Interactive Networked Music --
Tapping into the Internet as an
Acoustical / Musical Medium

Chris Chafe

Center for Computer Research in
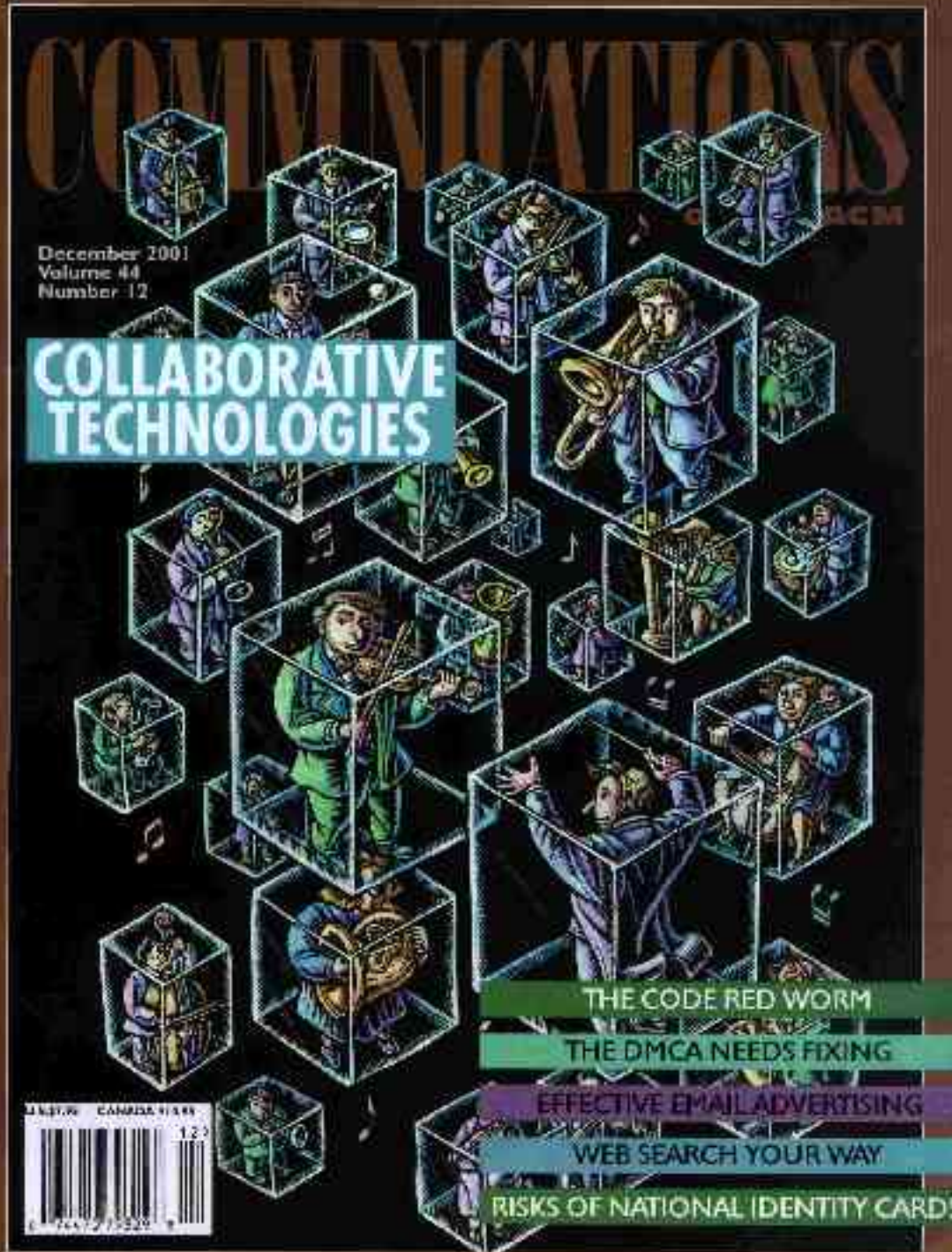Music and Acoustics (CCRMA)

Stanford University

Quantify effects of latency
Find "best delay"
Groundwork for further study

Networked Studios & Stages

...interesting use of our theme as a magazine cover...

Listening quiz – the drums are where?

London ⟶ ◯

◯ Montreal

◯ Chicago

next studio?
Berkeley?
◯ ◯ Denver
◯ Sacramento?
◯

Bass & Sax
at Stanford

NGI Jam Session
Stanford <--> ??
(2002)

Listening quiz – the drums are where?
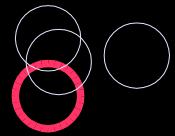
London →○

○ Montreal

○ Chicago

next studio?
Berkeley?
○○ Sacramento? ○ Denver
○

Bass & Sax
at Stanford
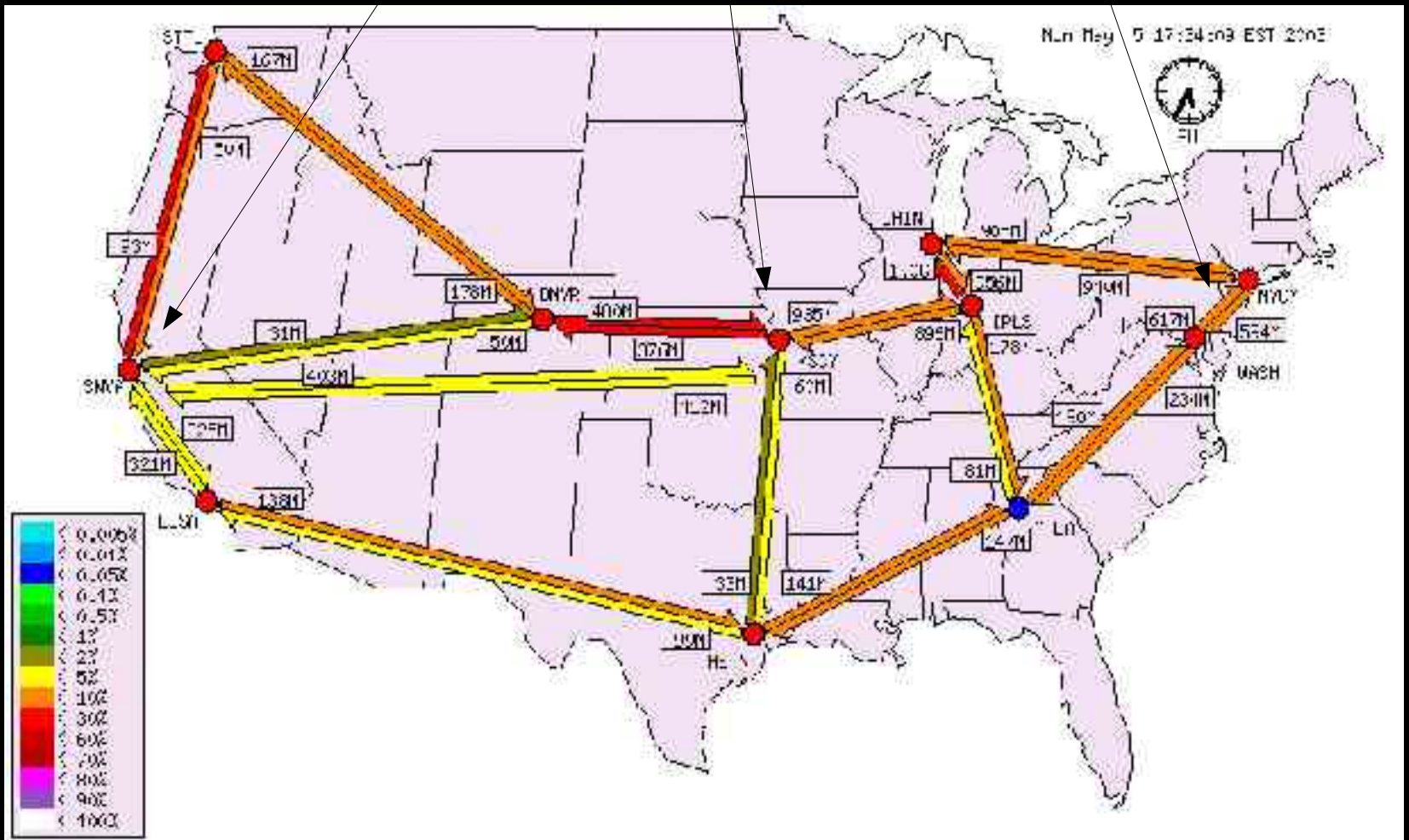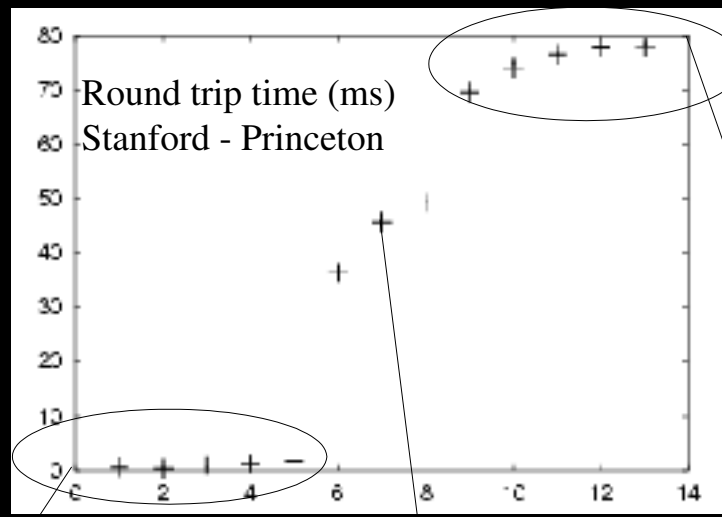
NGI Jam Session
Stanford <--> ??
(2002)

London

Drums are in
Montreal

Bass & Sax
at Stanford

NGI Jam Session
Stanford <--> McGill Univ.
(2002)

Networked ensembles
Related Applications
Experiment design
Results
Future

Round trip time (ms)
Stanford - Princeton

Trio (May, 2004)
Stanford (bass guitar)
Victoria, BC (sitar)
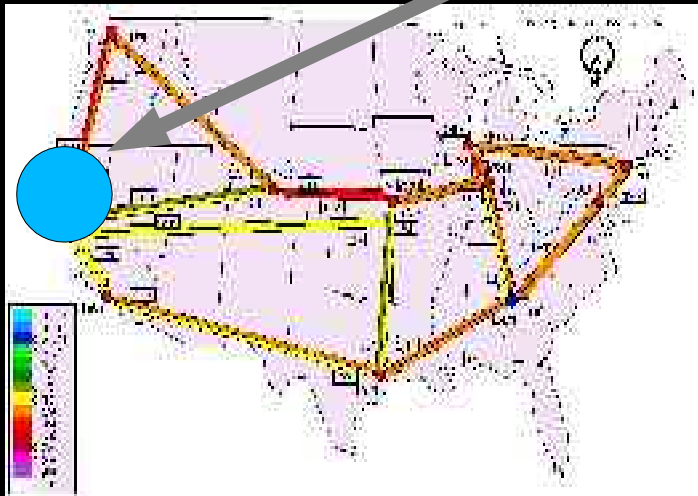### Missoula, MT (elec. Violin)

Piano Duo (July, 2004)
Stanford
Banff, Alberta

Quartet (June, 2004)
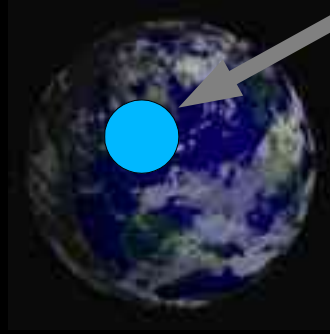Stanford (flute, elec. cello)
Stockholm (bass flute, piano)

Networked ensembles

Next gig?

Acoustical Monitoring for NOC's

NASA
Space Network Emulation
Meteor Crater (2004)
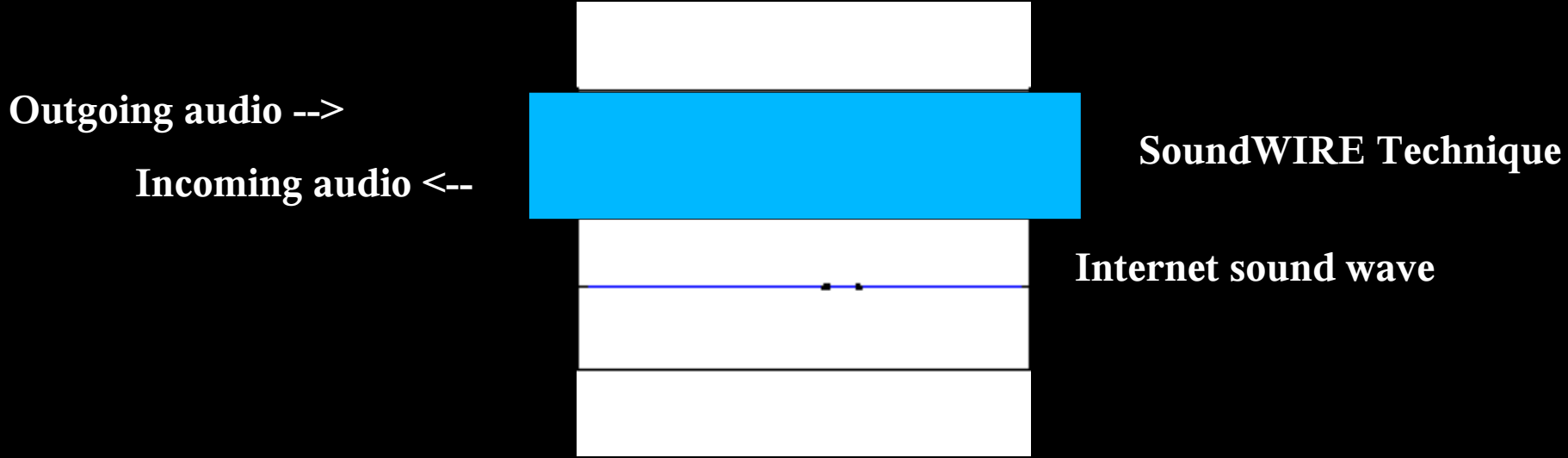
Acoustical Monitoring for NOC's

Acoustical Monitoring for NOC's

next...
"plucking the network"

Sets up acoustical waves
traveling as fine-grained, interactive
flows (Stanford <--> Seattle)

Acoustical Monitoring for NOC's

Outgoing audio -->

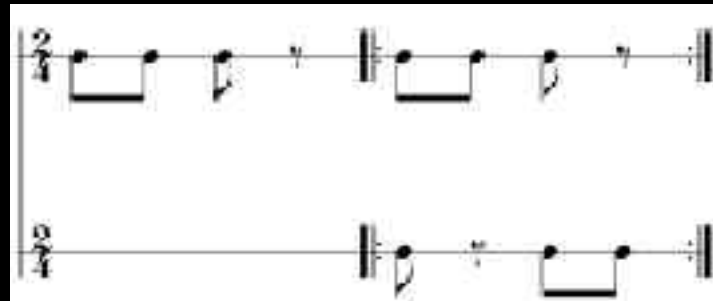**Incoming audio <--**

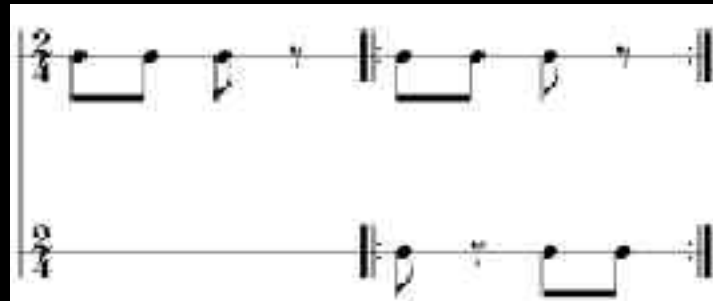**SoundWIRE Technique**

Internet sound wave

Experiment Designed to Determine Effect of Latency on Ensemble Accuracy

Subjects = students and staff at Stanford
(paired randomly)

Task = play rhythm accurately,
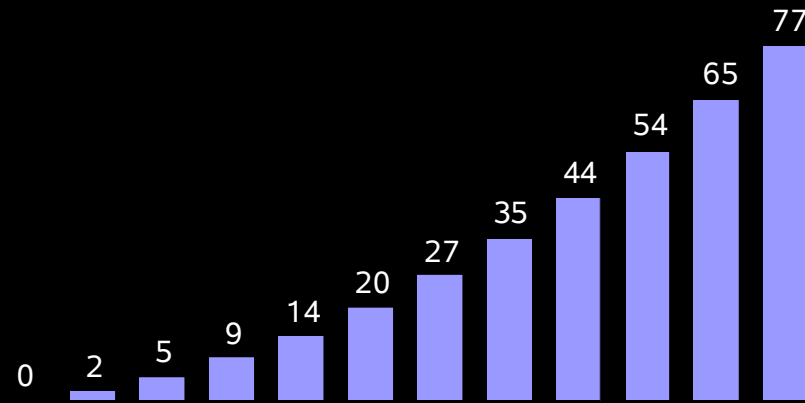   keep an even tempo
(no strategies given)

Interlocking rhythm

Sound
(2ms delay each direction, metronome cue = mm94)

Delays: 0 – 77ms (each way) in 12 steps

Experiment 1 with 17 pairs of subjects

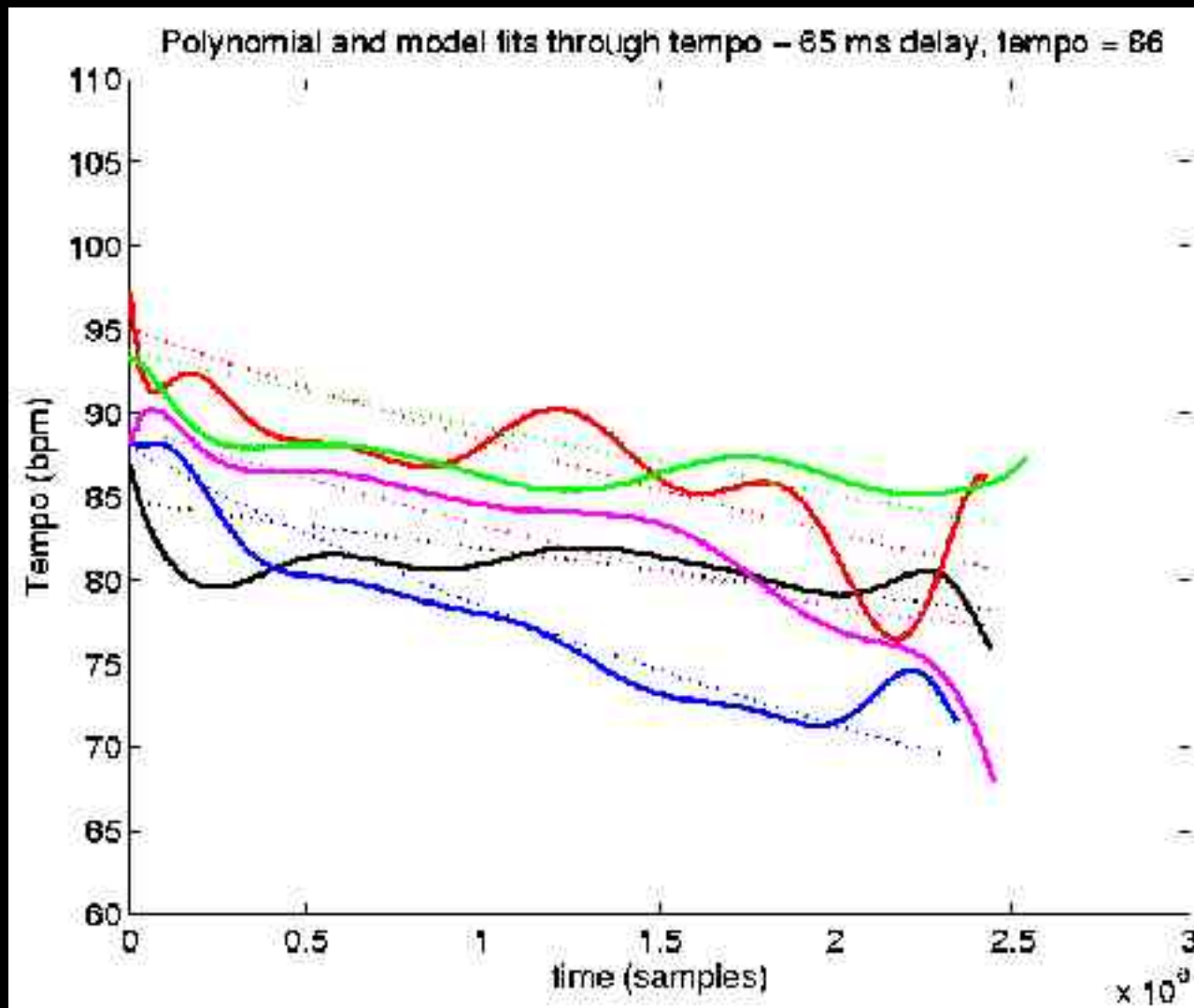Deceleration from longer delay
but where does it start to cause
trouble?

Sound

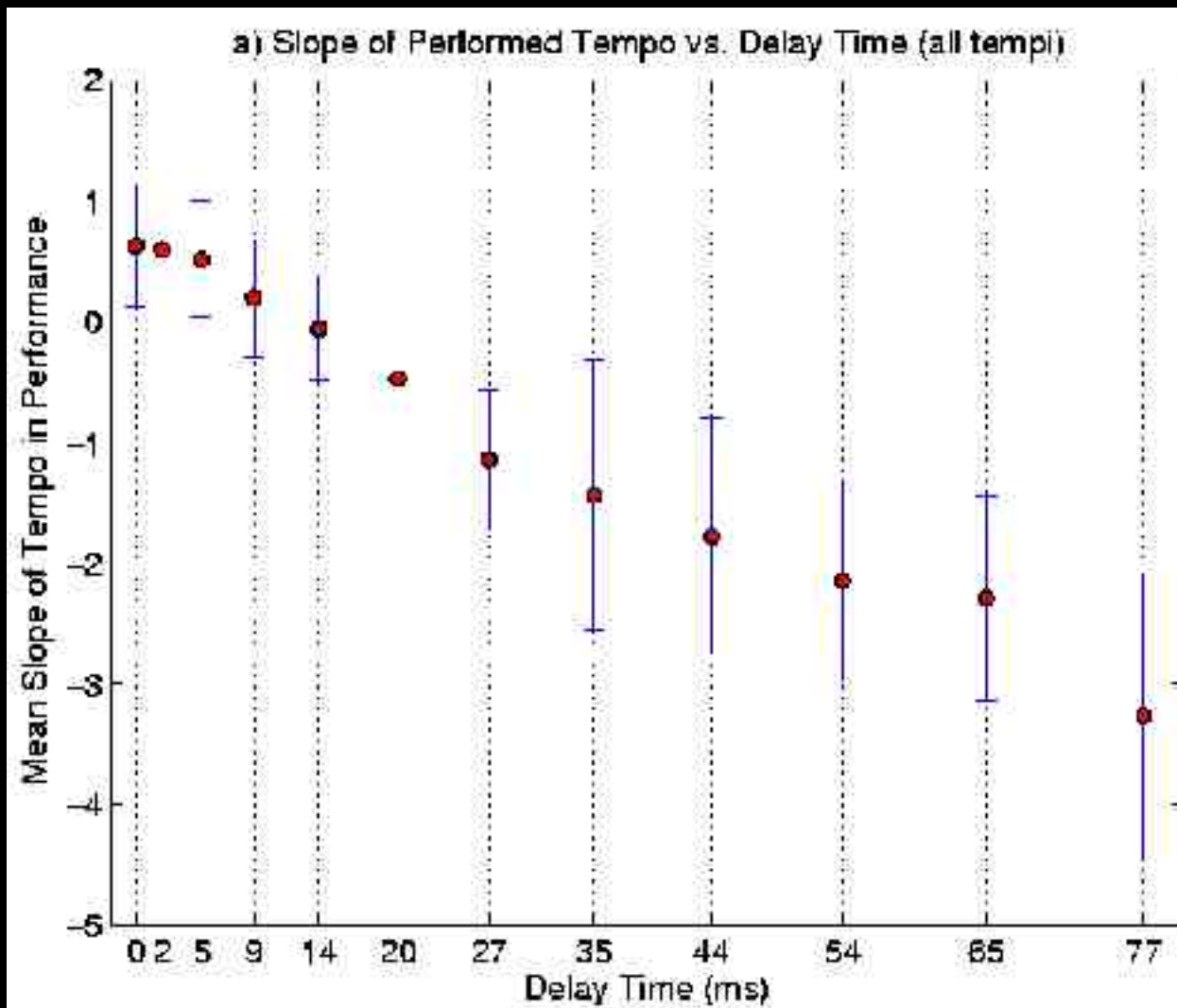(77ms delay each direction, metronome cue = mm90)

Results

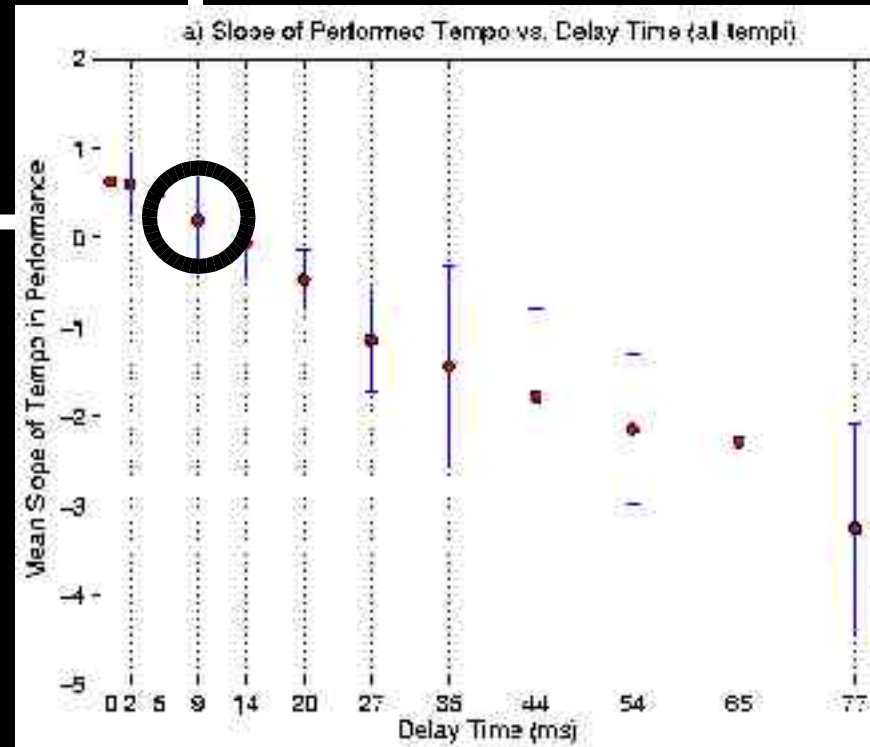Human clappers at 65ms delay

Acceleration vs. delay time
$(r^2 = 0.98)$

Tempo slope = 0

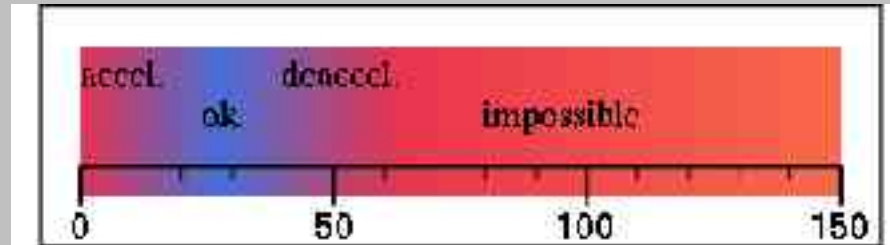Sweet Spot?

Delay = 11.5 ms

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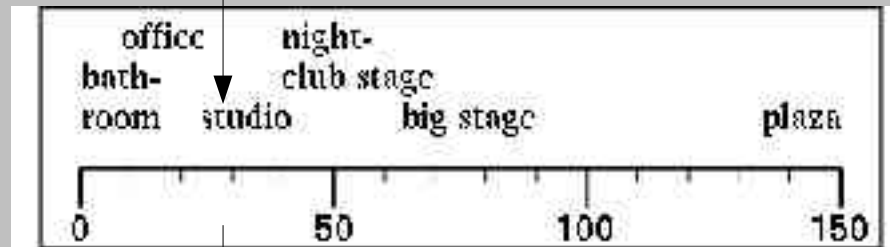@ Delay > 11.5 ms, 85% of trials slowed down

Tested two clappers holding a rhythm across different round-trip delays (ms).
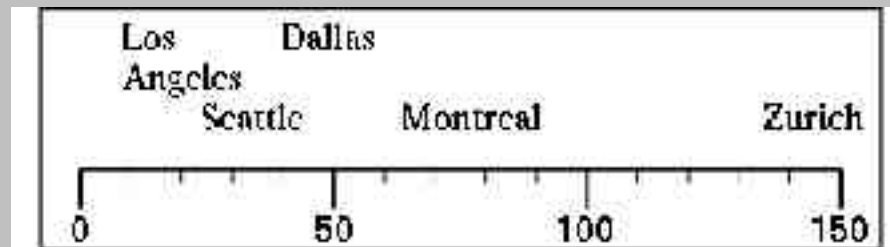

Equivalent separation at
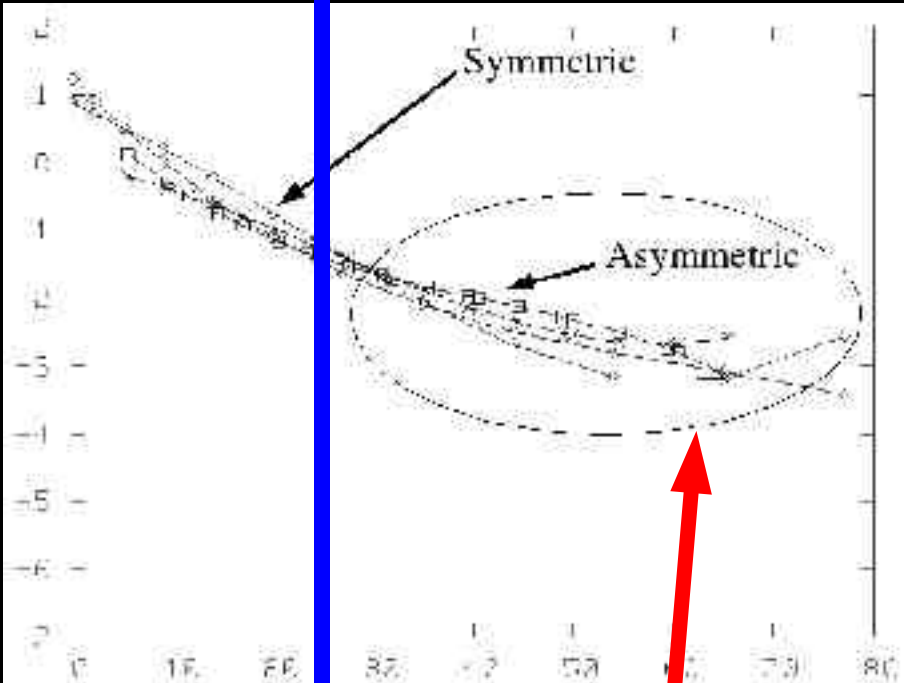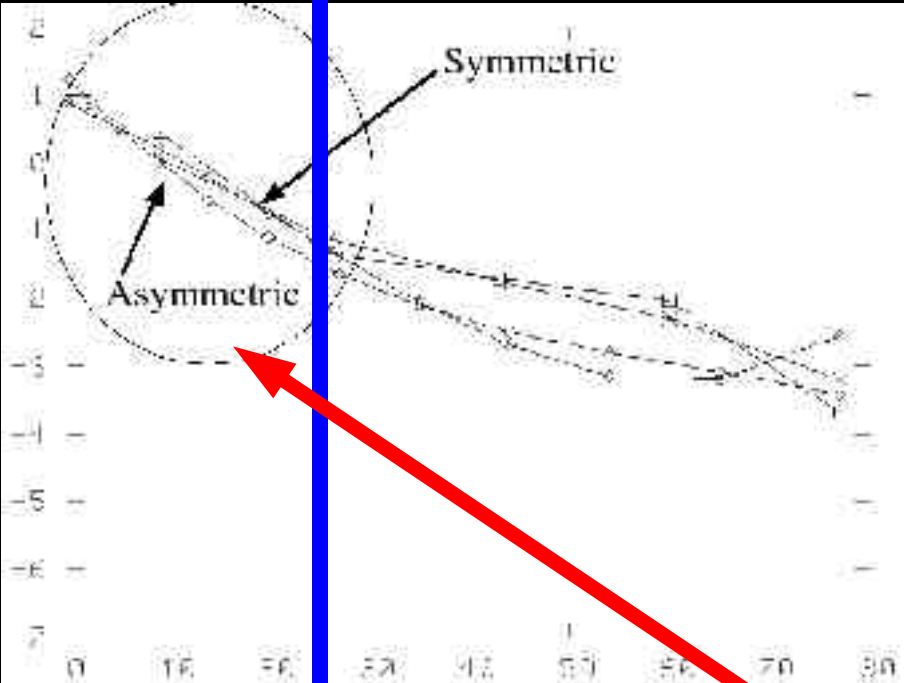
-- speed of sound

(1ft = 1ms)

-- speed of light

(0.7c for network transmission)

Asymmetry

Best match: < 25ms = longest delay
> 25 ms = mean of delays

Acoustical / Musical Media: air, water, earth, etc.

Current Projects

Internet Reverberation with "Echo Construction"
SlipStream Recording Technique
Integration with Ethernet-based Audio for Home Use

Longer-term Goals

Home-to-home Music Collaboration

Interactive Immersive Audio Environments (games, etc.)

Concert-qualityTeleconference Audio

Collaborators / Supporters

McGill University
Internet2
Banff Centre for the Arts
NetworkSound, Inc.

NSF
MediaX, Stanford
OTL, Stanford