

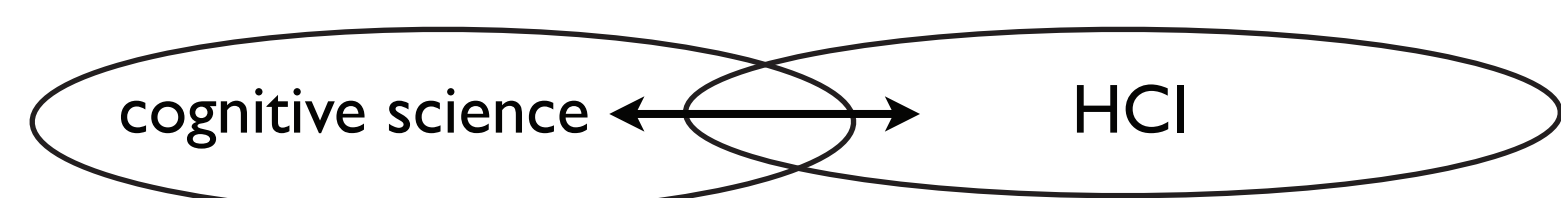
Sonic Feedback to Movement - Learned Auditory-Proprioceptive Sensory Integration

Tamar Regev^{1,2,3} Armin Duff² Sergi Jordá³

1- Edmond and Lily Safra Center for Brain Sciences, and the Interdisciplinary Center for Neural Computation, The Hebrew University of Jerusalem, Israel
2- SPECS -Synthetic Perceptive Emotive and Cognitive Systems, 3- MTG - Music Technology Group, Universitat Pompeu Fabra, Barcelona, Spain

Introduction

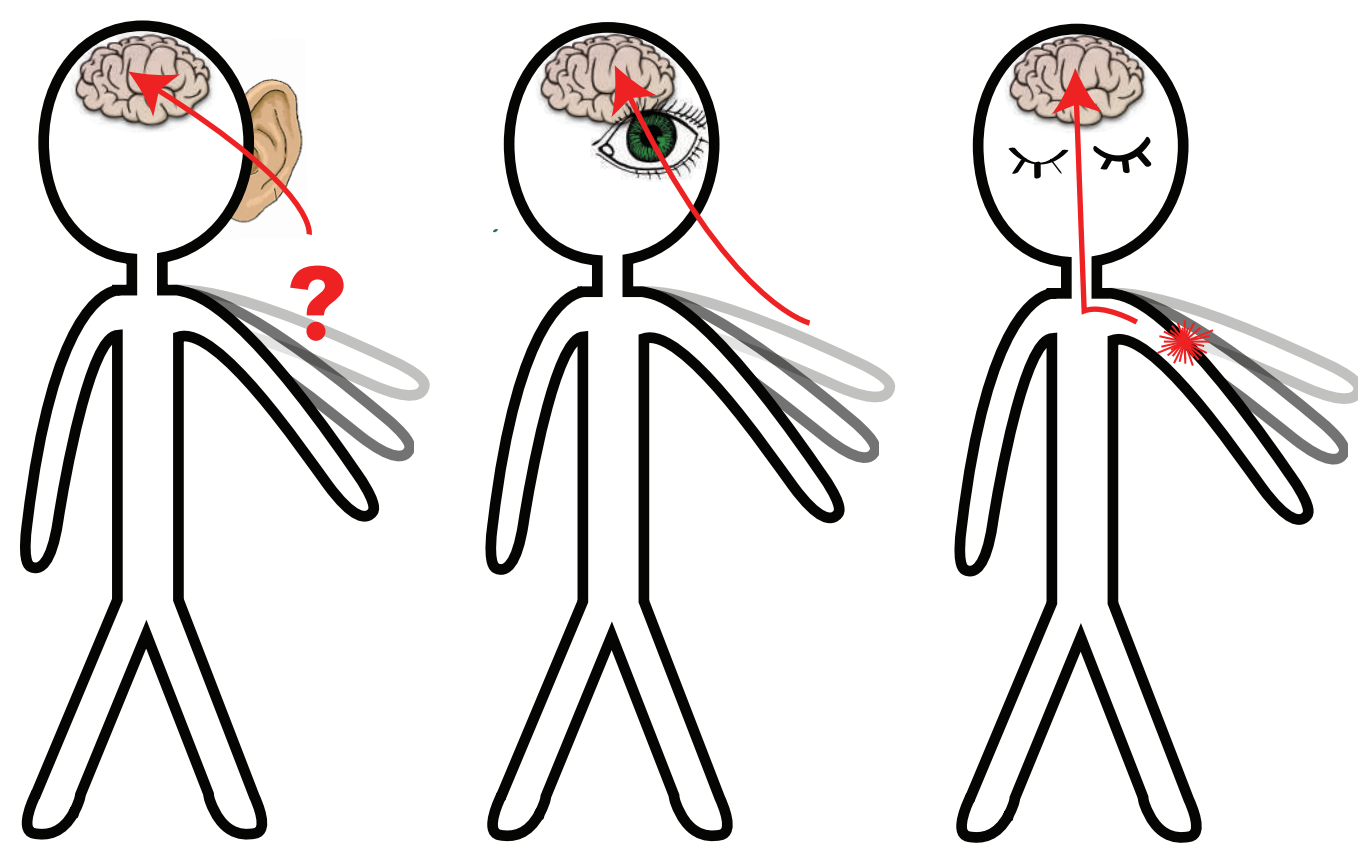
- Profound effect of **music** and **sound** on **bodily movement**
- Recent **technological advances** - Human Computer Interaction (HCI)
- Possible implications for **sonic movement rehabilitation**



- **Proprioception** 'proprius' = own knowledge of relative positions and movement of body parts

Sensory integration

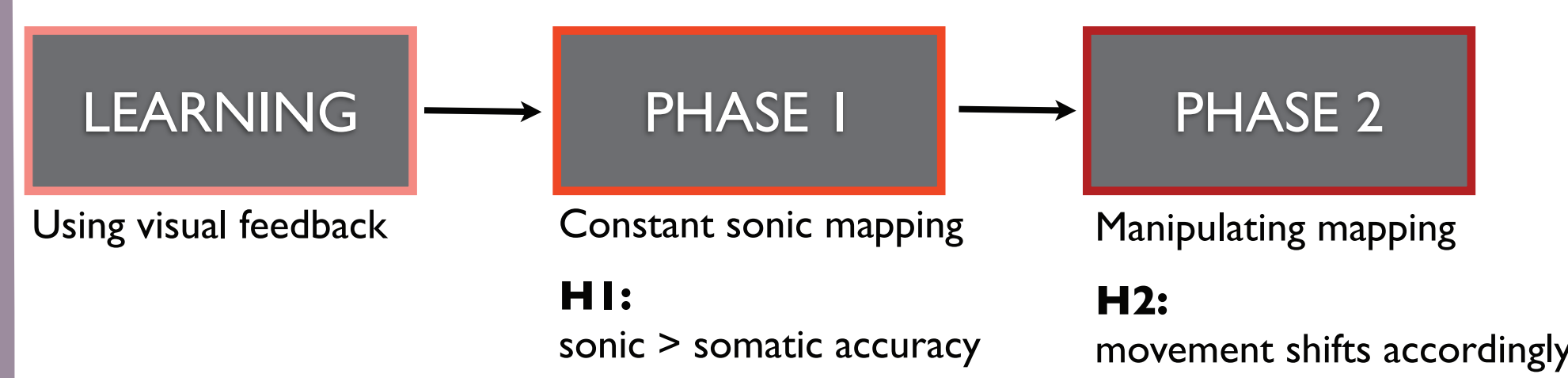
- natural
 - Somatic proprioception
 - Visual proprioception: Alien hand illusion [Nielsen 1960, Sorensen 2005]
 - Auditory proprioception?...



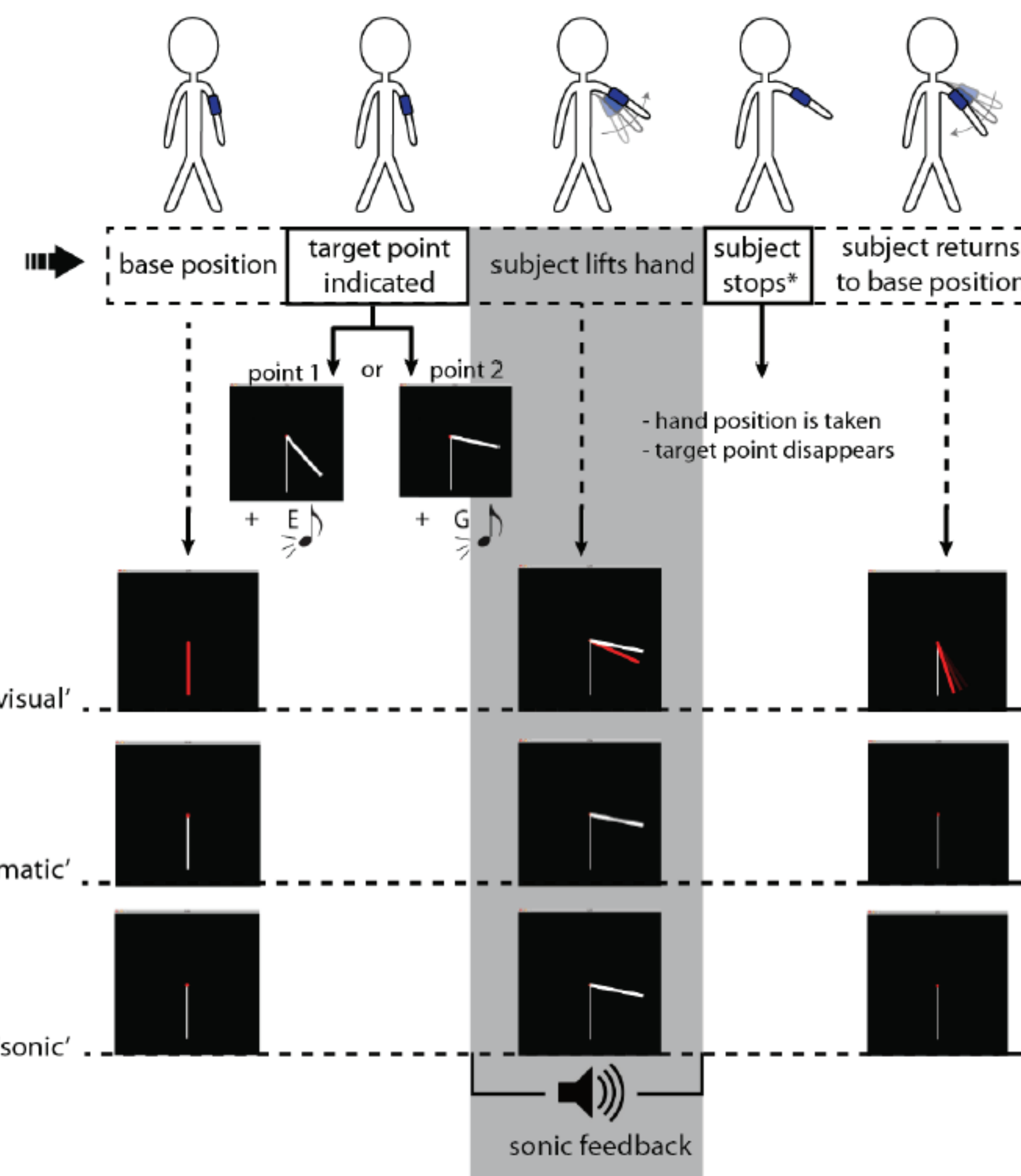
- learned
 - Sensory substitution [Bach-y-Rita 2003] fast, efficient, brain plasticity
 - Sound - Action association [Mutchler 2007] hand movement - piano melodies

Experiment Design

- **Goal** - assess effect of sound on movement
- **Operationalization** - motor task
- **Hypotheses** -
 - H1.** sonic feedback improves accuracy
 - H2.** manipulation of mapping affects movement accordingly



Motor Task -

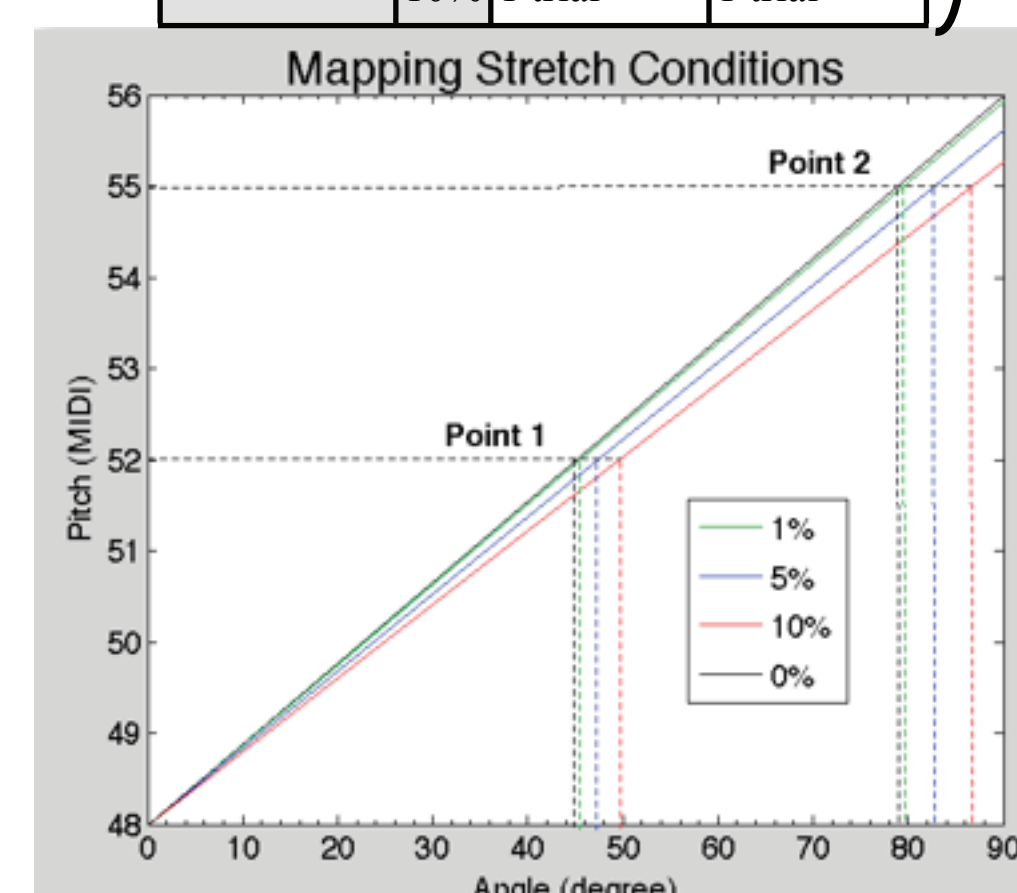


Conditions and stimuli -

	PHASE I		PHASE 2	
	Point 1	Point 2	Point 1	Point 2
Somatic	3 trials	3 trials	3 trials	3 trials
Sonic	3 trials	3 trials	1% 1 trial	1% 1 trial
			5% 1 trial	5% 1 trial
			10% 1 trial	10% 1 trial

x3

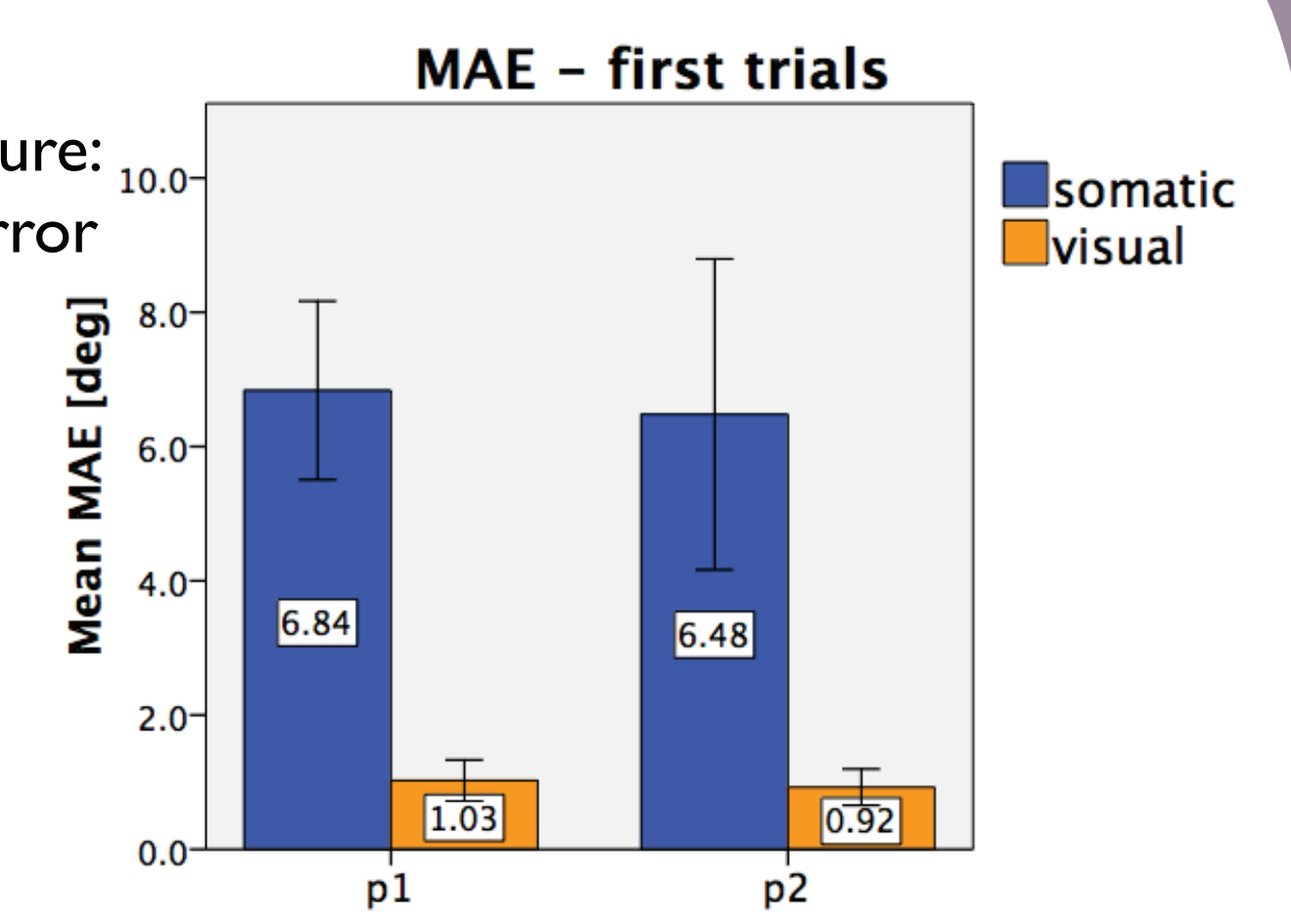
- Repeated measures
- Randomized



- Subjects not informed about manipulation
- Asked if noticed at the end

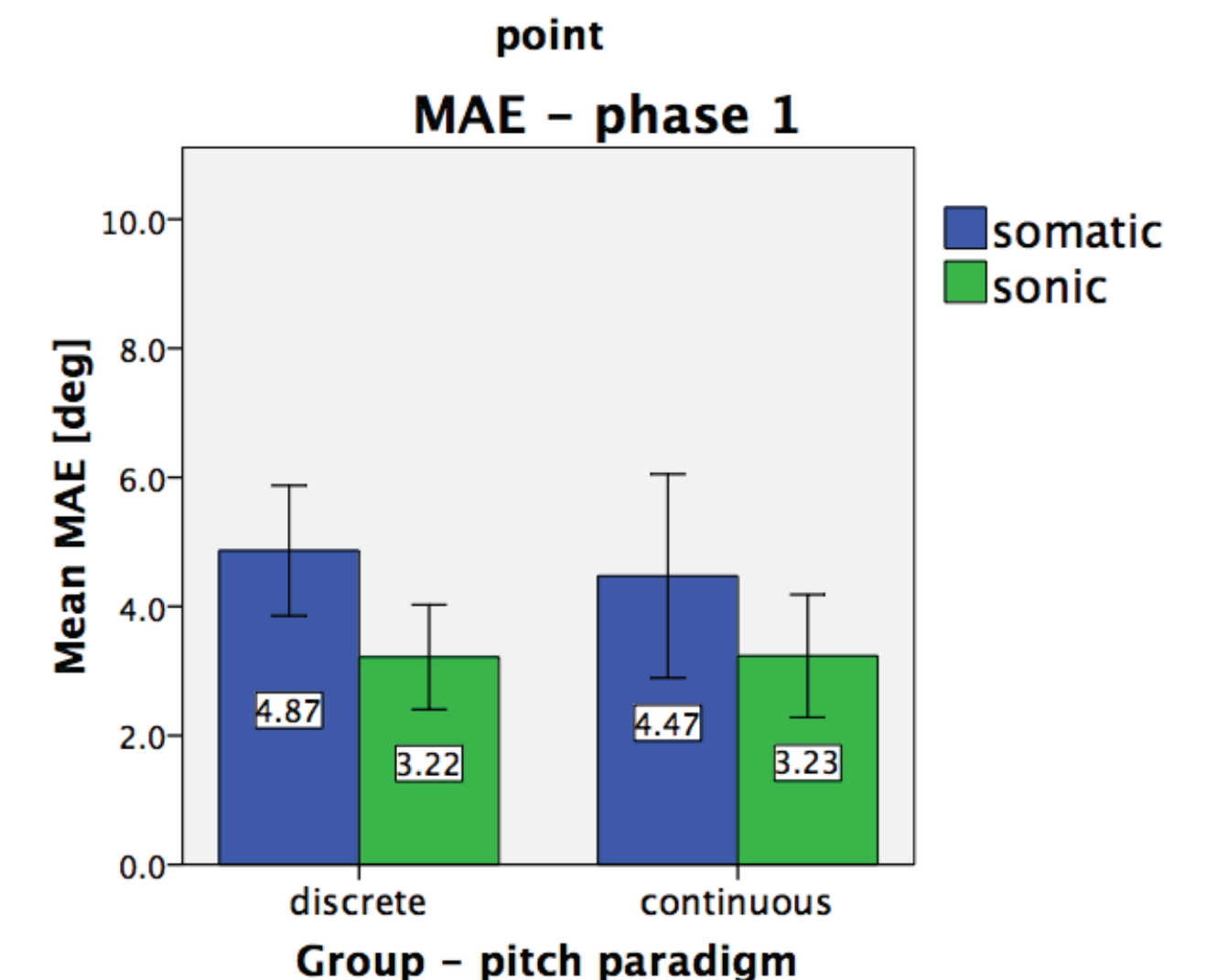
Results

- **Phase I - Accuracy** measure: Mean Absolute Error (per subject)

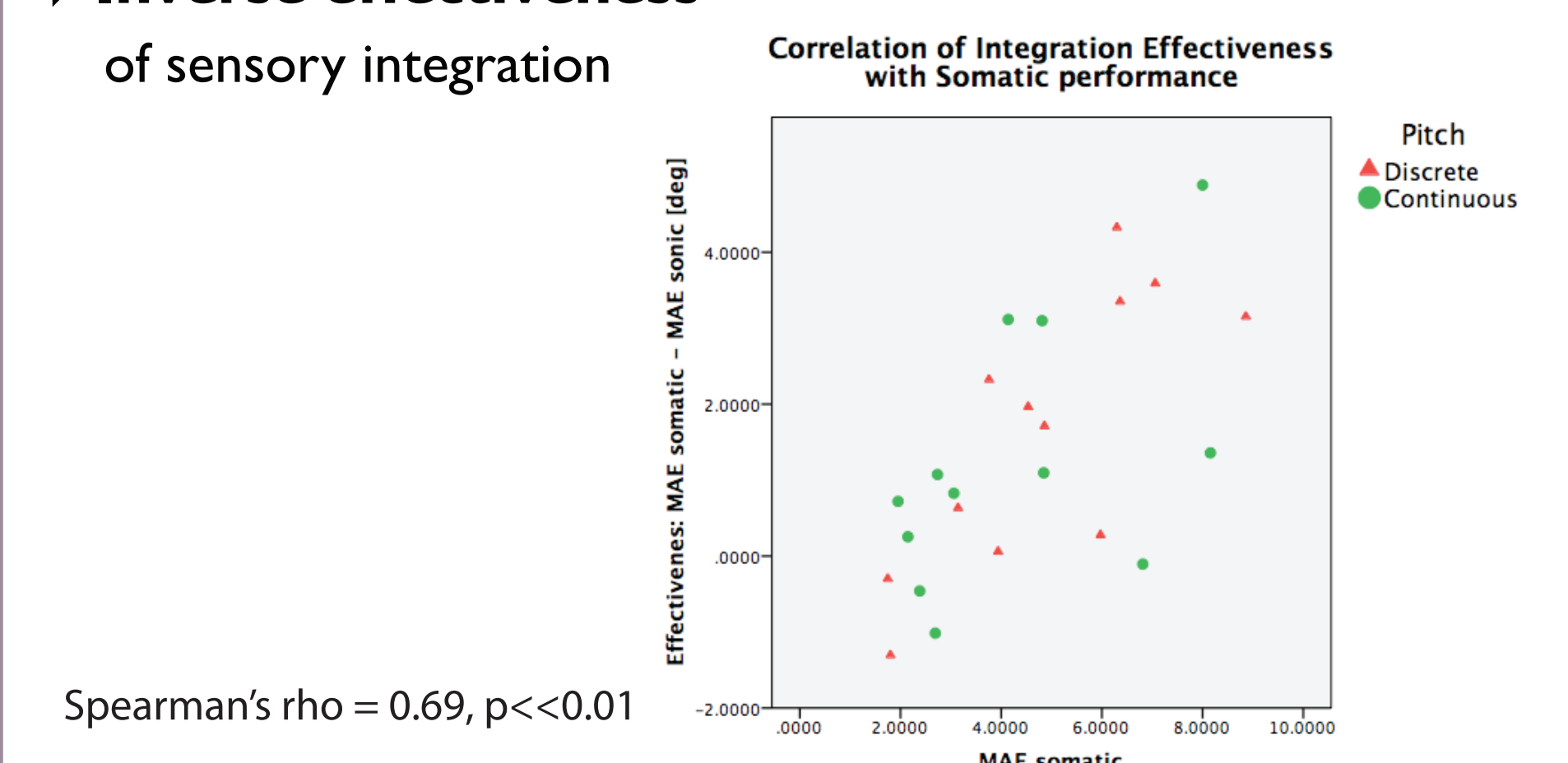


- **H1** significant in both groups

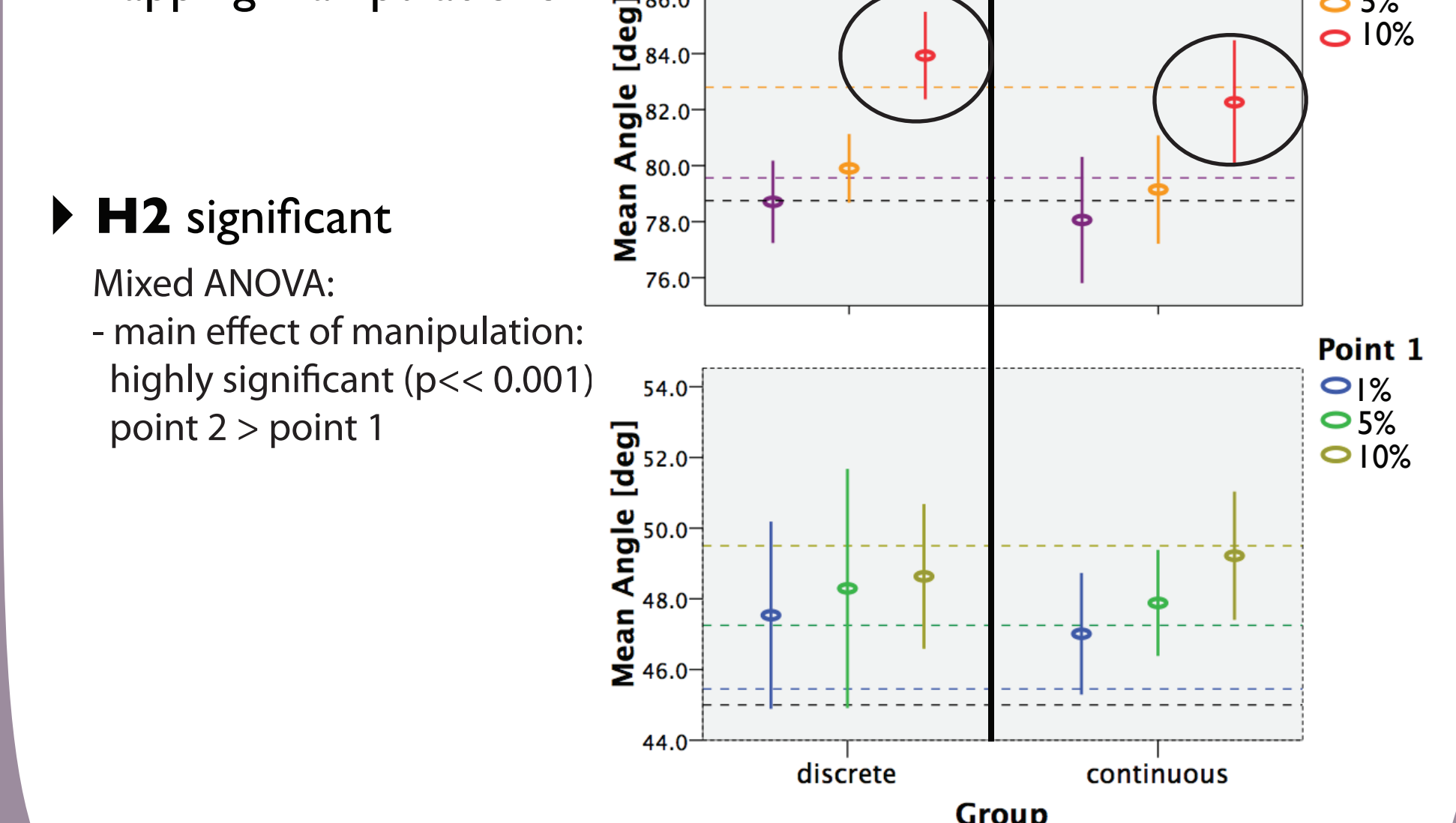
Discrete: $p = 0.015$
Continuous: $p = 0.023$ (2-tailed)



- **Inverse effectiveness** of sensory integration



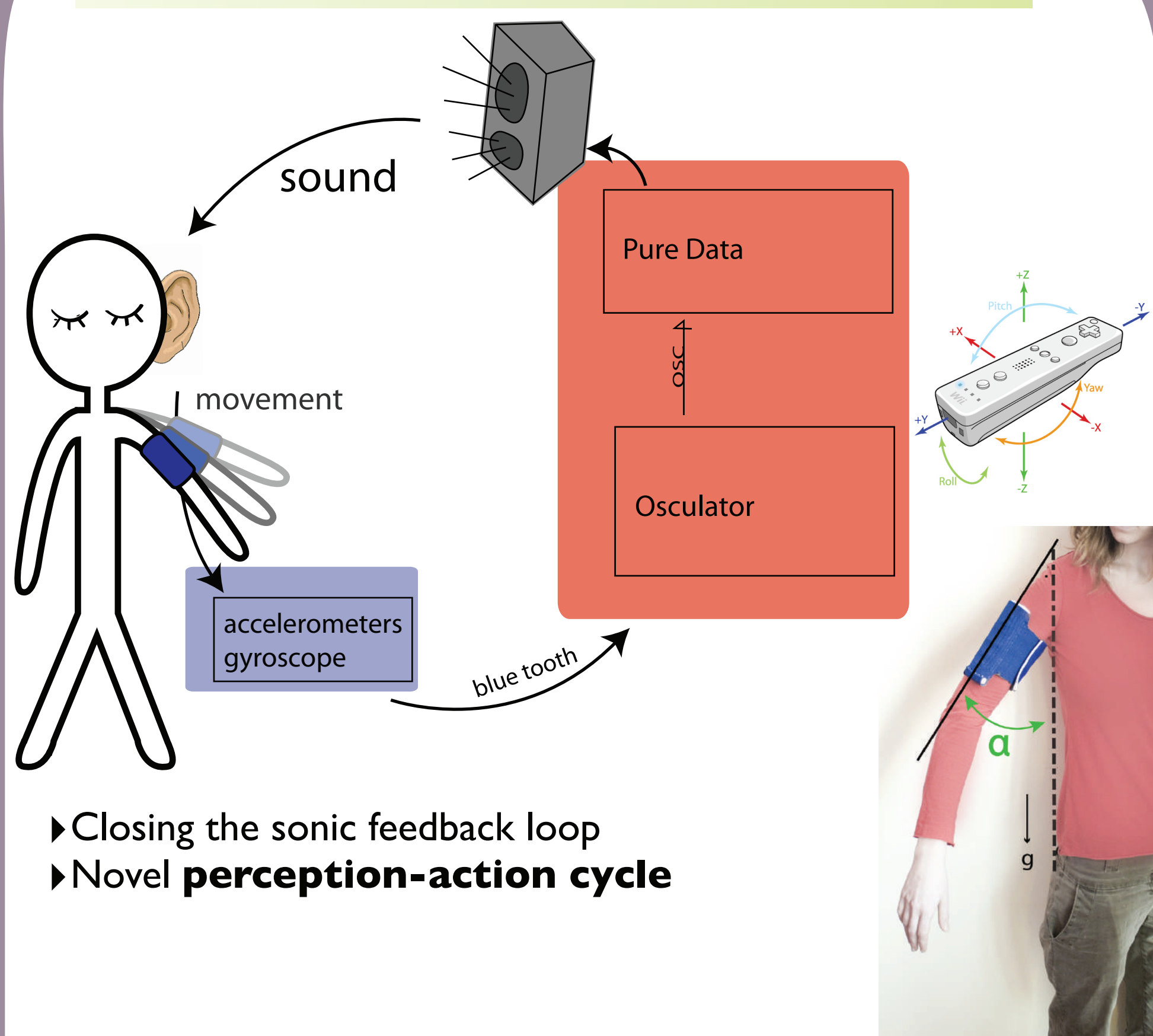
- **Phase 2 - Mapping manipulations**



- **H2** significant

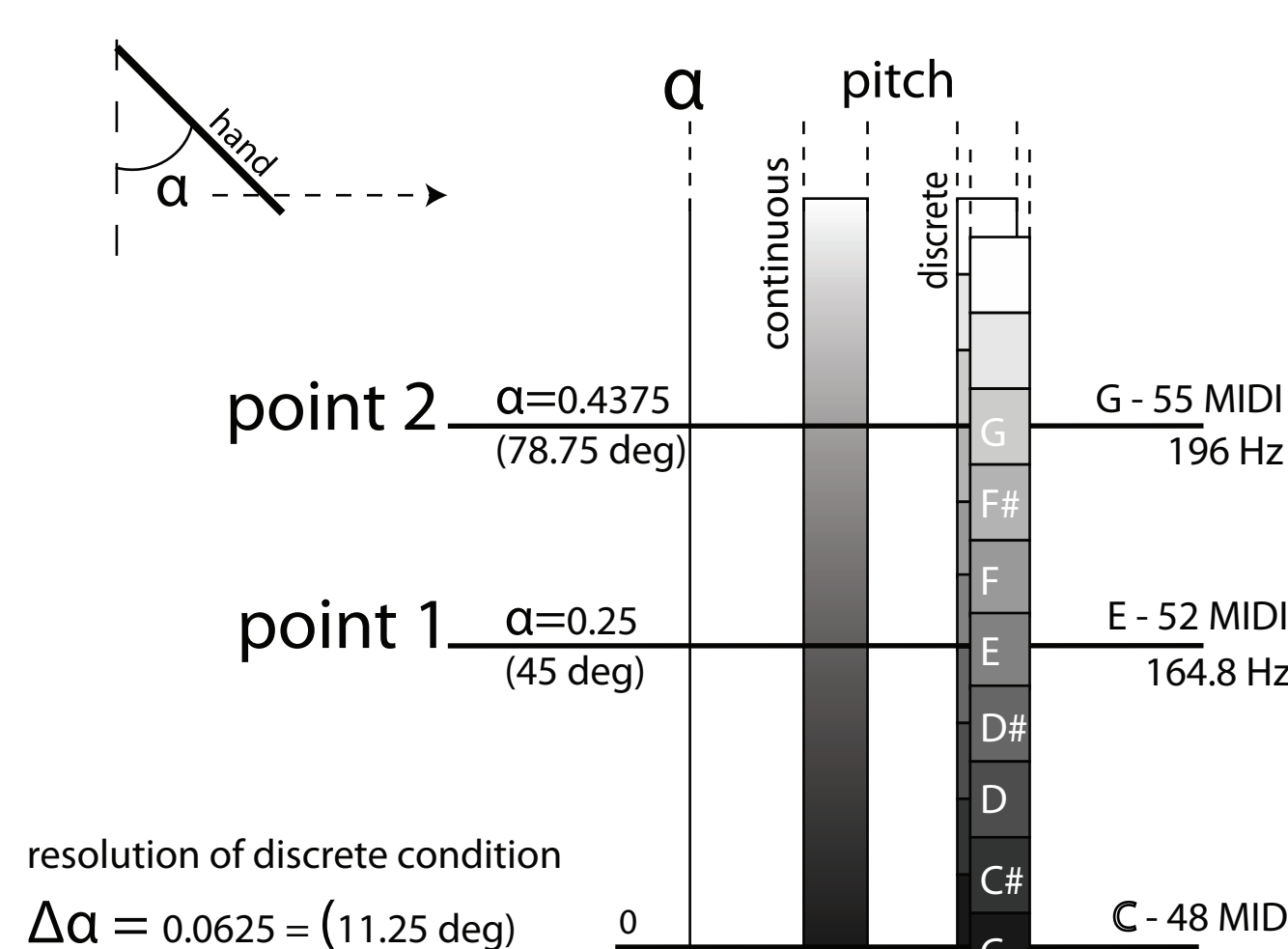
Mixed ANOVA:
- main effect of manipulation: highly significant ($p << 0.001$)
point 2 > point 1

Methods



- Closing the sonic feedback loop
- Novel **perception-action cycle**

- **Mapping** - α angle to pitch



Conclusion

- Quantitative assessment of **learned sensory integration**
- **Effective**, fast utilization of sonic feedback
- Manipulation of mapping - possible **technique for movement rehabilitation reinforcing sound**

Future Work

- Dependence on hearing abilities
- Continuous/discrete pitch
- Awareness to manipulation

Limitations

- Sound design
- Sensor design