“Second-Order Learning” as a Source of Structure Stabilization in Both Individual Learning and Cultural Evolution

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Outline

- Brief review of some learning mechanisms
- Describe potential sources of constraints on learning
- Explore ways infants might restrict set of generalizations they consider by drawing on prior experience in a domain-dependent way
  - Data from artificial grammar learning
- Speculate wildly about the implications for cultural evolution

A Classic Problem for Learning

- Any data set can be captured by an infinite number of generalizations
  - E.g., “2 4 8 16 32 64”
    - Integer powers of 2?
    - Even numbers?
    - Numbers less than 100?
    - Integers?
    - Black squiggles?

A Role for Statistics

- In the absence of deductive proof, statistical inference may be the best tool to form generalizations

Statistical Learning

- SL has been implicated in a number of learning areas related to language:
  - Segmentation (Saffran and colleagues)
  - Phonetic category learning (Maye & Gerken)
  - Sequential dependencies in an FSG (Gómez & Gerken, 1999)

Statistical Learning

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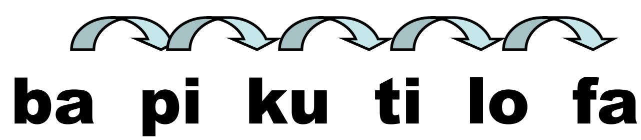

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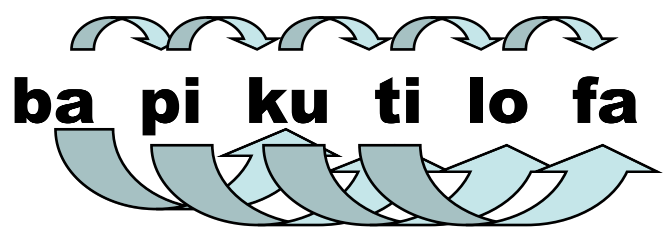

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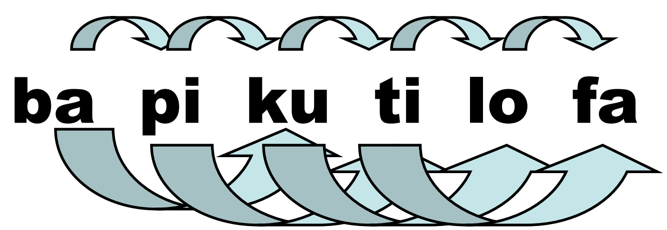

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Statistical Learning

- It gets even worse…

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A Need for Constraints

- Must be some source of restriction on possible generalizations, representations

Several Possible Classes of Constraints

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- Perceptual/Representational Constraints
  - Cannot learn what you cannot represent

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  - Meaningful units tend to comprise continuous regions in space and time
  - Gómez (2002): learners preferentially learn adjacent dependencies -- will only learn non-adjacent dependencies when adjacent ones sufficiently unreliable

Several Possible Classes of Constraints

- Multiple Converging Cues
  - Seems to be widespread in learning
  - Gerken, Wilson, & Lewis (2005)

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  - Could take the form of rich, innate knowledge structures (e.g. Principles and Parameters)
  - Could be more gradient, but still innate domain-specific biases

Example From "Rule-Learning"

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  - Familiarize 7m infants with several sequences, each of which has a particular abstract pattern (AAB or ABB)

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  - Familiarize 7m infants with several sequences, each of which has a particular abstract pattern (AAB or ABB)
  - Test on novel sequences, measure looking times to abstractly familiar, abstractly novel sequences
  - Finding is that when elements are syllables, 7-month-olds successfully discriminate, but not when elements are tones, animal sounds

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- Alternative (not mutually exclusive) possibility:
  - Infants take advantage of prior experience with each domain to constrain the generalizations they consider

Learning Domain Structure: Language

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- Phonetic tuning (Werker and colleagues)
  - Infants restrict phonetic discrimination to selectively perceive native phonological contrasts

Learning Domain Structure: Language

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  - 9m infants learn “stress heavy syllables”, but not “stress syllables beginning with /t/
  - 7.5m infants can learn “stress syllables beginning with /t/”
  - Can be attributed to infants’ experience with English, where heaviness, not onset, reliable cue for stress

Learning Domain Structure: Music

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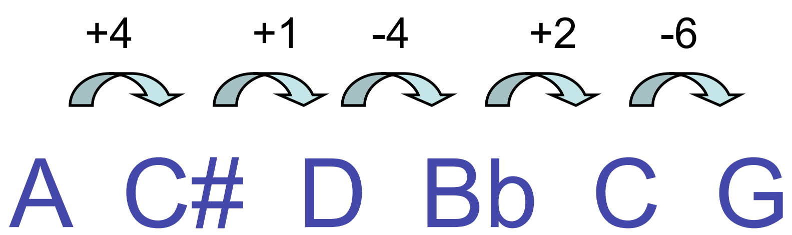
- Reliance on relative over absolute pitch for segmentation (Saffran and colleagues)
  - Intervals between pitches, not overall frequencies, define melodies



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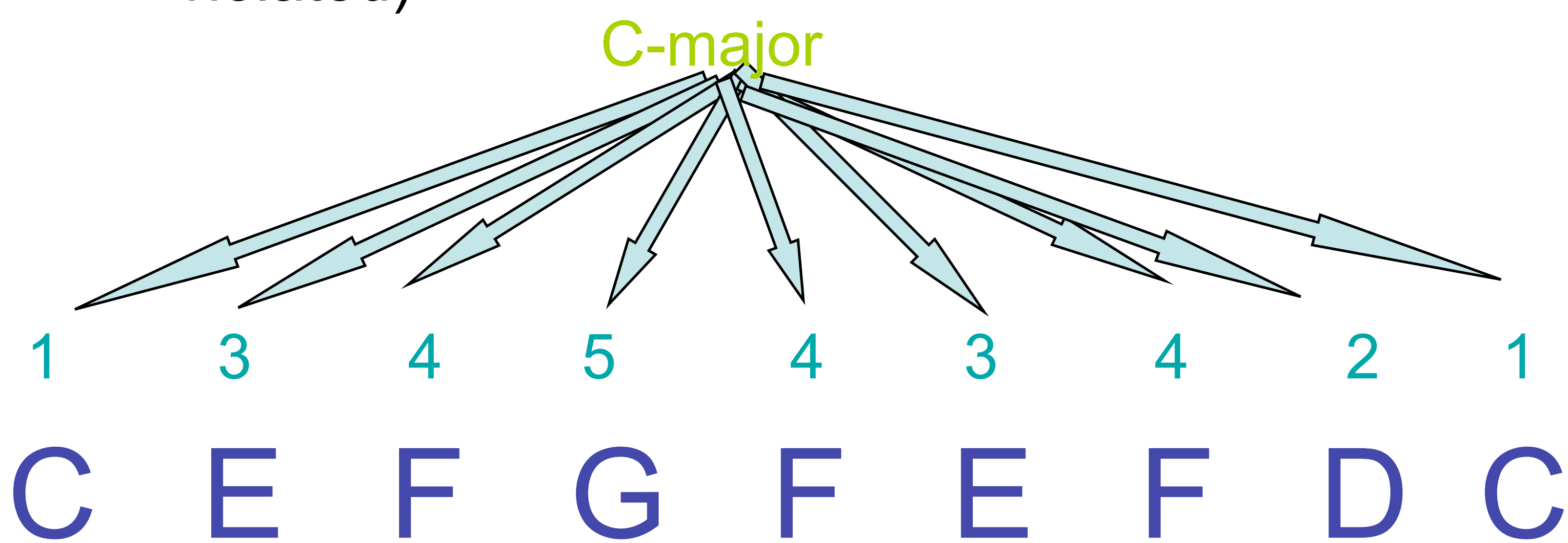

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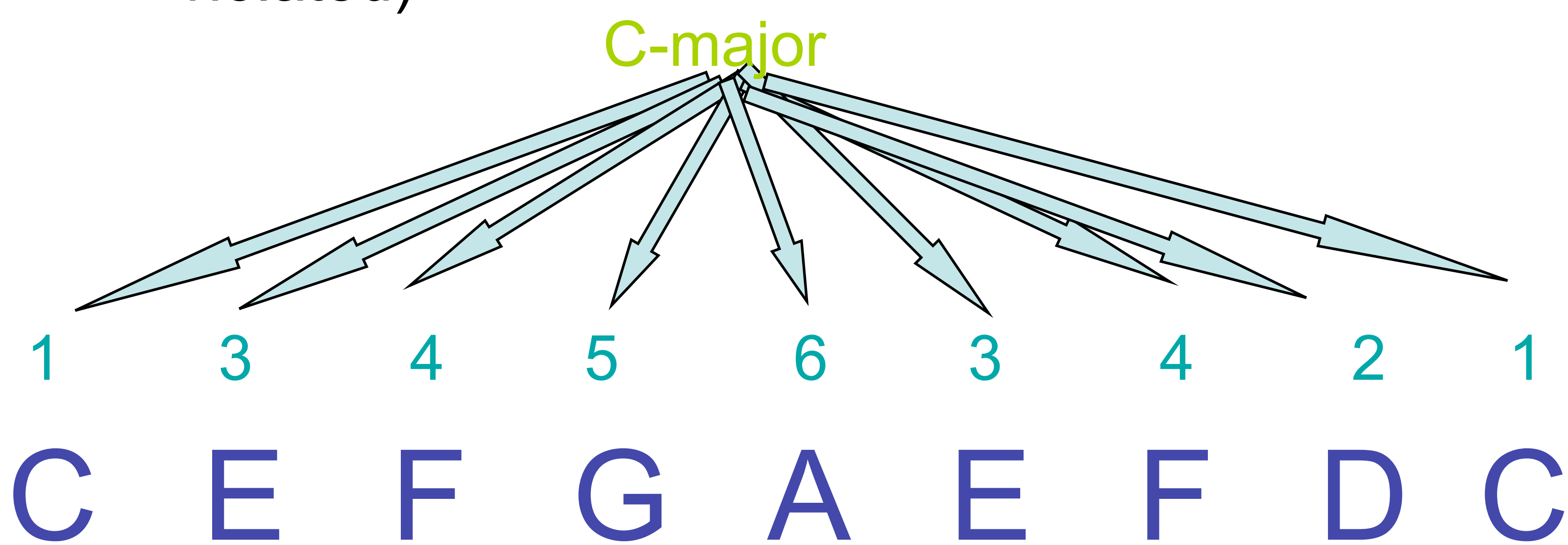

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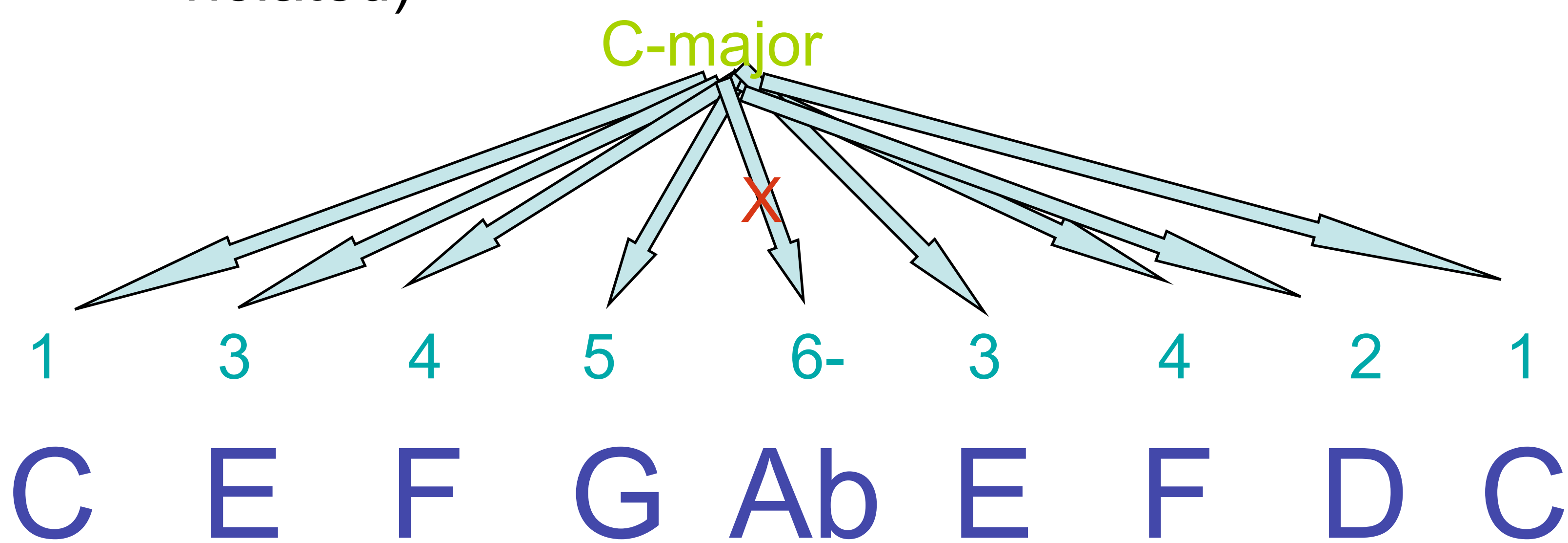

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  - Infants, not (North American) adults, sensitive to rhythmic changes that preserve small integer ratios

Learning Domain Structure

- Perhaps infants learn to attend to relationships characteristic of particular domains
- What merits attention in one domain may not in another

Two Predictions

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Experiment 1

Experiment 1

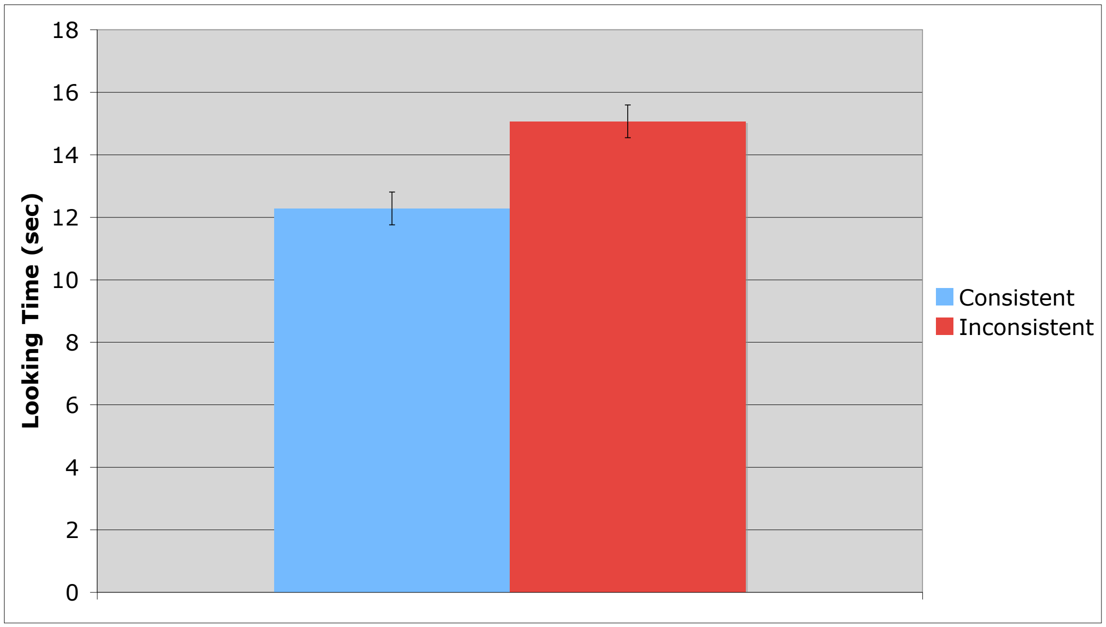
- Familiarize 18 4-month-old infants with phrases consisting of three chords
  - Half of infants familiarized with AAB, half with ABA
  - Four different “A” chords, four different “B” chords, occur in all combinations
    - Both “A”s and “B”s evenly split between major and minor triads
  - Balanced between pitch contours (rise vs. fall)

Experiment 1

- Test on novel phrases, containing two new “A” chords, two new “B” chords, in all combinations
  – Again split between major and minor triads
  – Again balanced between rise vs. fall

Experiment 1

- 4-month-olds look longer during test trials from novel grammar

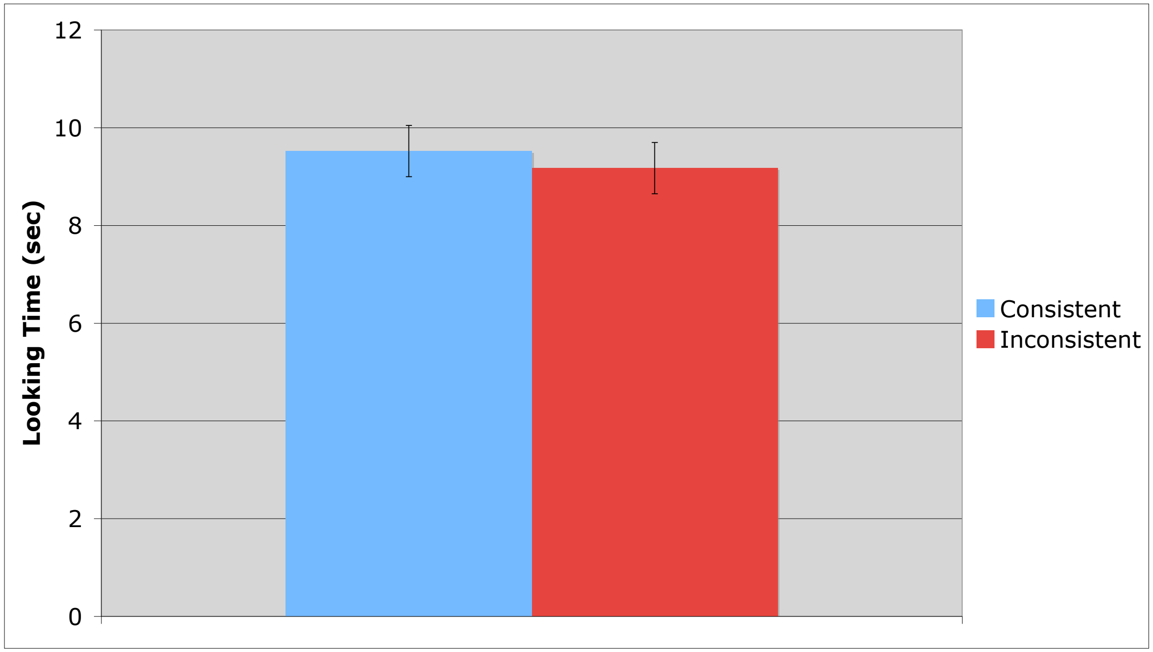


Experiment 2

- Want to make sure the effect is not driven by stimulus idiosyncracies
- Test 7.5-month-olds with same stimuli

Experiment 2

- 7.5-month-olds do not succeed, replicating MFJ '07

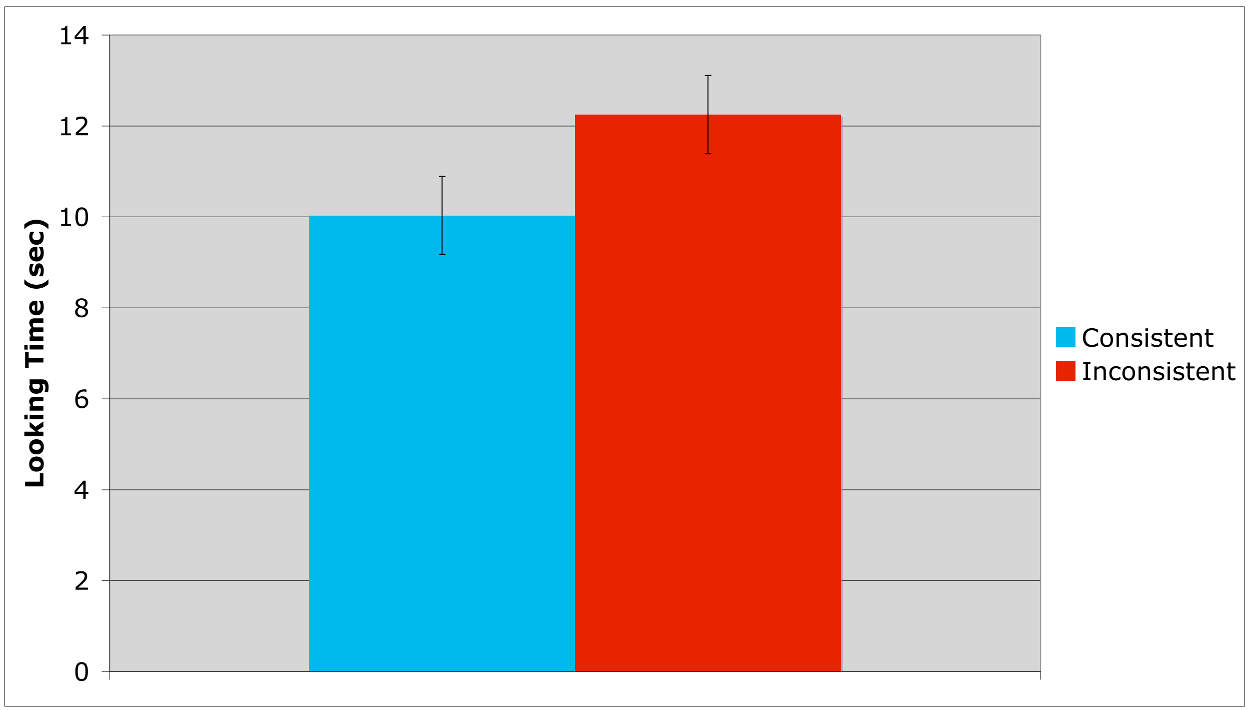


Experiment 3

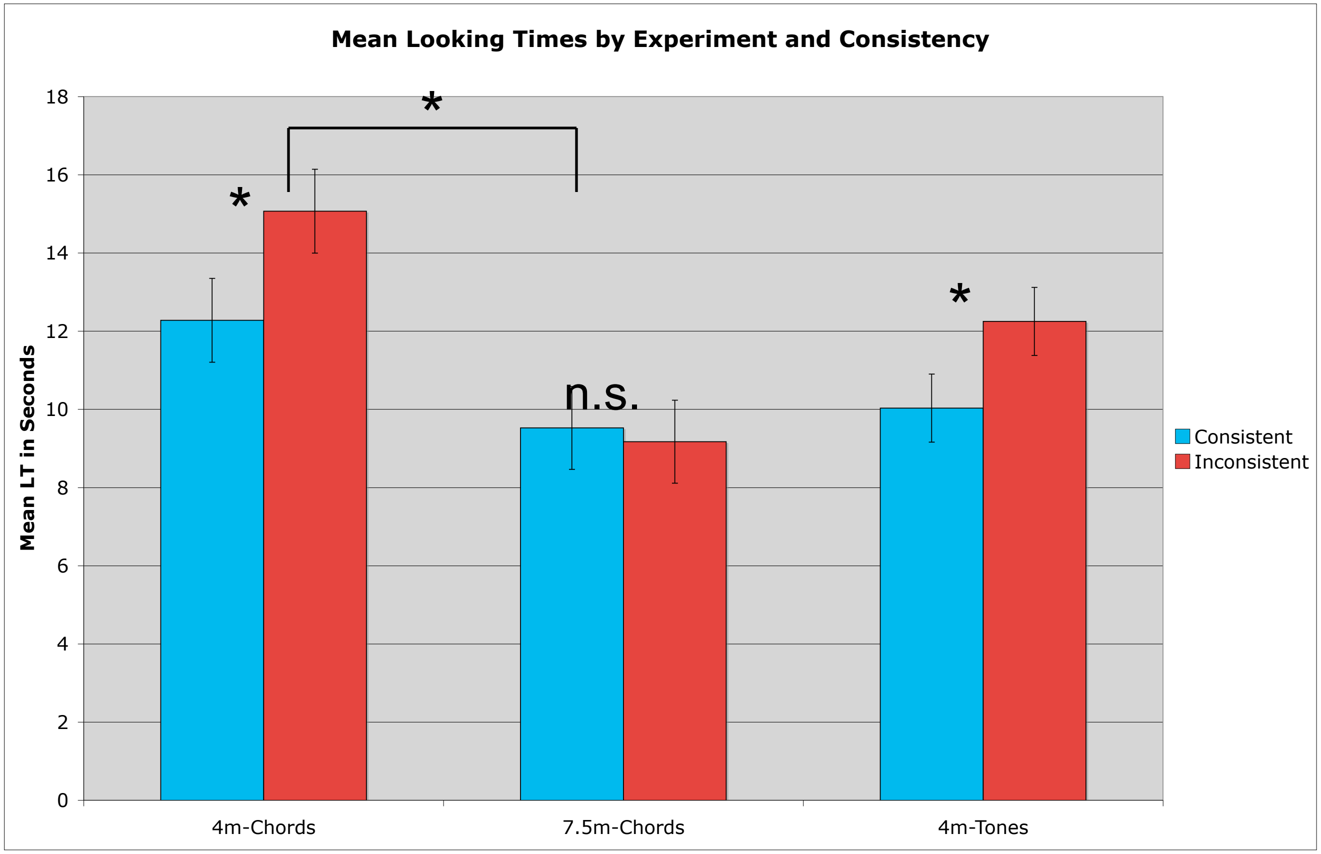
- Test 4-month-olds on single tones, to provide more direct comparison to MFJ '07

Experiment 3

- 4-month-olds looking times to single-tone stimuli



Experiments 1-3



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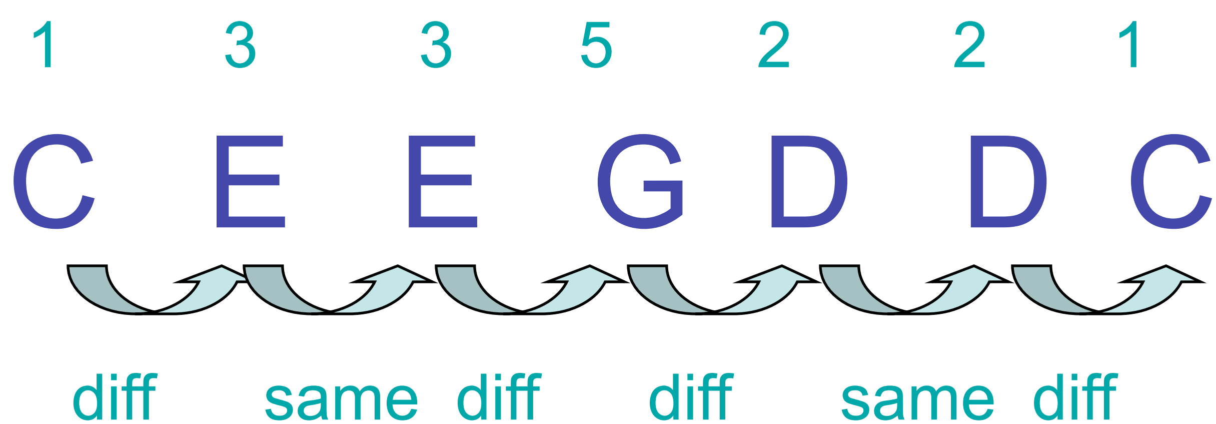
  - But what is actually typical and atypical of music?

Musical Corpus Analysis

- Prediction: Relationship of phrase-final chord to key reliable cue; serial identity relationships unreliable



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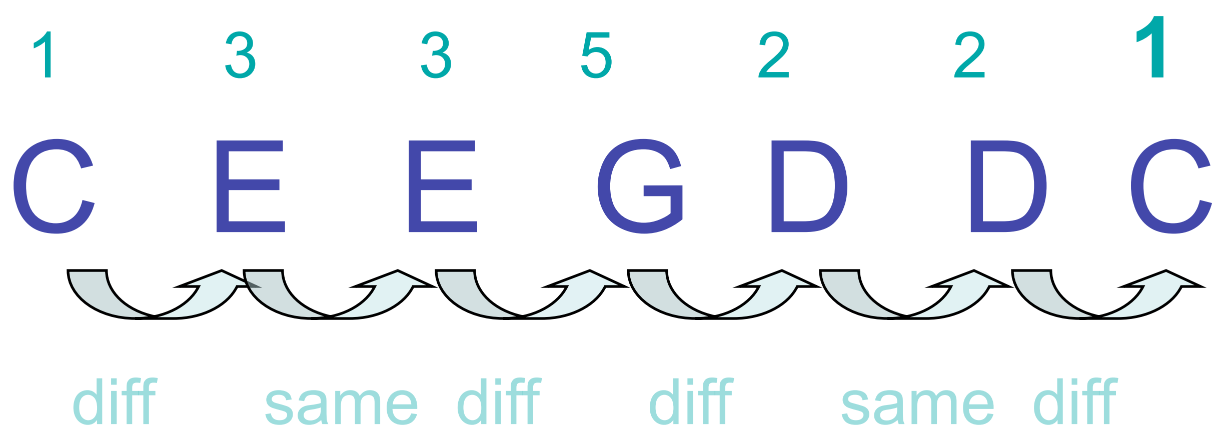

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- Each phrase coded for repetition pattern of last three notes (AAA, AAB, ABA, ABB, ABC), as well as final chord (printed above last note)

Musical Corpus Analysis

AAA	8 (5.8%)
AAB	23 (16.7%)
ABA	12 (8.7%)
ABB	17 (12.3%)
total w/ rep	**60 (43.5%)**
no reps (ABC)	**78 (56.5%)**
ends in I	90 (65.2%)
ends in V	38 (27.5%)
ends in I or V	**128 (92.7%)**
other	**10 (7.2%)**

Statistical Tests

- Chi-square goodness of fit tests:
  - Repetition (collapsing across all types) occurs statistically at chance ($p > 0.25$)
  - Phrases ending in I and ending in V each occur more often than chance ($p < 10^{-64}$ and $p < 10^{-5}$ respectively)

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    - **But what about domain-typical generalization for music?**

Experiment 4

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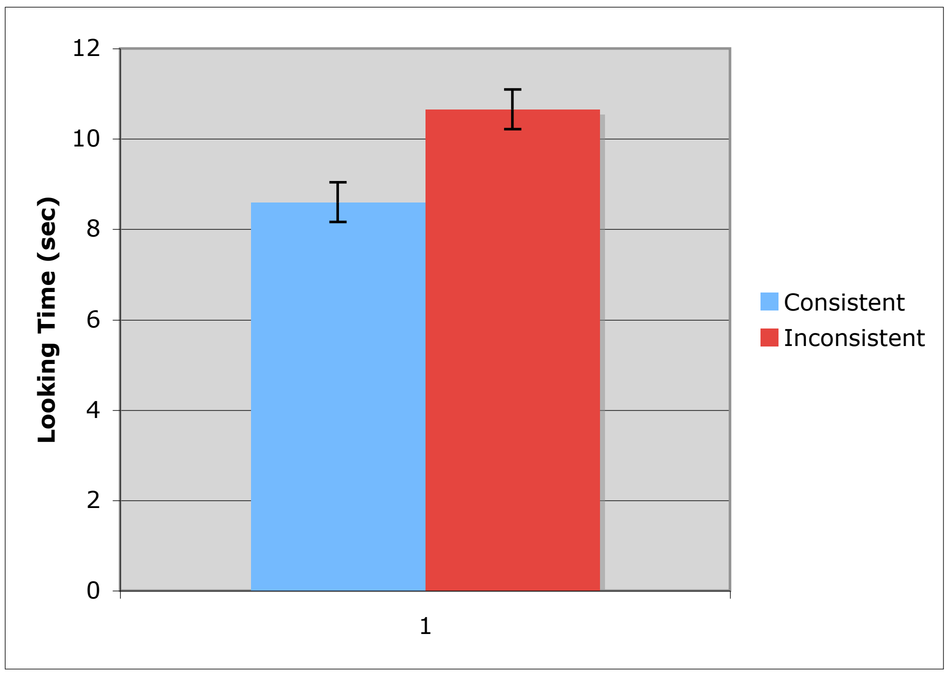
- Familiarize 7.5-month-olds with melodies that are constant with respect to scale degree of last note
  - Half familiarized with melodies ending on I (“do”), half ending on V (“sol”)
  - Eight different carrier melodies, each in a different key
  - Melodies prepended with I-V-I chord sequence to establish key

Experiment 4

- In “ends-in-I” grammar, I note appended to each carrier melody, V note for “ends-in-V” grammar
- Four new carrier melodies composed for test phase, in new keys
  - Same carrier melodies for “e1” trials and “e5” trials

Experiment 4

- 7.5-month-olds displayed significant preference for novel end chord



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- Younger infants appear to learn AAB vs. ABA in chords and tones
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- Younger infants appear to learn AAB vs. ABA in chords and tones
  - Inconsistent with idea that speech is privileged from the beginning
- Older infants' ability to learn relational generalizations in music appears to be related to reliability of type of relation in input
  - Similar to shape vs. material bias for objects vs. substances (Smith and colleagues)

Interim Conclusions

- Perhaps domain-specificity emerges as learners notice that low level features predict high-level structure
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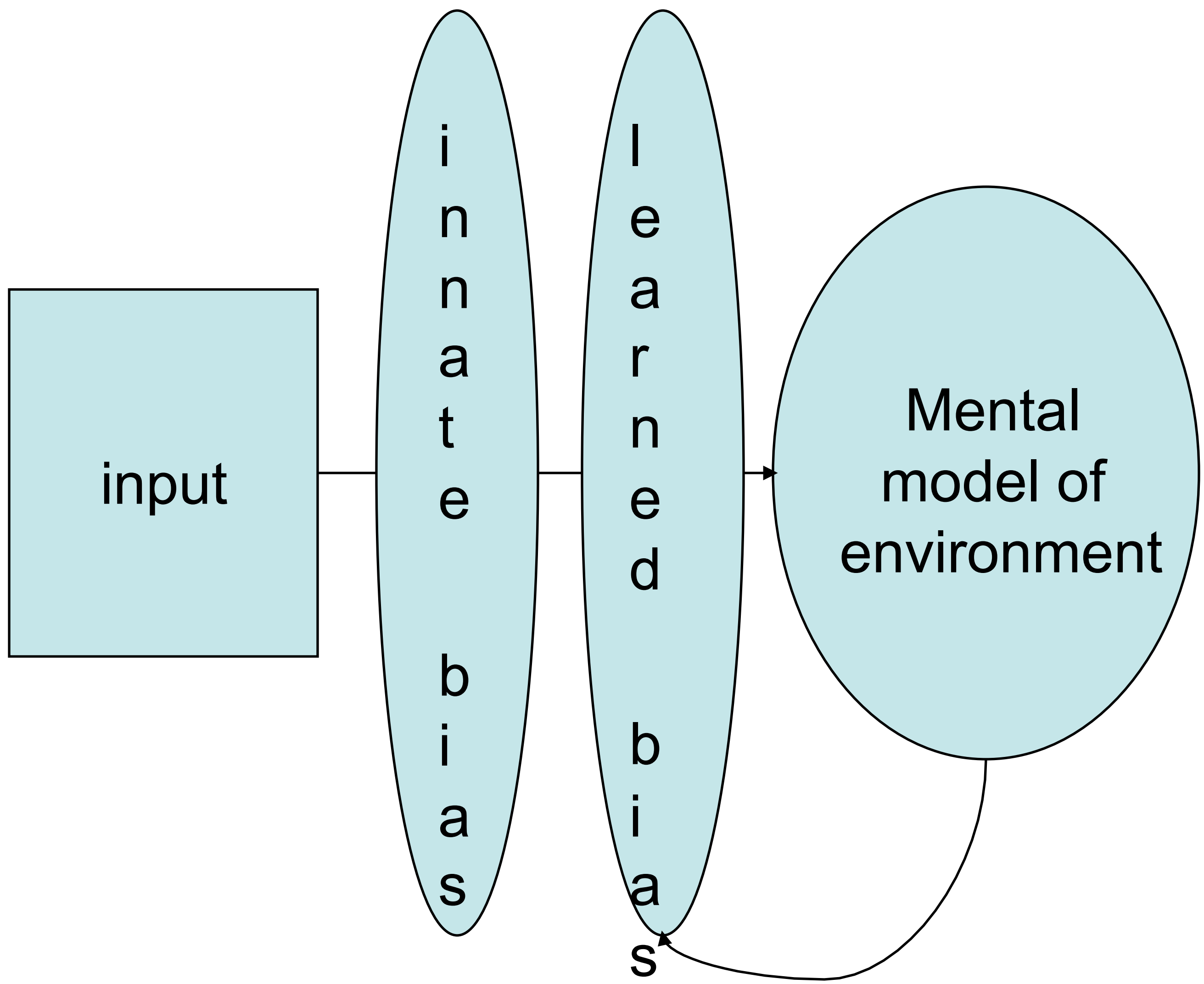
- Perhaps domain-specificity emerges as learners notice that low level features predict high-level structure
  - Represents “middle ground” between innate domain-specificity and completely domain-general learning mechanisms
- Might operationalize notion of “domain” to mean sets of environments across which same kinds of cues produce adaptive generalizations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innate bias
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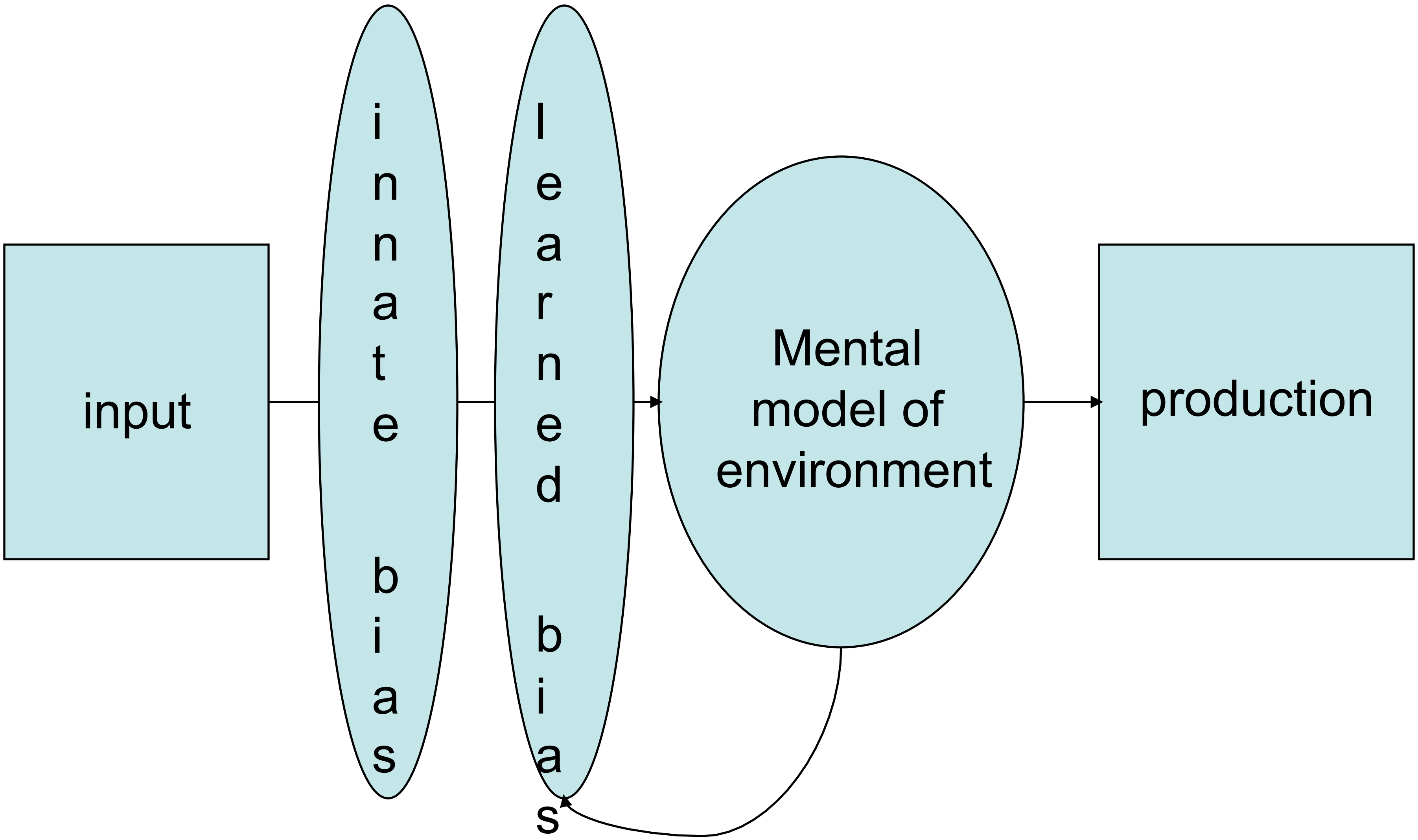
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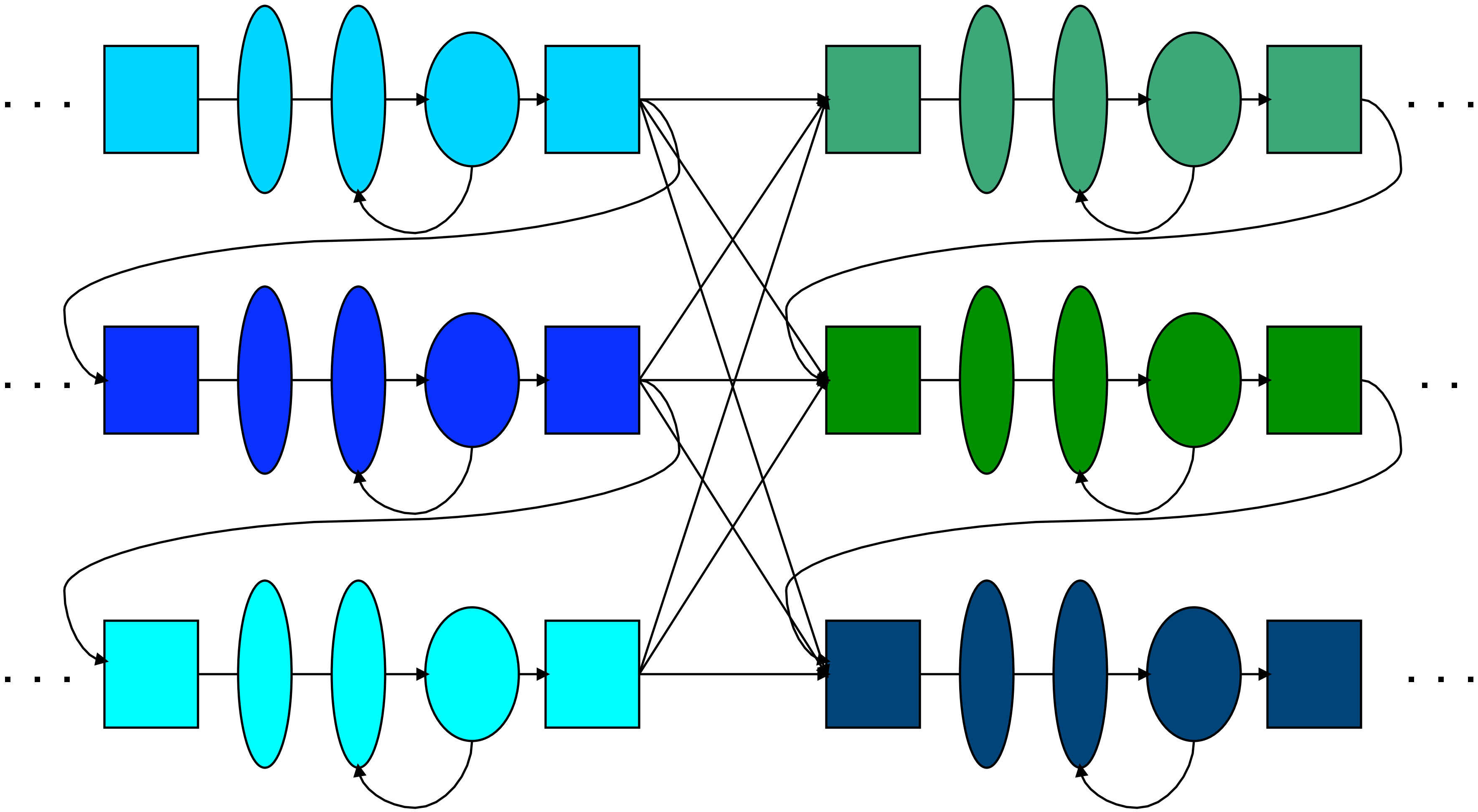

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