F0 correlates of perceived speaker surprise in American English: Accents vs. Edge Tones

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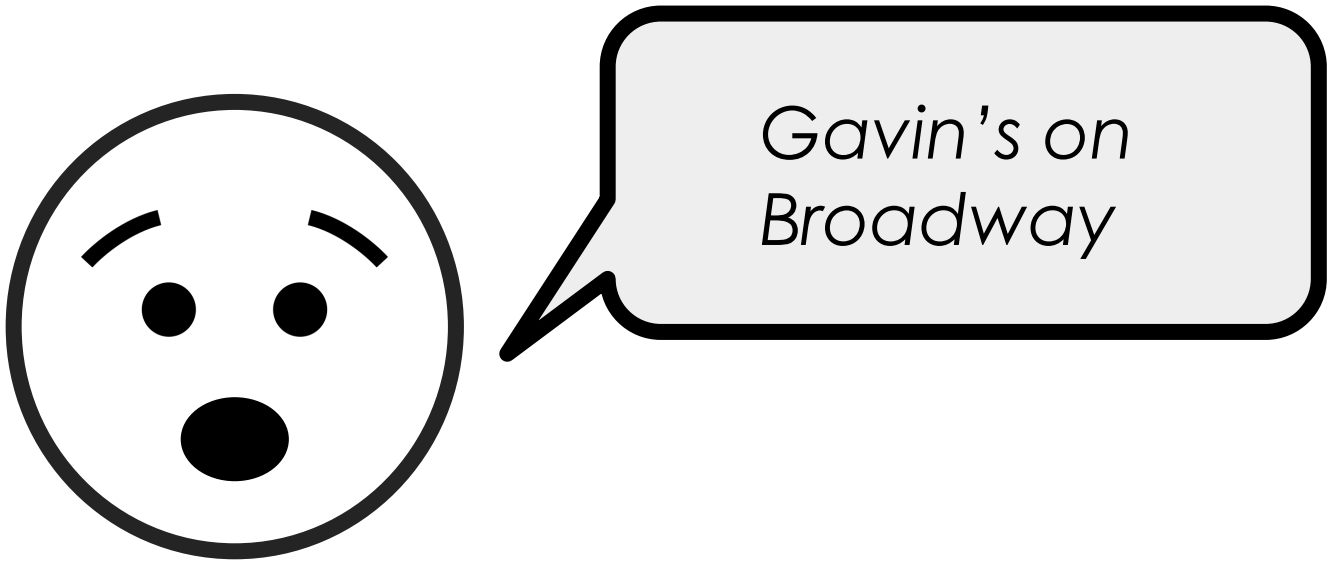
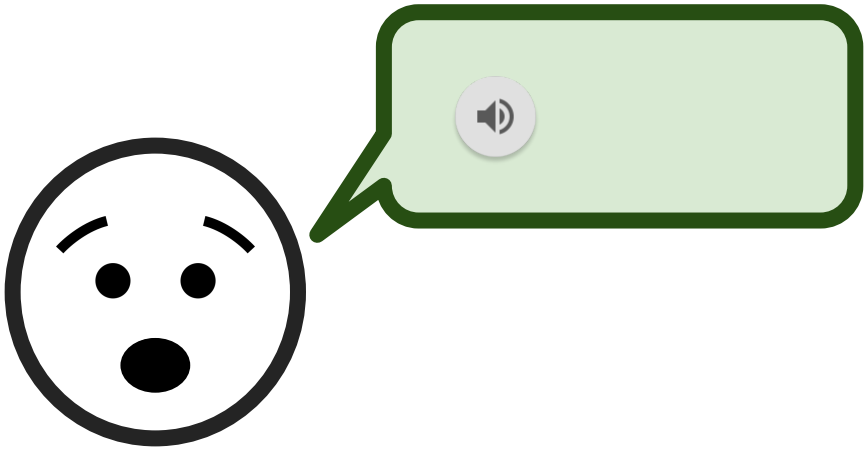
Imagine that you and a friend have just learned that one of your former high school classmates is performing in a Broadway show.

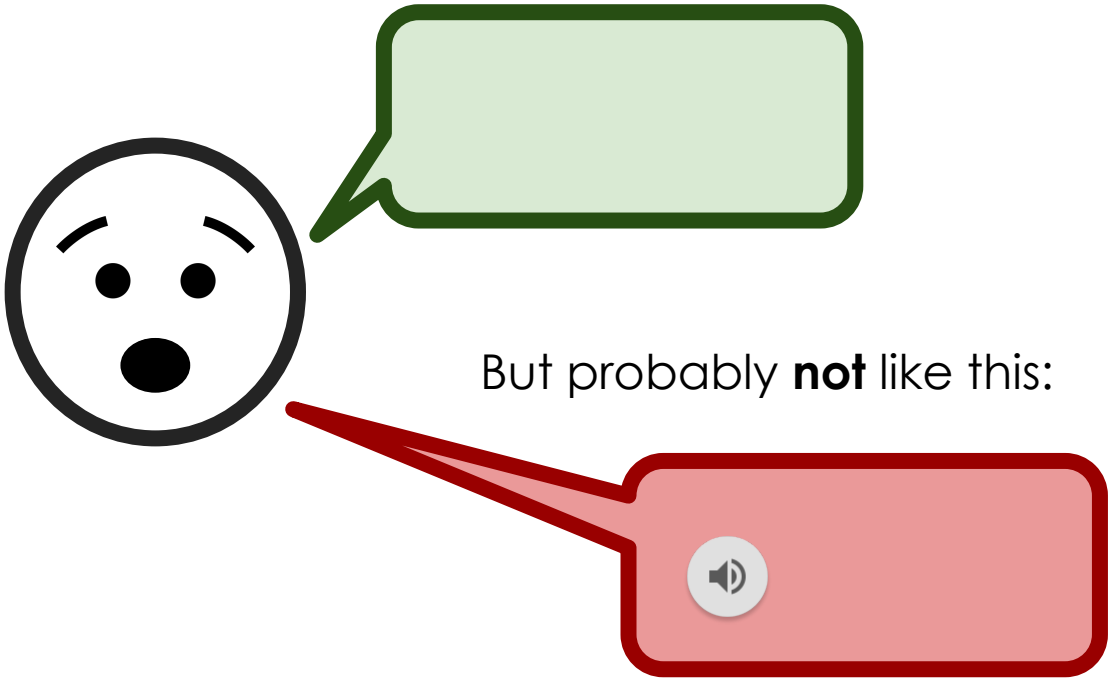
Your friend looks surprised, and says:



Your friend **might** sound something like this:



Your friend **might** sound something like this:

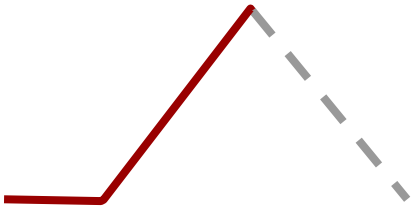


But probably **not** like this:

What features convey surprise?

One hypothesis:

> **the L+H* pitch accent is the core marker**
>
> **Rett & Sturman (2020)**



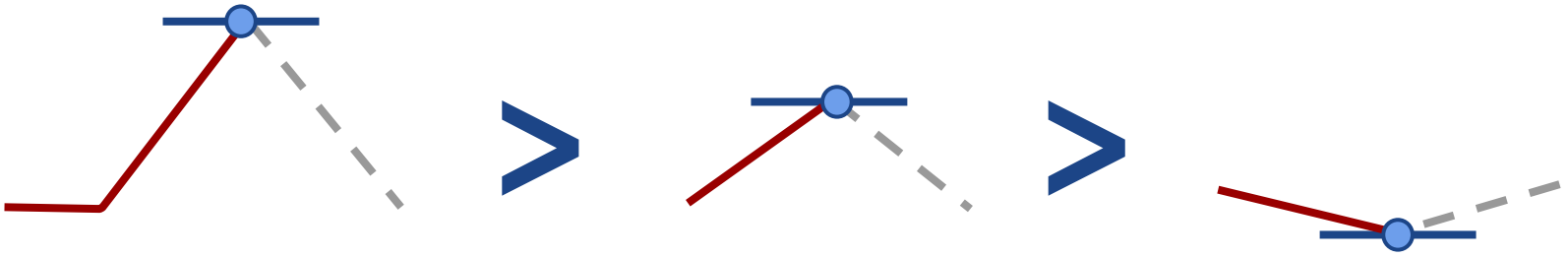
The problem: This hypothesis predicts that all utterances without L+H* pitch accents sound equally (un)surprised.

A revised hypothesis

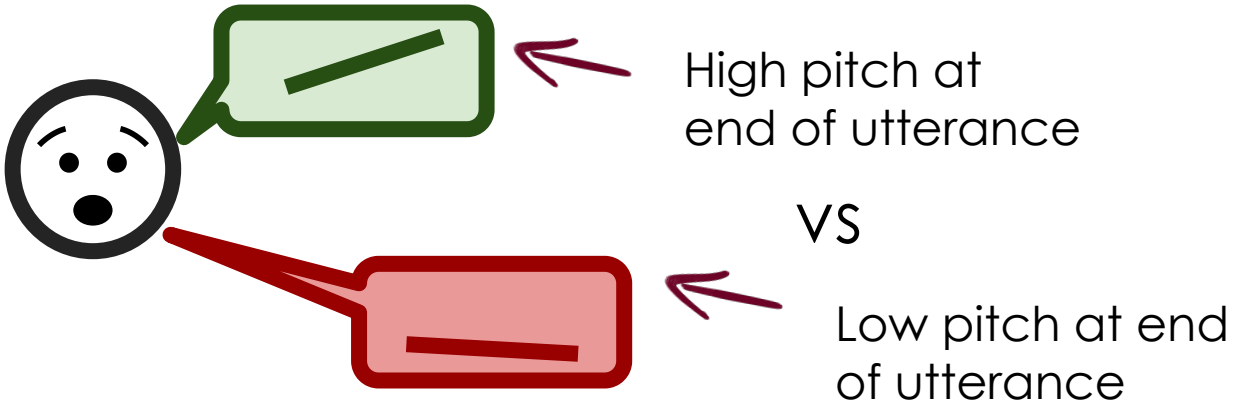
Maybe surprise is conveyed primarily through pitch accent **height.**

This would make L+H* sound more surprised than other accents…

….and also account for any variation we might find between those other accents.



But what about edge tones?



Studies in several languages have suggested that surprise is conveyed by changes to pitch range

This predicts that F0 at multiple points in the contour (including the F0 target that cues edge tones) should influence perceived surprise

Gussenhoven & Rietveld (2000); Ladd, Silverman, Tolkmitt, Bergmann, & Scherer (1985); Liu, Xu, Zhang, & Tian (2021)

Questions so far

1. Does variation in the height of pitch accents other than L+H* drive variation in perceived surprise?
2. Is conveying surprise just about pitch accent, or do multiple parts of the contour contribute?

If multiple parts of the contour contribute, **are they weighted differently?**

Is having a high pitch accent more important for conveying surprise? Or are the edge tones more important?

Research questions

1. Does variation in the height of pitch accents other than L+H* drive variation in perceived surprise?
2. Is conveying surprise just about pitch accent, or do multiple parts of the contour contribute?
    a. Is having a high pitch accent more important for conveying surprise? Or are the edge tones more important?

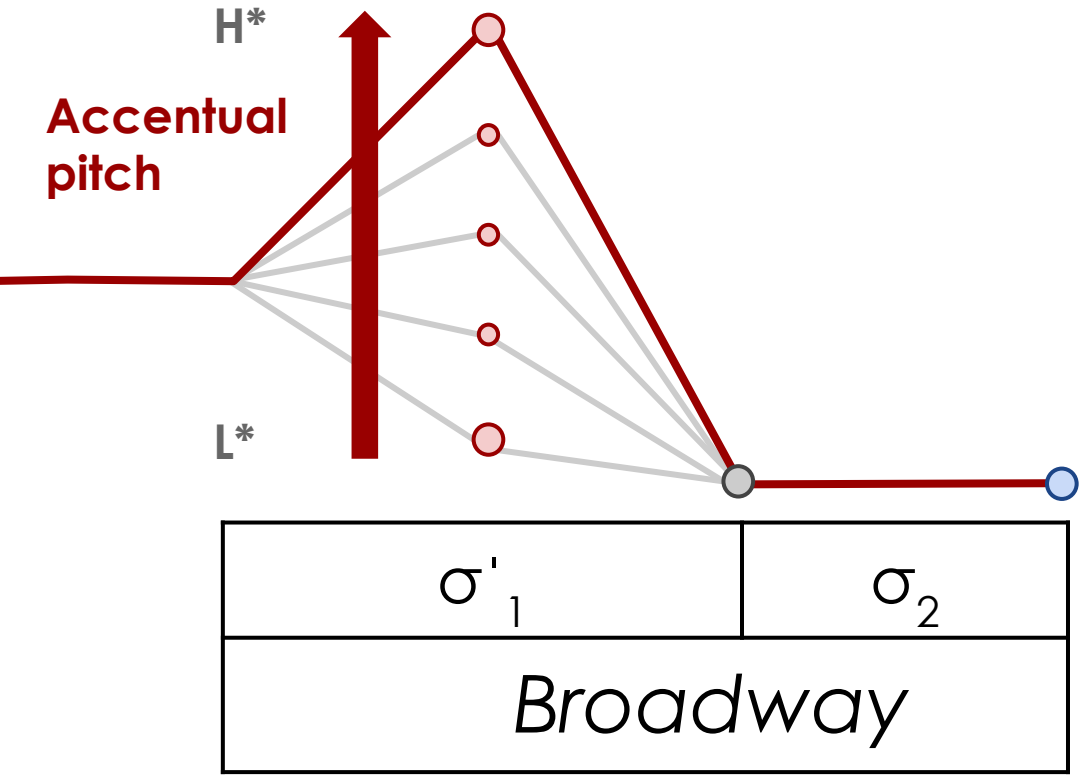
Rating task

= 55

How surprised does the speaker sound?

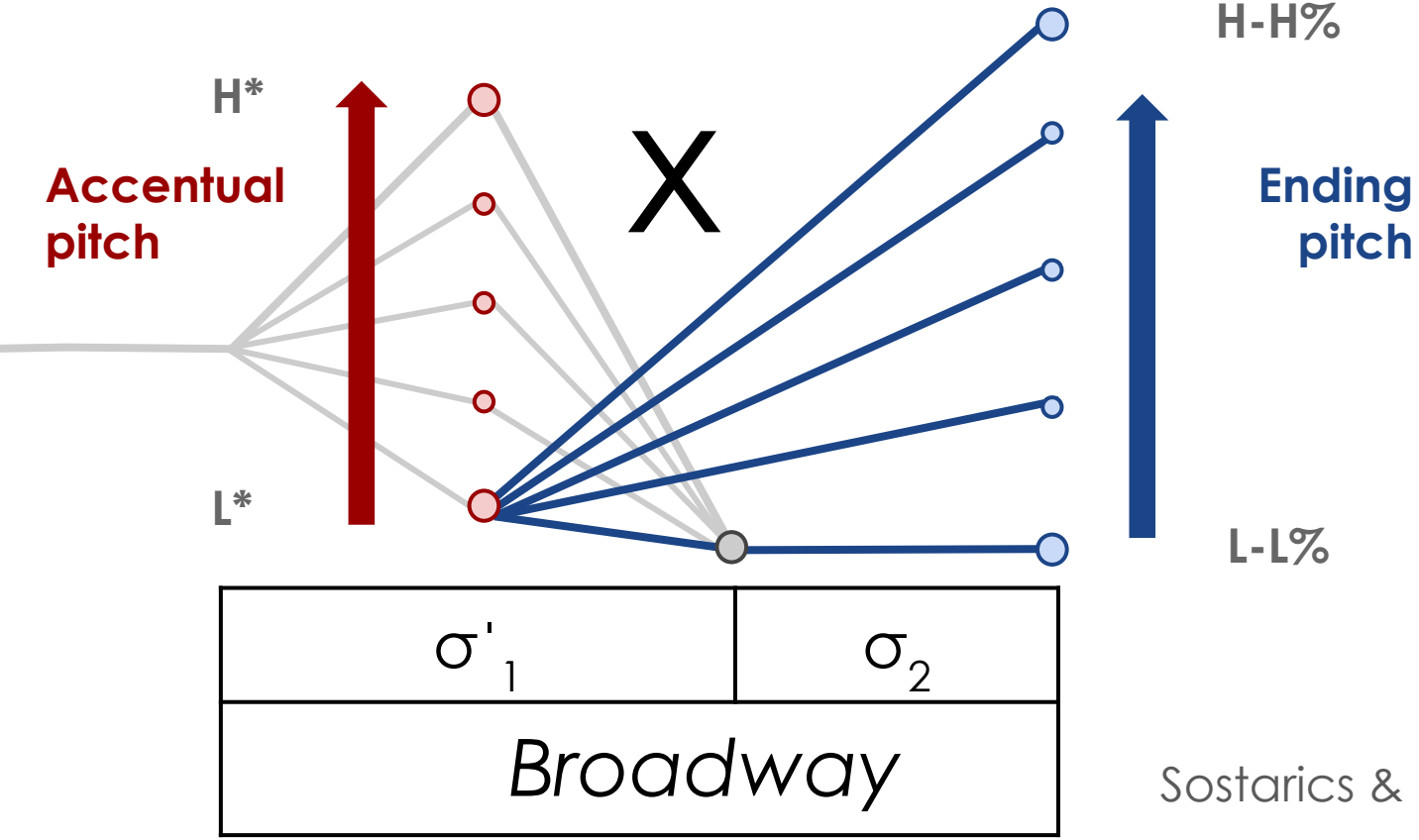
Not surprised ○ ○ ○ ○ ○ ○ Very surprised

Stimuli: varying F0 on the nuclear word



Sostarics & Cole (2023)

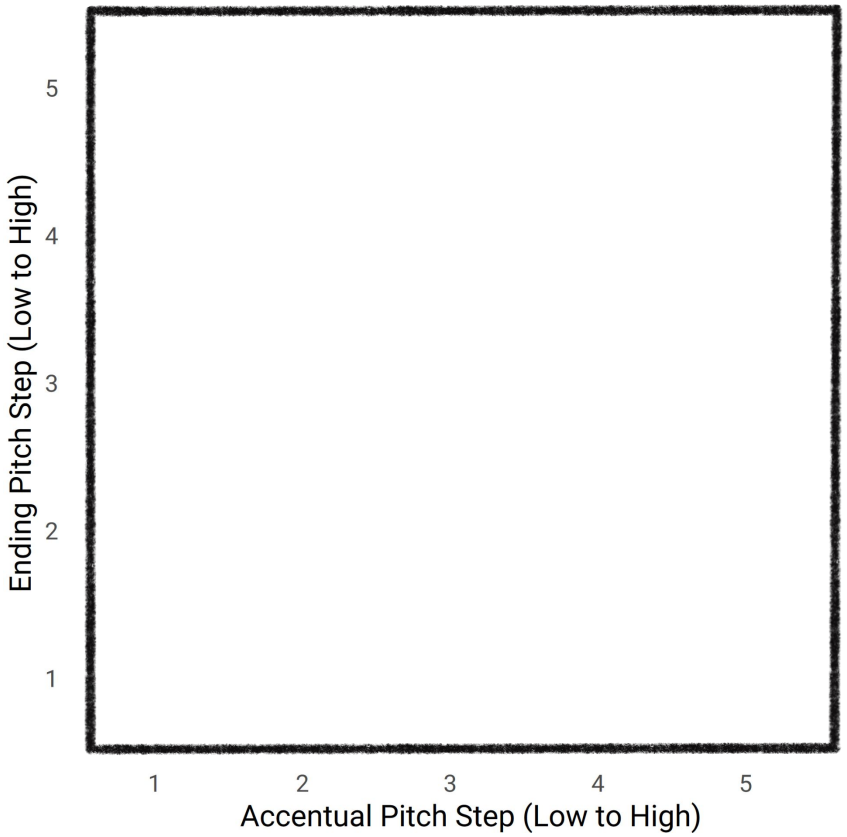
Stimuli: varying F0 on the nuclear word



Sostarics & Cole (2023)

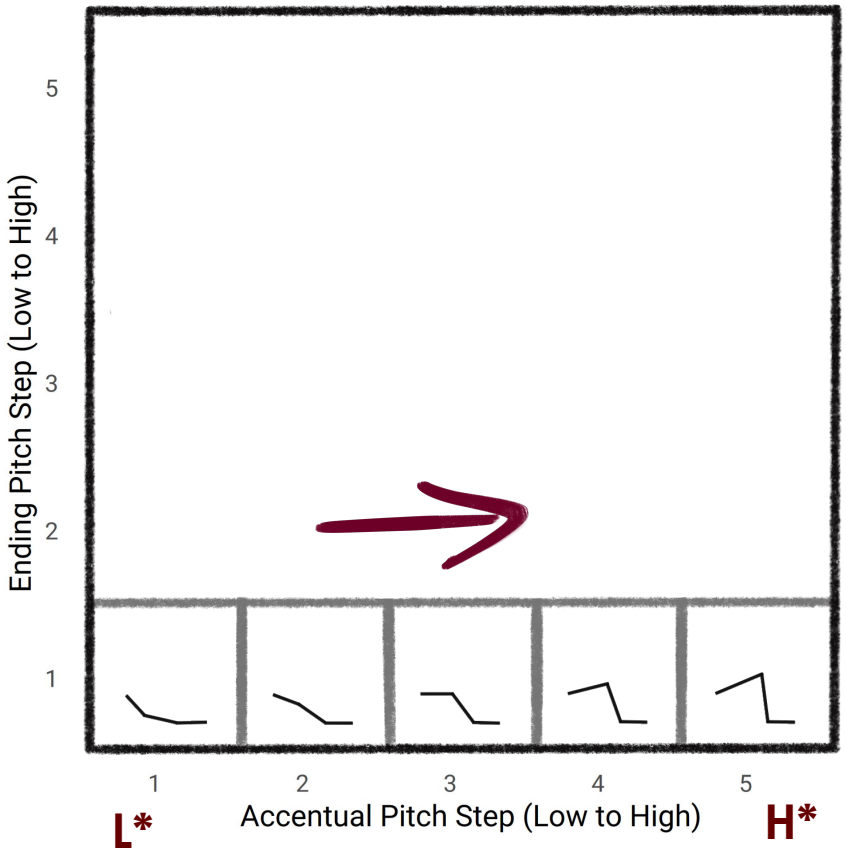
Stimuli

Sostarics & Cole (2023)



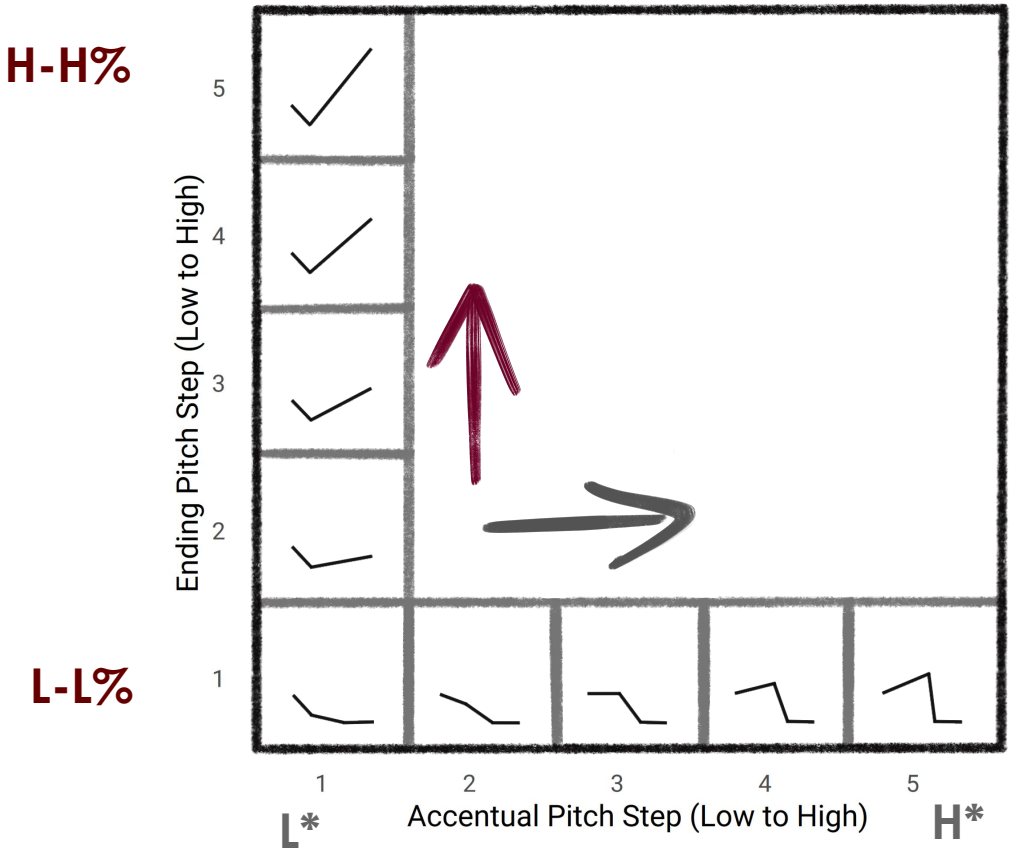
Stimuli

Sostarics & Cole (2023)



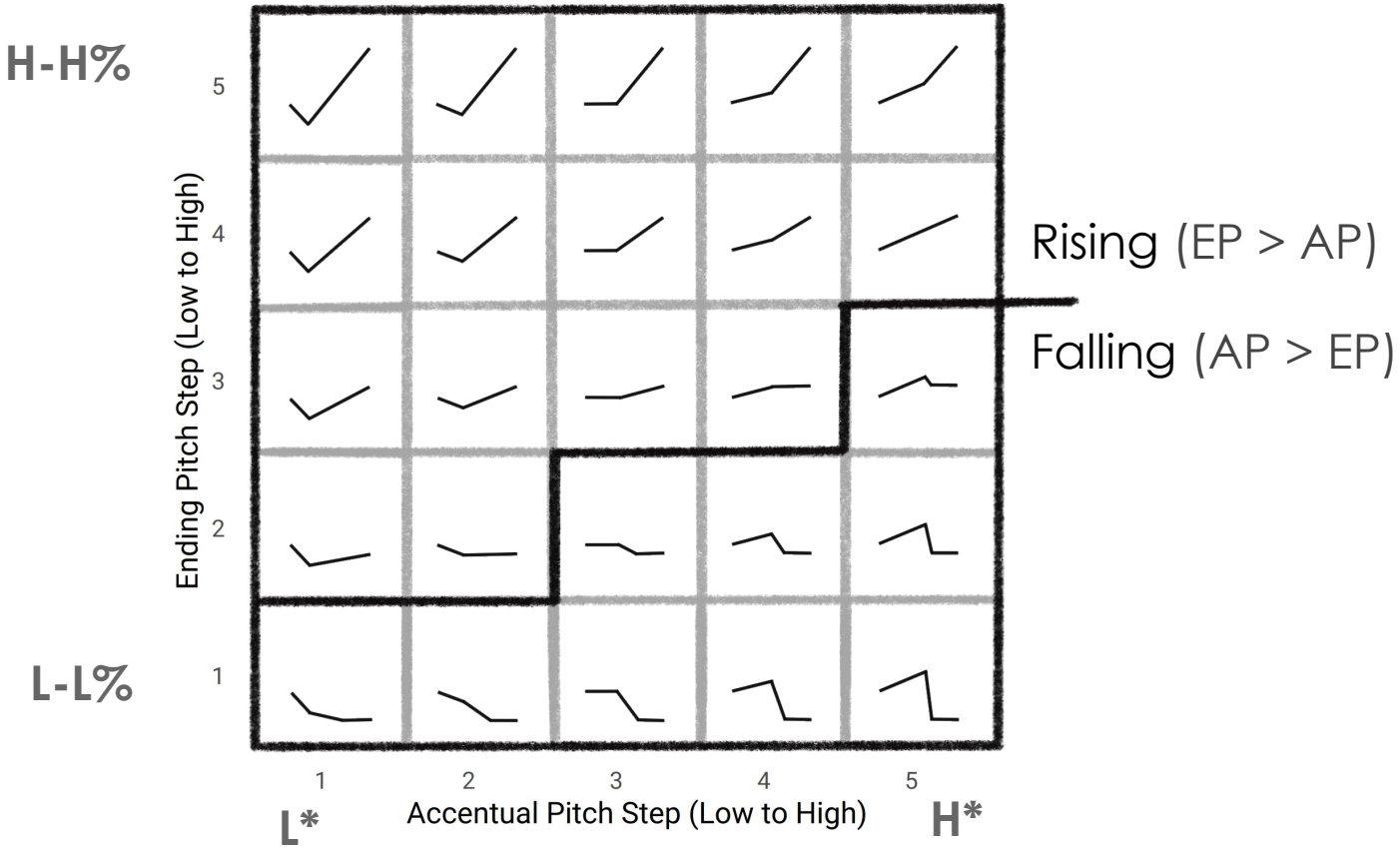
Stimuli

Sostarics & Cole (2023)

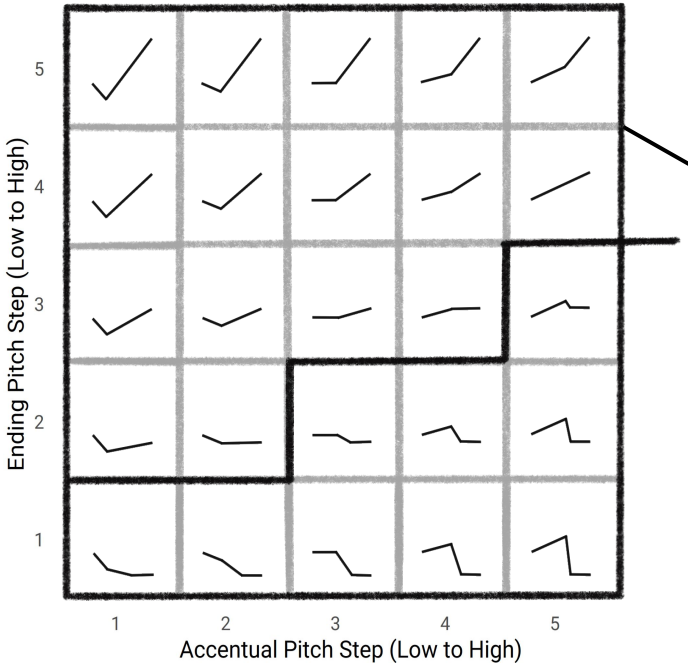


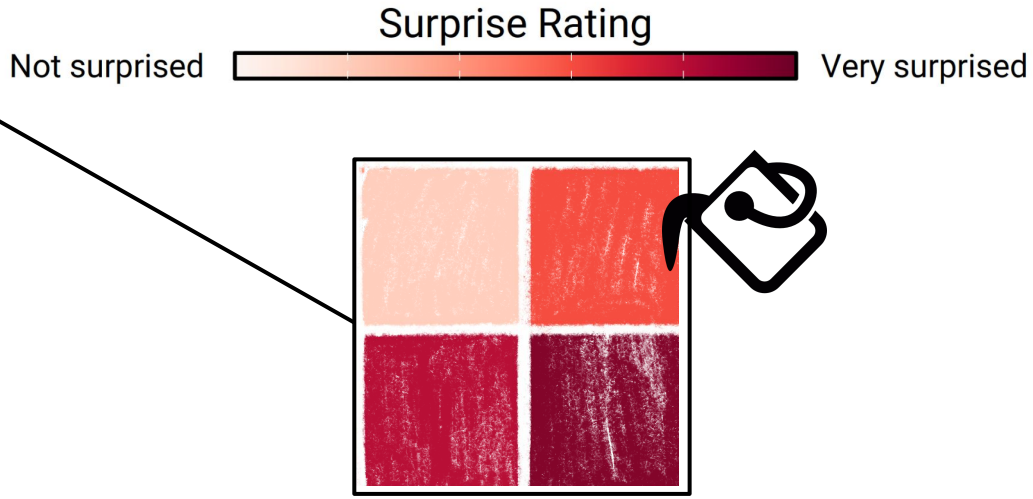
Stimuli

Sostarics & Cole (2023)



Sketching out predictions

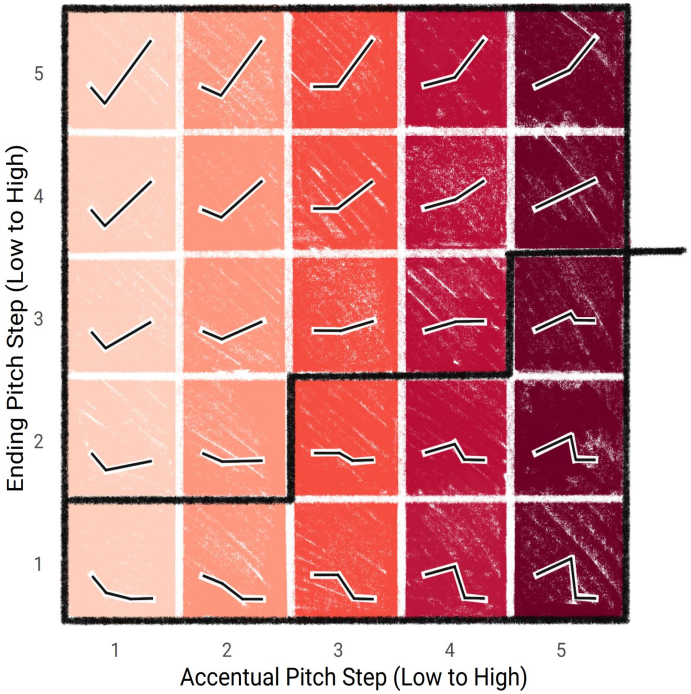




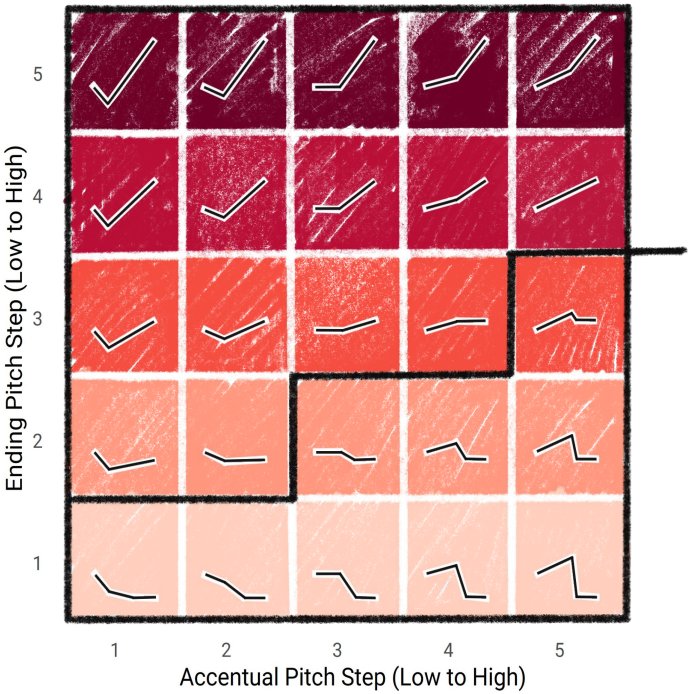
We'll use cell background color to represent the predicted mean rating

Predictions

If perceived surprise is driven solely by the **pitch accent…**



If perceived surprise is driven solely by the **edge tones…**



Bayesian ordinal regression analysis

rating ~ accentual pitch * ending pitch + (1 + ap * ep | participant) + (1 | utterance)

DV

Predictors

Random slopes & intercepts for participants; random intercepts for utterances

Tells us the effect of each part of the contour on surprise ratings

Bayesian ordinal regression analysis

rating ~ accentual pitch * ending pitch + (1 + ap * ep | participant) + (1 | utterance)

DV

Predictors

Random slopes & intercepts for participants; random intercepts for utterances

A credible effect of _____	**would tell us that_____**

Bayesian ordinal regression analysis

rating ~ **accentual pitch** * ending pitch + (1 + ap * ep | participant) + (1 | utterance)

DV

Predictors

Random slopes & intercepts for participants; random intercepts for utterances

A credible effect of _____	**would tell us that_____**
accentual pitch	variation in the height of pitch accents other than L+H* affects perceived surprise

Bayesian ordinal regression analysis

rating ~ accentual pitch * **ending pitch** + (1 + ap * ep | participant) + (1 | utterance)

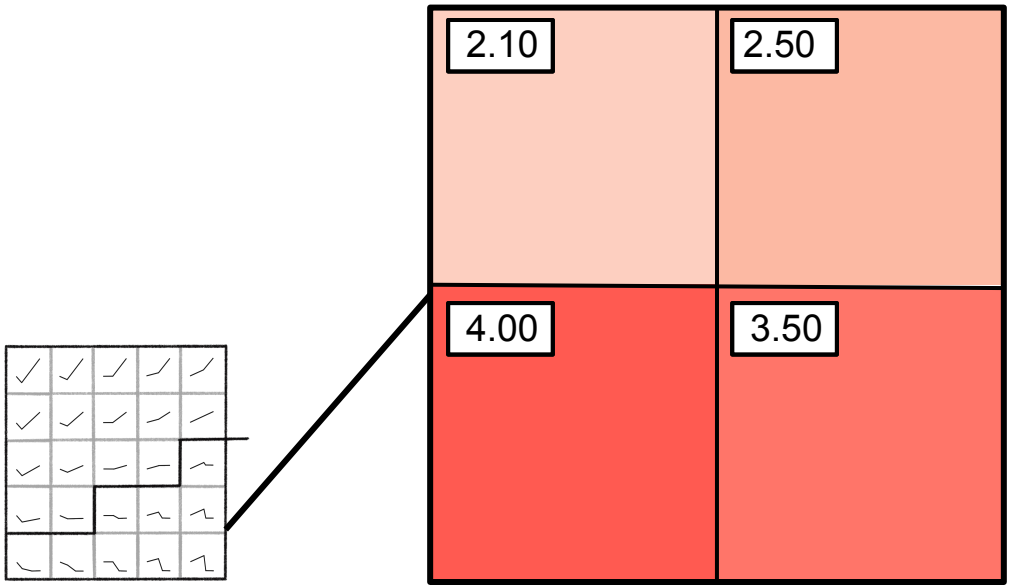
DV

Predictors

Random slopes & intercepts for participants; random intercepts for utterances

A credible effect of _____	**would tell us that_____**
accentual pitch	variation in the height of pitch accents other than L+H* affects perceived surprise
ending pitch	ending pitch contributes to perceived surprise

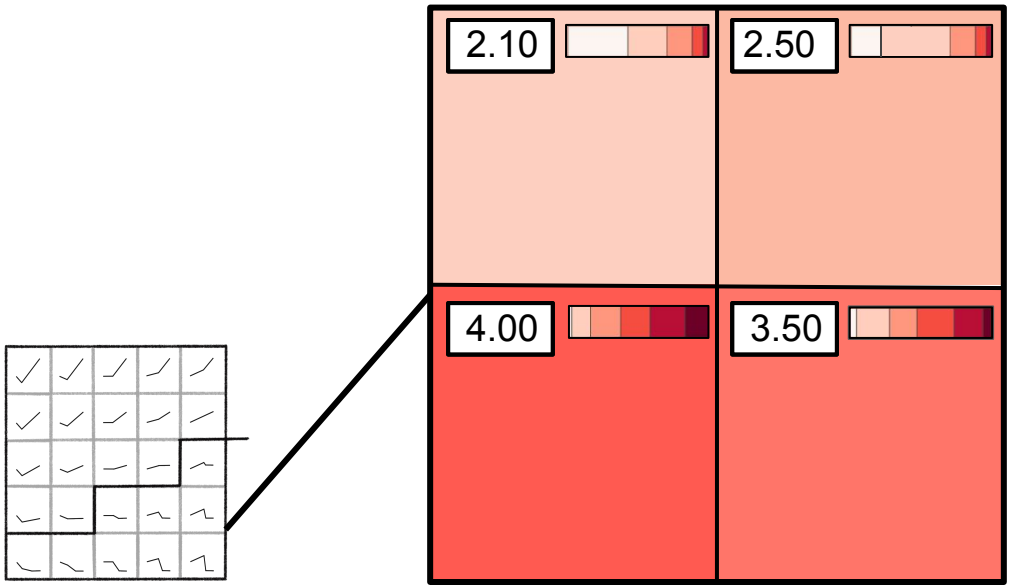
How to read the results



Mean rating

Not surprised — Very surprised

How to read the results

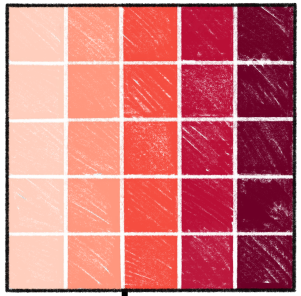


Mean rating

Distribution of ratings

Not surprised — Very surprised

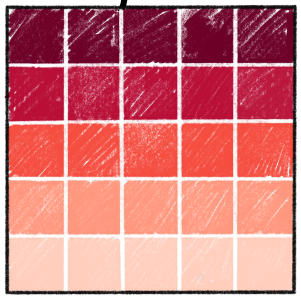
ACCENTUAL PITCH



$\hat{\beta}$ = 0.11

$\hat{\beta}$ = -0.03

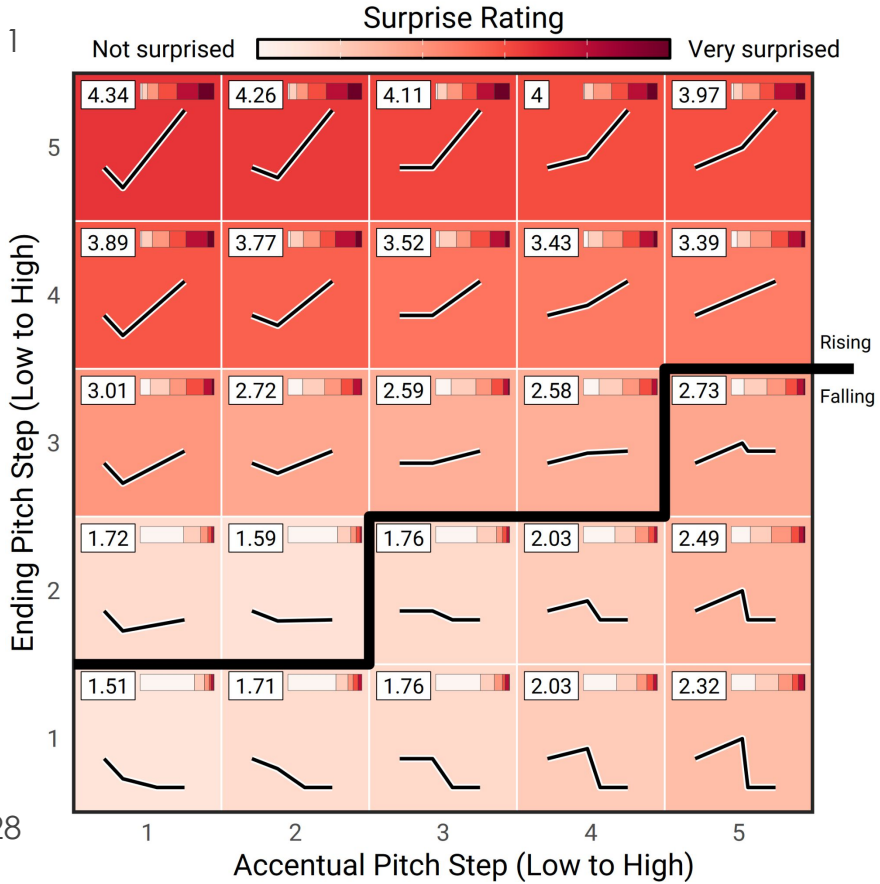
AP * EP



$\hat{\beta}$ = 0.28

ENDING PITCH

Fig. 1: Empirical mean surprise ratings



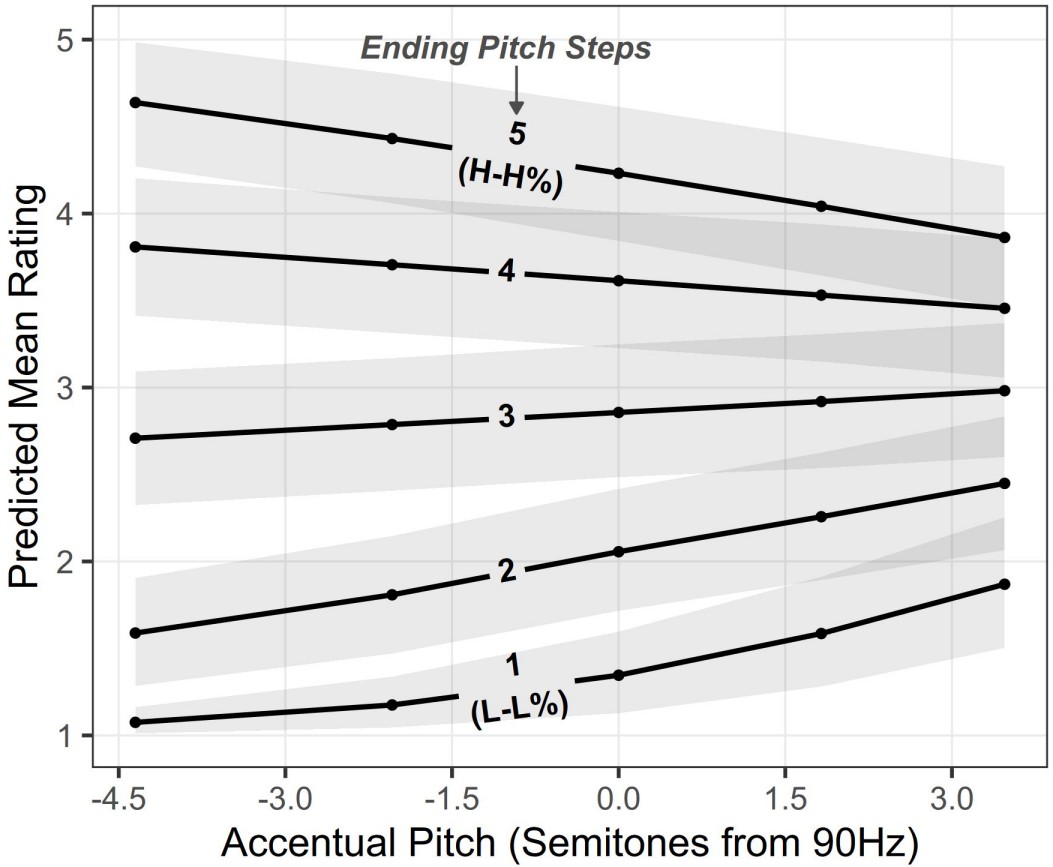
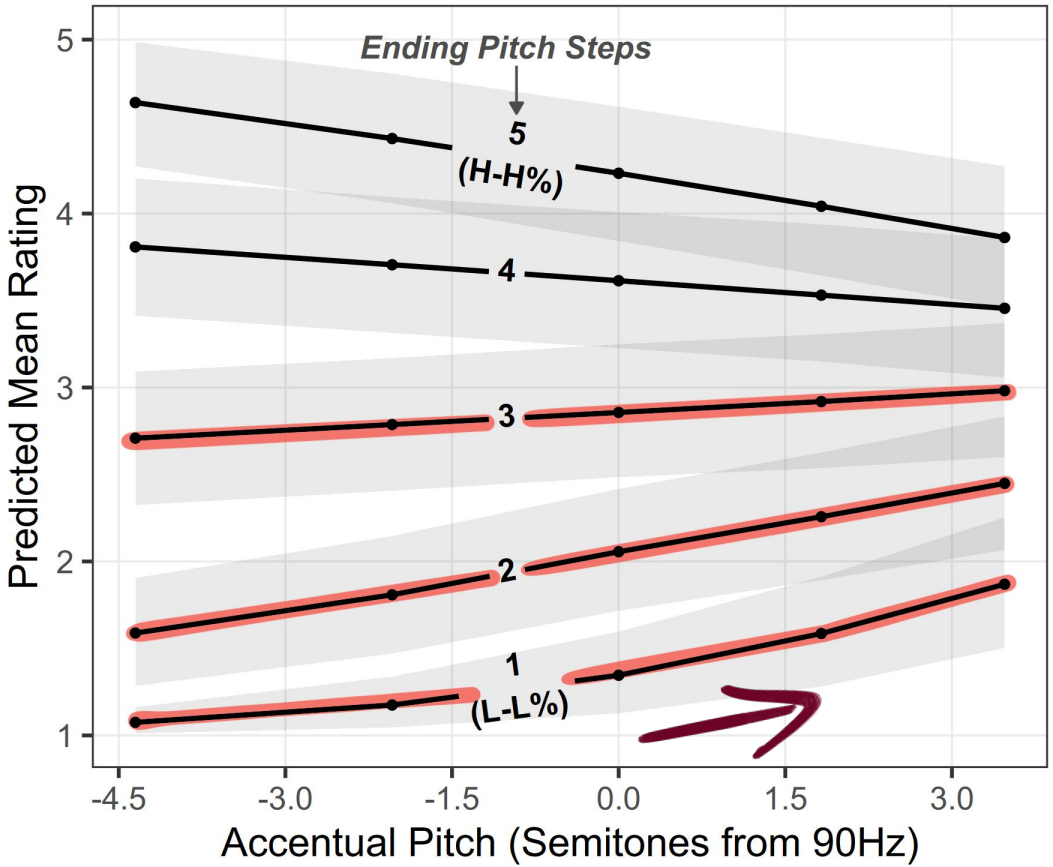
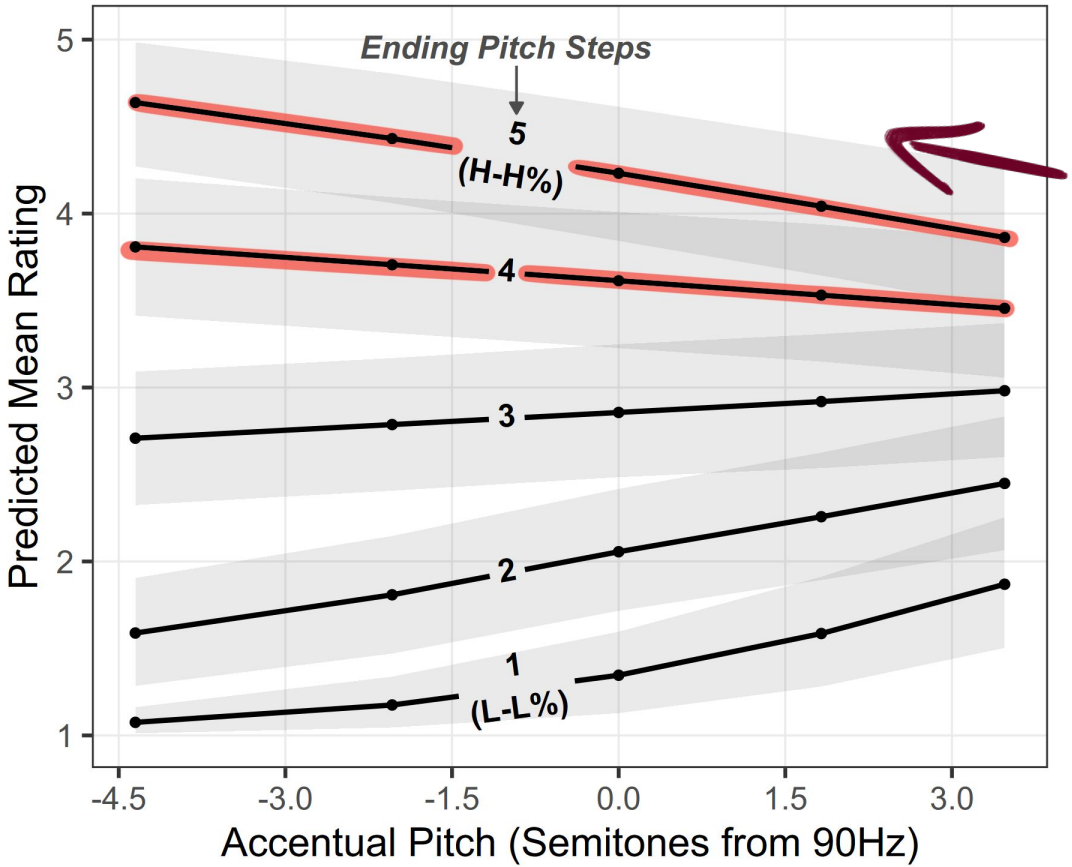


Fig. 2: The effect of accentual pitch on the predicted mean rating within each ending pitch step



When **ending pitch** is **low**, **higher accentual pitch** leads to greater perceived surprise.

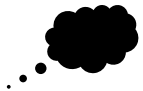


When **ending pitch** is **high**, **lower accentual pitch** leads to greater perceived surprise.

Interim conclusions

1. Does variation in the height of pitch accents other than L+H* drive variation in perceived surprise? ➡ **Yes;** we find variation in perceived surprise among accentual pitch targets that range from L* to H*.
2. Is conveying surprise just about pitch accent, or do multiple parts of the contour contribute? ➡ **Both pitch accent and edge tones contribute.**
    a. Is having a high pitch accent more important for conveying surprise? Or are the edge tones more important? ➡ **Edge tones seem to have a greater influence on perceived surprise.**

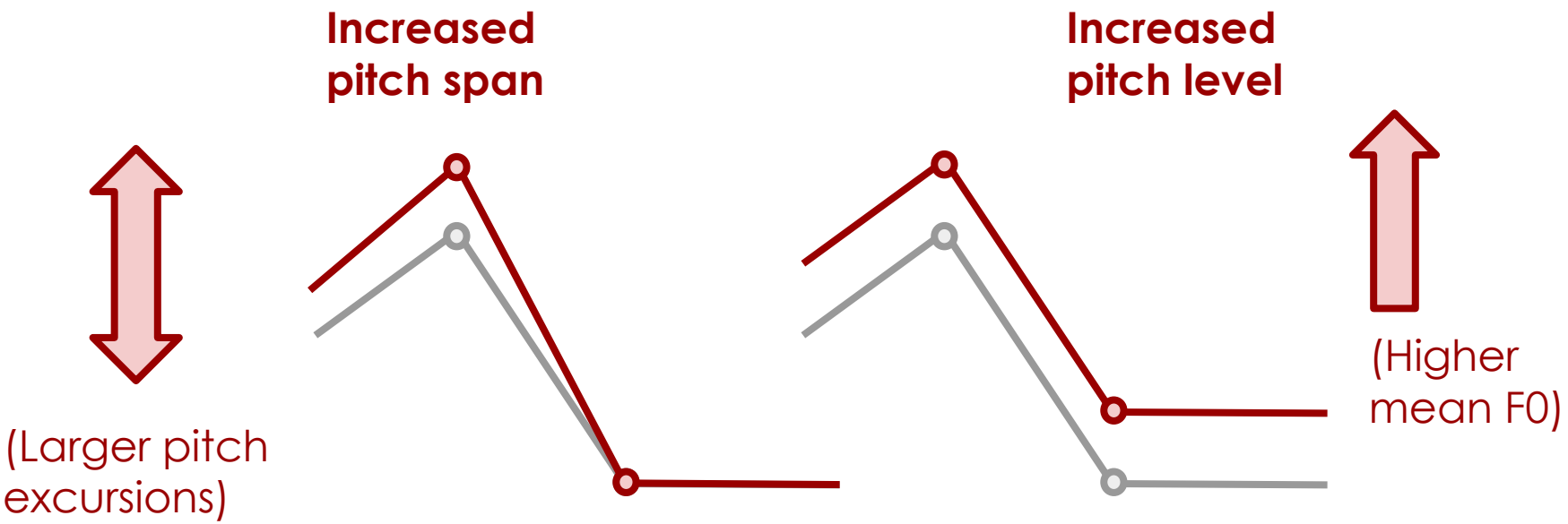
A lingering question



Remember that previous studies have suggested that surprise is conveyed by changes to pitch range

➡ How do our results relate to these accounts?

Two ways of changing pitch range:

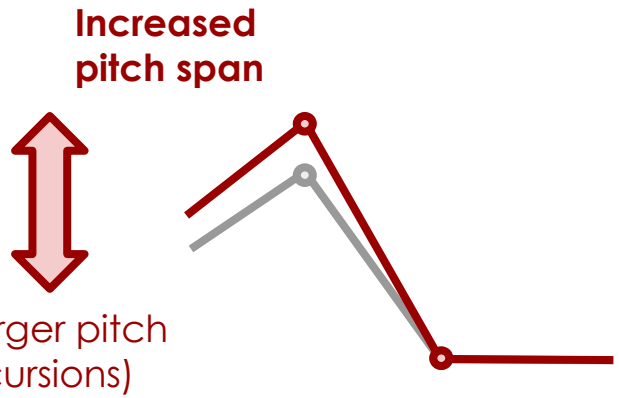


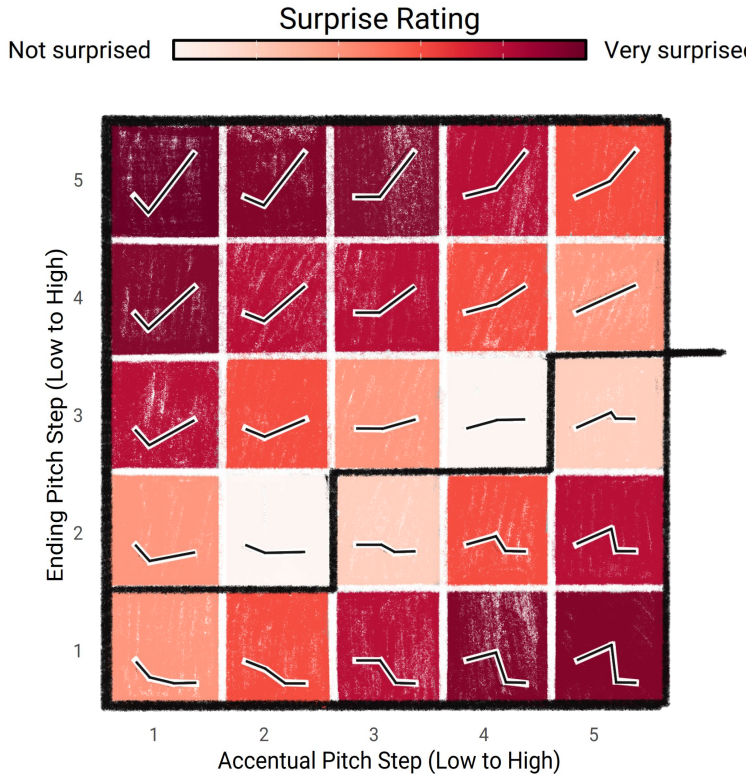
Patterson & Ladd (1999)

Our stimuli in terms of pitch span

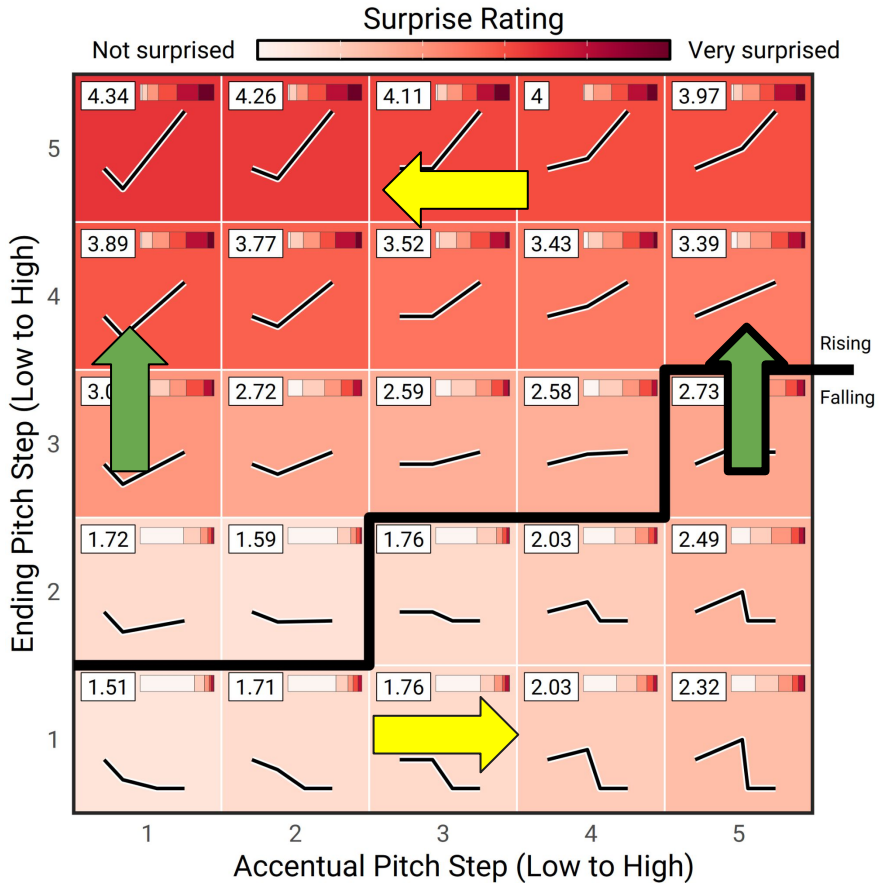
Contours where AP and EP are far away from each other have larger pitch excursions / higher pitch span

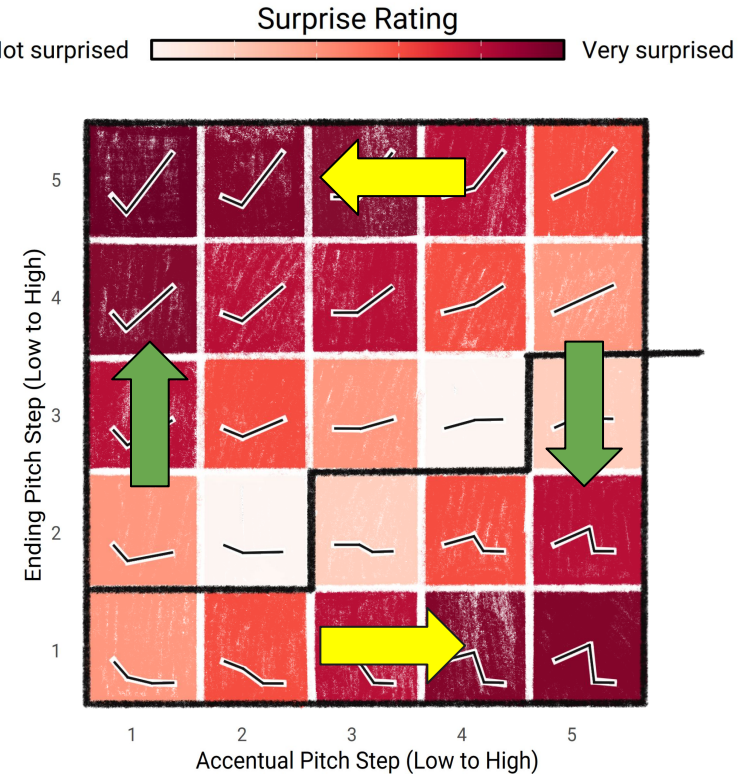
Both rising and falling contours have a variety of excursion sizes



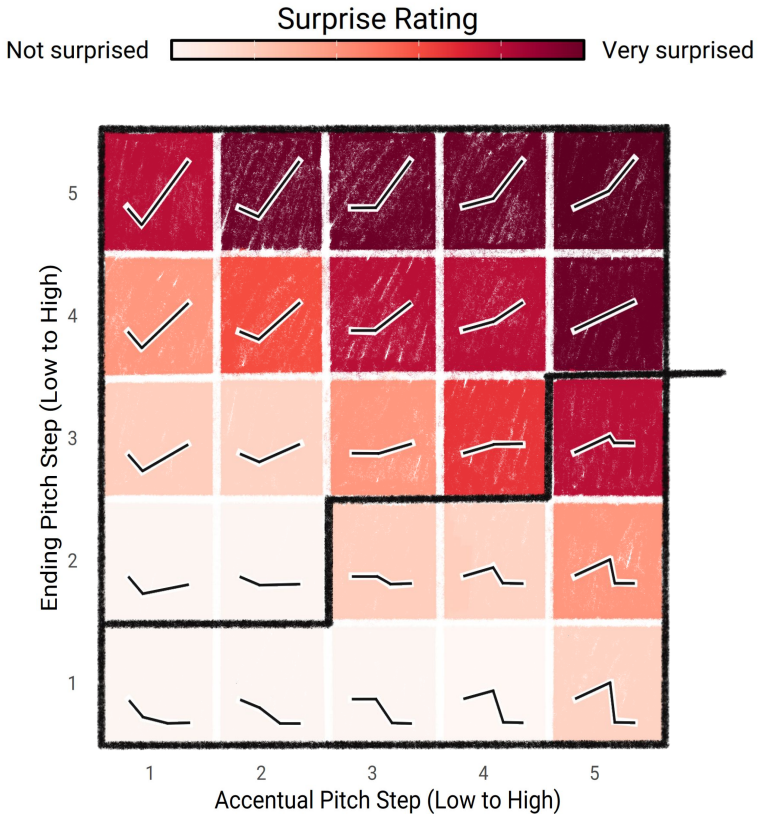


Our stimuli in terms of pitch span

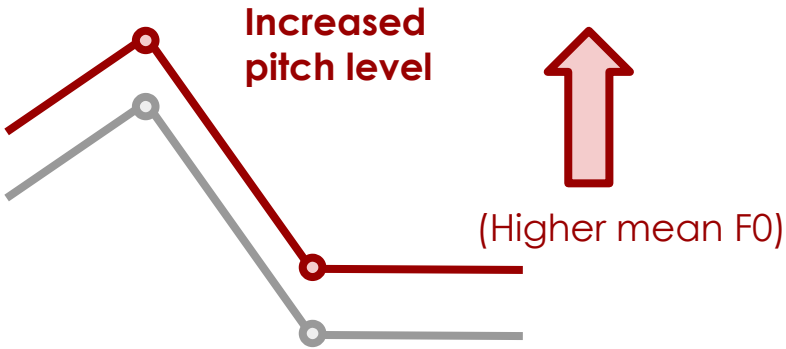




Stimuli in terms of pitch level



Contours where both ending pitch and accentual pitch are high have the highest mean F0/pitch level



Conclusions

1. Variation in the height of pitch accents other than L+H* drives variation in perceived surprise.
2. Both accentual pitch and ending pitch contribute to perceived surprise, but edge tones have a greater effect.
3. While pitch span and level do explain some of the variation in our data, pitch range measures alone don't predict our results; it also matters where in the contour high and low pitch targets are realized.

Acknowledgements

- ProSD Lab and Phonatics group at Northwestern
- Chun Chan for experiment implementation

Pitch span analysis

BAYESIAN ORDINAL REGRESSION MODEL

Rising or falling

rating ~ centered excursion size * contour shape + (1 + centered excursion size * contour shape | participant) + (1 | utterance)

We find credible effects of:

- **centered excursion size** ($\hat{\beta}$=0.09, CI [0.07, 0.11])
- **contour shape - rising** ($\hat{\beta}$=1.05, CI [0.84, 1.27])
- **centered excursion size : contour shape - rising** ($\hat{\beta}$=0.15, CI [0.12, 0.18]

Pitch level analysis

BAYESIAN ORDINAL REGRESSION MODEL

rating ~ mean F0 (in nuclear region) * contour shape + (1 + mean F0 * contour shape | participant) + (1 | utterance)

We find credible effects of:

- **mean F0** ($\hat{\beta}$=0.35, CI [0.28, 0.44])
- **contour shape - rising** ($\hat{\beta}$=0.61, CI [0.43, 0.81])
- **mean F0 : contour shape - rising** ($\hat{\beta}$=0.13 , CI [0.09, 0.17])