

JORDAN B. L. SMITH  
MATHEMUSICAL CONVERSATIONS STUDY DAY, 12 FEBRUARY 2015  
RAFFLES INSTITUTION

# EXPLAINING AND PREDICTING THE PERCEPTION OF MUSICAL STRUCTURE

# OUTLINE

- What is musical structure?
- How do people perceive structure?
  - Gestalt-based theories
  - Implication-Realization theory
  - Listener considerations
- Conclusion

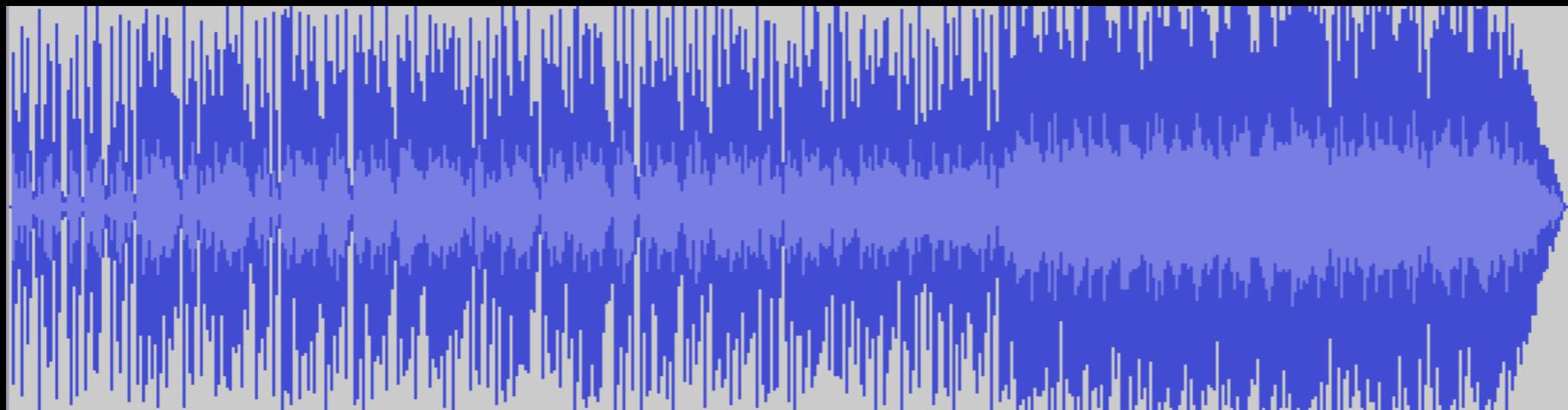
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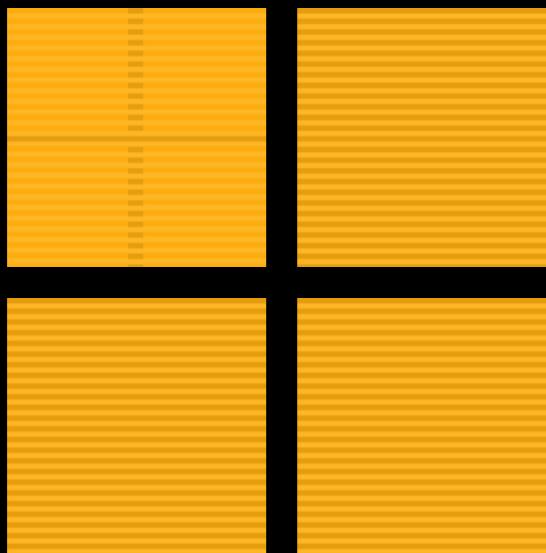
“Shake It Off” by Taylor Swift

# WHAT IS STRUCTURE?

- How did you **hear** this piece of music?

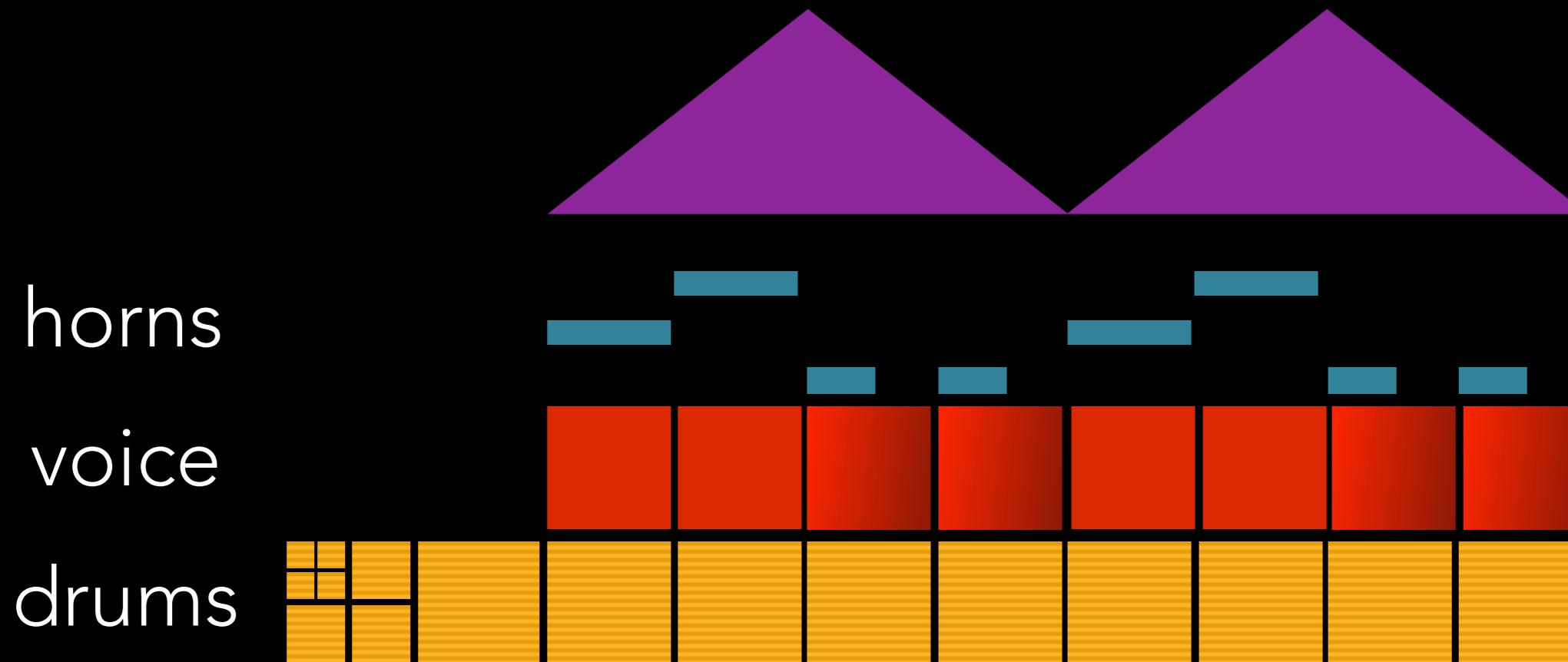


- How did you **perceive** this piece of music?



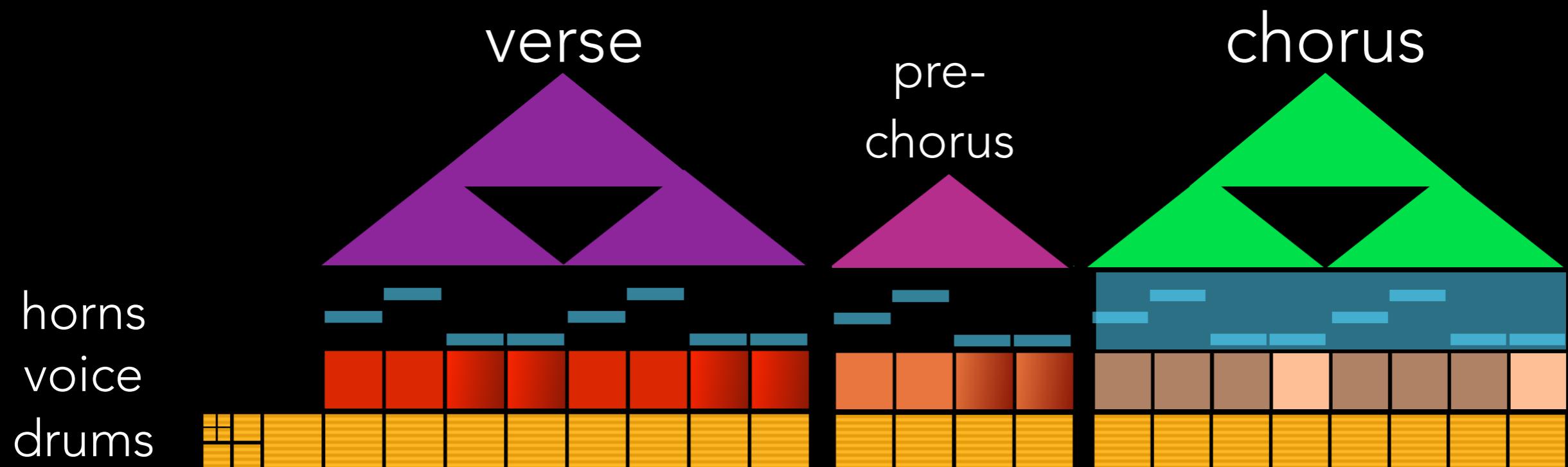
# WHAT IS STRUCTURE?

- How did you **perceive** this piece of music?



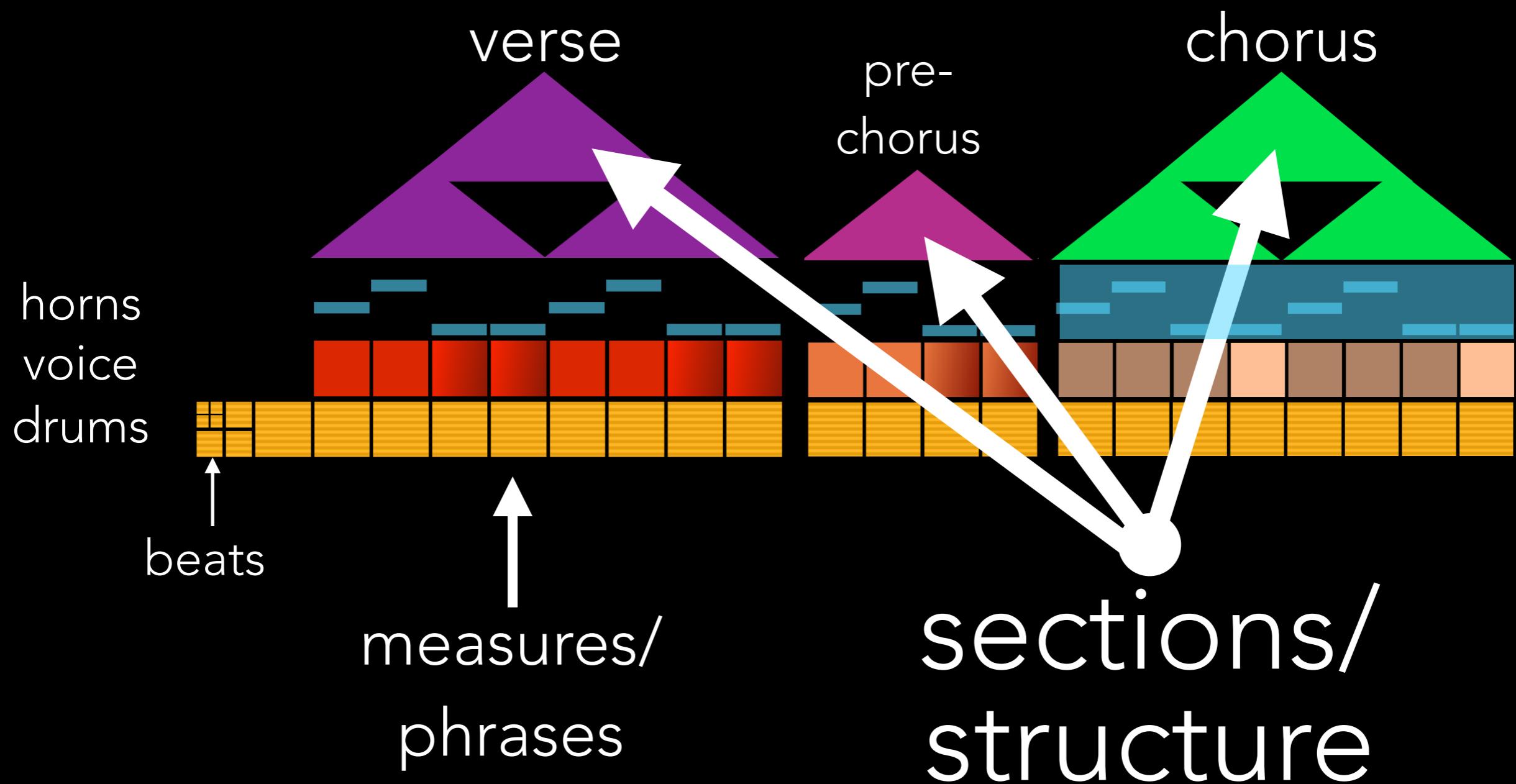
# WHAT IS STRUCTURE?

- How did you **perceive** this piece of music?



# WHAT IS STRUCTURE?

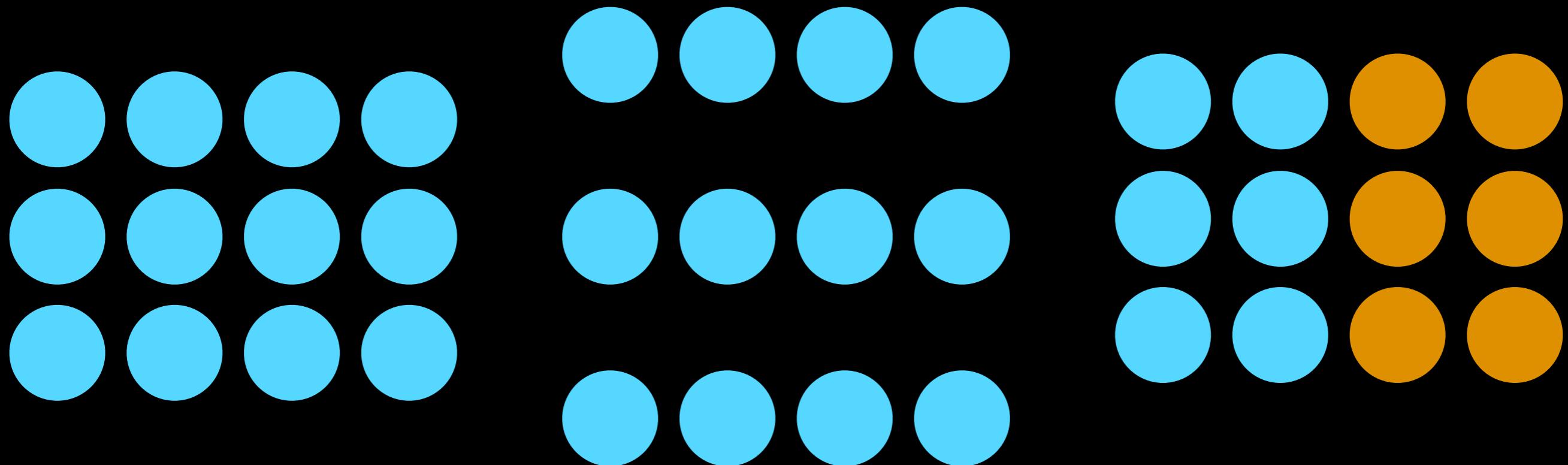
- How did you **perceive** this piece of music?



# HOW DO PEOPLE PERCEIVE STRUCTURE?

- Gestalt-based theories
- Implication-Realization theory
- Listener considerations

# GESTALT-BASED THEORIES



Proximity

Similarity

# GENERATIVE THEORY OF TONAL MUSIC

3.7

a



3.8

a



b



## Principle of Proximity

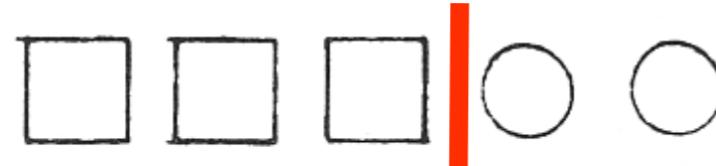
Lerdahl and Jackendoof 1983

image credit: [http://noike.info/~kenzi/roughly/paper/GTTM/12/12\\_Psychological\\_and\\_Linguistic\\_Connections.html](http://noike.info/~kenzi/roughly/paper/GTTM/12/12_Psychological_and_Linguistic_Connections.html)

# GENERATIVE THEORY OF TONAL MUSIC

3.9

a



b



3.10

a



b



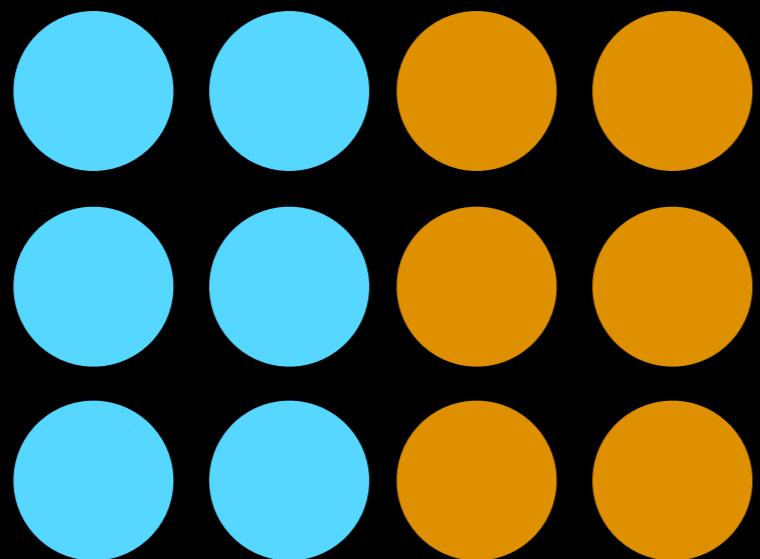
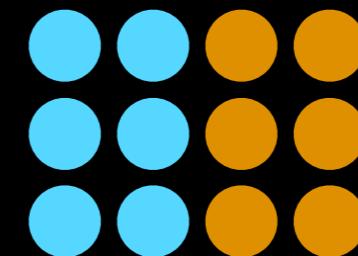
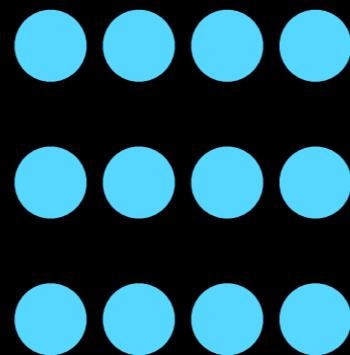
## Principle of Similarity

Lerdahl and Jackendoof 1983

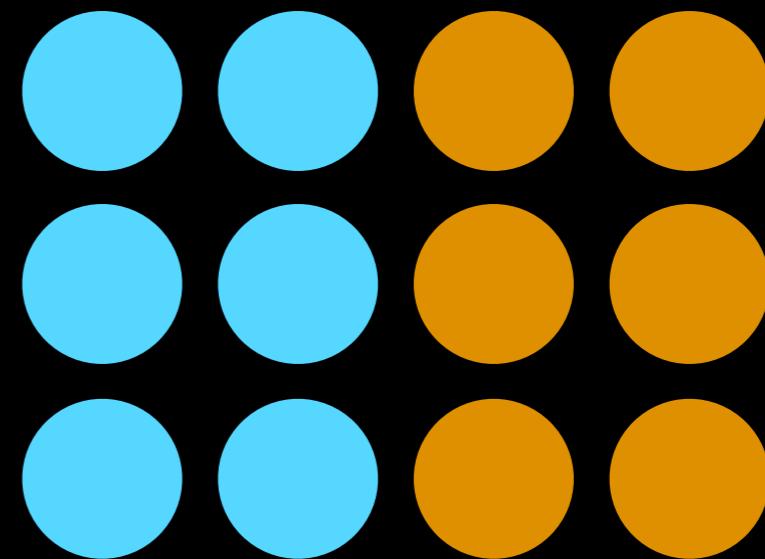
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# GENERATIVE THEORY OF TONAL MUSIC

Two rules:

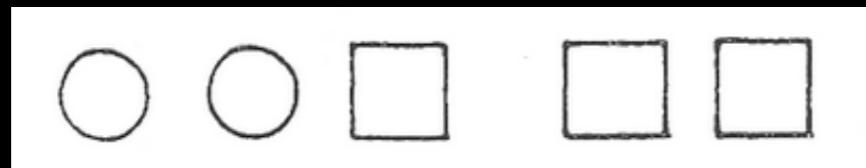


Cooperation



Conflict

# GENERATIVE THEORY OF TONAL MUSIC

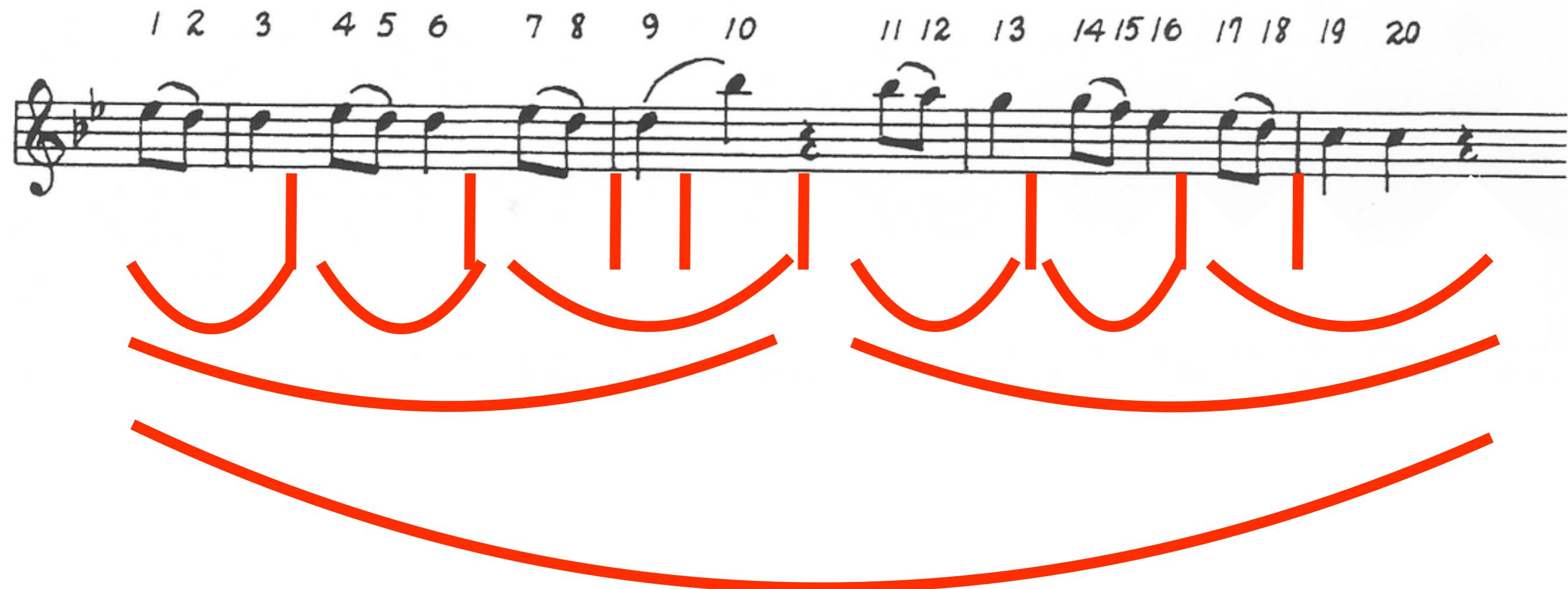


Conflict of Rules

Lerdahl and Jackendoof 1983

image credit: [http://noike.info/~kenzi/roughly/paper/GTTM/12/12\\_Psychological\\_and\\_Linguistic\\_Connections.html](http://noike.info/~kenzi/roughly/paper/GTTM/12/12_Psychological_and_Linguistic_Connections.html)

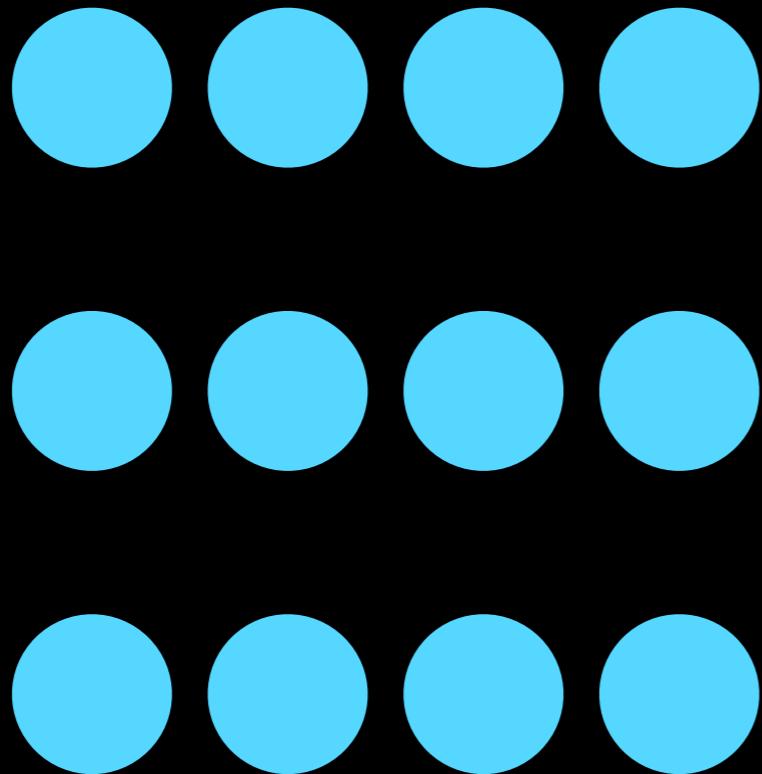
# GENERATIVE THEORY OF TONAL MUSIC



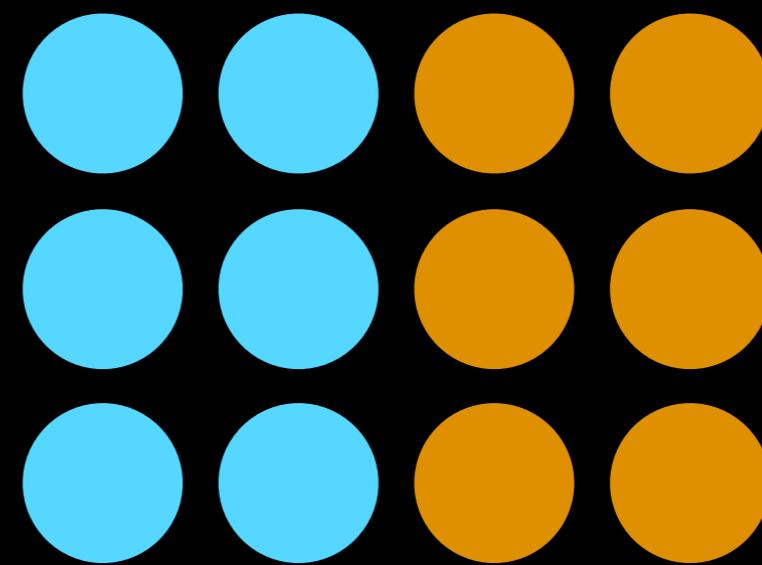
Goal of GTTM: to devise a set of rules from which a complete hierarchical grouping structure can be inferred

Lerdahl and Jackendoof 1983

# GESTALT-BASED THEORIES



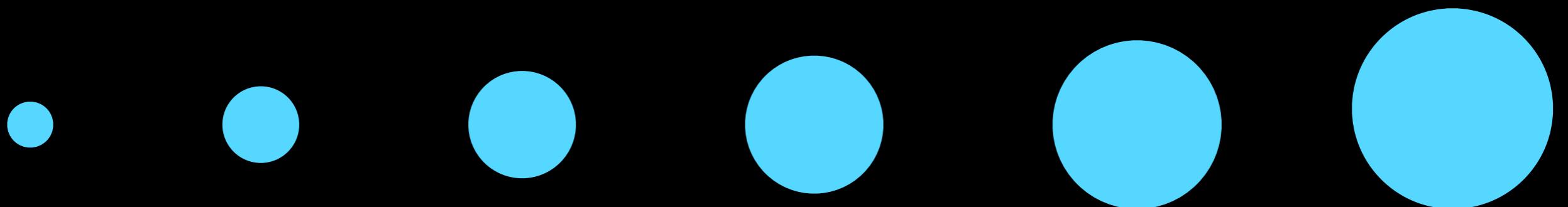
Proximity



Similarity

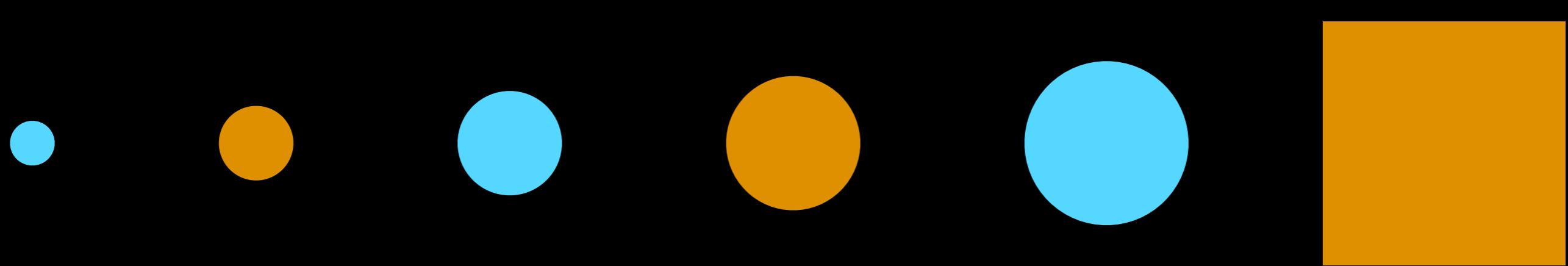
# GENERATIVE THEORY OF TONAL MUSIC

- Fred Lerdahl and Ray Jackendoff, 1983
- Goal of GTTM: to devise a set of rules from which a complete hierarchical grouping structure can be inferred
- Inspired by Gestalt theory and by ideas of “universal grammar” in language
- Assumes an ideal listener familiar with Western tonal music

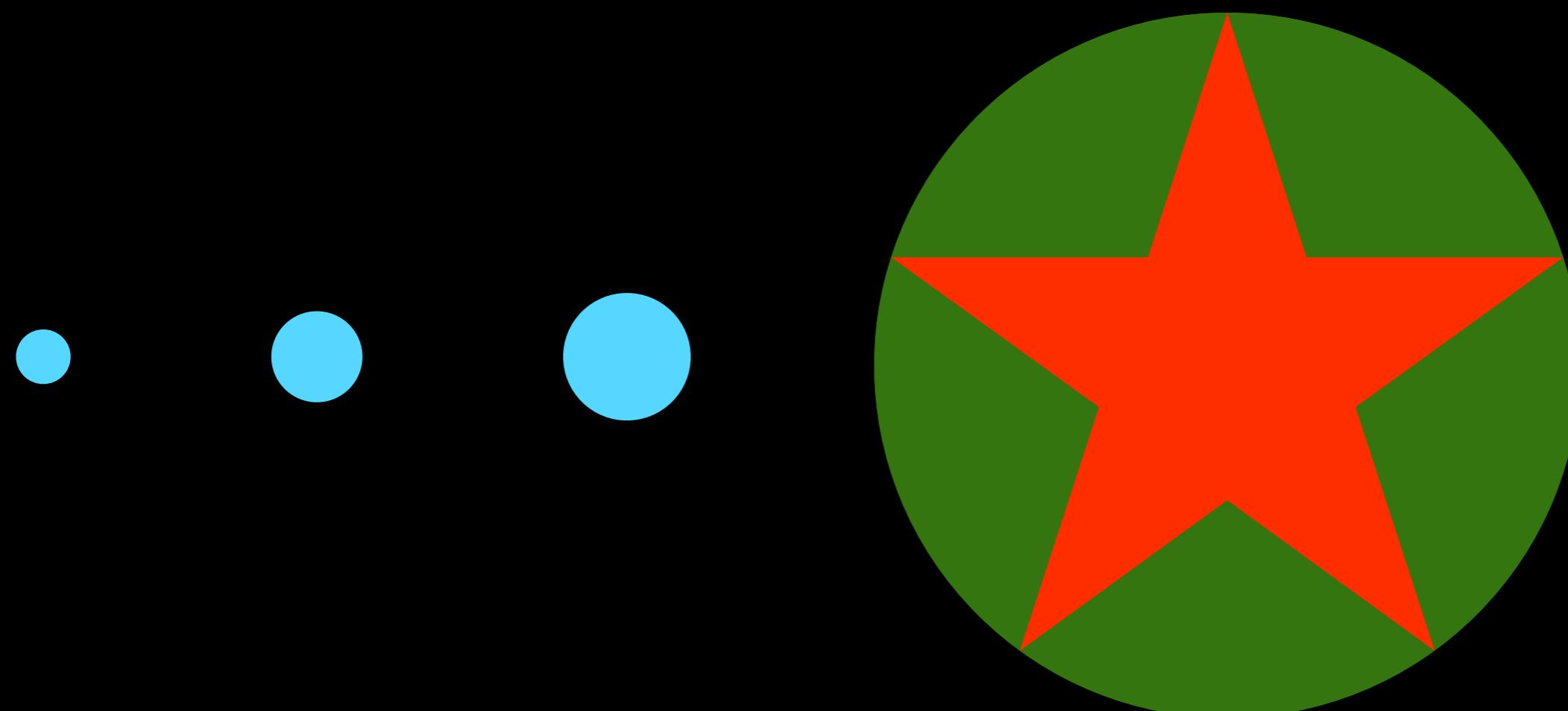


Good Continuation

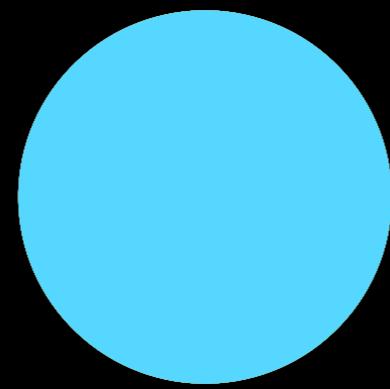
# MELODIC EXPECTATION



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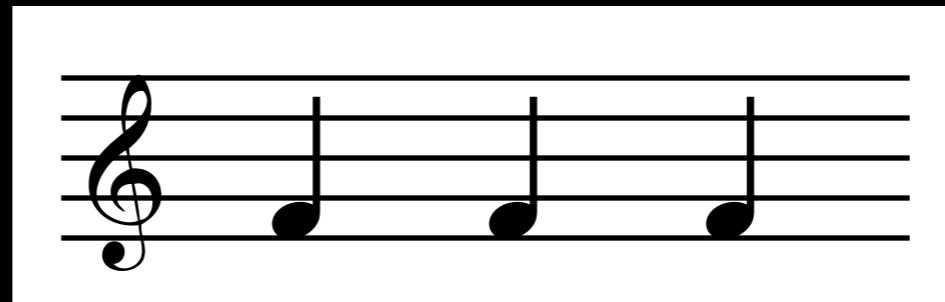
# IMPLICATION-REALIZATION THEORY

- Eugene Narmour, 1990
- Goal of I-R Theory: to devise a set of rules from which a complete hierarchical grouping structure can be inferred
- ...using explicit reference to human cognitive processes
- ...while carefully separating what is universal from what is culturally learned

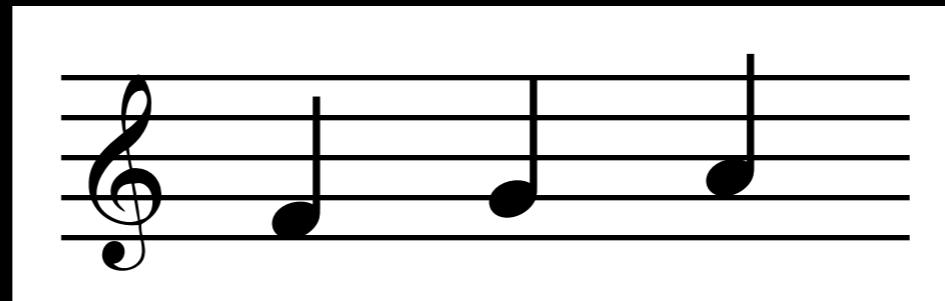
# IMPLICATION-REALIZATION THEORY

- Two expectations are universal:

- $A + A \rightarrow A$



- $A + B \rightarrow C$



# IMPLICATION-REALIZATION THEORY

- Refinements of these expectations, based on interval size and direction, are culturally learned. For example:
  - Large intervals usually followed by smaller intervals
  - Large intervals usually followed by a change in direction

# IMPLICATION-REALIZATION THEORY

- How does expectation lead to structure?
  - Surprise leads to boundaries
  - Closure leads to boundaries

# WHAT IS STRUCTURE?

- How did you **perceive** this piece of music?



# IMPLICATION-REALIZATION THEORY

- I-R model focuses almost exclusively on melody as a sequence of intervals.
- What about harmony, rhythm, timbre?
  - Narmour hinted at theory in 1977...
  - *The Analysis and Cognition of Basic Melodic Structures: The Implication-Realization Model* published in 1990...
  - Parts 2–4 forthcoming...

# LISTENER CONSIDERATIONS

- Previous theories all posit ideal listeners
  - i.e., for a given melody, there is a “best” analysis.
- But, listeners differ in many ways!
  - Cultural knowledge
  - Level of musical training
  - Listening context
  - Familiarity with the music

# EXPERIMENTS ABOUT LISTENER DIFFERENCES

- Elizabeth Margulis:  
*What is the effect of repeated listenings?*
  - Listeners heard the same piece four times in a row
  - Each time, they indicated every single literal repetition they identified
  - Margulis tallied the correct indications and their lengths

*Suite en mi*  
*Tambourin*

*Jean-Philippe Rameau*  
(1683-1764)

The musical score consists of three staves of music for two voices. The top staff uses a treble clef and a key signature of one sharp (F#). The bottom staff uses a bass clef and a key signature of one sharp (F#). The time signature is 2/4 throughout. The first section (measures 1-4) is labeled "Vif". The second section (measures 5-10) begins with a repeat sign and includes a first reprise. The third section (measures 11-16) concludes the piece.

1  
2  
Vif

5  
1<sup>re</sup> Reprise

11

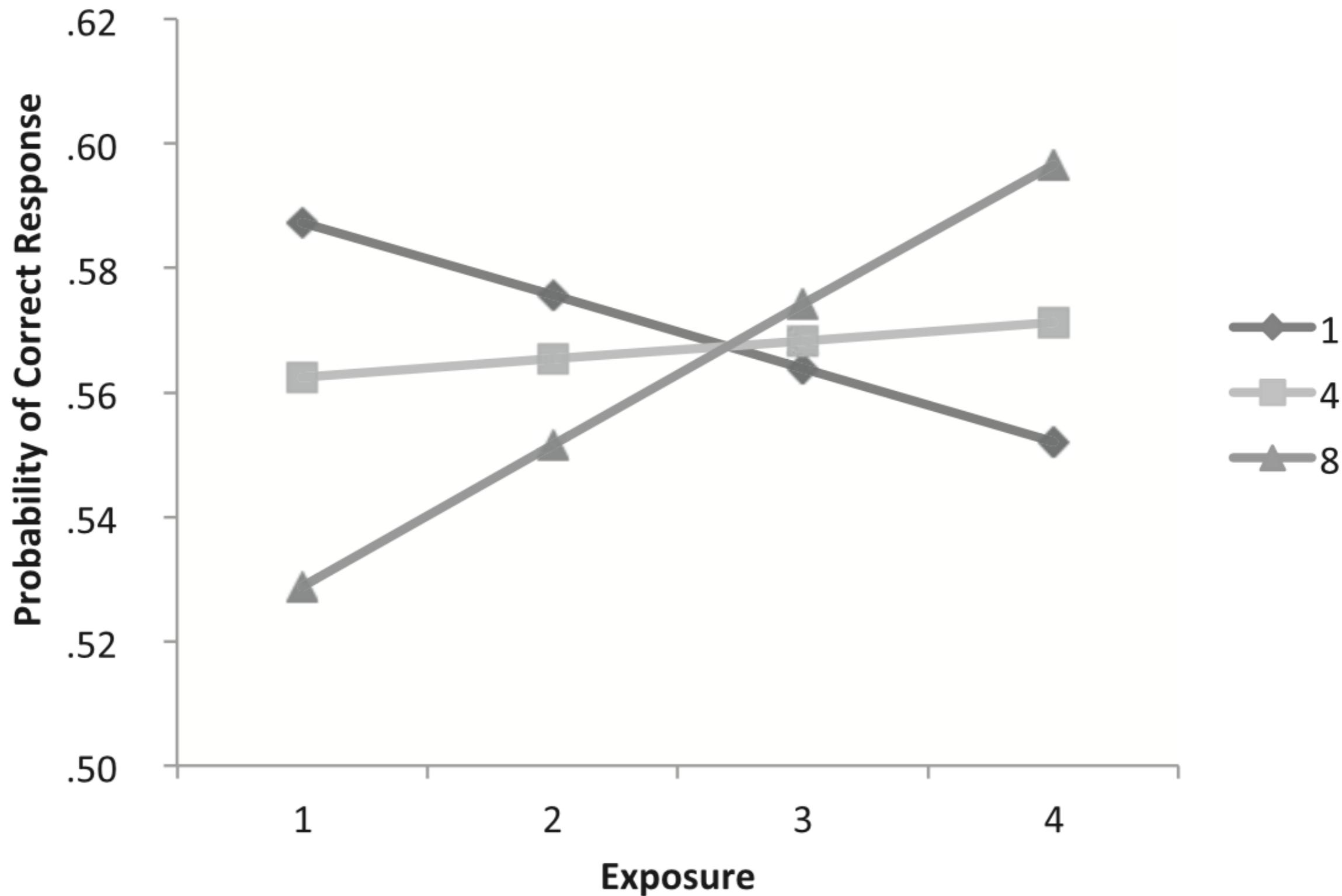


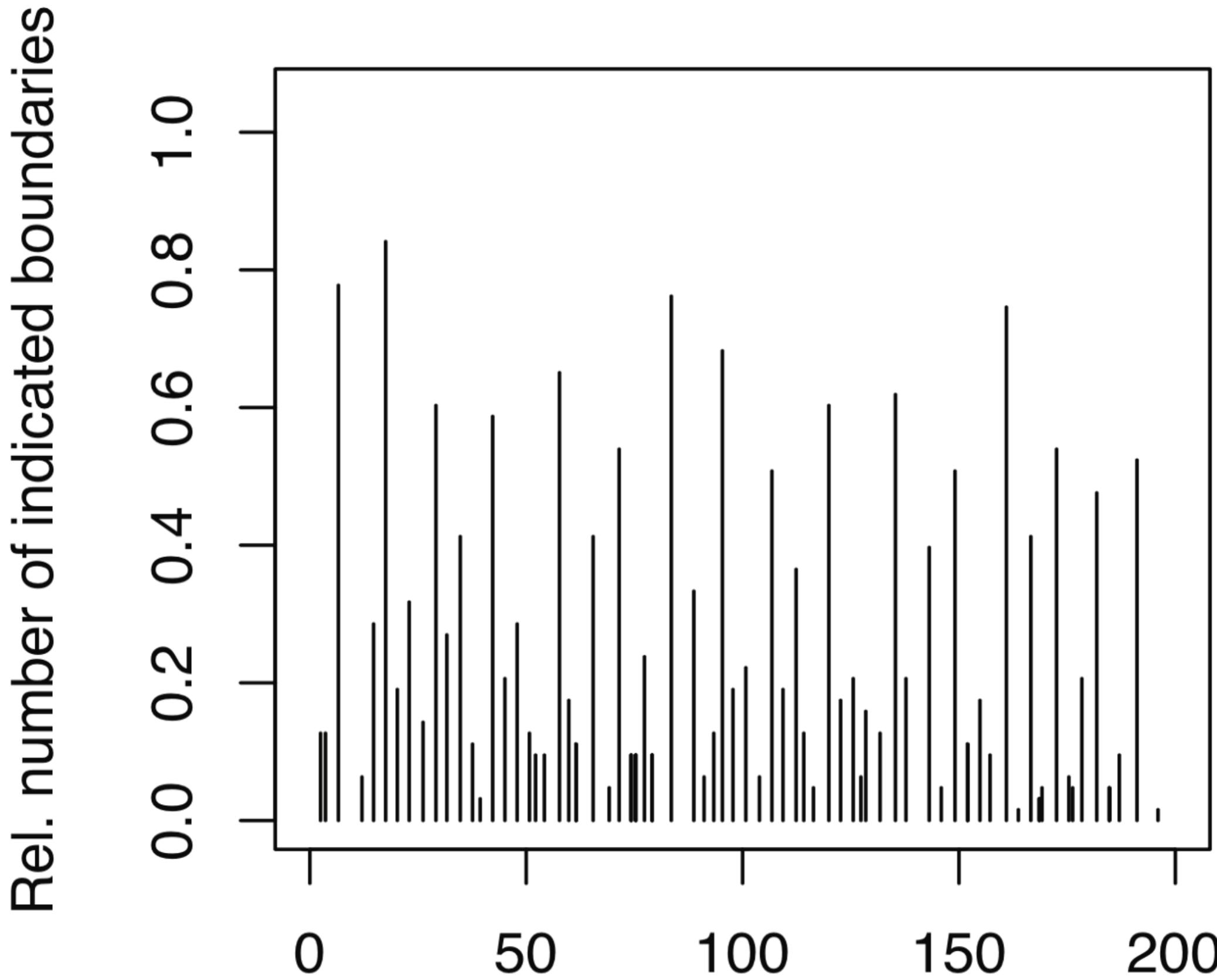
FIGURE 3. Probability of correct response by exposure for repetitions with LRU<sub>s</sub> of 1, 4, and 8 s.

Margulis 2012

# LISTENER CONSIDERATIONS

- Some listener disagreements seem less predictable...

# Heart to hurt



# WHAT CAUSES A LISTENER TO HEAR A BOUNDARY?

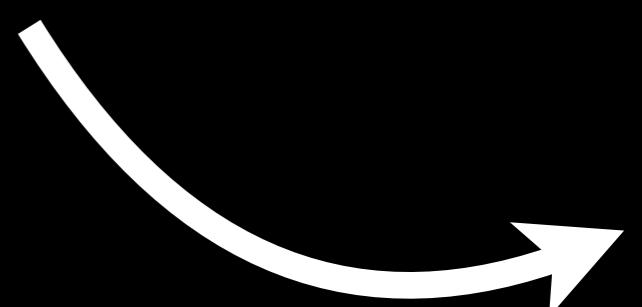
Clarke and Krumhansl 1990:

- pause (silence)
- return of material (chordal)
- change of dynamic
- new material
- change of rhythm
- change of pitch content
- change of articulation
- start of development
- change of register (expansion)
- change of dynamic contour
- change of texture

Bruderer et al. 2009:

- change in harmonic progression
- change in melody
- change in tempo
- change in rhythm
- change in timbre
- change in loudness / dynamics
- breaks
- global structure
- repetitions

# WHAT CAUSES A LISTENER TO HEAR A BOUNDARY?

- 
1. Were listeners paying attention to these features, or were these features attention-grabbing?
  2. Can we trust the listeners to self-report the correct features?
- 

# WHAT CAUSES A LISTENER TO HEAR A BOUNDARY?



*What is the viewer paying attention to?*

*What is the listener paying attention to?*



ear tracking

Web

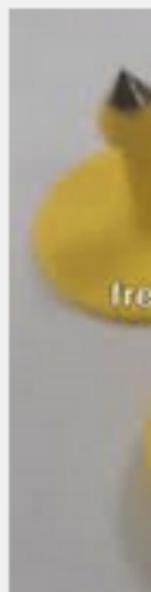
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# EXPERIMENTS ABOUT LISTENER DIFFERENCES

- I ran an experiment last year on...

# EXPERIMENT 1: ATTEND TO THE PATTERN

## Part 2 of 4: Does the pattern occur?

*In this set of questions, a musical pattern of some kind will be shown to you. Your goal is to judge whether this pattern occurs in the longer musical excerpt that follows. We then ask you to re-listen to the excerpt, and state whether you prefer form AAB or ABB.*

This section should take less than 12 minutes.

Now, please listen to the excerpt again. (The following clip is identical to the previous clip.)



**Question 2.** Which of the following analyses do you think best fits the excerpt?

A    A    B

A    B    B

**Question 3.** How certain are you about your choice of analysis?

- Totally certain
- Very certain
- Both certain and uncertain
- Very uncertain
- Not at all certain

[Next >>](#)

# EXPERIMENT 1: ATTEND TO THE PATTERN

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[Next >>](#)

# EXPERIMENT 2: BOUNDARY SALIENCE

## Part 3 of 4: Salience of change

*Every excerpt in this part has a single pattern repeated 4 times, with a change in some feature between the 2nd and 3rd instances; i.e., it has form AABB. We ask you to focus on a particular aspect of the music while listening, and tell us: how significant was the change at the half-way point?*

This section should take less than 6 minutes.

### Trial 4 of 12

Please pay attention to the **chords** of the following excerpt.



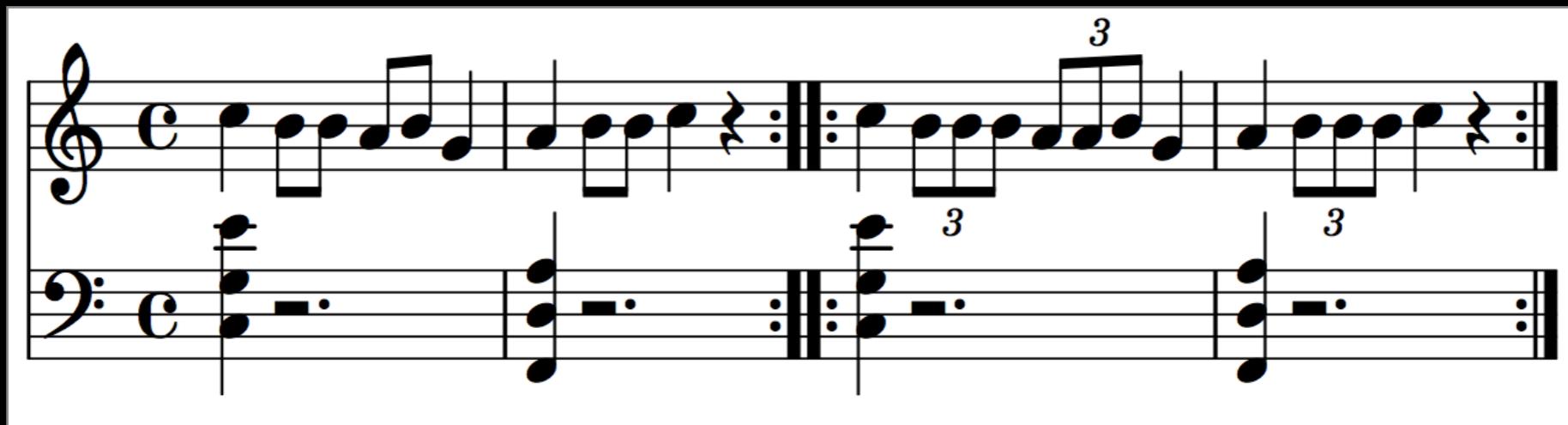
**Question 1.** How strong is the change at the midpoint of the excerpt?

- 5. Extremely strong
- 4.
- 3.
- 2.
- 1. Not strong at all

[Next >>](#)

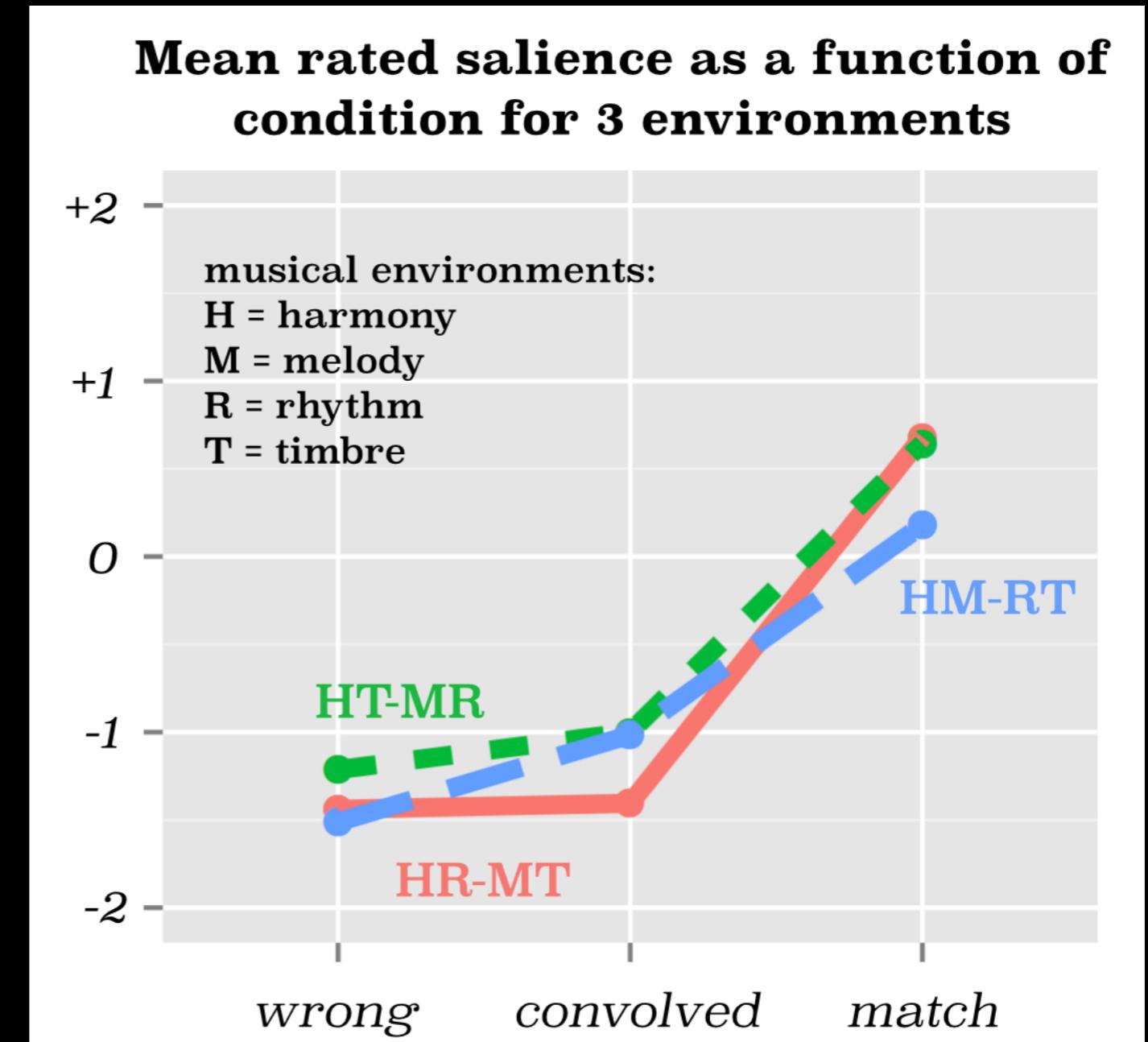
# EXPERIMENT 2: BOUNDARY SALIENCE

- Hypothesis: focusing on a feature makes changes in that feature more salient.
  - Participants focused on a single feature while listening to an AB-pattern clip, then rated salience of the change they heard
  - Independent variable: Match between focal and changing feature varies: match, convolved, or wrong



# EXPERIMENT 2: BOUNDARY SALIENCE

- Result: Yes, attention did affect the salience of the changes!



# EXPERIMENT 1: ATTEND TO THE PATTERN

- Hypothesis: focusing on a feature makes one more likely to perceive groups according to that feature
- Participants *secretly primed* to focus on a feature with a distractor task: detect whether a pattern occurs
- Then they indicated their preferred grouping.
- Independent variables: relevance of probe; presence of probe.

# EXPERIMENT 1: ATTEND TO THE PATTERN

Organ

A

B

B

65/35

present, relevant:



absent, relevant:



50/50

present, irrelevant:

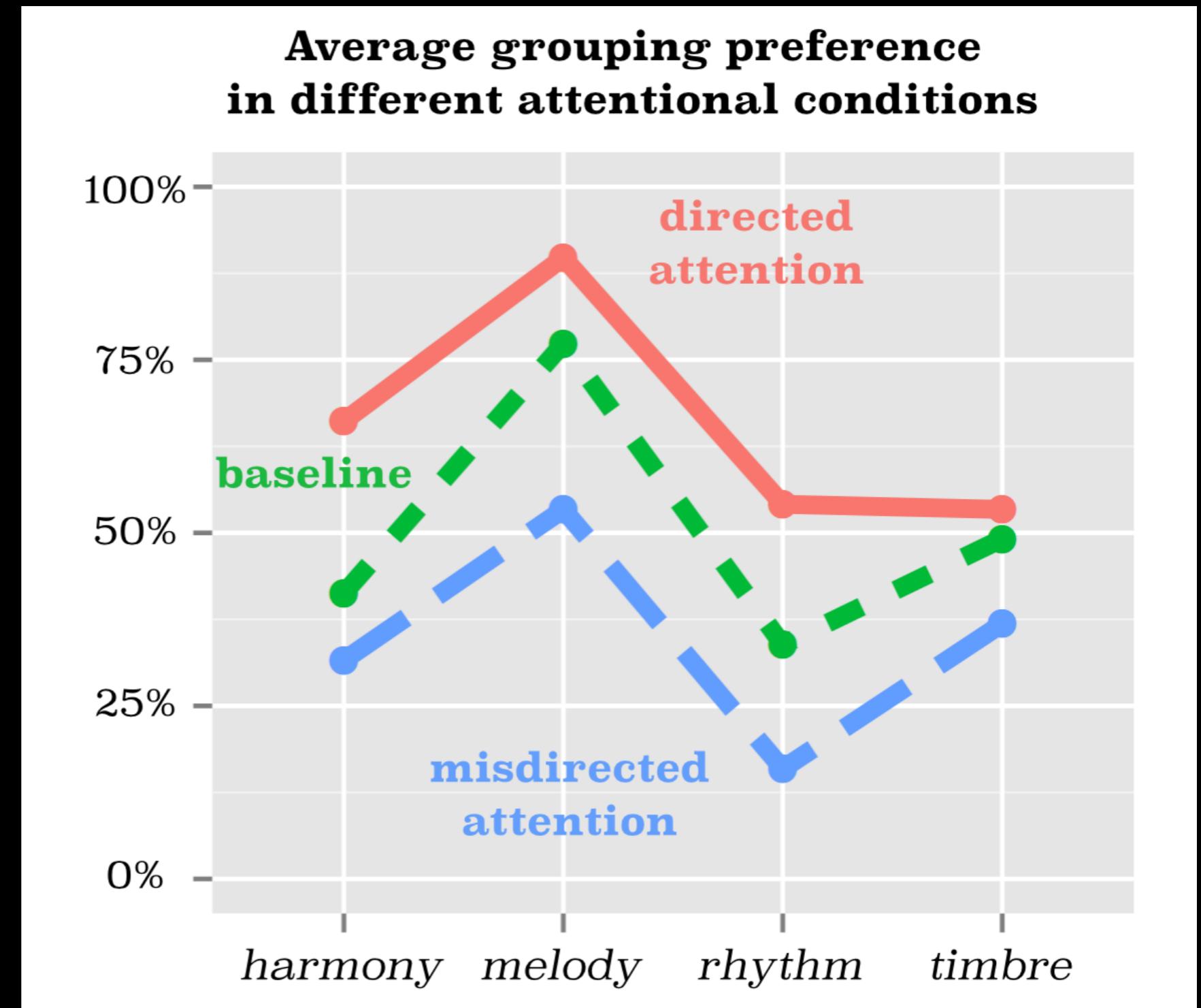


absent, irrelevant:

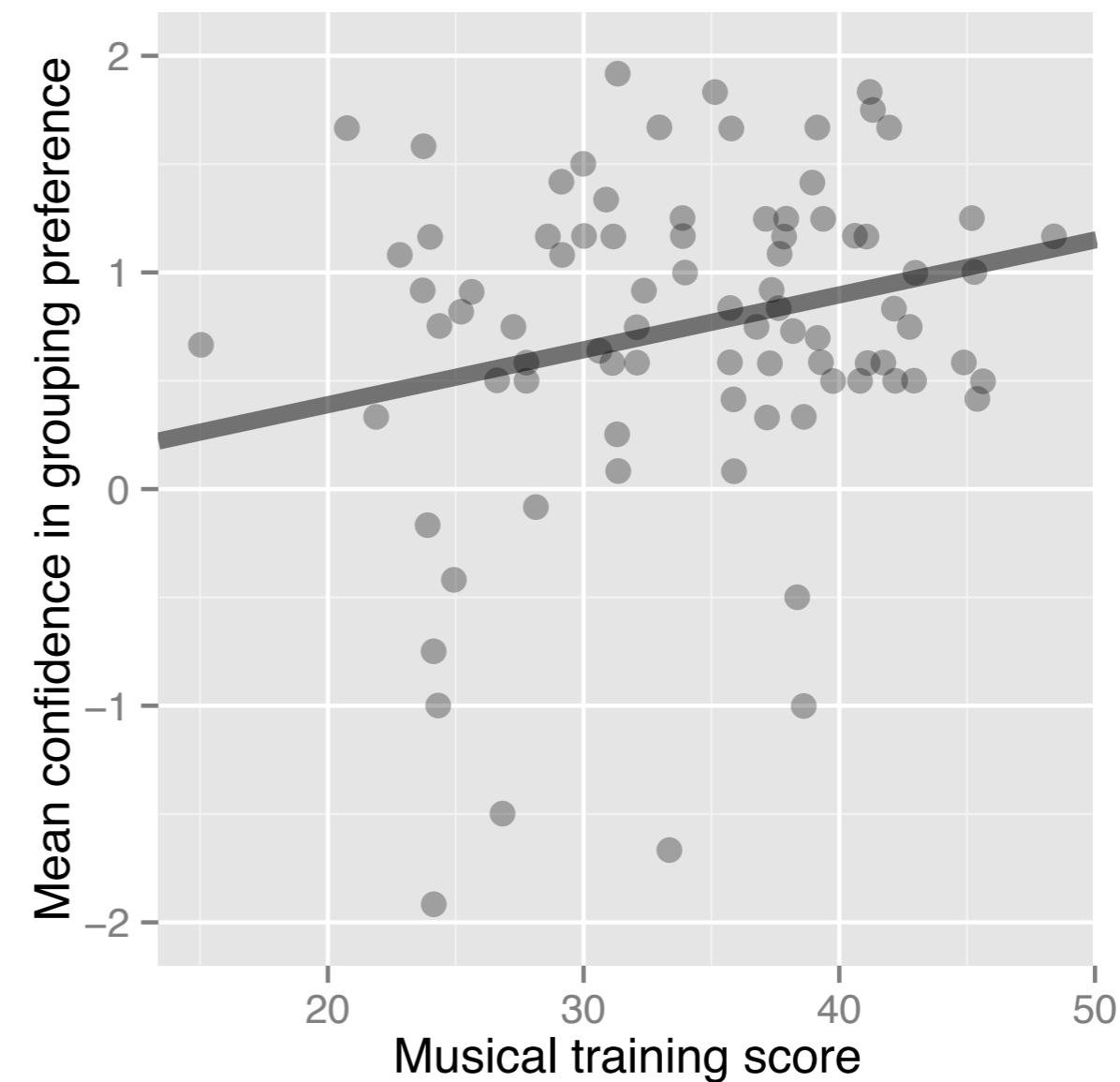
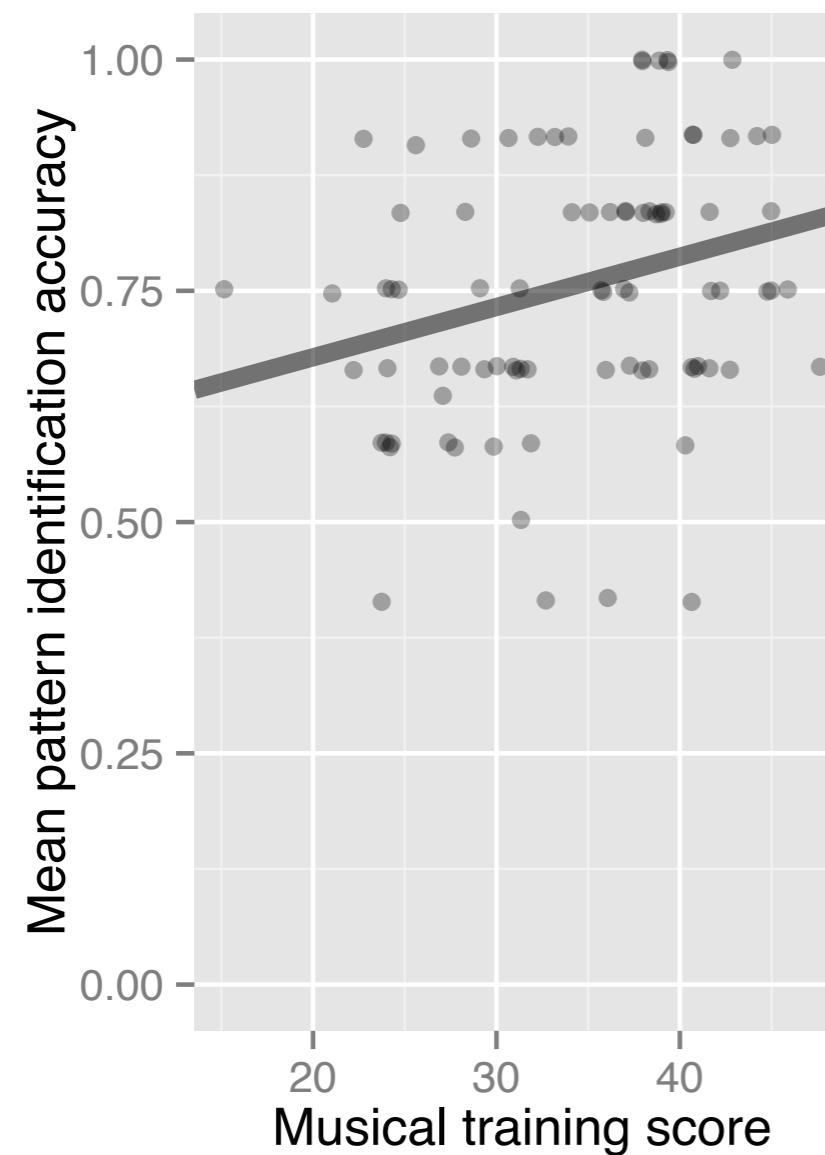


# EXPERIMENT 1: ATTEND TO THE PATTERN

- Result: Yes, attention did influence the perceived groupings!
- Effect varied with feature



# EXPERIMENT 1: DEPENDENCE OF GROUPING STRUCTURE ON ATTENTION



# EXPERIMENT IMPACT

- Attention impacts the perception of groupings for listeners
- Disagreements between listeners could be **caused** by differences in attention
- Add it to the (growing) list: familiarity, training,

# CONCLUSION

- **Generative Theory of Tonal Music**
  - Explicit set of rules for generating hierarchical analyses of tonal music
- **Implication-Realization Theory**
  - Expectation has a central role in music perception
  - Founded in cognitive science; makes testable claims
- **Listener differences challenge both theories**
  - Consider the non-ideal listener

# THANK YOU!

- Hillel Aviezer, Yaakov Trope, and Alexander Todorov. Body cues, not facial expressions, discriminate between intense positive and negative emotions. *Science*, 338:1225–1229, 2012.
- Michael Bruderer, Martin McKinney, and Armin Kohlrausch. The perception of structural boundaries in melody lines of Western popular music. *MusicæScientæ*, 13(2):273–313, 2009.
- Eric F. Clarke and Carol L. Krumhansl. Perceiving musical time. *Music Perception*, 7(3):213–51, 1990.
- Fred Lerdahl and Ray S. Jackendoff. A Generative Theory of Tonal Music. MIT Press, 1983.
- Elizabeth Margulis. Musical repetition detection across multiple exposures. *Music Perception*, 29(4):377–385, 2012.
- Eugene Narmour. The Analysis and Cognition of Basic Melodic Structures: The Implication-Realization Model. University of Chicago Press, Chicago, IL, USA, 1990.
- Jordan B. L. Smith. Explaining listener differences in the perception of musical structure. PhD thesis, Queen Mary University of London. 2014.

# THANK YOU!



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