Effects of Latency on Networked Music Performance

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- Quantify effects of latency
- Find "region of best delay
- Groundwork for further st

Networked ensembles
Experiment design
Analysis
Results
Modeling
Future

Experiment Design

New York

San Francisco

Subject

Subject

Asst.

Subjects = students and staff at Stanfo

(paired randomly)

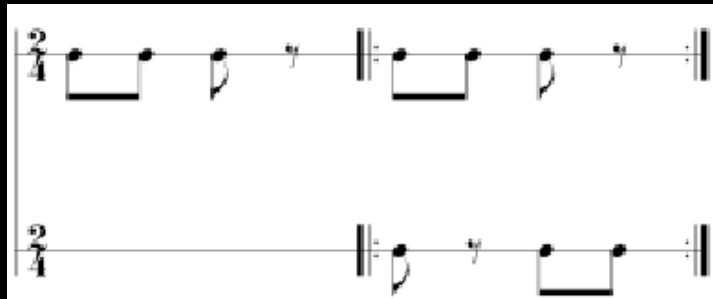Task = play rhythm accurately,

keep an even tempo

(no strategies given)

Interlocking rhythm
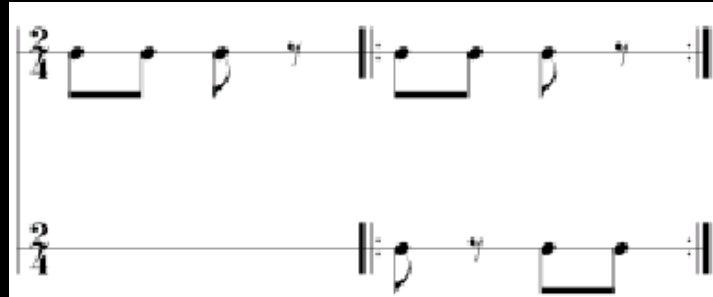
Sound

(2ms delay each direction, metronome cue = mm94)
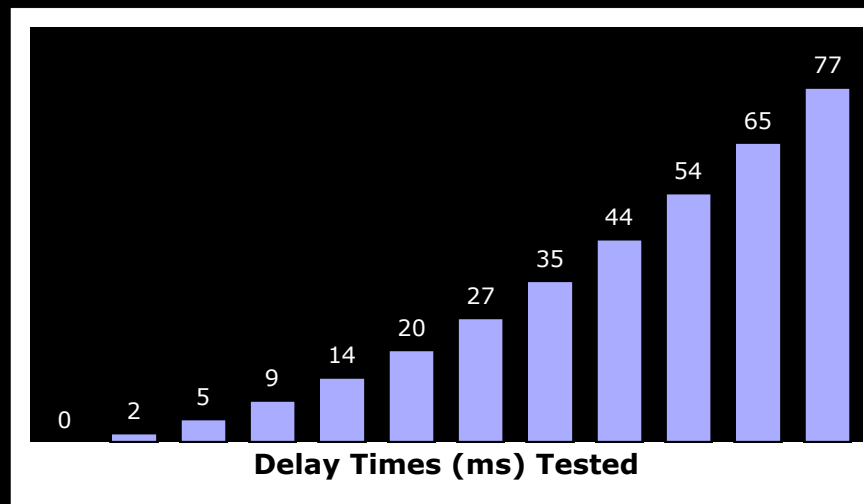
Delays: 0 – 77ms (each way) in 12 steps

Tempo: [86 90 94] bpm
(random choice for each trial)

Experiment 1 with 17 pairs of subje

New York

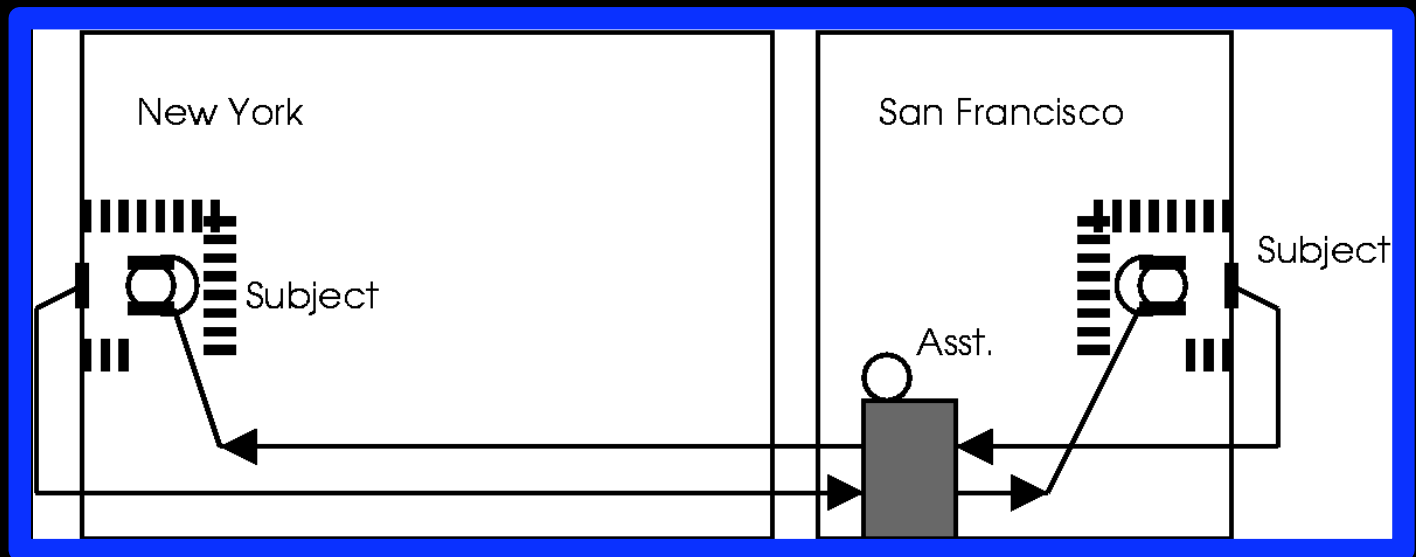San Francisco

Subject

Subject

Asst.

initiator is randomly chosen
audio switches on
initiator hears metronome for initial tempo
initiator starts clapping
follower starts clapping
...30 secs...
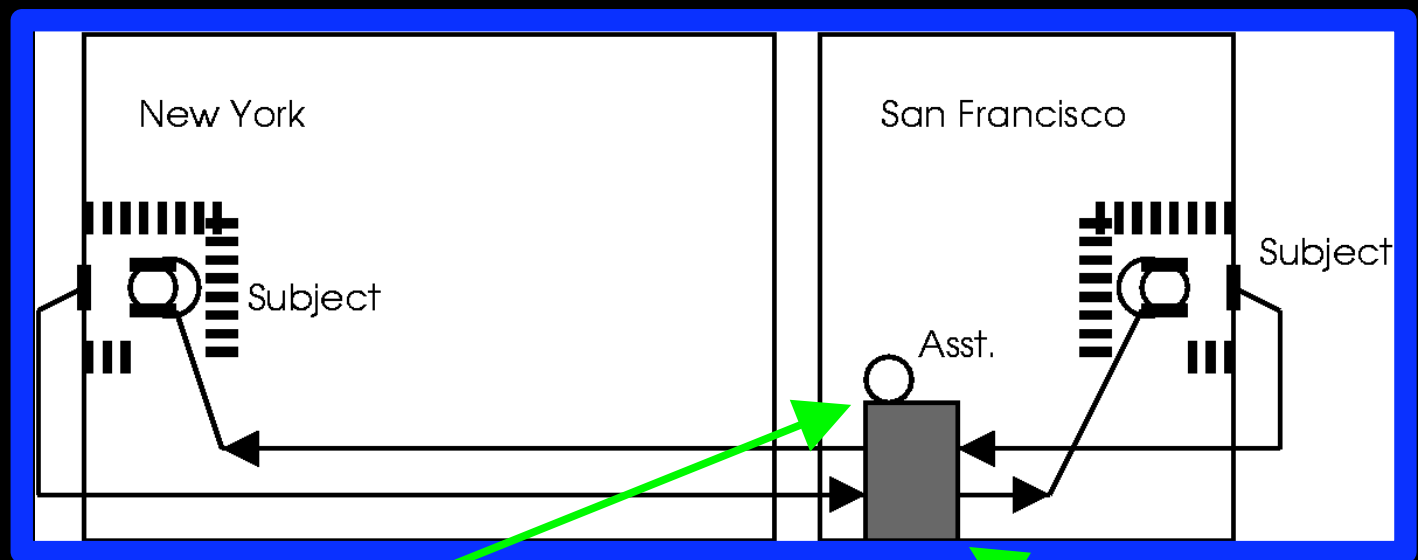room-to-room audio switches off

New York   San Francisco

Subject

Asst.

Subject

Assistant to advance (or retake) trials

Linux audio with delay guarantees

delays verified by scope
isolated, damped studio rooms
subjects inside foam enclosures
low-leakage headphones, close mic
fully-automated experiment

Analysis

Deceleration from longer delay
but where does it start to cause
trouble?

Sound
(77ms delay each direction, metronome cue = mm90)

Measuring ensemble accuracy
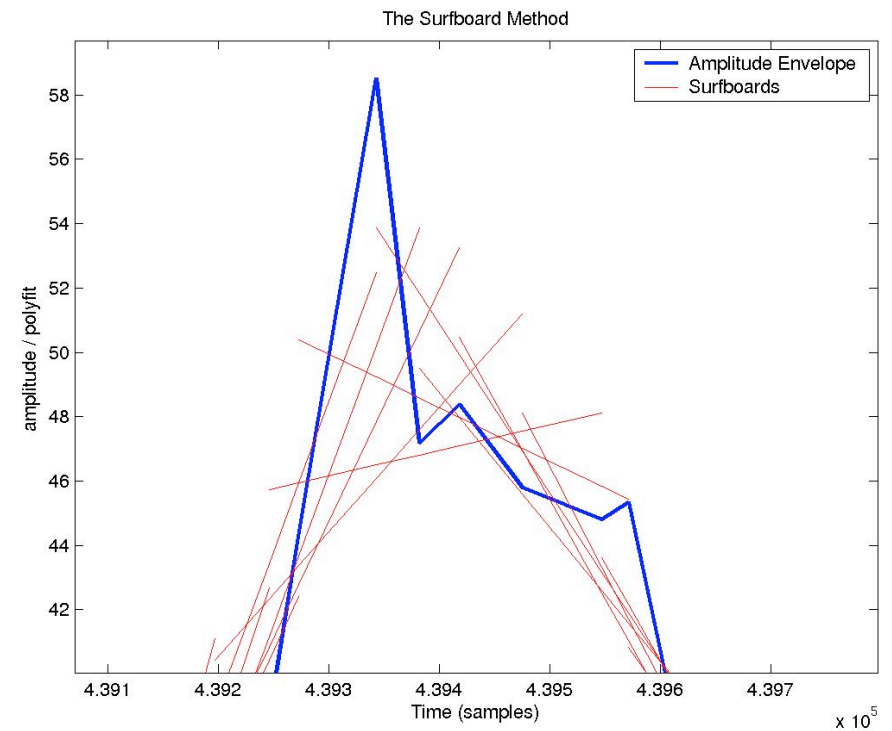
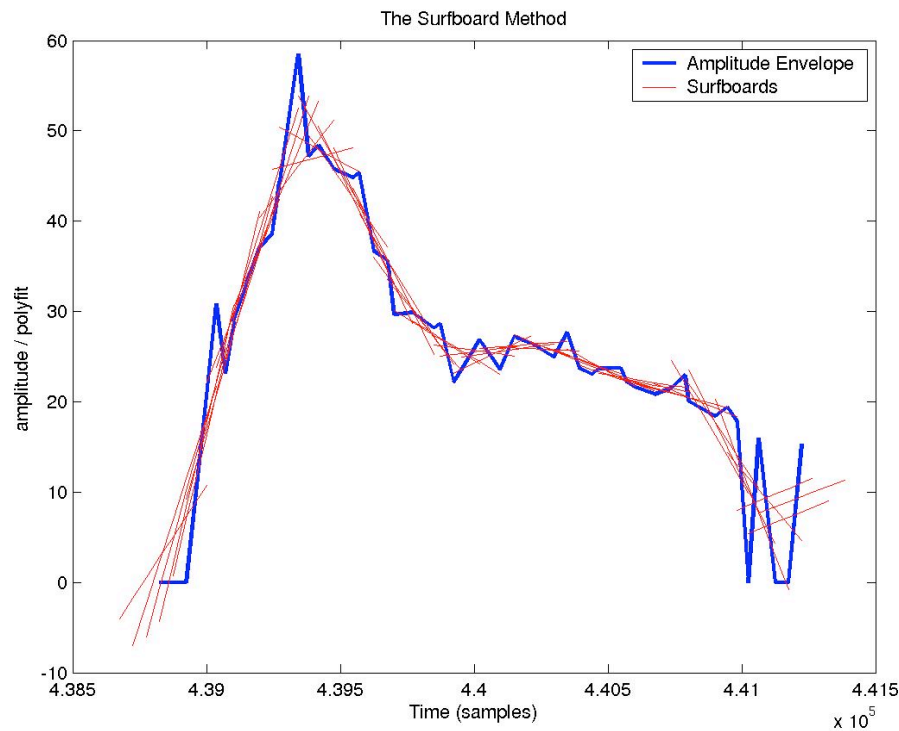detect onsets (each performer)

measure IOI's

merge IOI's

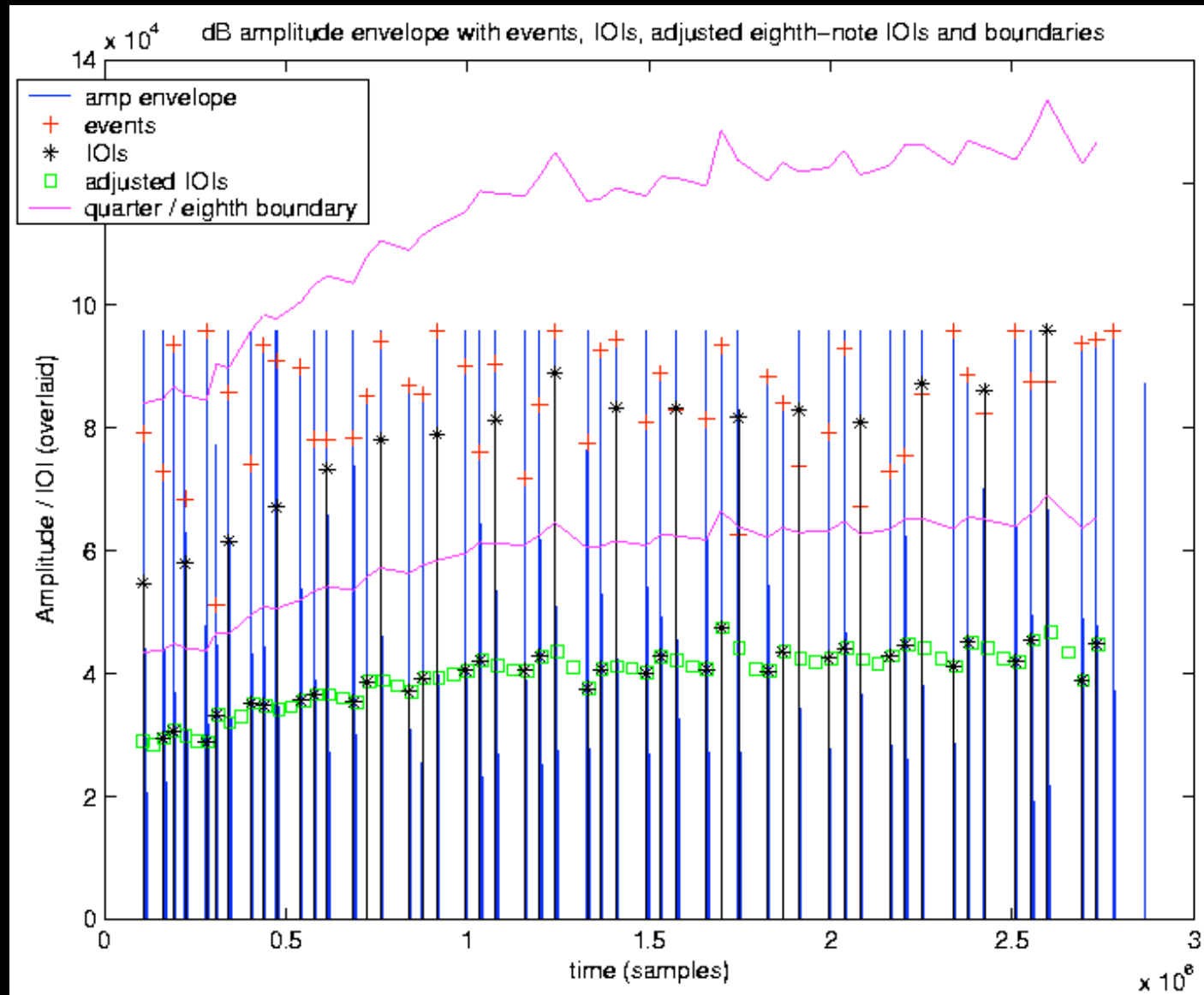track tempo

determine tempo slope (acceleration),
tempo jitter

Onset detection with amplitude "surboard" (Schloss, Smith) ±0.25ms resolution

Short linear regressions at every amplitude envelope point give the instantaneous slope.

High-slope points are candidate events.
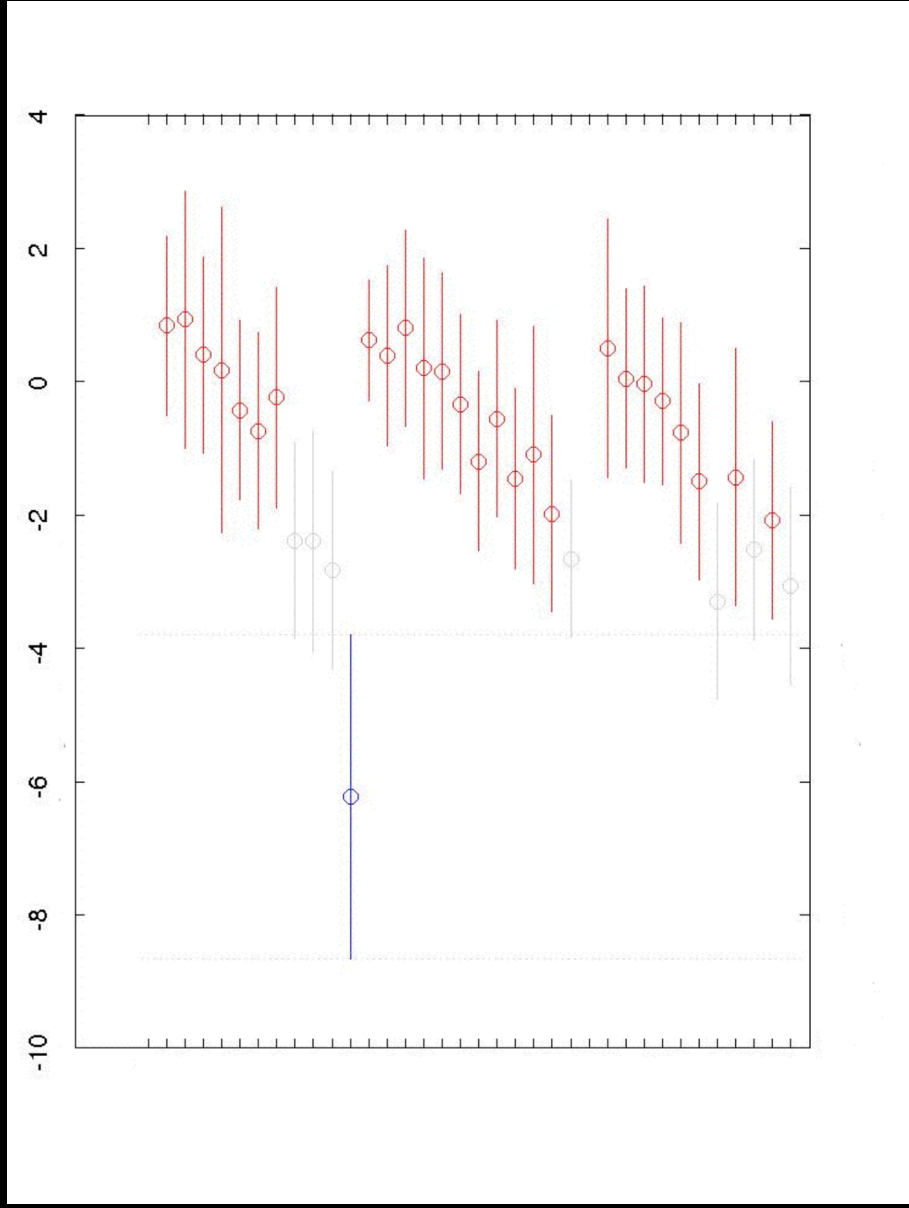
One trial – surfing all events

Results

a) Slope of Performed Tempo vs. Delay Time (all tempi)
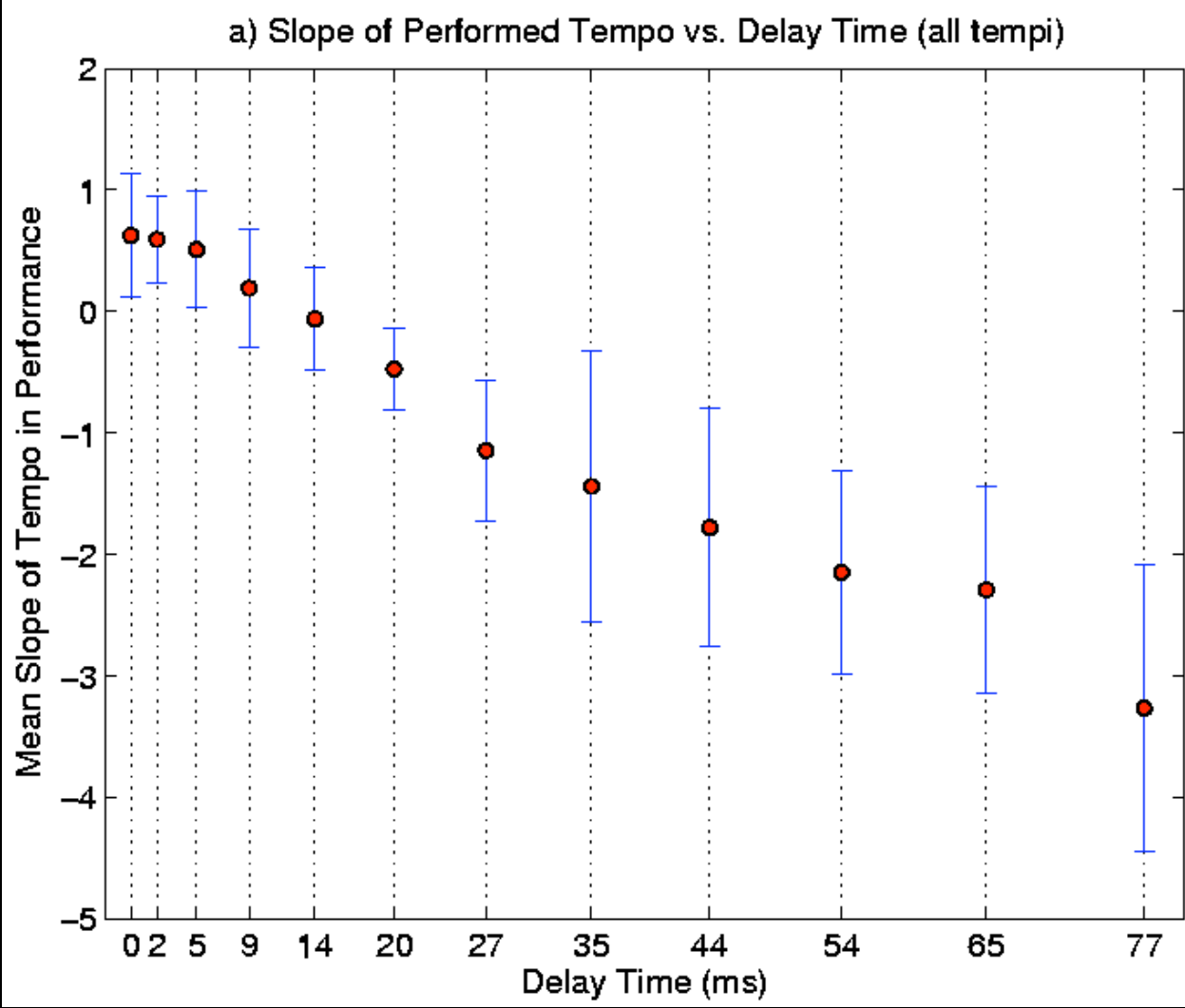
Acceleration vs. delay time
($r^2 = 0.98$)

Starting tempi [86, 90, 94]
no significance

Tempo slope = 0

a) Slope of Performed Tempo vs. Delay Time (all tempi)
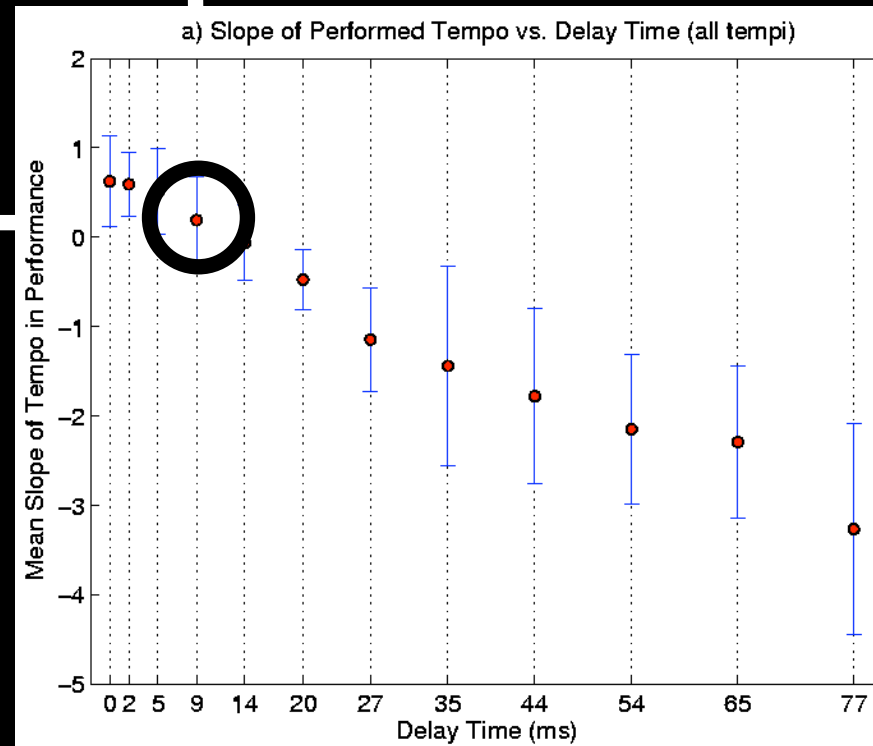
Delay = 11.5 ms

@ Delay < 11.5 ms, 74 % of trials sped up
@ Delay > 11.5 ms, 85% of trials slowed dow

Results
Modeling
Future
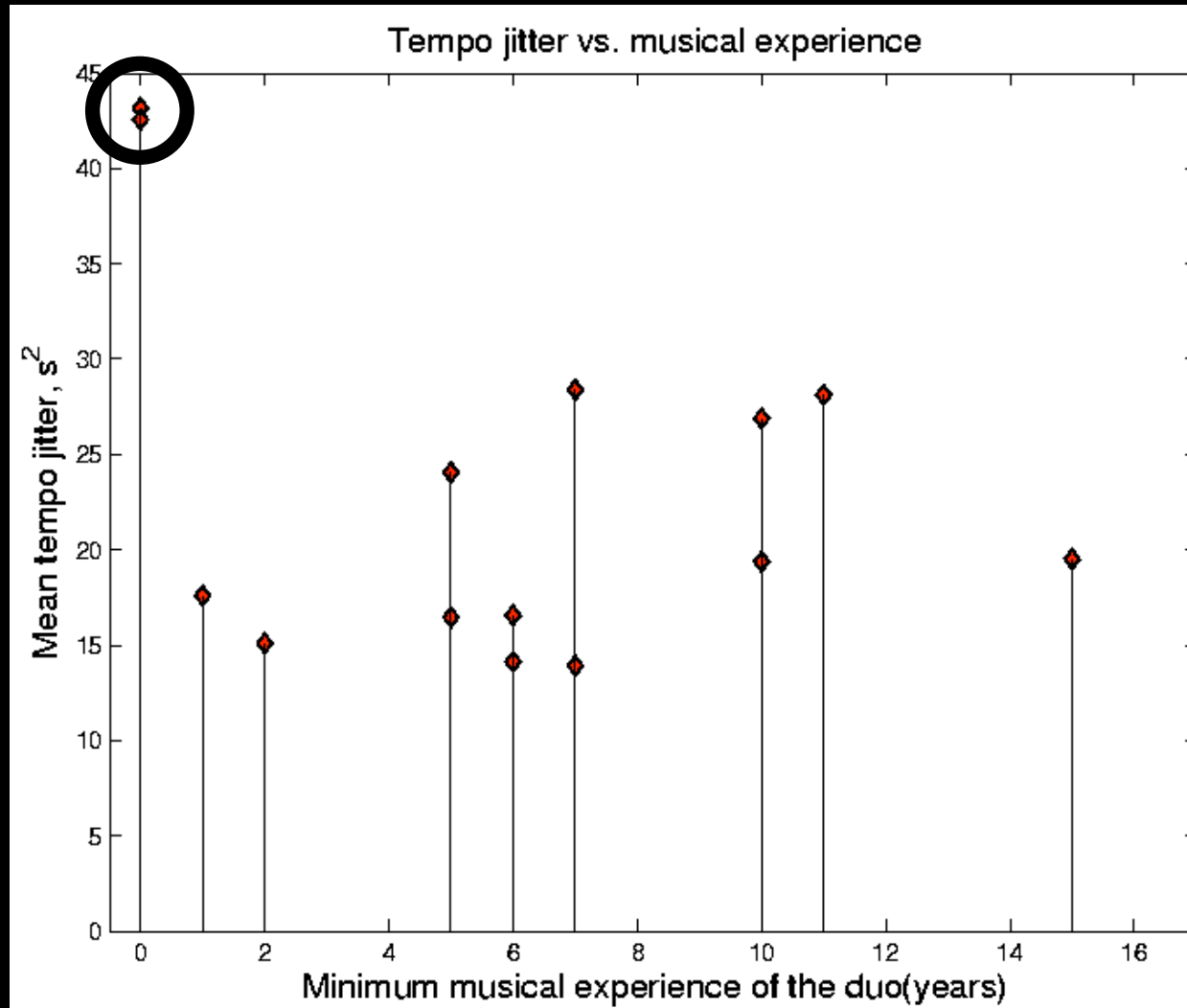
Musical experience

Modeling
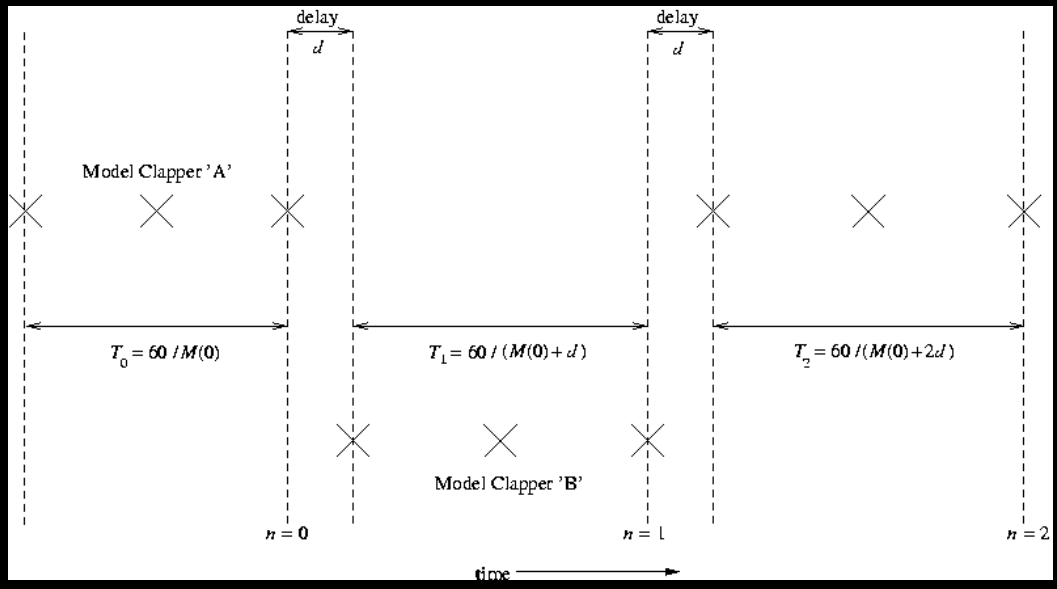
Hypothetical memory-less clapper

Hypothetical memory-less clapper

Polynomial and model fits through tempo – 65 ms delay, tempo = 86
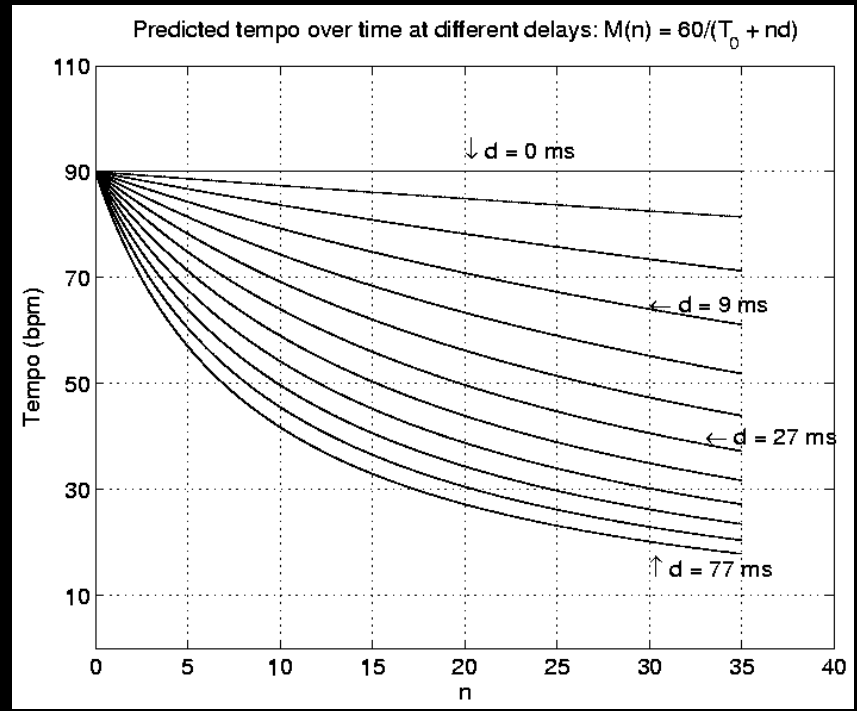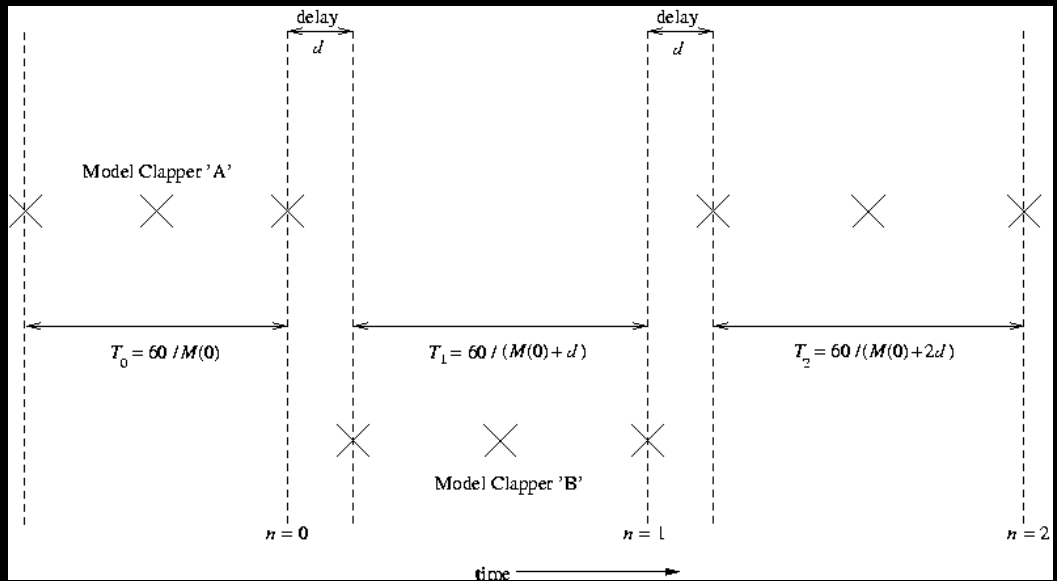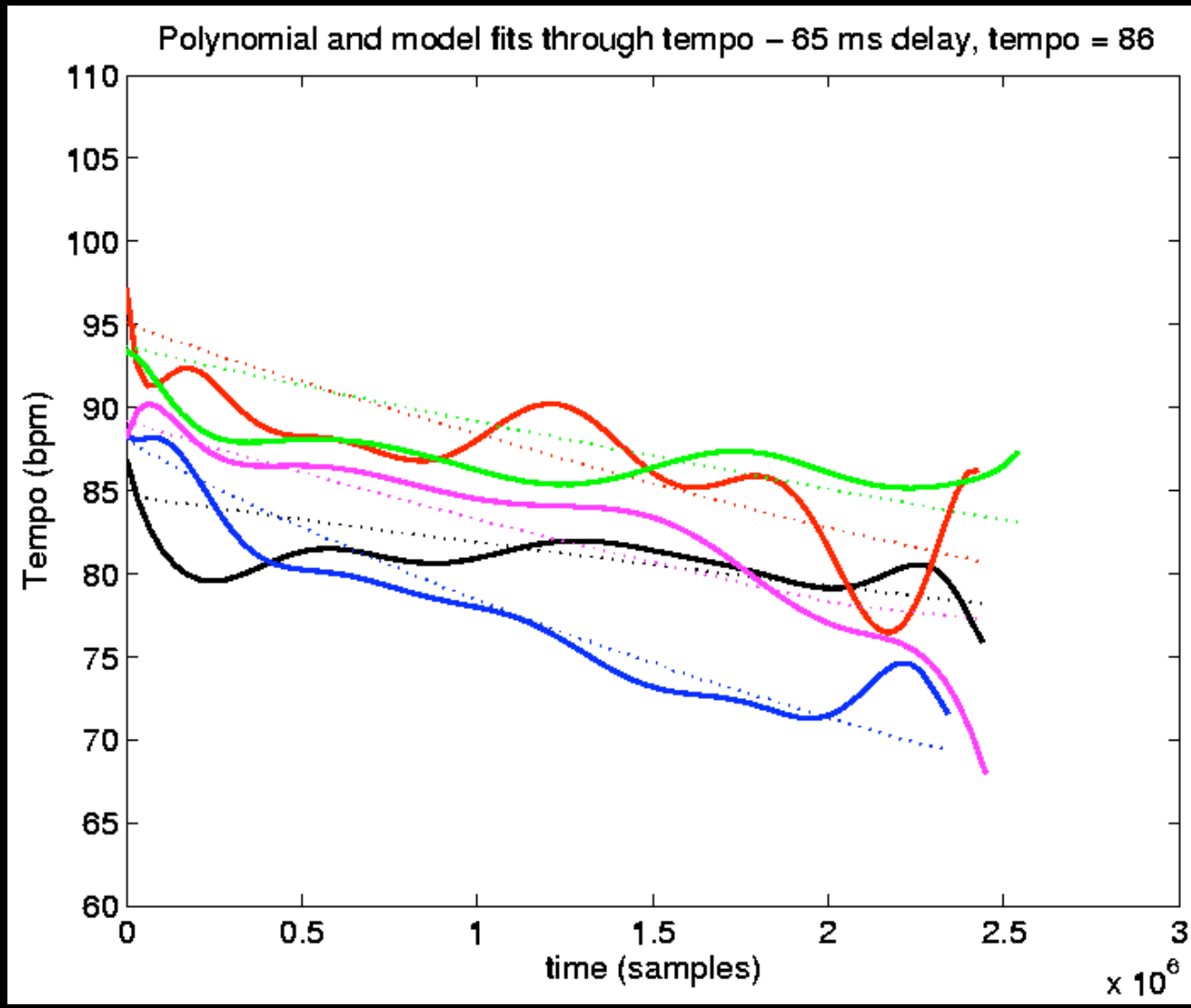
Human clappers at 65ms delay

b) Mean Equivalent Delay vs. Delay Time (all tempi)

Modeling
Future
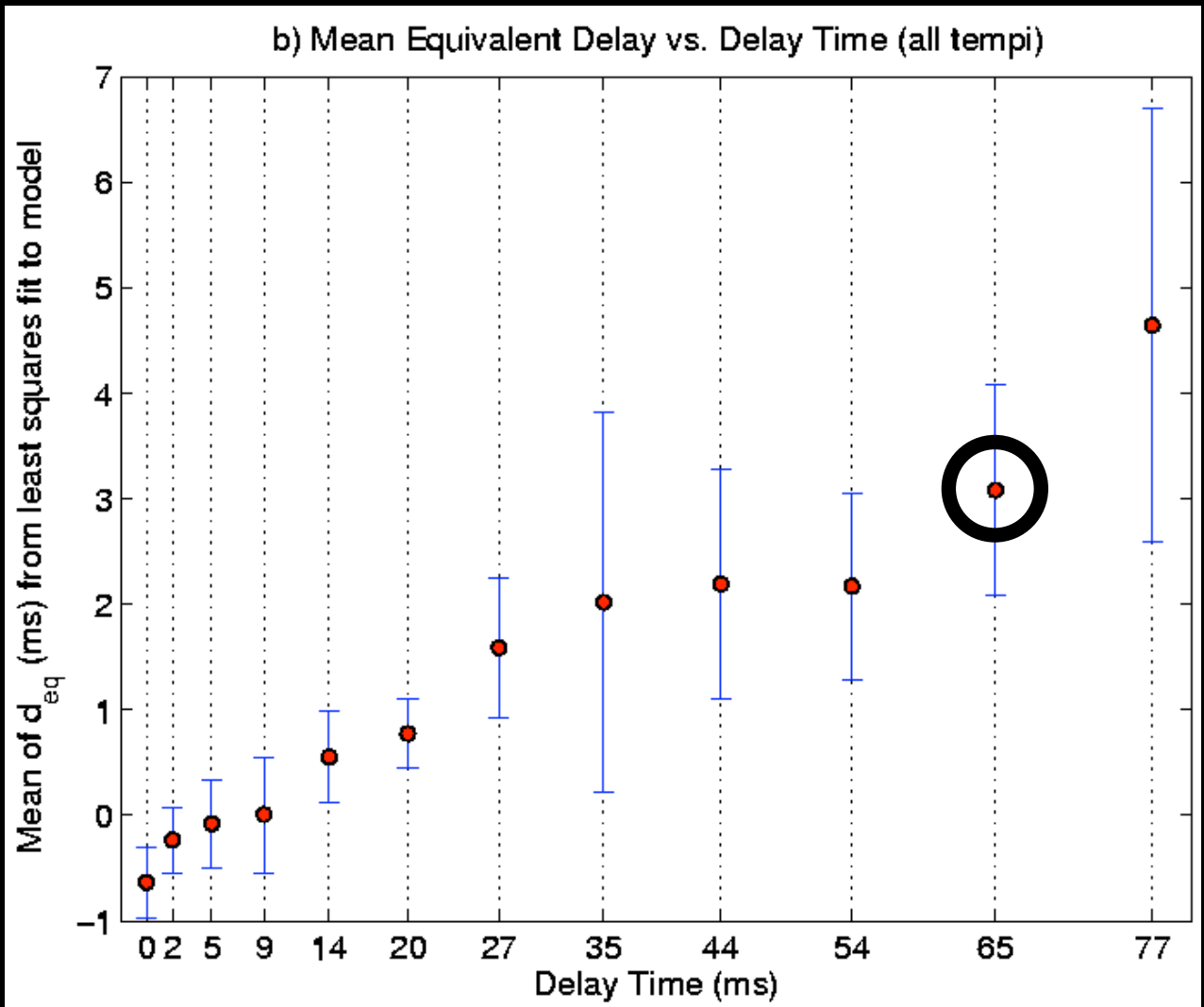
Strong
compensation!!

At 65ms, tempo dropped
only as much as the
memory-less model
at 3ms

Memory-less model equivalent
for human performance at each delay

Future

Experiment 2: asymmetric delays
Experiment 3: tempi from 60 – 120bpm

Future Directions:
Real Music
Real Rooms
Artificial Reverberation