Synchronization in Music

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Outline of Talk

1. Leftovers/completion from previous lecture
2. Human versus machine partners
3. When n > 2: Followers versus leaders
4. Concluding remarks

1. Leftovers . . . (?)

2. Humans vs. Machines

Measuring Human Rhythmicity

- Most studies of human synchronization (as well as non-human synchronization) have involved testing how well we can coordinate a motor behavior with a mechanical/computer timekeeper.
- Our rhythmic capacities did not evolve to do this.
- Moreover, this masks an important problem . . .

Measuring Human Rhythmicity

- If humans are not perfect rhythm generators (as we know), then we have the “bad drummer problem”:

  If you are a “bad drummer,” how can I rely on you to provide the “target” for my own rhythmic behavior?

- Indeed, given the variability shown by many subjects in tapping tests, it is amazing we can coordinate are activities at all . . .

Measuring Human Rhythmicity

- But we can.
- Not only that, but two humans performing a rhythm are often <u>better</u> in terms of their collective synchronization than they are individually synchronizing with a metronome(!)
- How/Why?

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- Not only that, but two humans performing a rhythm are often <u>better</u> in terms of their collective synchronization than they are individually synchronizing with a metronome(!)
- How/Why?
  A: Both humans are using adaptive error correction.

A Taxonomy of Synchrony

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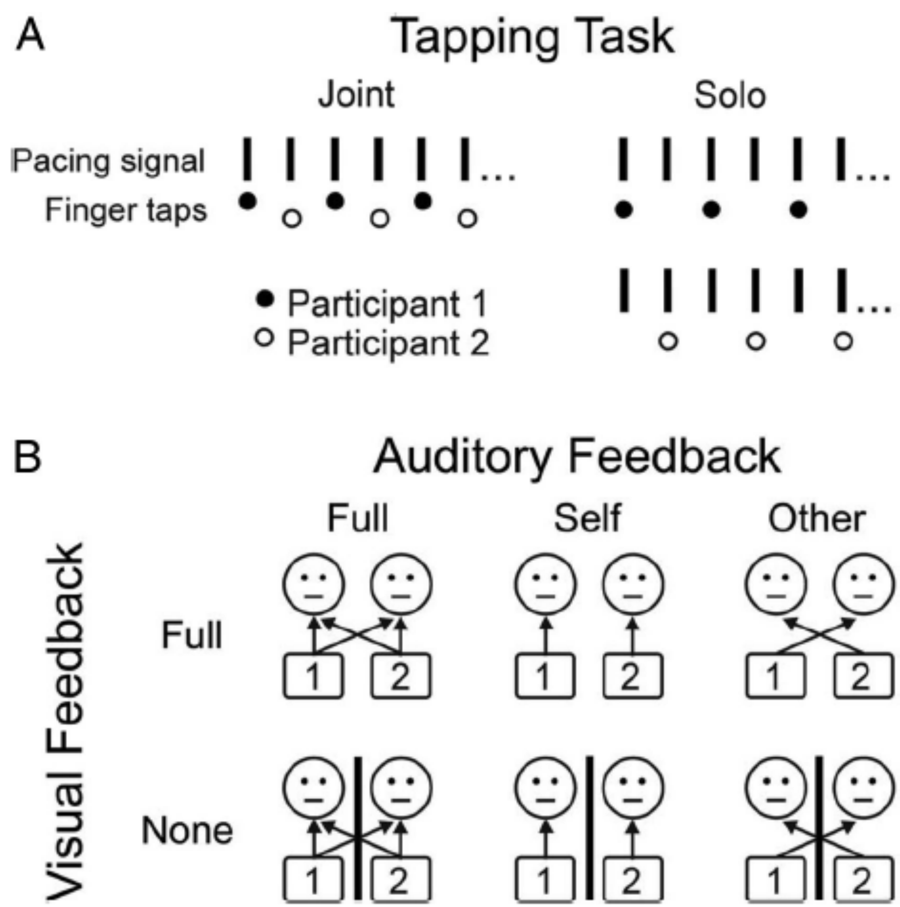
4. Entrainment of 2+ <u>mutually adaptive</u> processes.
5. Social entrainment: entrainment behaviors in a social/joint action context.

Tapping with Another Person

Nowicki, et al (2013) extended the tap-with-the-metronome paradigm to having dyads tap to the metronome in alternation. They also:

- Varied the auditory feedback (hearing only yourself, and/or only the other tapper, and/or the pacing metronome;
- Varied whether or not tappers could see each other.

Tapping with Another Person



Tapping with Another Person

Three possible responses to this general context:

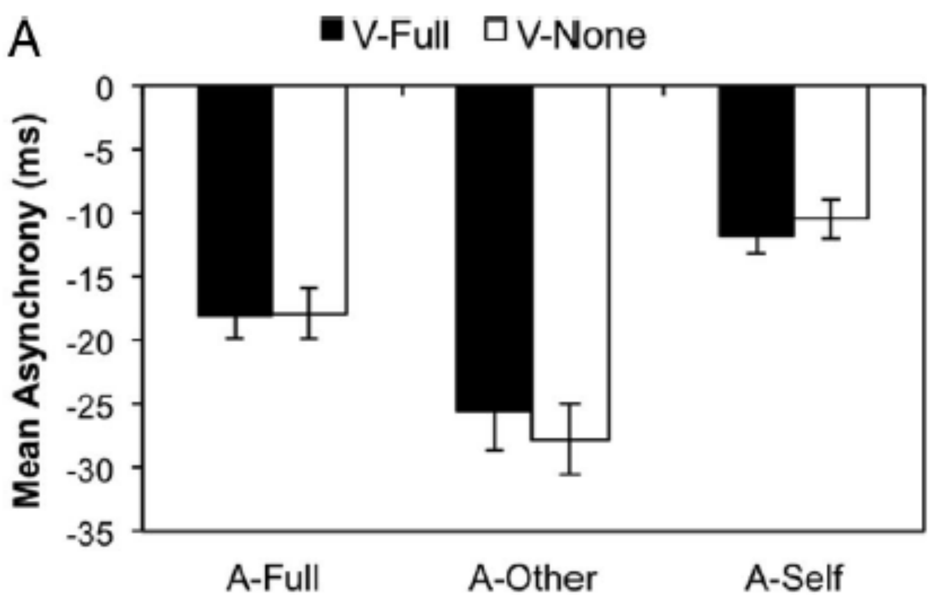
- Focus on the metronome, maintaining coordination with it, as well as tempo stability ("compensation", i.e., usual error correction)

  → This was the goal given to participants

- Focus on your partner and try and stay together ("assimilation")
- Try to do both (divided attention/task).

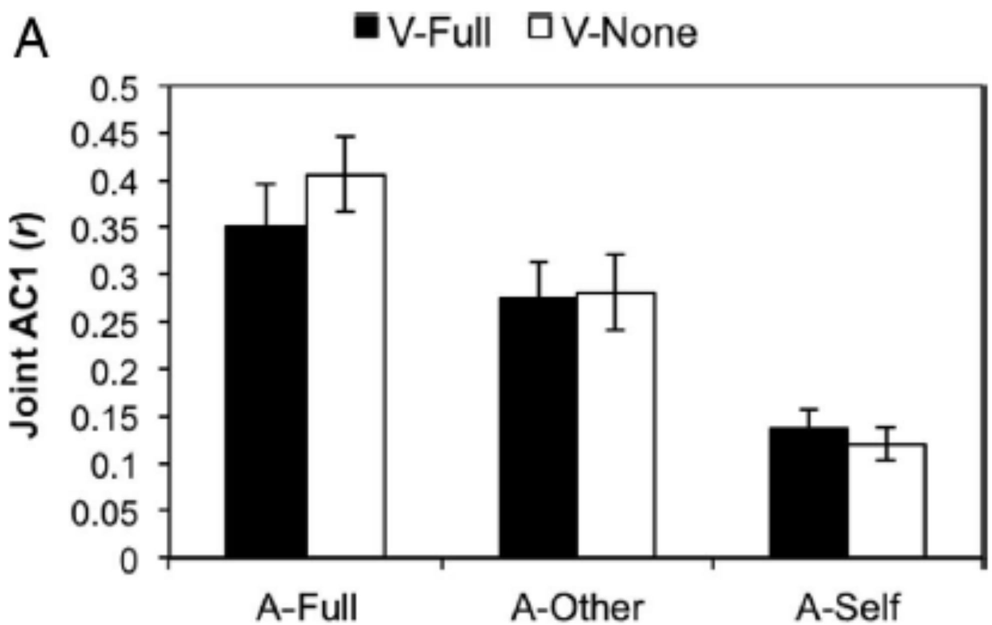
Tapping with Another Person

Nowicki et al had two measures. First was the asynchrony of taps relative to the metronome, dependent on auditory condition:



Tapping with Another Person

Their second measure was lag-1 autocorrelation, which (when positive) indicated the extent of assimilation:



Tapping with Another Person

- They found no effect of visual feedback
- Mutual adaptive timing in this task is characterized by assimilation: you follow your partner.
- This does not, however, wholly disrupt your own error-correction mechanisms which keep you (both) on track with the metronome.
  - → We seem to be able to control the “gain” of our error correction parameter.

Tapping with Another Person

Himberg (2014) studied the tapping behavior of dyads in a number of conditions:

- Tapping together, tapping antiphase, or tapping an interlocking rhythm
- Tapping with a human partner and/or with various pacing metronomes (or without a pacing metronome)
- Tapping with various kinds of auditory feedback (hearing the pacer vs. the human partner)

→ Participants did not know if they were tapping with a human partner or a computer.

Tapping with Another Person

1. With another human in actual interaction (both heard each other, mutual adaptation was possible). This condition hereinafter referred to as "Human".
2. With a deadpan computer tapper (computer tapper had no phase nor period variability). "Deadpan".
3. With a computer tapper with human-like phase jitter (phase variability but constant period). "Phasevar".
4. With a computer tapper that was speeding up (phase variability plus constantly shortening period). "Fast".
5. With a computer tapper that was slowing down (phase variability plus constantly lengthening period). "Slow".
6. With a non-responsive human tapper following a computer with steady tempo (the other participant heard either the *Deadpan* or *Phasevar* computer tapper, thus was not responding to the participant). "Non-responsive steady".
7. With a non-responsive human tapper following a computer with varying tempo (the other participant heard either the *Fast* or *Slow* computer tapper, thus was not responding to the participant). "Non-responsive periodvar".

Tapping with Another Person

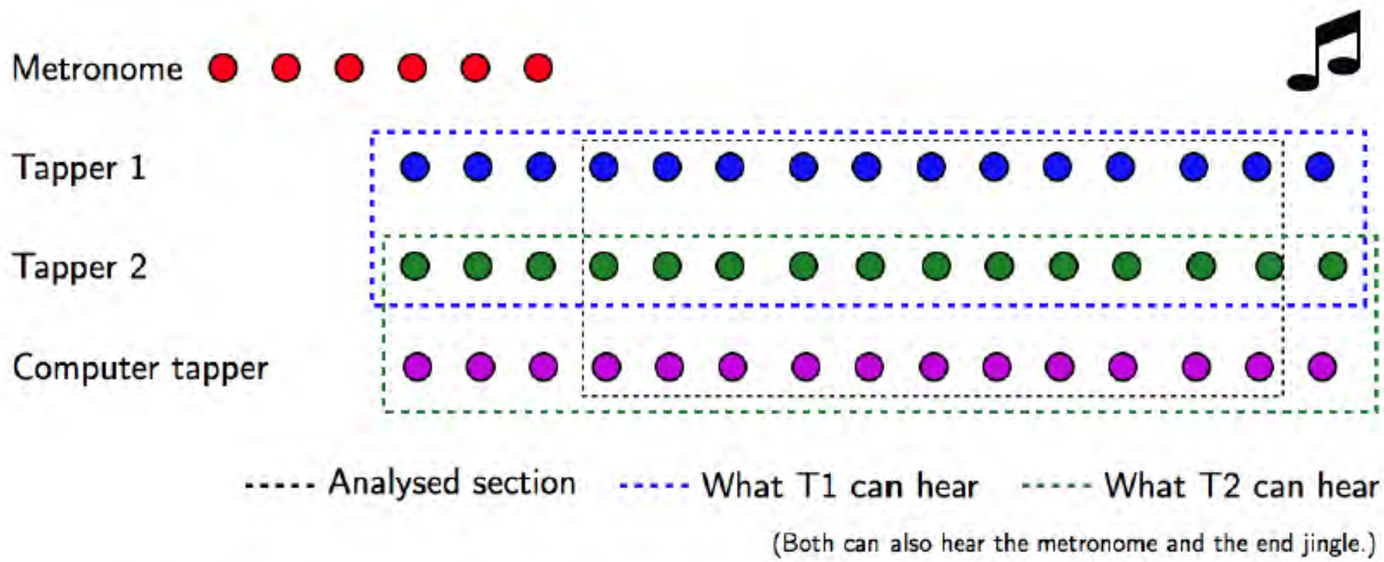
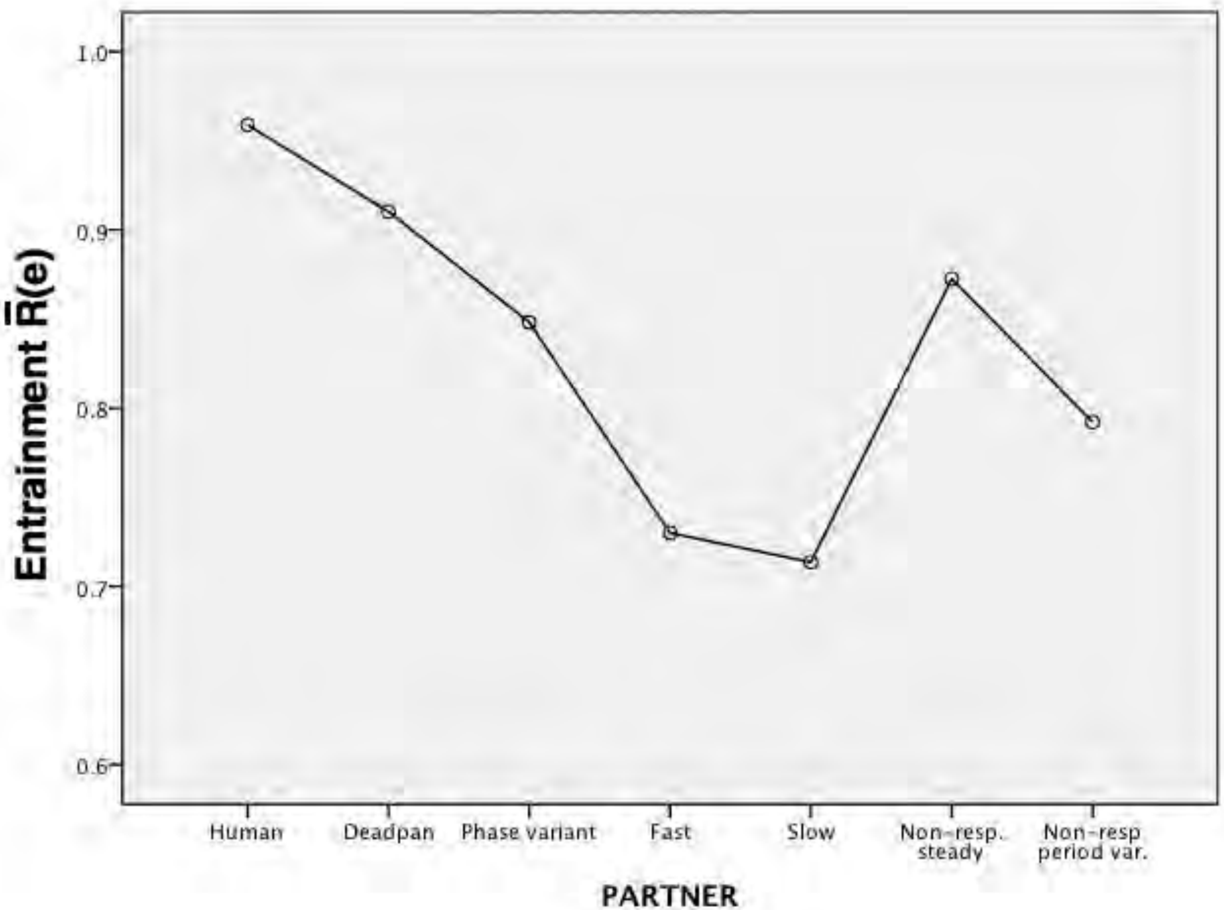


Figure 7.1: Structure of the tapping trial. Both participants could always hear the channel with the metronome and end jingle, as well as feedback of their own tapping. Depending on the trial, they could either hear the other tapper, or a computer tapper.

Tapping with Another Person



Tapping with Another Person

- Without a metronome, we can use phase correction with our partner for extremely tight synchronization.
- It is better if the metronome doesn't try to act like a person—we can tell it lacks mutual error correction.
- As expected, tempo changes weaken synchronization.

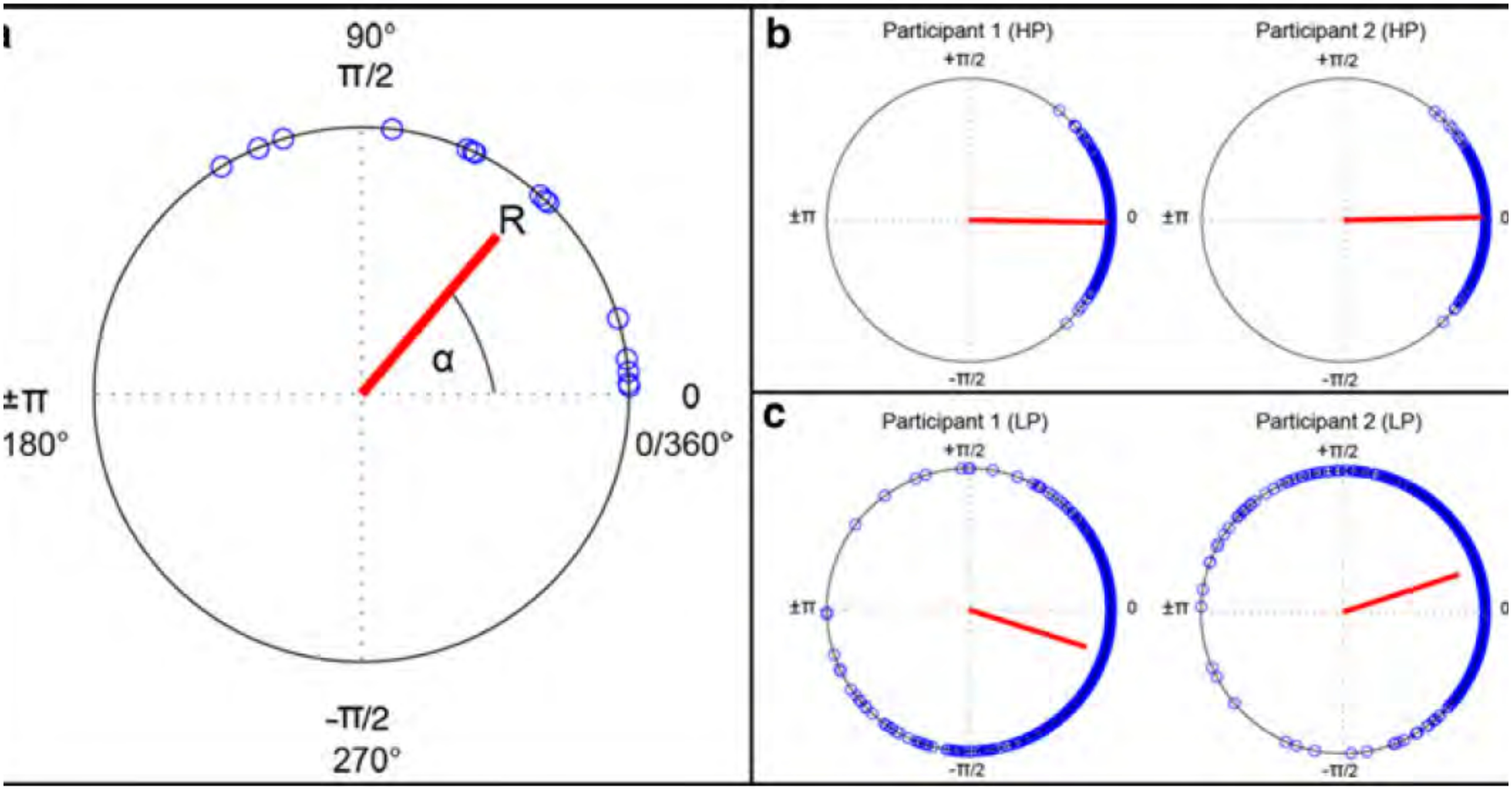
Tapping with Someone Like You

Pecenka & Keller (2009) studied differences in our ability to track regular fluctuations in tempo.

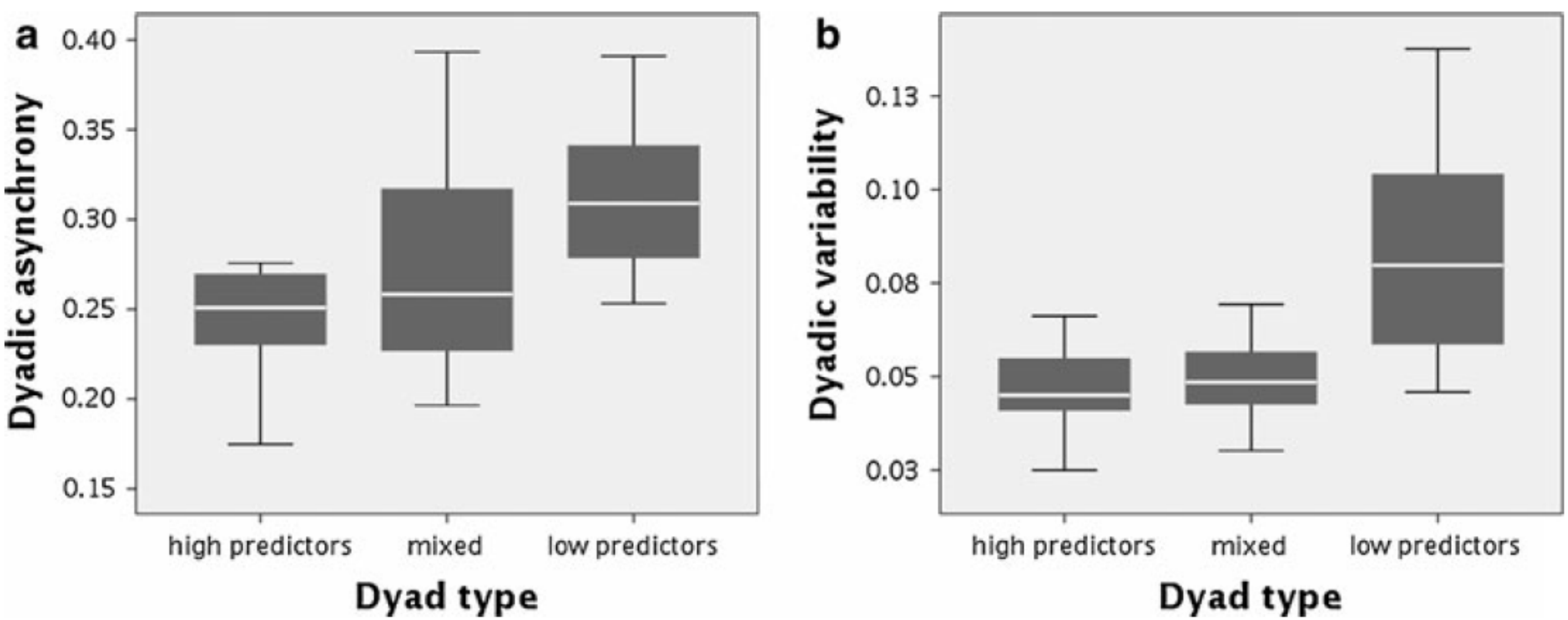
- Some participants clearly were able to anticipate tempo changes
- Other participants' behaviors were more reactive

Pecenka & Keller (2011) studied synchronization amongst participants systematically matched and mis-matched according to their ability to anticipate tempo changes

Tapping with Someone Like You



Tapping with Someone Like You



3. When $n > 2$: Followers vs. Leaders

Beyond Dyads

- The use of auto-correlation measures can be extended. It can encompass:
  - Larger musical ensembles, and/or
  - Multiple lags—to see if a musician is monitoring not just the previous notes, but perhaps the previous 3 or 4 (or more) notes played by her fellow musicians.

Beyond Dyads

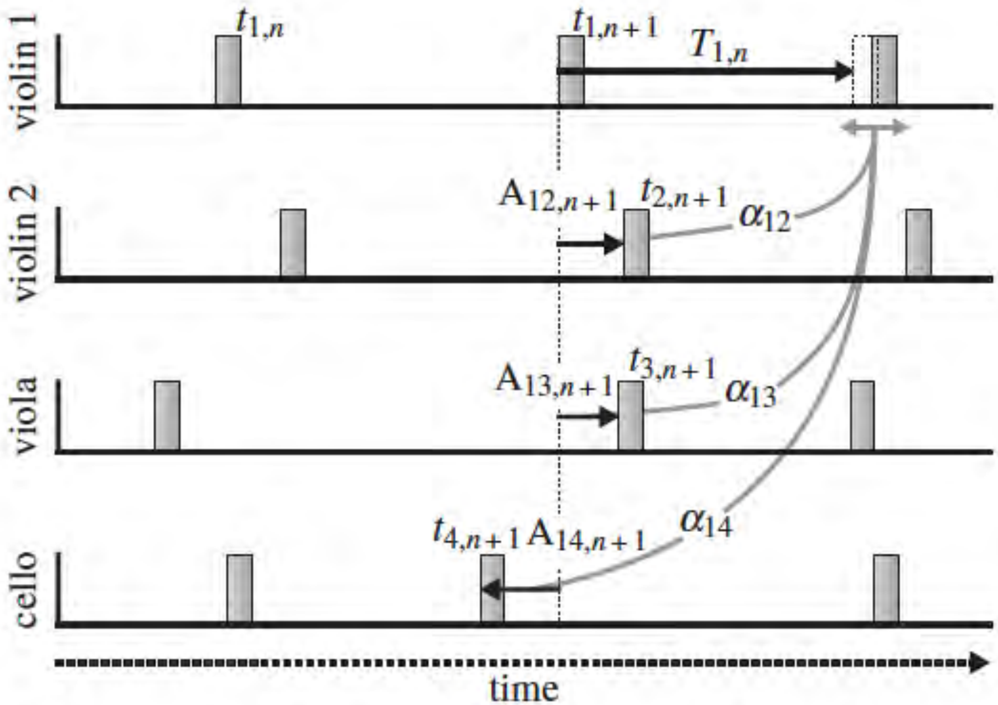
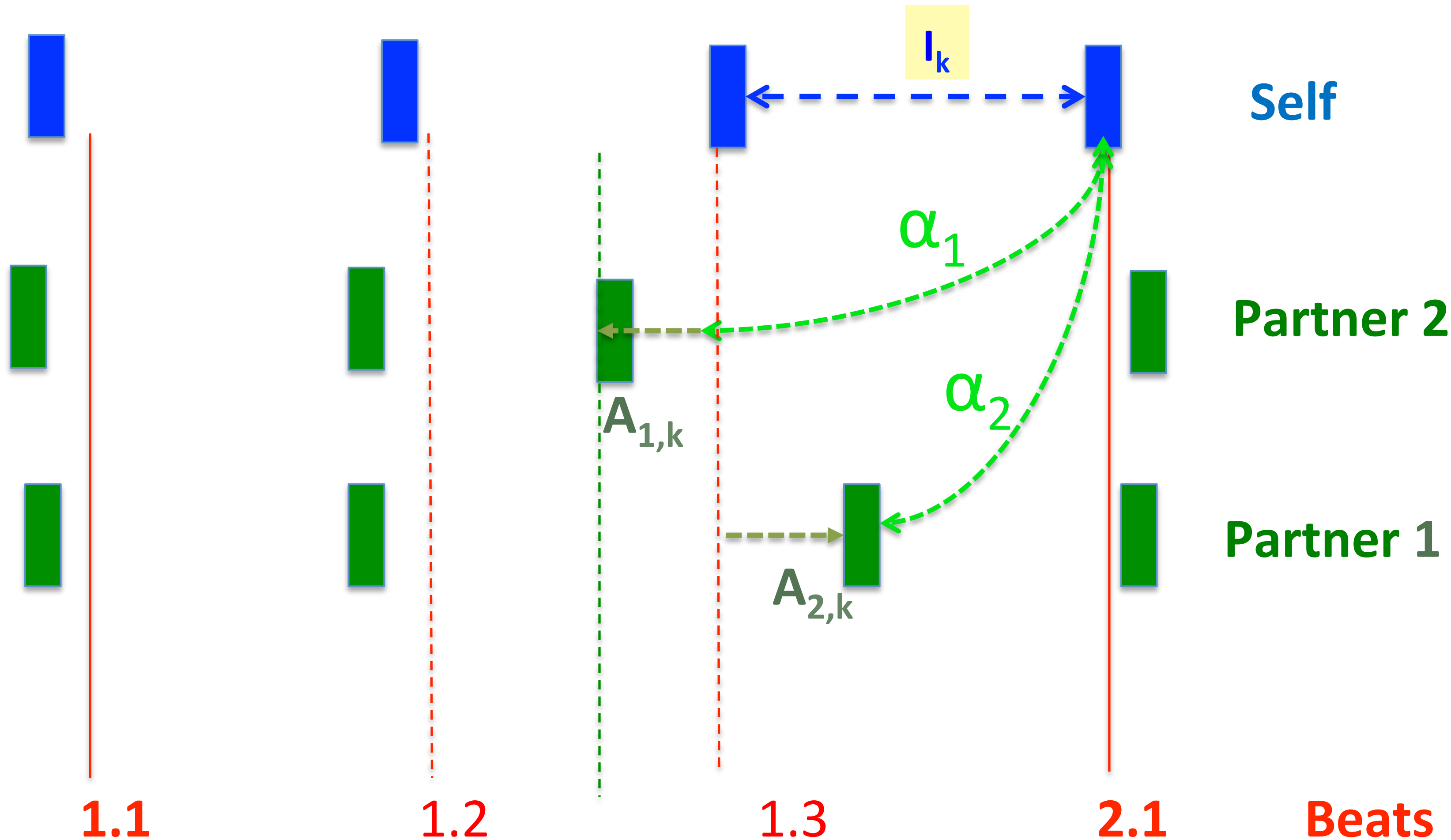


Figure 1. Schematic of the phase correction model for quartet synchronization from the perspective of violin 1 (i.e. player 1 in the notation of equation (2.1)).

Ensemble Phase Correction Model



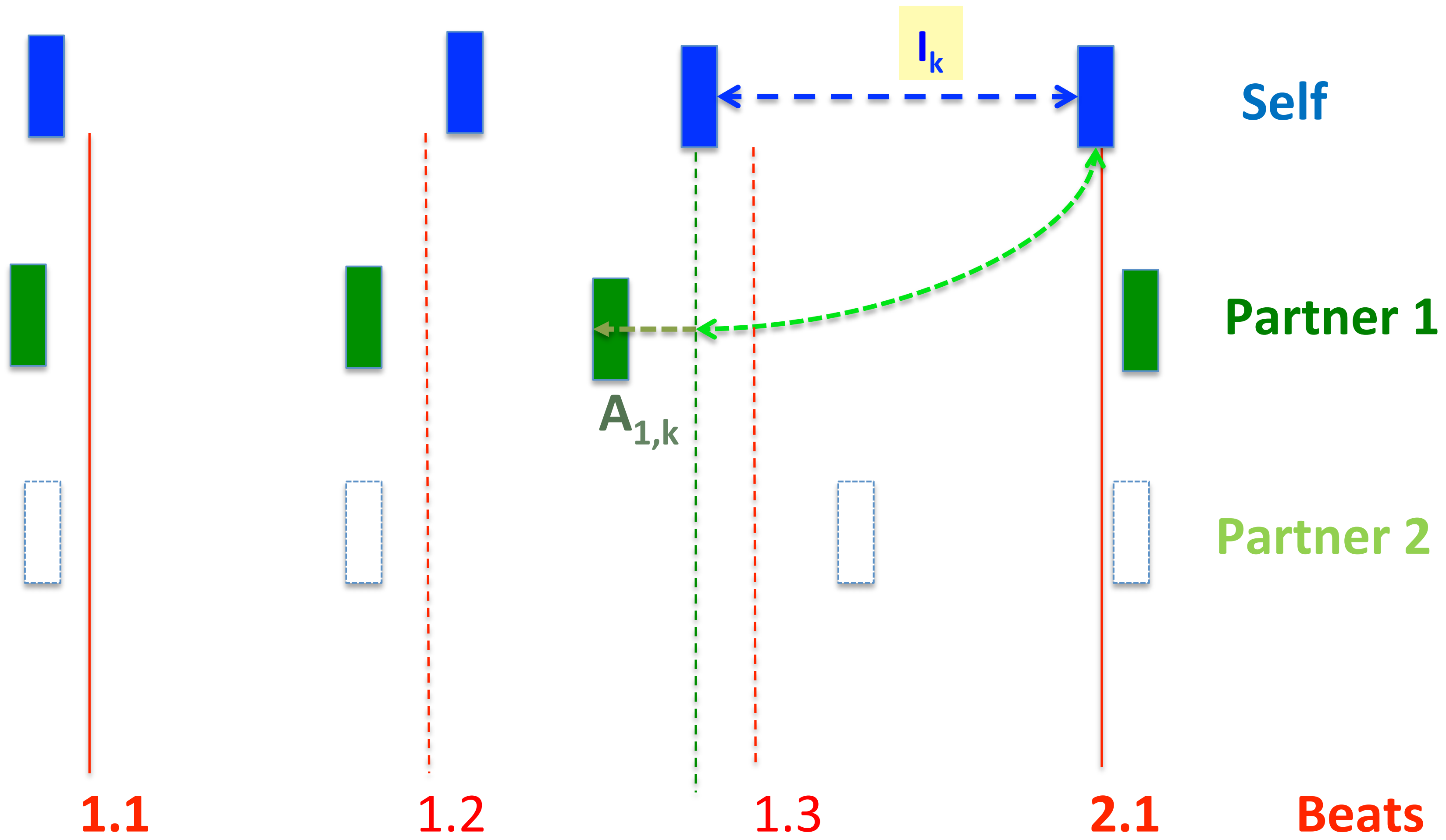
$$I_k = \Sigma_j(-\alpha_j)A_{j,k} + T_k + M_{k+1} - M_k$$

α_j Phase correction constants

T_k Timekeeper noise

M_k Motor noise

Pairwise Grainger causality



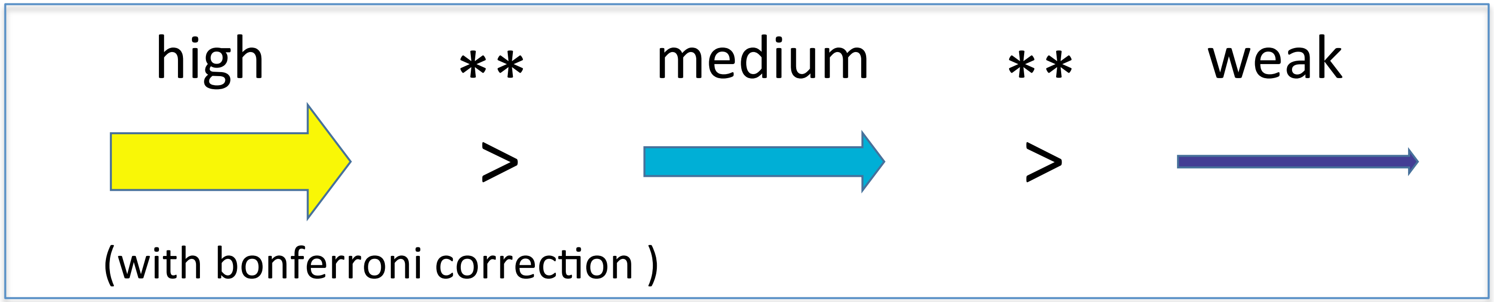
Glowinski et al. 2012

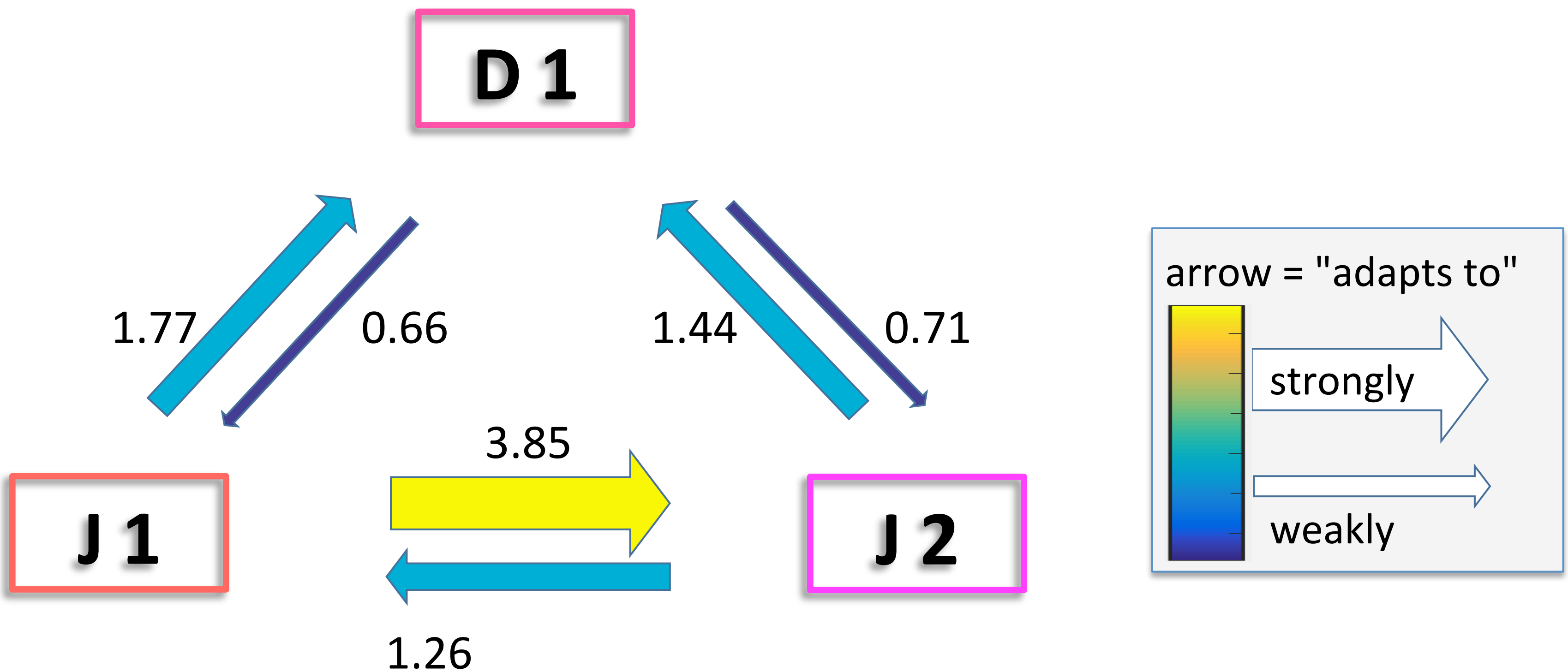
Data Collection

- Piece: “Suku”
  - 74 takes, 3 hours total running time
- 4 distinct ensembles
  - 8-11 takes per lineup
- jembe players switch roles

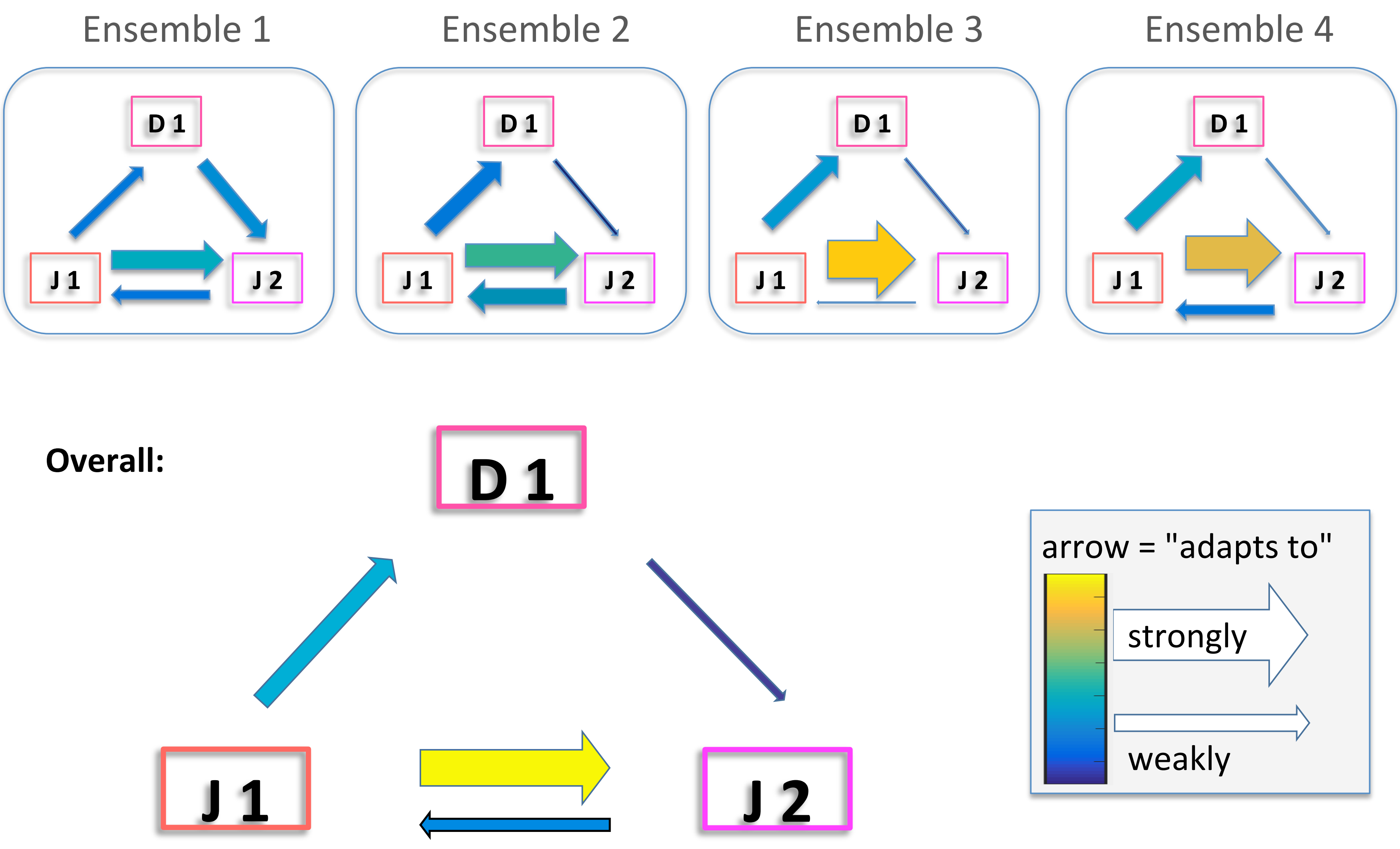
Jembe 1 lead-drum	Jembe 2 accompaniment	Dundun timeline
Player A	Player B	Player C

Adaptation per G-Causality (general pattern)

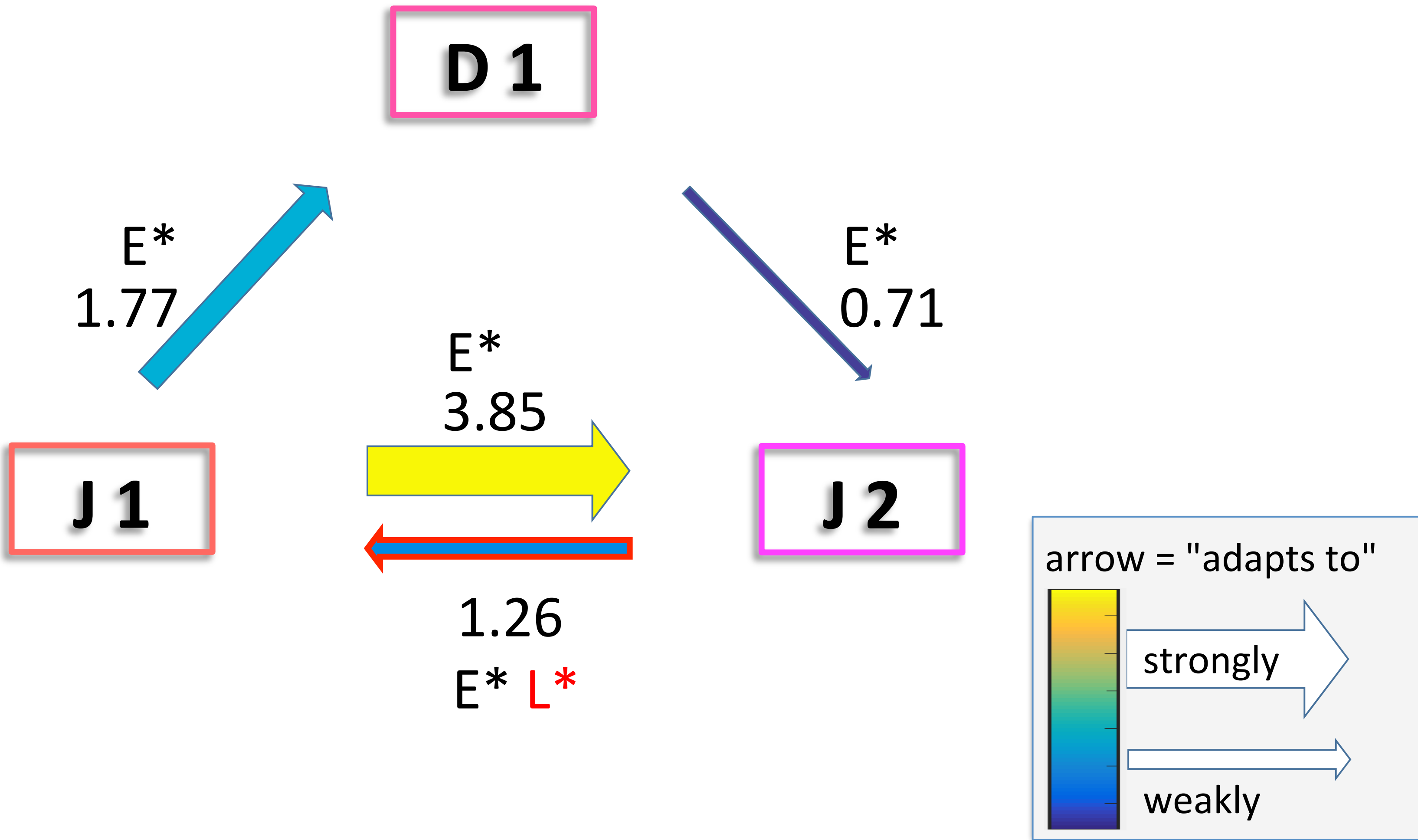




Adaptation by Ensemble



Lineup main effect (L*)

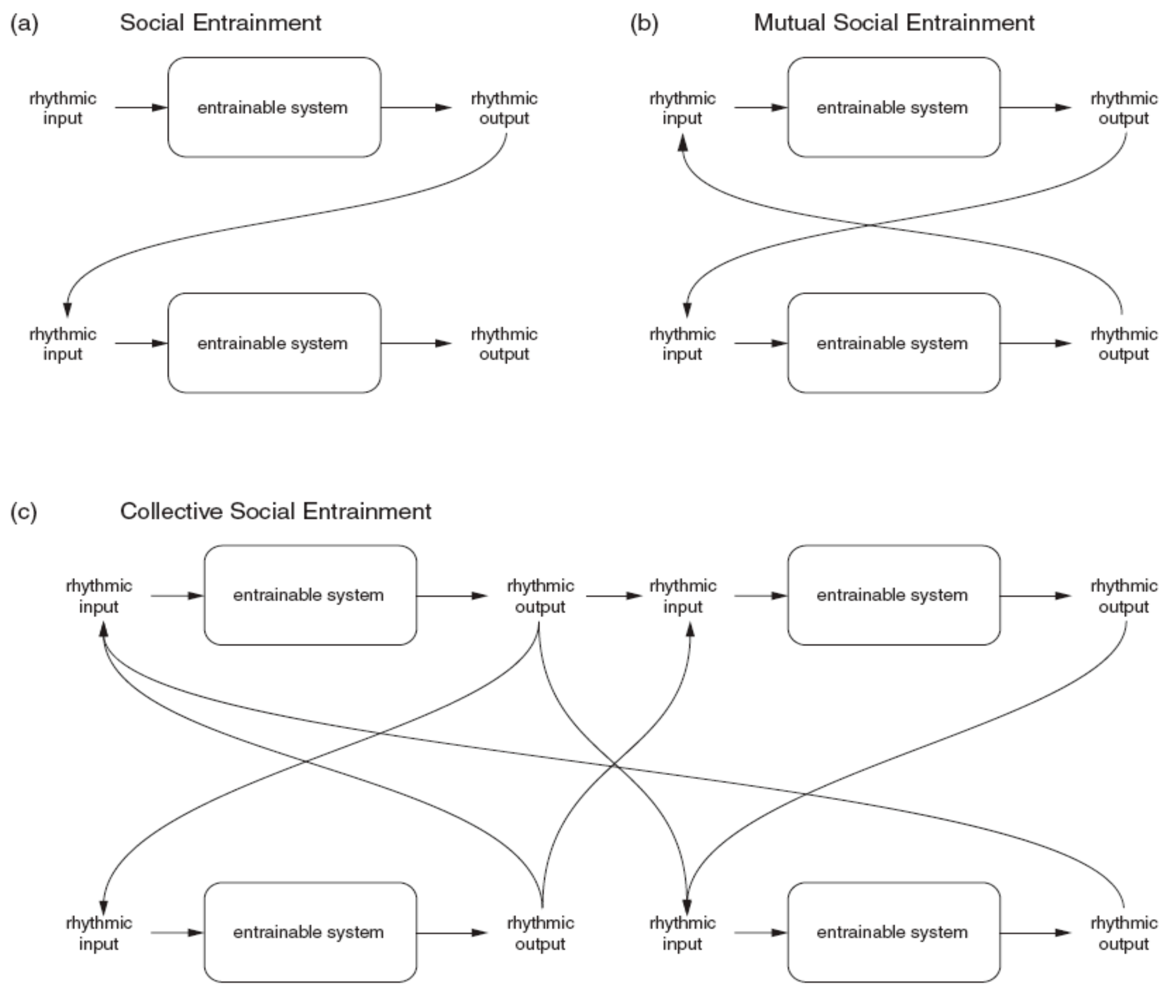


Adaptation by Ensemble and Lineup

Jembe Conclusion

- Individual player makes a difference, but . . .
- Individuals do not drastically modify the role-based pattern of adaptation
- Lead drum delegates time-keeping to other parts
- Time-keeping is established by timeline *plus* accompaniment (not by the timeline alone)

4. The Big Picture


(a)
Social Entrainment
rhythmic input
entrainable system
rhythmic output
rhythmic input
entrainable system
rhythmic output
(b)
Mutual Social Entrainment
rhythmic input
entrainable system
rhythmic output
rhythmic input
entrainable system
rhythmic output
(c)
Collective Social Entrainment
rhythmic input
entrainable system
rhythmic output
rhythmic input
entrainable system
rhythmic output
rhythmic input
entrainable system
rhythmic output
rhythmic input
entrainable system
rhythmic output

Systems of Social Entrainment

- Afford detection of intentionality in the rhythms of another agent.
  - In rhythmic terms, this is deviation from mechanical regularity.
- A shared social context is a pre-requisite for social entrainment.
- A shared social context may also provide a shared intentionality (i.e., “let’s play this piece” or “let’s dance together”).

Systems of Social Entrainment

- Musical performances are paradigmatic examples of shared social contexts:
  - Performer to Performer
  - Performer to Listener
  - Listener to Lister
- Many musical contexts are expressly social events (religious rituals, sporting events, dances, life-cycle occasions).
- Music may have "evolved" as a means of enhancing the sense of shared intentionality in these social contexts.

Music **is** Social Synchronization

- Musical synchronization, as opposed to metronome synchronization, shows aspects of temporal coordination that are <u>socially grounded.</u>
- Musical synchronization is best studied in musical (i.e., ecologically valid) contexts.
- Even the simplest contexts – dyads of performers or performer-listener—give rise to complex systems of entrainment.

Music **is** Social Synchronization

- Rhythmic perception involves a deep engagement of the sensorimotor system; it is a textbook example of embodied cognition.
- It is also highly sensitive to one's social context . . .

. . . so when we listen to music, we are, quite literally, "social minds (and bodies) in the connected world."

End of Lecture #3

Next Lecture: Virtuosity

The End

Vielen Dank für Ihre freundliche Aufmerksamkeit

Khasonka Dundunba: “*Bire*”

- Part of a suite called “Jeli Dòn” (Dance of the Griots)
- Musicians in this recording are Koly and Toutuo Sacko (two brothers) who are Griots
- Data collected Jan-March 2012, Mahina, Mali

Bire Performance

- Core piece: a duet for two players; a third player may be added.
- Each musician plays <u>two</u> instruments:
  - A bell, played with the non-dominant hand (actuated by wrist, and struck with ring worn on the thumb)
  - A drum, played with a curved stick
- Ensemble roles:
  - Accompanist: bell timekeeper + drum hook part
  - Soloist: lead drum, plus secondary bell (bell takes either lead or timekeeper roles_

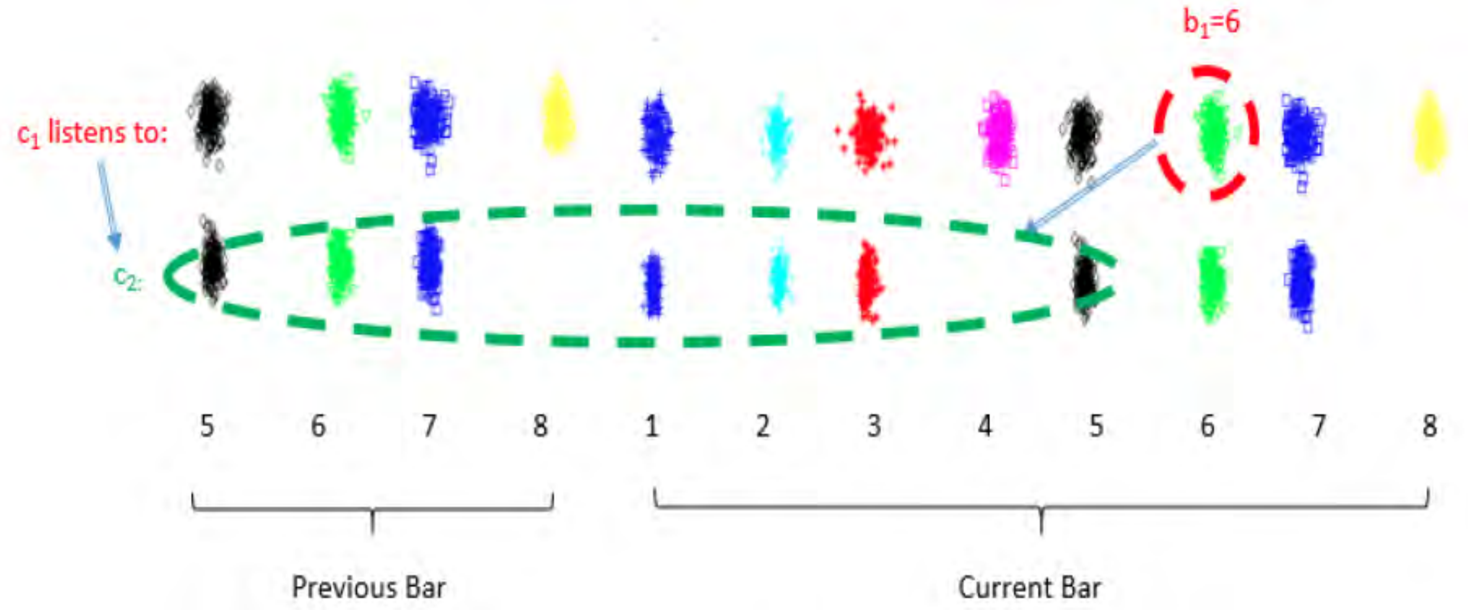
Bire Performance

Bire Performance

- In Bire, unlike a classical string quartet, the accompaniment/timekeeper and soloist roles are fixed, simplifying aspects of the analysis
- The rhythms are also constant and repetitive, allowing for stronger autocorrelation measures—can have a denser sample.
- Data collected from real audio, which is more ecologically valid (motor timing delays already accounted for).

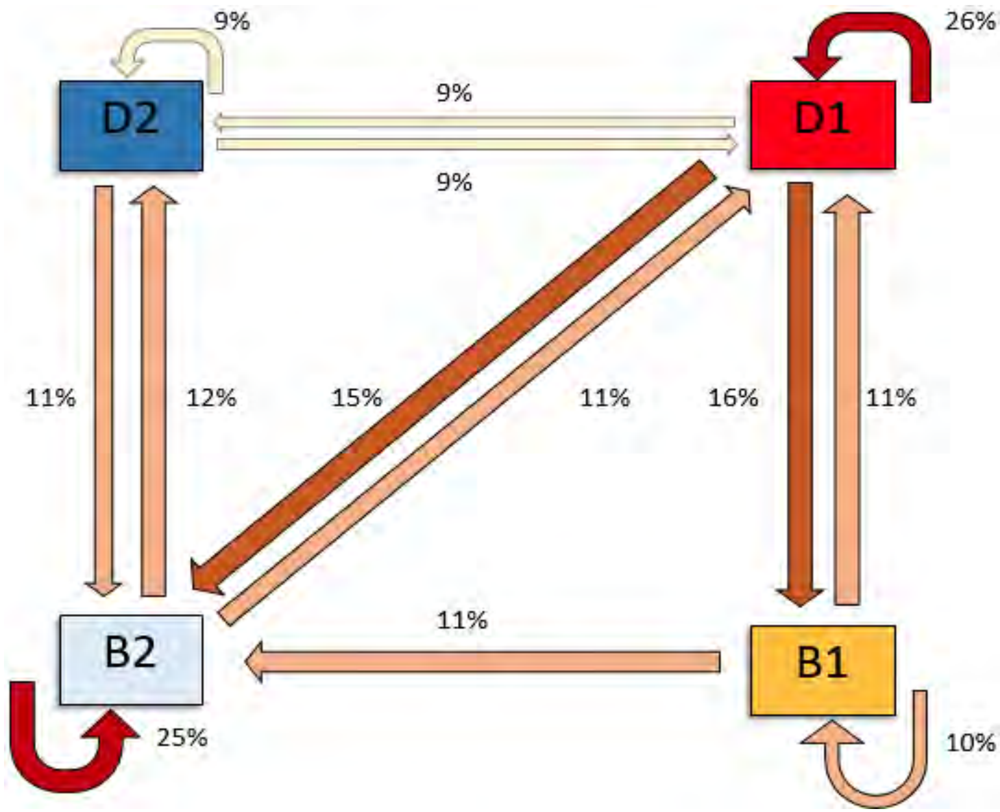
Bire Performance

This allows us to look at more than just the previous event . . .



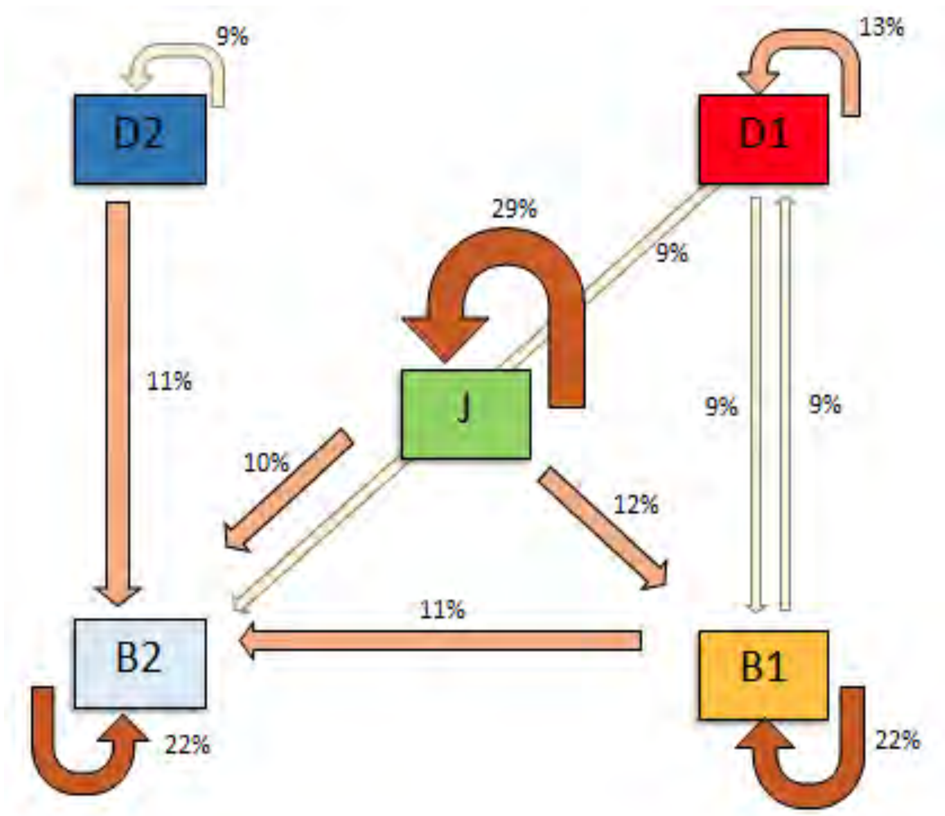
Bire Performance

Duet:



Bire Performance

Trio:



Bire Performance

Trio Summary:

- Everybody listens to the accompaniment bell;
- Jembe listens equally to both bells;
- Soloist (D1) ignores the Jembe & D2;
- B2, B1, and Jembe are more self-coupled than they are to D1 and D2;
- An asymmetry in the hands of the core musicians: B2 not coupled to D2, but D2 is coupled to B2. More symmetry between B1 and D1.

Bire Performance

Trio Summary:

- Couplings reflect social roles: Lead drummer (D1) pays less attention to the other drums as he is the focus of the musical attention.
- Couplings reflect attentional load: Bell playing a more reflexive activity, hence higher degree of self-coupling
- Asymmetries between D1/B1 and D2/B2 are evidence of different skill levels between the two, but also of different task demands.