Introduction to Music Processing

Iterated Learning or
'MCMC with People'

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How does “culture” emerge?

Many important phenomena (incl. music, language, arts etc.) are <u>cultural</u>.

- They develop over a long time.
- They depend on <u>*customs/habits*</u>, <u>*social interactions*</u>, <u>*knowledge*</u>, <u>*norms*</u>, <u>*beliefs*</u> etc.

Thought experiment:

- What if all humans forgot (at the same time) everything they ever learned?
- How would a new “culture” emerge?
- Would it be the same or different to ours?

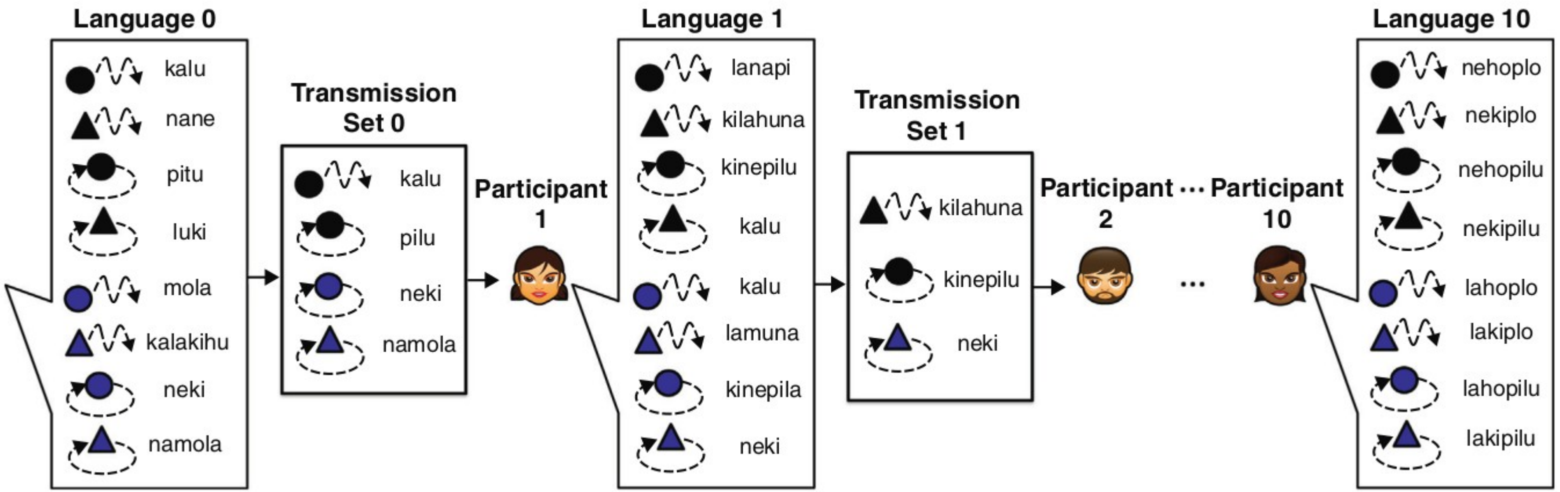
How do we know:

- What is <u>biologically</u>/physically determined?
- What is <u>evolutionarily</u> acquired and has become innate?
- What is <u>individually</u> learned?

Iterated Learning

Framework for studying **cultural transmission** (language, music, behaviour etc.)

- Knowledge is passed down through successive generations of learners
- Each learner's output serves as the input for the next
- Systematic/structured changes emerge over time influenced by cognitive and communicative biases/constrains



(Kirby S, Griffiths T, Smith K, 2014)

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Iterated Learning for Rhythms

Self Experiment

Tap along and make a note how difficult you found it (easy / medium / hard)

1) 111
2) 223
3) 233
4) 122
5) 112
6) 123
7) 132
8) 113

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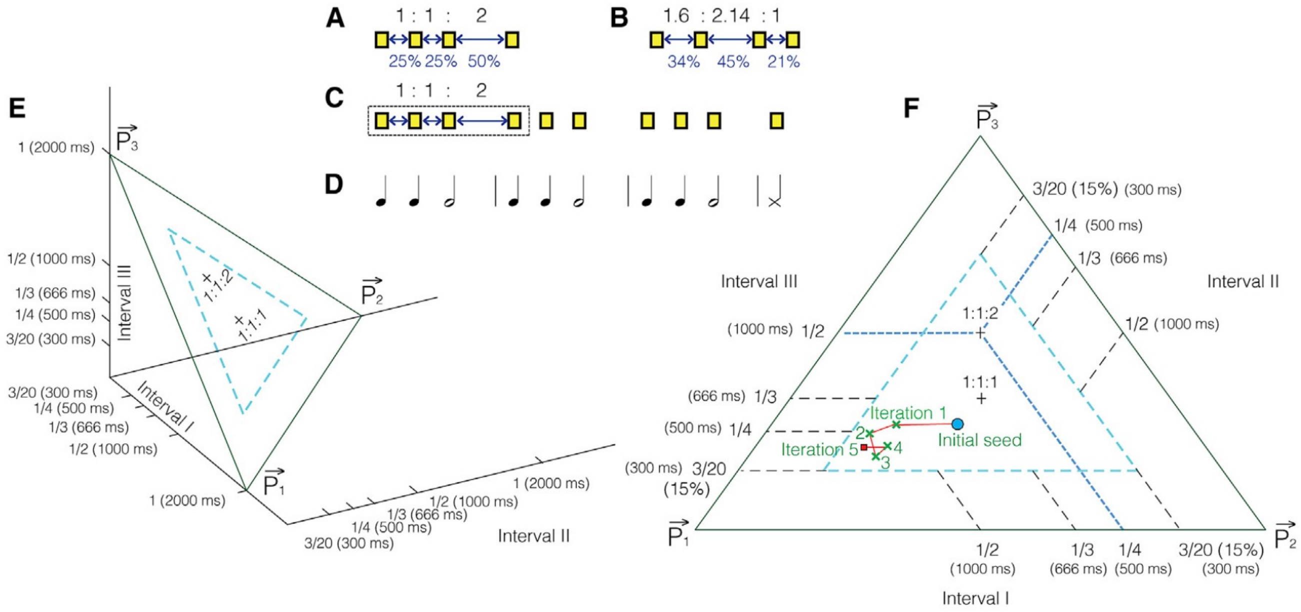
Integer Ratio Priors in Rhythms

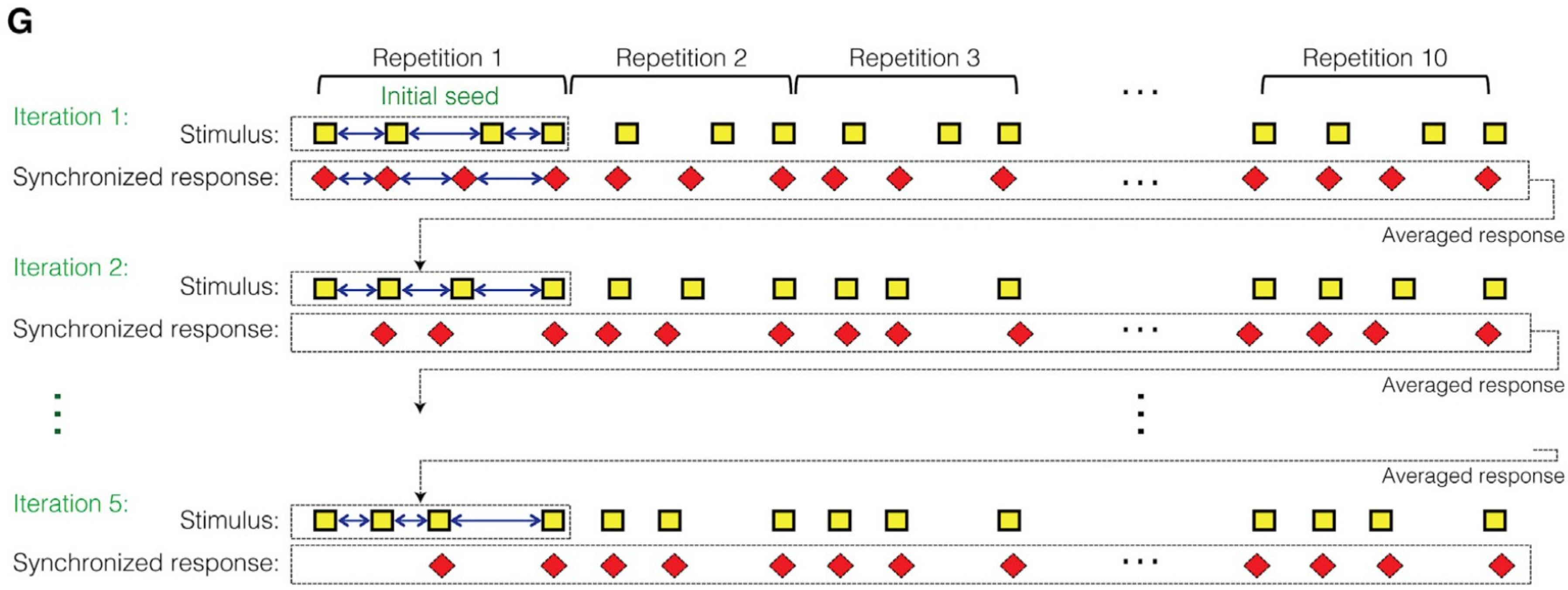
(Jacoby & McDermott, 2017)

Are "small integer ratios" in rhythms a cross-cultural universal?

- Start with random 3-beat patterns repeated multiple times (+1 terminal beat)
- Have people reproduce (tap along, tap from memory, vocalise)
- Repeat 5 times



Integer Ratio Priors in Rhythms



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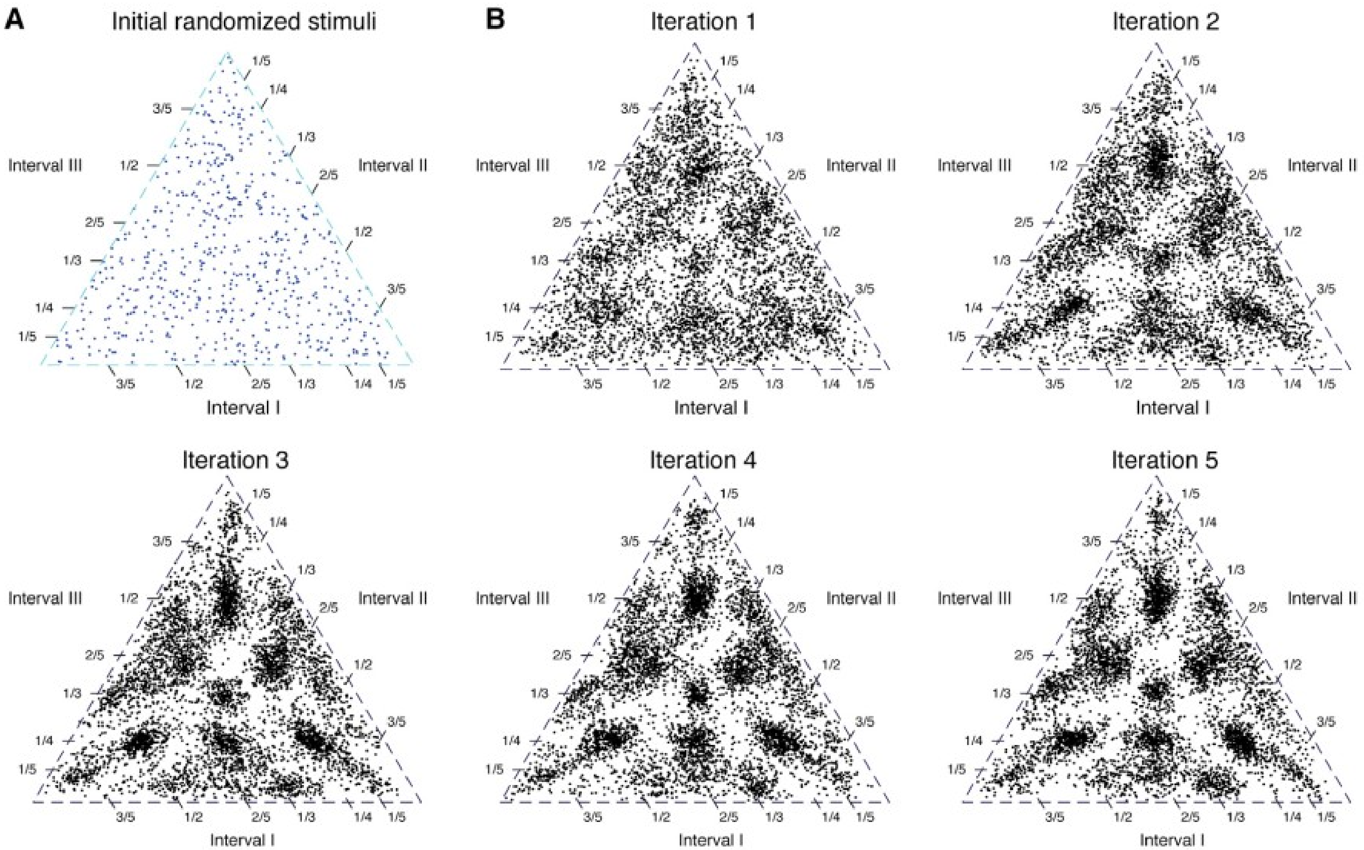
Integer Ratio Priors in Rhythms



Integer Ratio Priors in Rhythms

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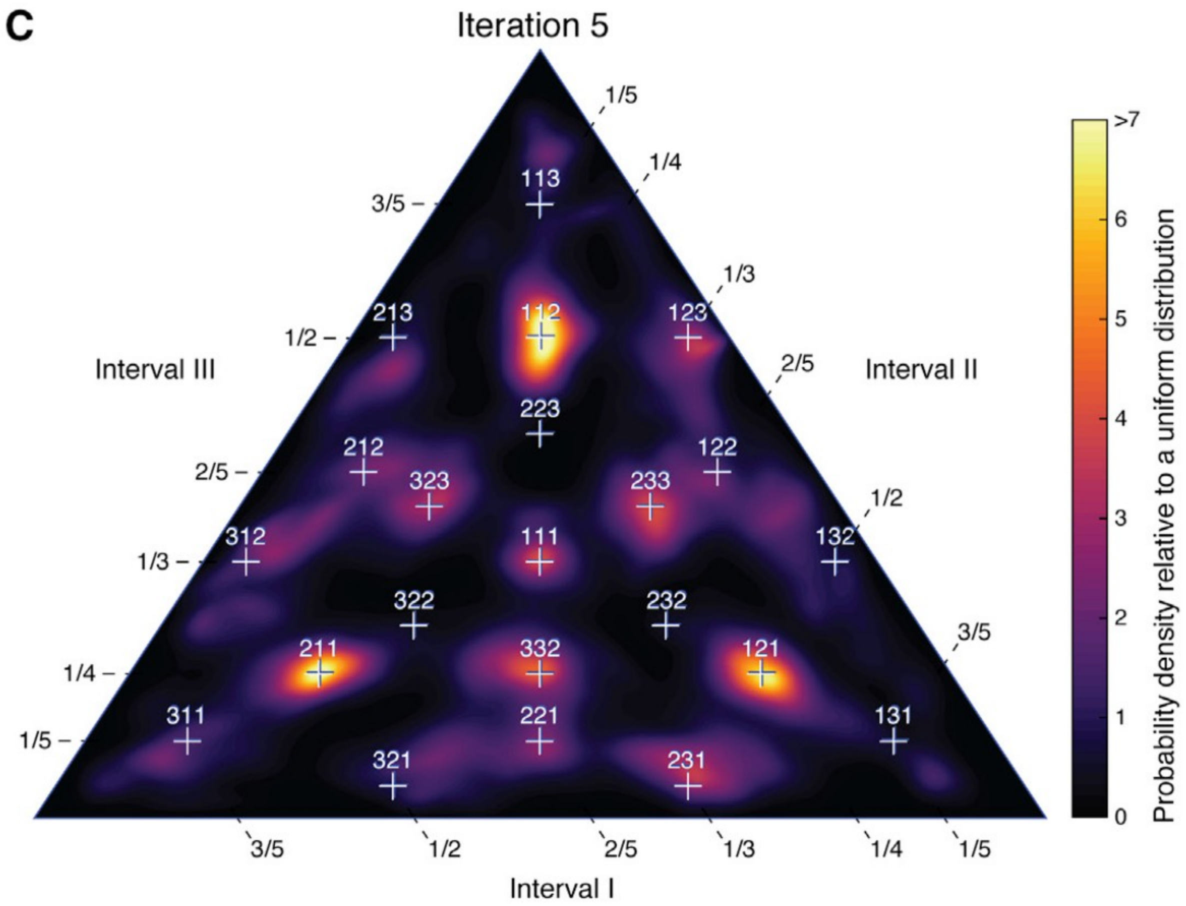

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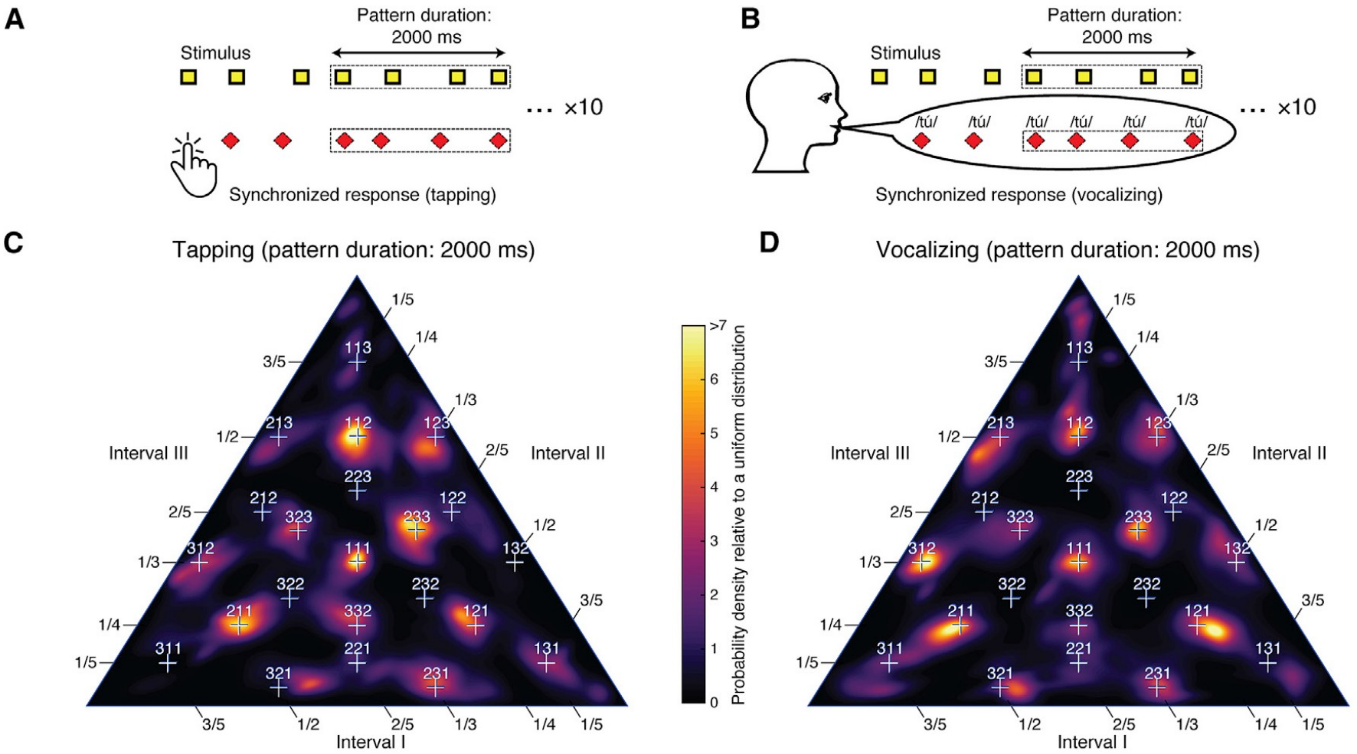
Integer Ratio Priors in Rhythms

How do we control for production biases?



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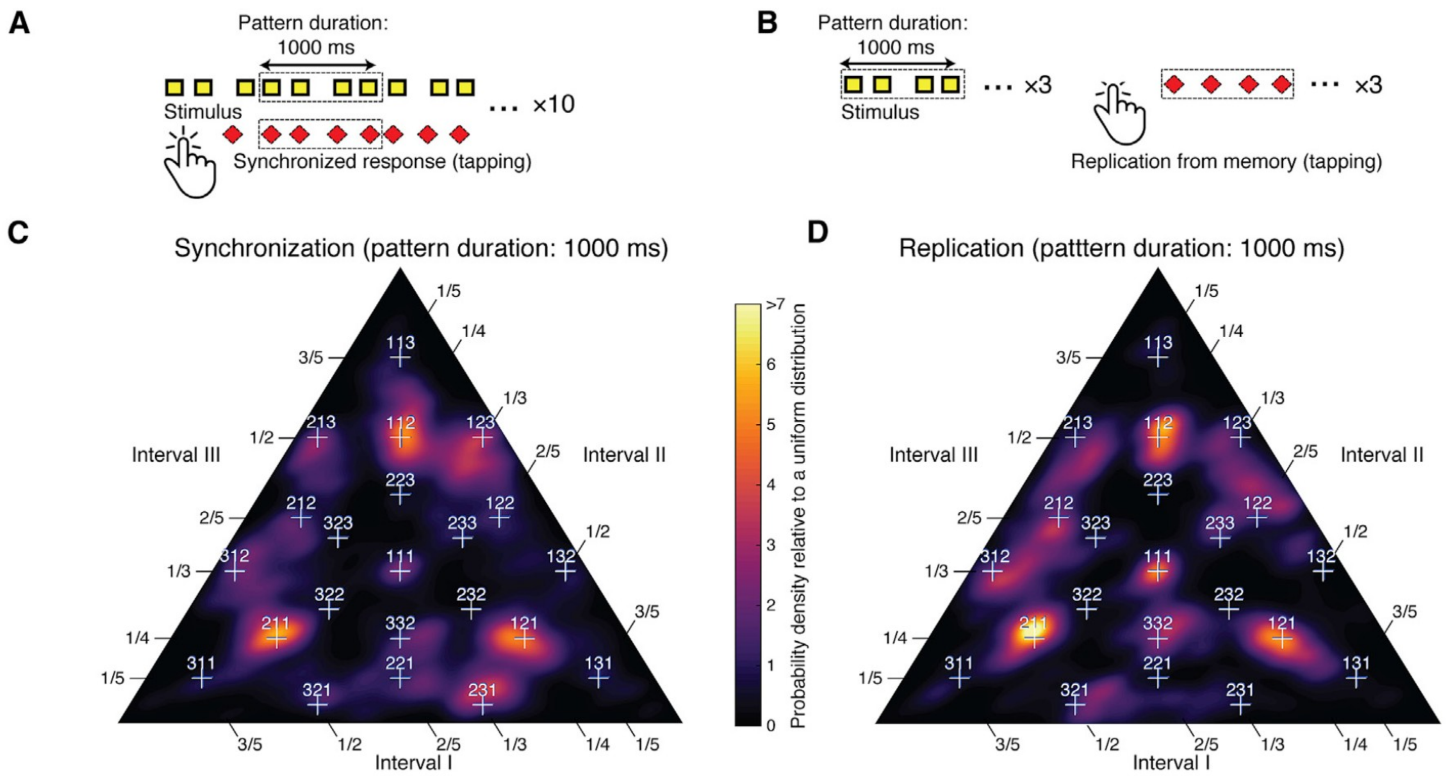
Integer Ratio Priors in Rhythms

How do we control for synchronisation biases?



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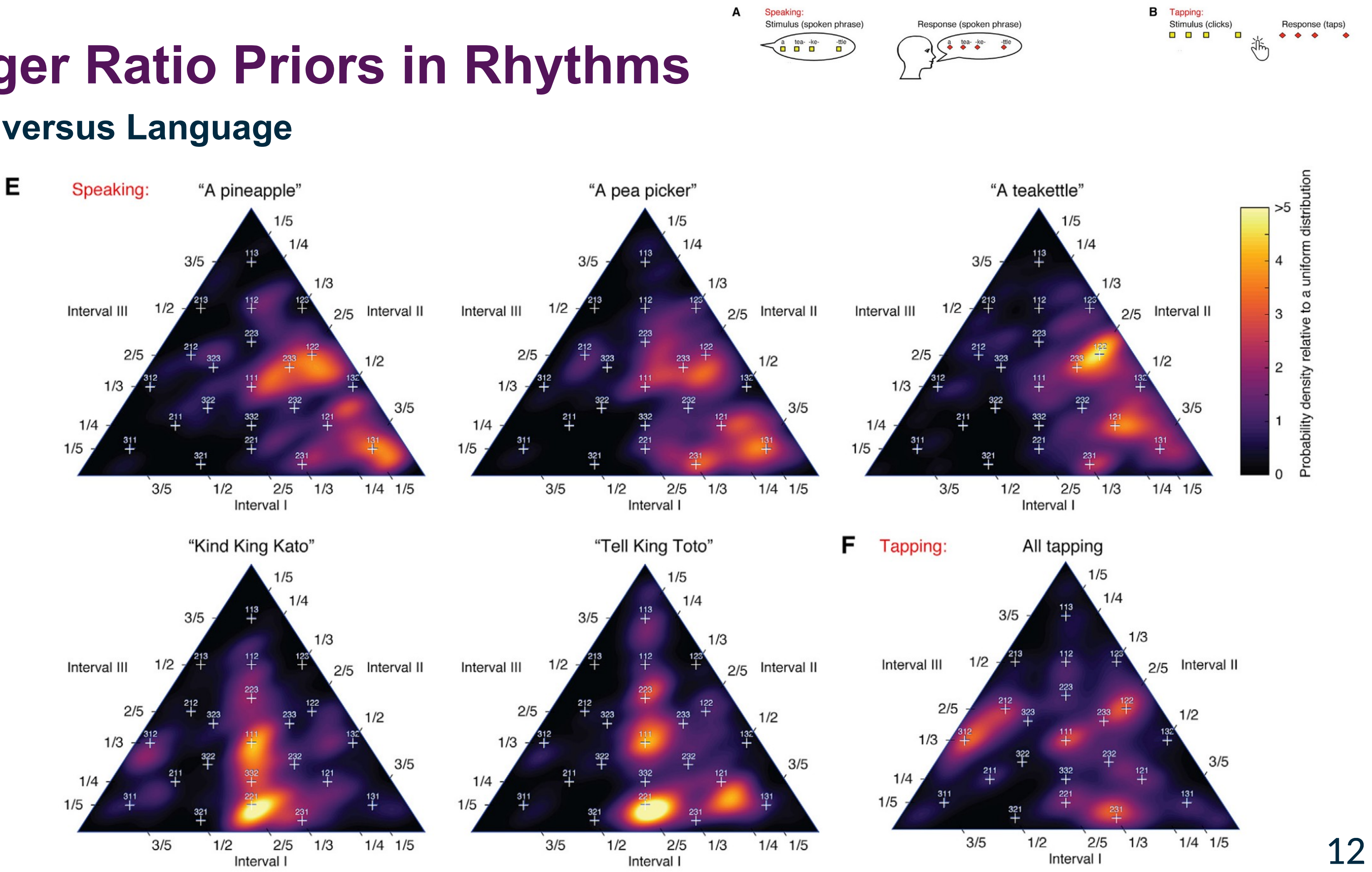
Integer Ratio Priors in Rhythms

Music versus Language



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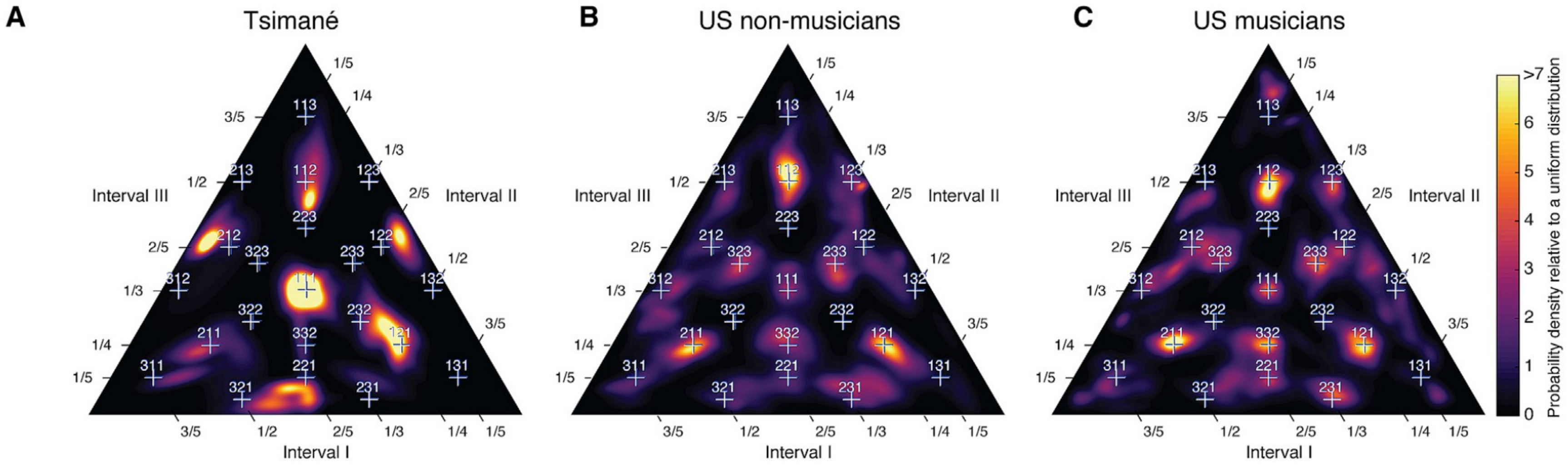
Integer Ratio Priors in Rhythms

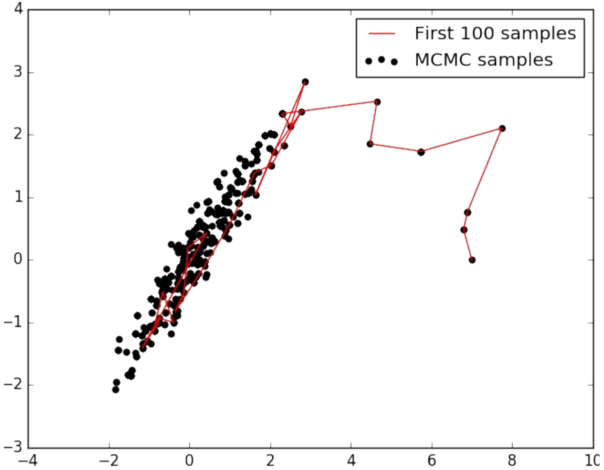
What role does cultural background play?



Markov Chain Monte Carlo

(with People)

Metropolis–Hastings



Sampling from an arbitrary unnormalised distribution

- full distribution is: $p(\mathbf{z}) = \widetilde{p}(\mathbf{z})/Z_p$
- but we can only compute: $\widetilde{p}(\mathbf{z})$

Strategy: Create a Markov chain of samples with *equilibrium* distribution $p(\mathbf{z})$

- start from $\mathbf{z}$
- use proposal distribution: $q_k(\mathbf{z}^\star|\mathbf{z}^{(\tau)})$
- accept / reject proposal with probability: $A_k(\mathbf{z}^\star, \mathbf{z}^{(\tau)}) = \min\left(1, \frac{\widetilde{p}(\mathbf{z}^\star)q_k(\mathbf{z}^{(\tau)}|\mathbf{z}^\star)}{\widetilde{p}(\mathbf{z}^{(\tau)})q_k(\mathbf{z}^\star|\mathbf{z}^{(\tau)})}\right)$
- for symmetric proposals (Metropolis) this simplifies to: $A(\mathbf{z}^\star, \mathbf{z}^{(\tau)}) = \min\left(1, \frac{\widetilde{p}(\mathbf{z}^\star)}{\widetilde{p}(\mathbf{z}^{(\tau)})}\right)$

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Gibbs Sampling
(special case of Metropolis–Hastings)

1. Initialize $\{z_i : i = 1, \ldots, M\}$
2. For $\tau = 1, \ldots, T$:
   - Sample $z_1^{(\tau+1)} \sim p(z_1 | z_2^{(\tau)}, z_3^{(\tau)}, \ldots, z_M^{(\tau)})$.
   - Sample $z_2^{(\tau+1)} \sim p(z_2 | z_1^{(\tau+1)}, z_3^{(\tau)}, \ldots, z_M^{(\tau)})$.

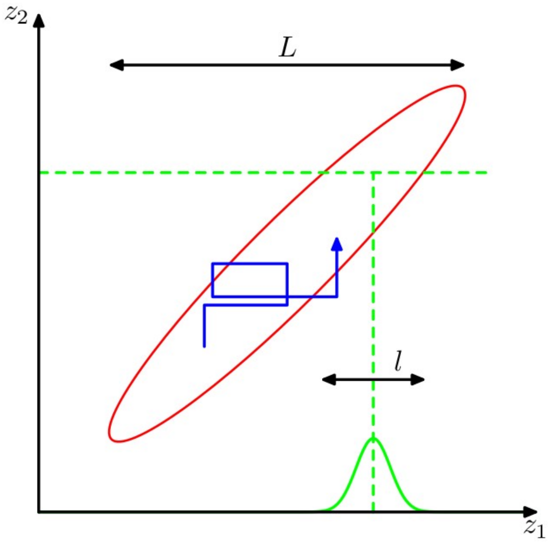
     $\vdots$
   - Sample $z_j^{(\tau+1)} \sim p(z_j | z_1^{(\tau+1)}, \ldots, z_{j-1}^{(\tau+1)}, z_{j+1}^{(\tau)}, \ldots, z_M^{(\tau)})$.

     $\vdots$
   - Sample $z_M^{(\tau+1)} \sim p(z_M | z_1^{(\tau+1)}, z_2^{(\tau+1)}, \ldots, z_{M-1}^{(\tau+1)})$.

Be more efficient for multiple variables

- sample proposals for one variable at a time
- choose proposals such that they are always accepted
- $\rightarrow$ sample one variable *conditional* on the other variables

$$A(\mathbf{z}^\star, \mathbf{z}) = \frac{p(\mathbf{z}^\star) q_k(\mathbf{z}|\mathbf{z}^\star)}{p(\mathbf{z}) q_k(\mathbf{z}^\star|\mathbf{z})} = \frac{p(z_k^\star|\mathbf{z}^\star_{\setminus k}) p(\mathbf{z}^\star_{\setminus k}) p(z_k|\mathbf{z}^\star_{\setminus k})}{p(z_k|\mathbf{z}_{\setminus k}) p(\mathbf{z}_{\setminus k}) p(z_k^\star|\mathbf{z}_{\setminus k})} = 1$$

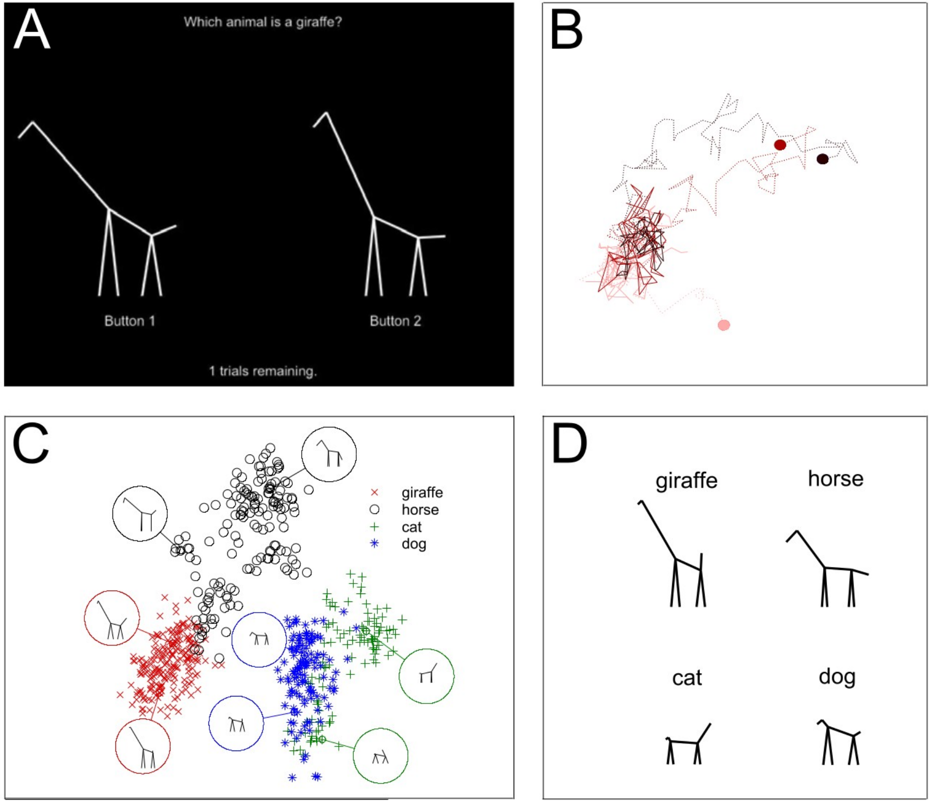


Markov Chain Monte Carlo with People (MCMCP)

(Sanborn & Griffiths, 2007)

MCMC with people as acceptance "functions"

- start with a random sample
- generate a modified proposal
- present both to the participant
  → they reject / accept
- repeat



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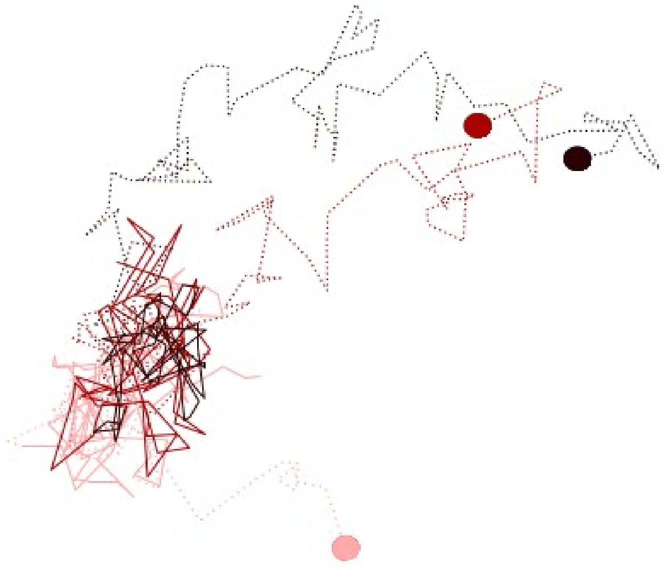
Markov Chain Monte Carlo with People

Problems with MCMCP

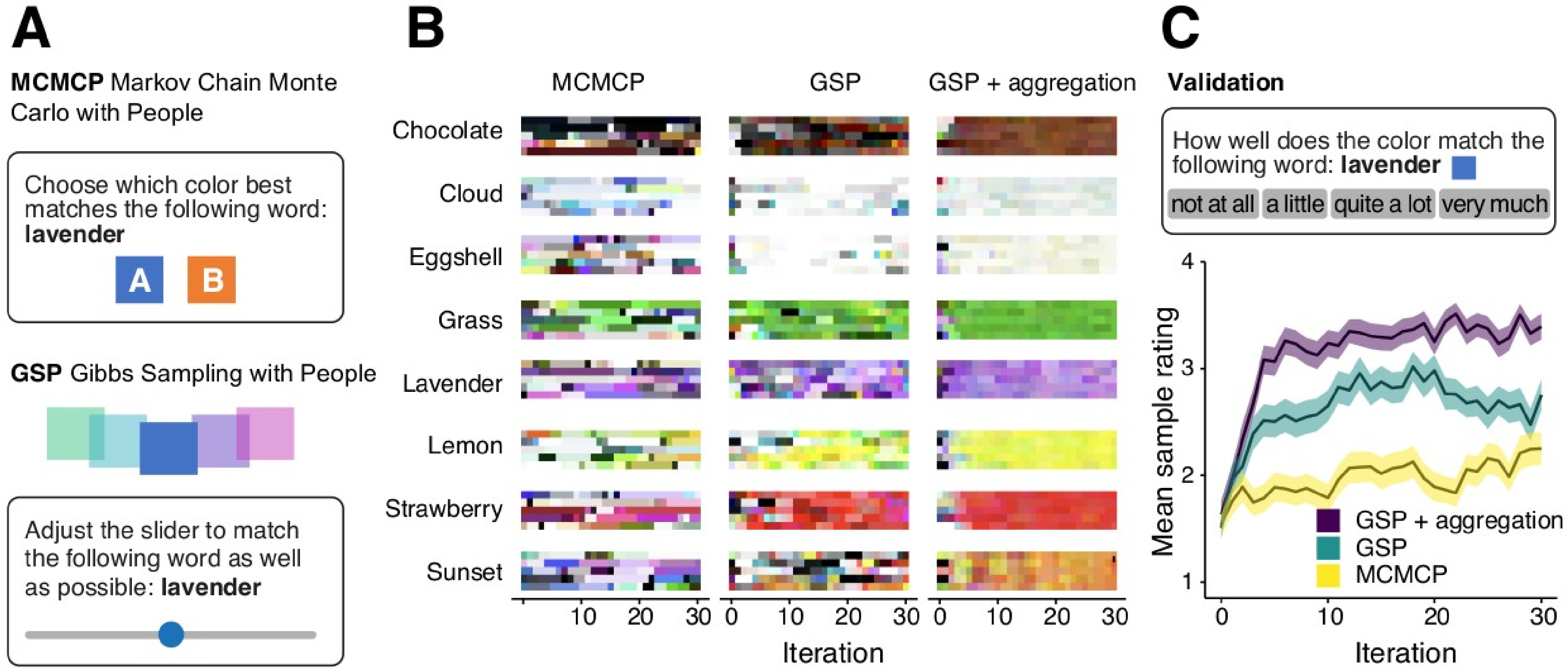
- binary choices generate little information
- local proposals
    - make it slow to explore entire space
    - make it hard to find narrow modes



Gibbs Sampling with People

(Harrison et al, 2020)

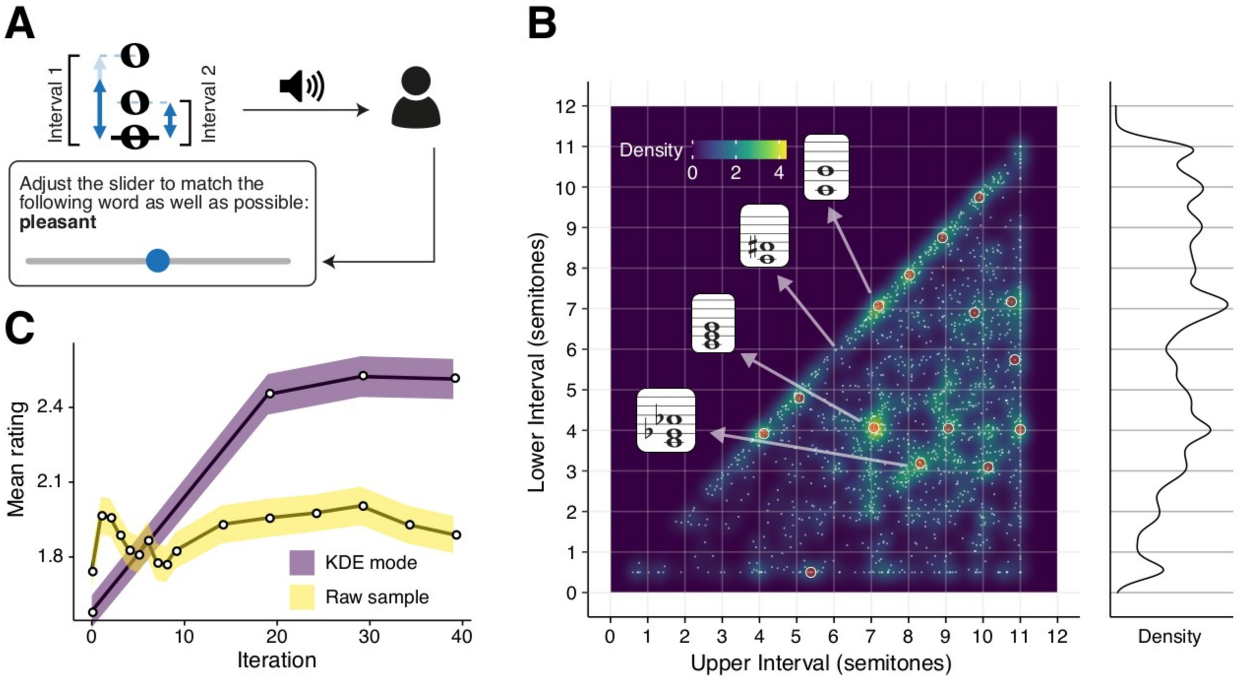
Replace binary decision with continuous slider



Gibbs Sampling with People

"Pleasantness" of musical chords

- maxima at semitones (esp. harmonic overtones)
- dips at minor second and tritone
- clusters at common chords (e.g. major triad)
- aggregation (clusters) gives better ratings



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