et al., 2015), Embosi (Rialland and Embanga Aborobongui, 2017).

Final lowering occurs in tone languages:

1. It occurs for all tones, e.g. Kipare (Herman, 1996), Moro (Chung et al., 2016), Embosi (Rialland and Embanga Aborobongui, 2017)
2. It only occurs with low and falling tones, e.g. Mambila (Connell, 2017), Taiwanese (Peng, 1997), Akan (Kügler, 2017).
Methods: positional effects on tone

- 20 tonal melodies were analyzed (1.1, 1.3, 1.42...) in disyllabic words in non-final contexts (before a PP/Adv) and utterance-final contexts.

\[ \text{Sa}^{4}\text{Si}^{24}=\text{Ra}^{2}\text{n}^{3}\text{Si}^{4} \text{ ‘He is eating corn.’} \]
\[ \text{Sa}^{4}\text{Si}^{24}=\text{Ra}^{2}\text{n}^{3}\text{Si}^{4} \beta^{3}\text{ti}^{3} \text{ ‘He is eating corn now.’} \]

- The post-target word always had tone /3/.
- 288 repetitions for each speaker (36 words x 2 conditions x 4 repetitions); 9 speakers.
- Initial transcription in ELAN and segmentation in Praat. We used a script to analyze F0 dynamics and duration.
- F0 was normalized and all data was analyzed using the same methods as experiment 1.
Results II: duration

Onset duration by stress and utterance position

Vowel duration by stress and utterance position
Results II: level tone melodies

Effect of sentence position on level tonal melodies /1.1, 3.3, 4.4/

- Higher
- Lower
Results II: falling and rising melodies

Effect of sentence position on tonal melodies
/3.2, 4.1, 4.2, 4.3/

Effect of sentence position on rising tonal melodies
/1.3, 1.4, 3.4/

Final raising with /1.4, 3.4/

Final lowering with /3.2, 4.1/
Results II: melodies with final contours

Effect of sentence position on tonal melodies /1.42, 3.42, 1.32/

- Penult
- Ultima

Effect of sentence position on tonal melodies /4.24, 4.13/

- Penult
- Ultima

Utterance position
- Non-final
- Final

Tonal melody
- 1.42
- 3.42
- 1.32

Final lowering of /42, 32/

Levelling allotony: /24/ > 3/4_T

Utterance position
- Non-final
- Final

Tonal melody
- 4.24
- 4.13

Allotony: /13/ > 42/4_T

DiCanio et al. (UB/SEP)
Discussion - experiment 2

1. Tone /4/ undergoes final raising.

2. Tone /3/ does not change.

3. Final lowering occurs only for lower register tones. Tones /2, 1/ and falling tones /42, 32/ lower in utterance-final position.

4. Rising tones ((/13, 24/) have distinct allotones in non-utterance-final position.
Methods: Declination

- We analyzed sentences that consisted of only level tone sequences.
- 10 sentences between 4-7 syllables in length; 2 with tone /4/, 4 with tone /3/, 4 with tone /1/.
- 10 sentences x 4 repetitions; 9 speakers.
- Initial transcription in ELAN and segmentation in Praat. We used a script to analyze F₀ dynamics and duration.
- F₀ was normalized and all data was analyzed using the same methods as experiment 1.
- Two statistical methods to disambiguate declination from final lowering: trajectory modelling with and without utterance-final syllable.
Results - declination

Occurs in sequences of tone /1/ and /3/, but not with tone /4/.
F0 change across utterances with identical level tones, medial 60% of vowel. Solid lines = entire lmer fit; Black, dashed lines = fit without final syllable
Declination, final lowering, or allotony?

- All of them occur in YM!
- Final raising occurs with tone /4/, final lowering occurs with lower register tones; declination occurs with tones /3/ and /1/; and positional allotony occurs with rising tones /13, 24/.
- Declination is a distinct phenomenon from final lowering.
Are there boundary tones?

No. If they were to exist, we would have to stipulate that they be extensions of the same preceding tones, i.e. H% only after /4/.

Tonal changes in utterance-final position result from tonal hyperarticulation which expands the tonal range (Krivokapić and Byrd, 2012).
Final allotony

$F_0$ rises require more time than level or falling trajectories, thus we might expect that they be limited to contexts with longer phonetic duration, e.g. phrase-final position (Sundberg, 1979; Zhang, 2004).

Allotony results from durationally-induced $F_0$ levelling. Levelling is induced via articulatory undershoot (Parrell, 2014; Mücke and Grice, 2014).
Discussion

Variation in the production of rising tones

Effect of sentence position on tonal melodies /4.24, 4.13/, by speaker

- Levelling
  - Speakers who maintain /24/ as a rising tone.

- Utterance position
  - non-final
  - final

- Tonal melody
  - 4.24
  - 4.13

- Speakers who maintain both rising tones.
Both narrow focus (at utterance-initial position) and utterance-final position involve tonal range expansion and hyperarticulation.

The *type* of range adjustment differs with respect to low tones. Final lowering occurs with low or falling tones in utterance-final position, but no active lowering occurs for low tones under focus.

Phrase-final effects occur in addition to range expansion.
Prosody in YM is marked primarily by adjustments to $F_0$ range and hyper/hypoarticulation (de Jong, 1995; de Jong and Zawaydeh, 2002).

Change in range = postural target adjustment?

```
H
M
L
-----
H
M
L
-----
```
Future plans

1. Parallel research on Itunyoso Triqui (IT) prosody.

2. Tone production in the YM and IT corpora.

3. EMA research in the UB Phonlab on the supralaryngeal articulation of information structure in English and Korean.
Acknowledgements

- Support from NSF DEL/RI grant 1603323, *Understanding Prosody and Tone Interactions through Documentation of Two Endangered Languages*

- Team Mixtec: Rey Castillo García (SEP, México), Jonathan Amith (Gettysburg College), and Joshua Benn (University at Buffalo)

- Commentary from audiences at CILLA VIII and UC Santa Cruz.
Results - declination by speaker

F0 change across utterances with identical level tones, medial 60% of vowel; by speaker

- ACG
- CTB
- CTC
- GNS
- JSM
- MRG
- SGB
- VTR
- ZGS

Tone
- /4/
- /3/
- /1/

Syllable number from end of utterance
Prosodic marking

**Accentual marking of heads/edges** – intonational pitch accents are attracted to prominent positions in the prosodic hierarchy or on constituents with narrow focus (Gussenhoven, 2004; Pierrehumbert and Beckman, 1988).

**Non-accentual phonological marking of domains** – prominent positions in the prosodic hierarchy license the application of specific phonological processes, e.g. tone spreading domains (Hsu and Jun, 1996; Hyman, 1990; Hyman and Monaka, 2011; Lee, 2014), positional neutralization (Barnes, 2006).

**Phonetic marking of domains** – prominent positions in the prosodic hierarchy undergo processes of phonetic enhancement, e.g. domain-initial strengthening (Fougeron and Keating, 1997; Keating et al., 2000), focal $F_0$ range expansion (Xu, 1999), stress-related hyperarticulation (Byrd and Choi, 2010; de Jong, 1995; Krivokapić and Byrd, 2012).


Kuznetsova, A., Brockhoff, P. B., and Christensen, R. H. B. (2013). *lmerTest (R package)*.


