# Optimizing Signal Parameters to Enhance Echoacoustic Perception in Humans

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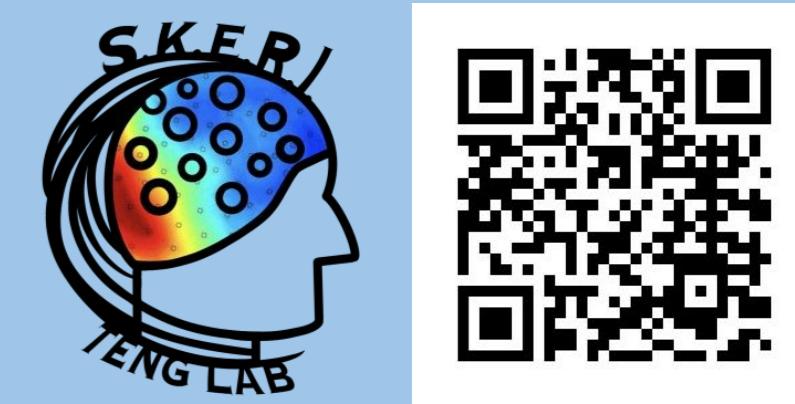
Introduction

Background

- Some blind humans use tongue-click echolocation to perceive and navigate their environment [1,2].
- Some echolocation aids use bat-inspired ultrasonic echoes, which carry higher spatial resolution to aid navigation and perception. [3,4,5].
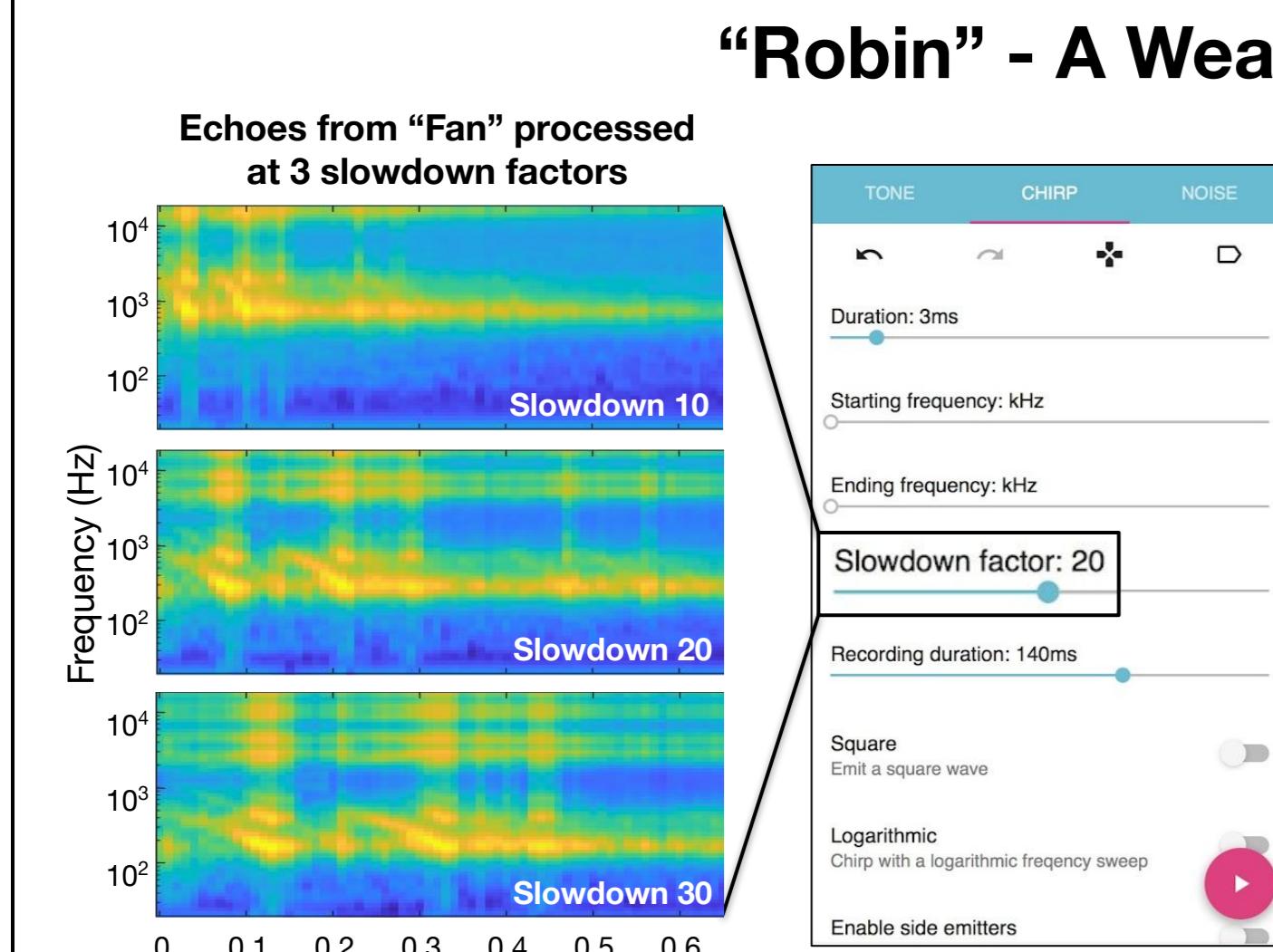
Research Questions

1. Can novices discriminate slowed ultrasonic echoes from different objects or scenes?
2. Can novices match slowed ultrasonic echoes from objects or scenes to their images?
3. Does echoacoustic perception benefit from slower echoes?

**"Robin" - A Wearable Echolocation Aid**
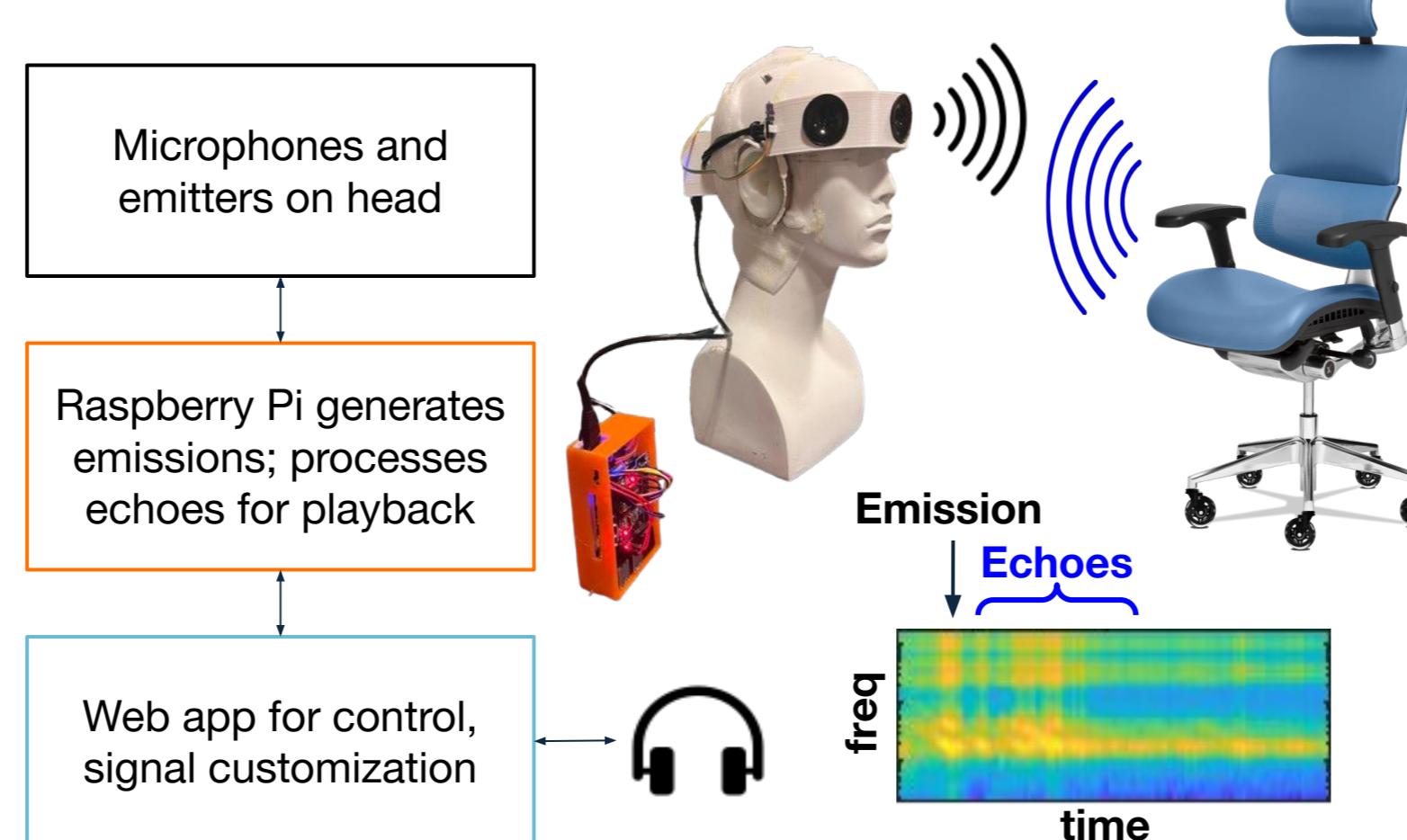

General Methods

Tasks:

E1: Echo discrimination (unimodal)
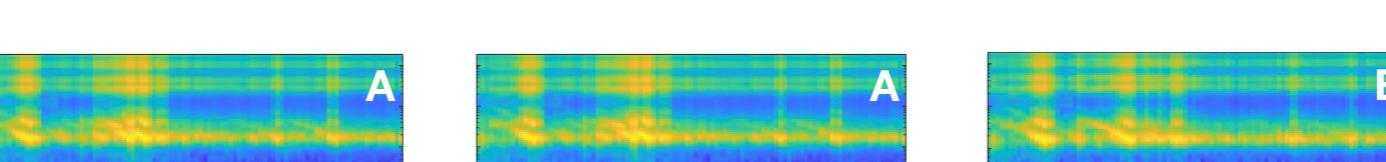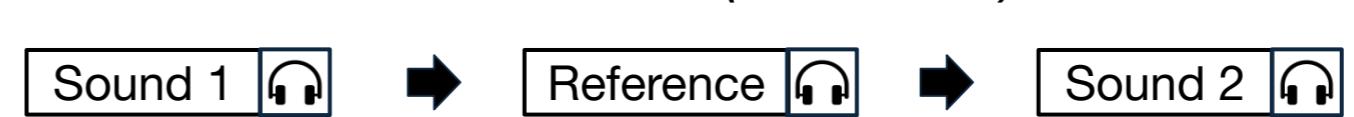
Which sound matches the reference? 1 2

E2: Echo-visual matching (cross-modal)
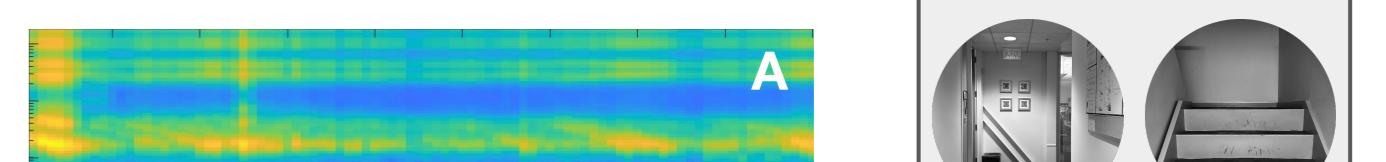
Which image matches the echo? < >

Stimuli:
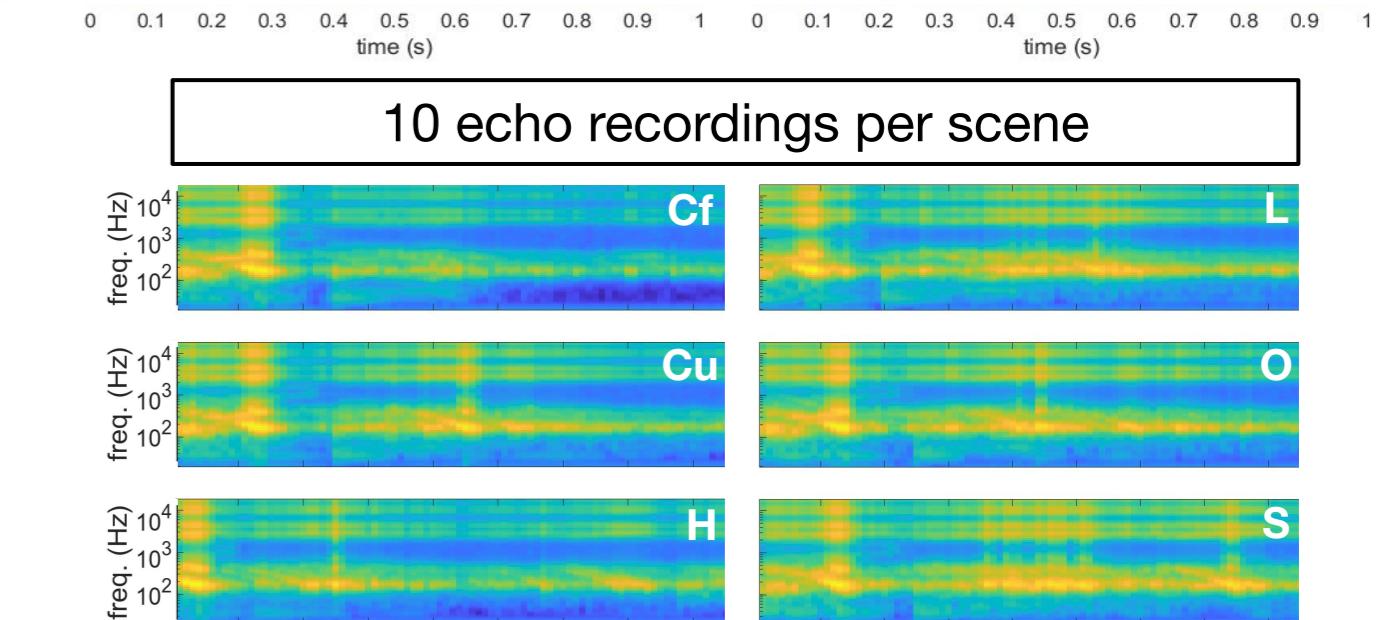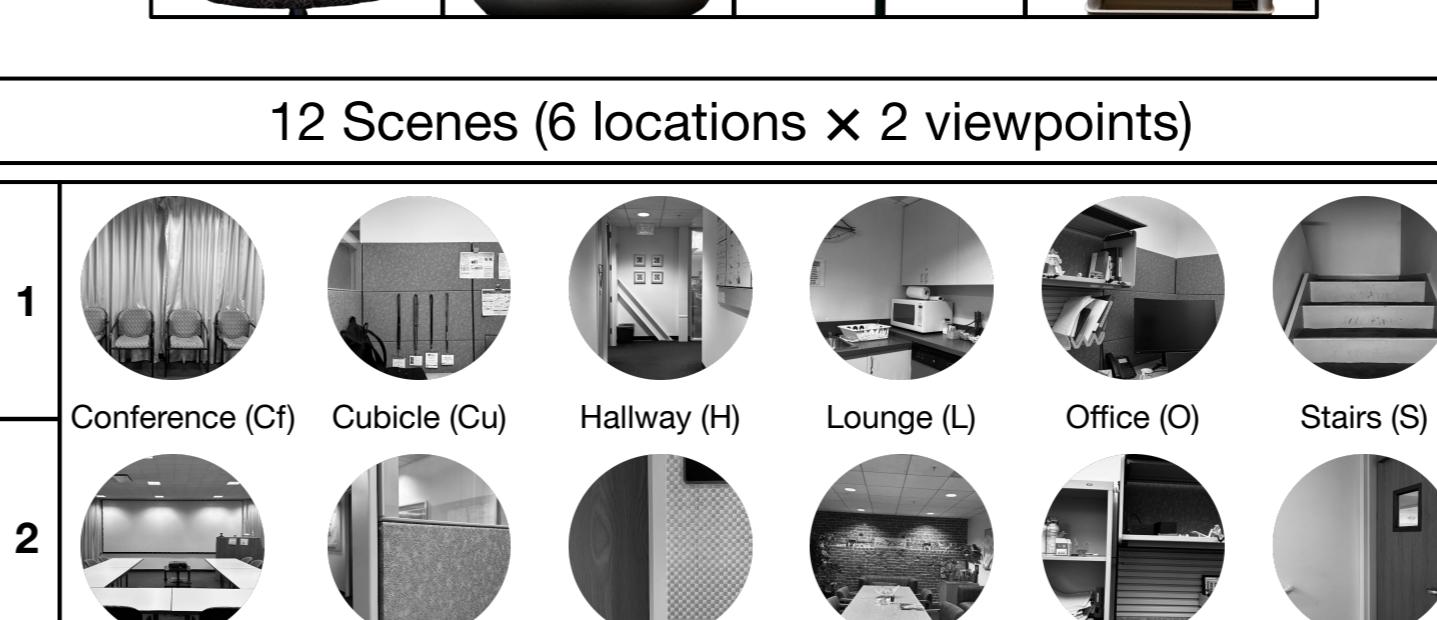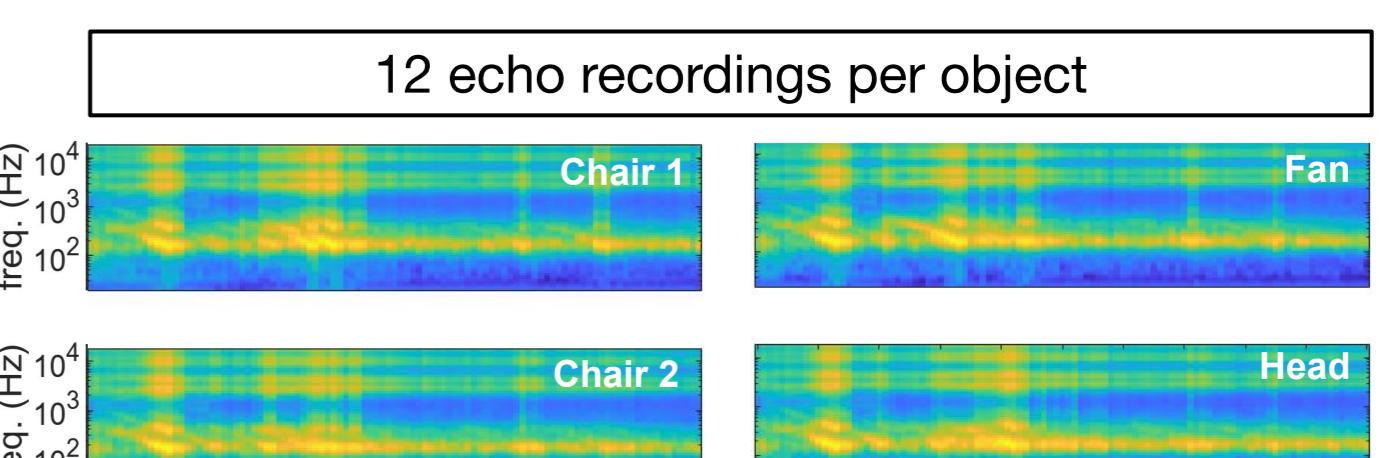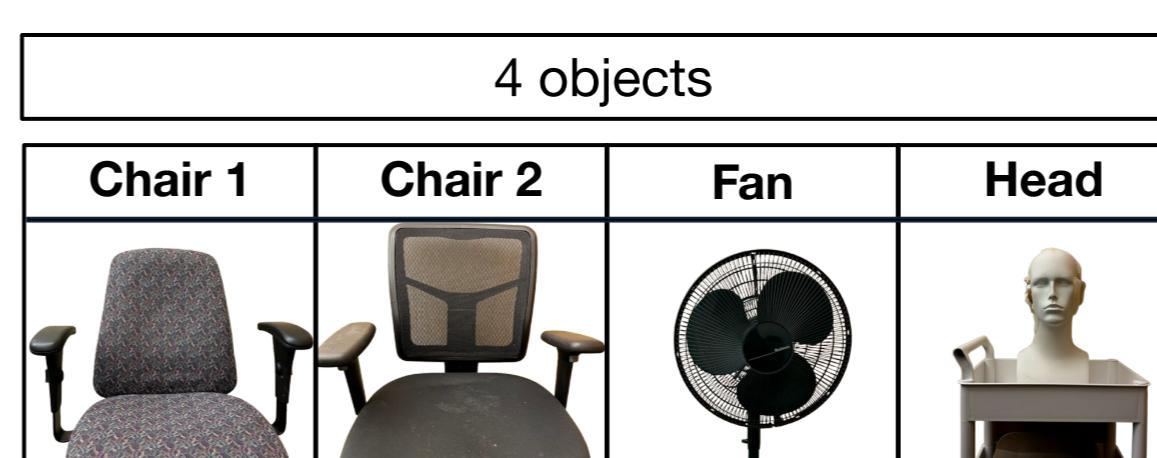
Experiment 1: Echo discrimination (unimodal)

Objects

Increasing the slowdown factor improves performance

Participants: 25 sighted adults (8 male; 28.68y ± 11.36)
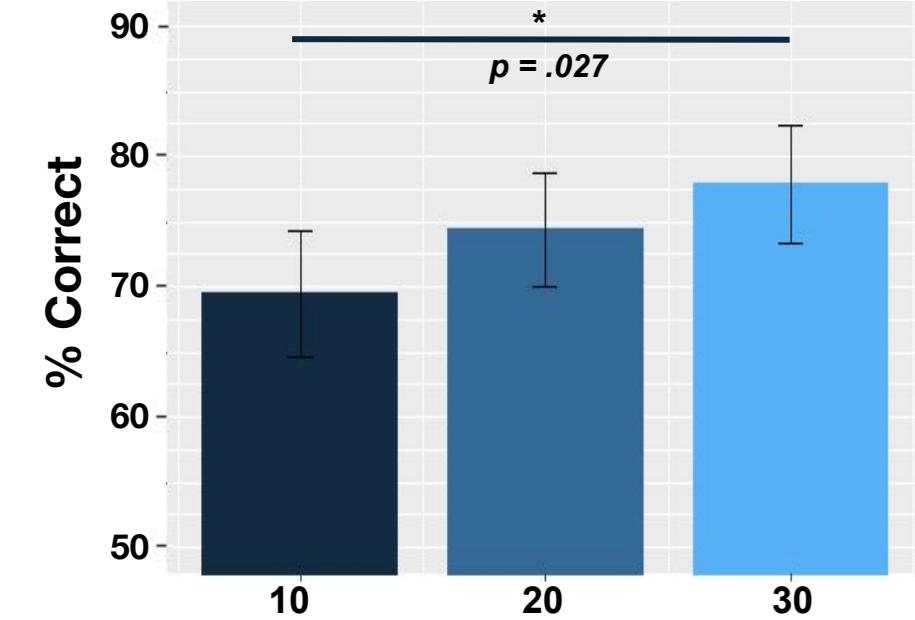
- Above-chance performance overall (M=73.9%, p<.001).
- Increasing slowdown improves performance (p=.002).
- Significant pairwise difference between slowdown 10 and 30 (p=.027).

Some object pairs are harder to discriminate than others
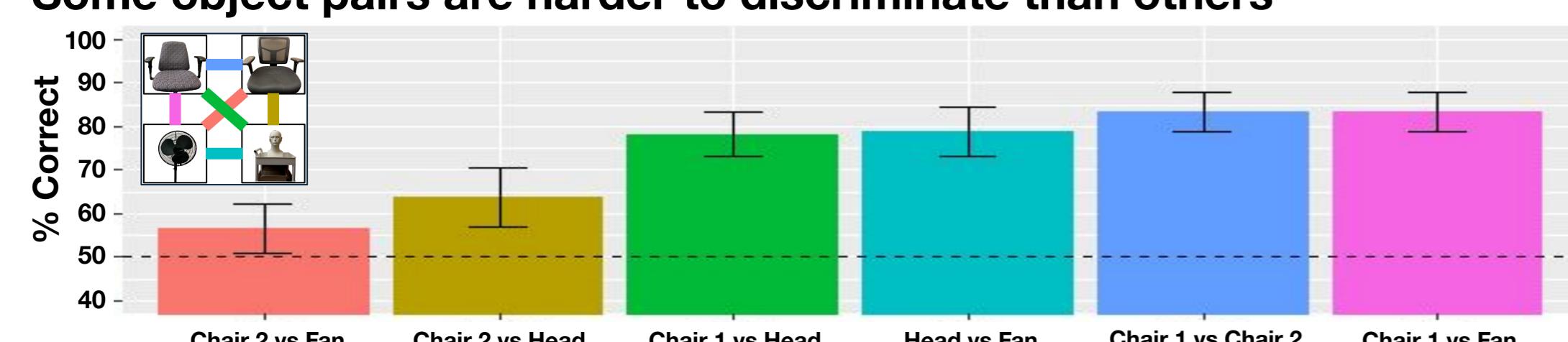
Performance varied across object pairs (p<.001)

Slowdown effect varies across object pairs
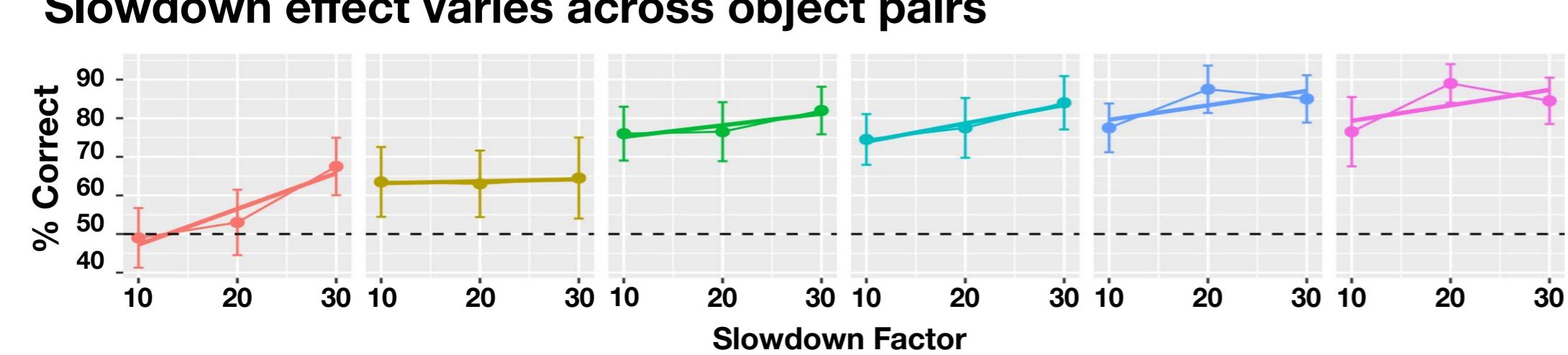
Significant interaction between slowdown factor and object pair (p=.022).

Scenes

Slowdown factor modulates performance non-linearly

Participants: 20 sighted adults (10 male; 25.5y ± 7.49)
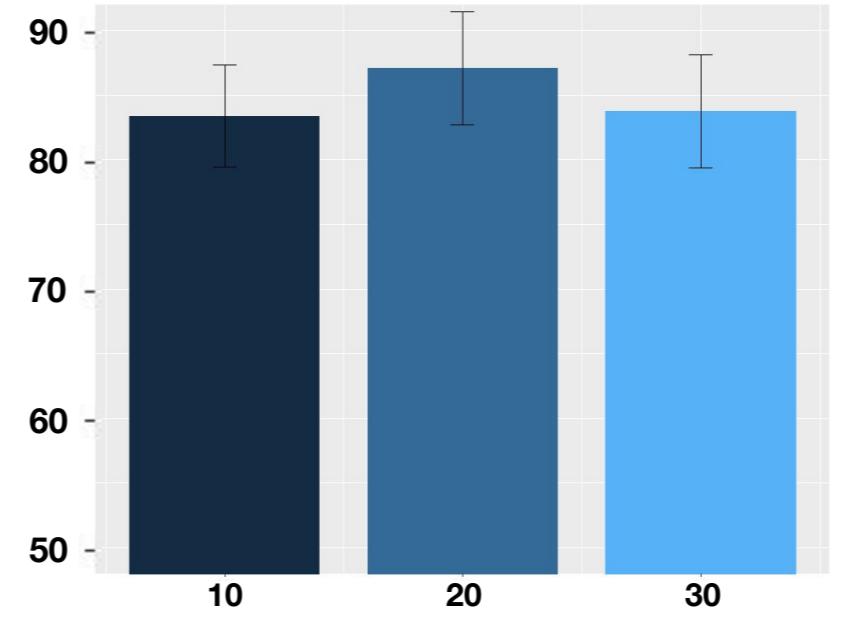
- Above-chance performance overall (M=84.7%, p<.001)
- Slowdown modulates performance non-monotonically (p=.008), peaking at slowdown 20.

Some scene pairs are harder to discriminate than others
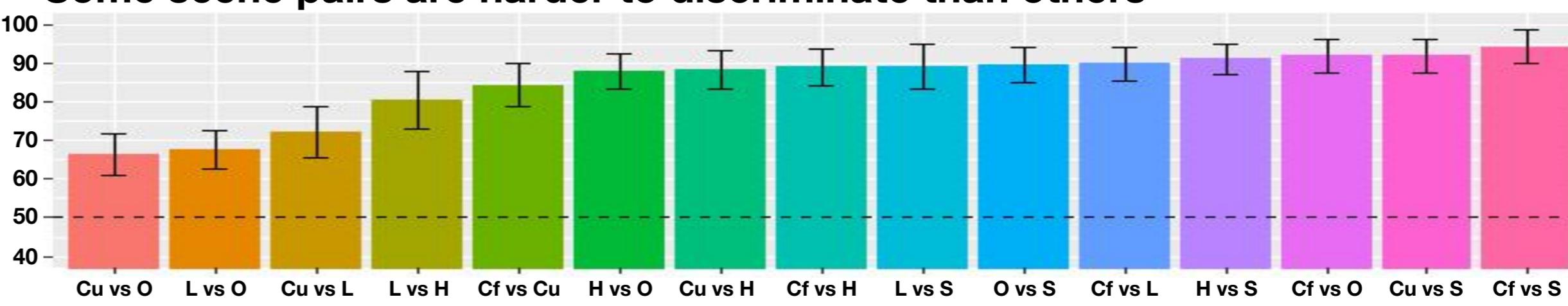
Performance varied across scene pairs (p<.001)

**Slowdown affects performance similarly across scene pairs**
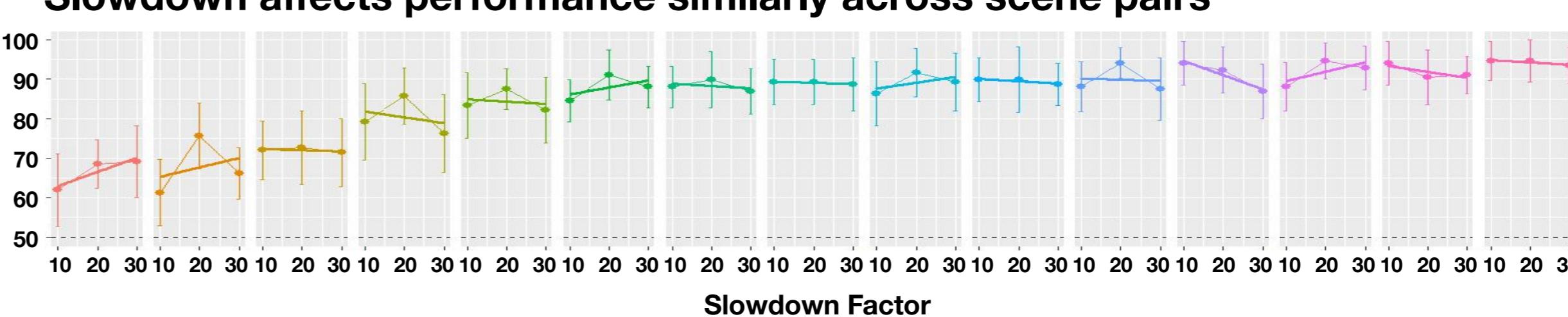
No significant interaction between slowdown factor and scene pair (p=.36)

## Experiment 2: Echo-visual matching (cross-modal)

Objects

Increasing the slowdown factor improves performance

Participants: 15 sighted adults (7 male; 30.2y ± 11.33)
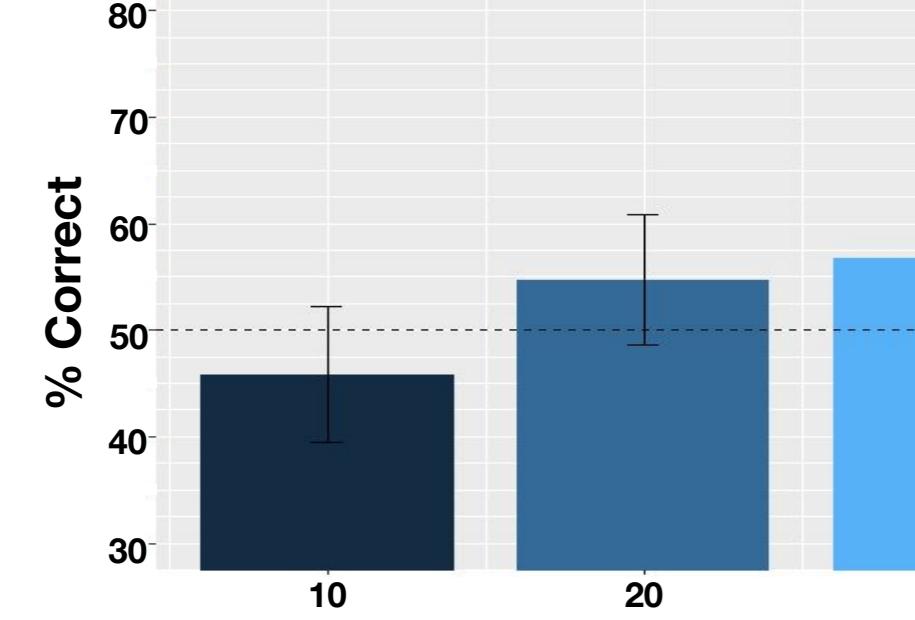
- Performance at chance overall (M=52.4%, p=.123); above-chance at slowdown 30 (M=56.7%, p=.039).
- Increasing slowdown improves performance (p=.009).

**Echo-visual matching difficult for most objects**
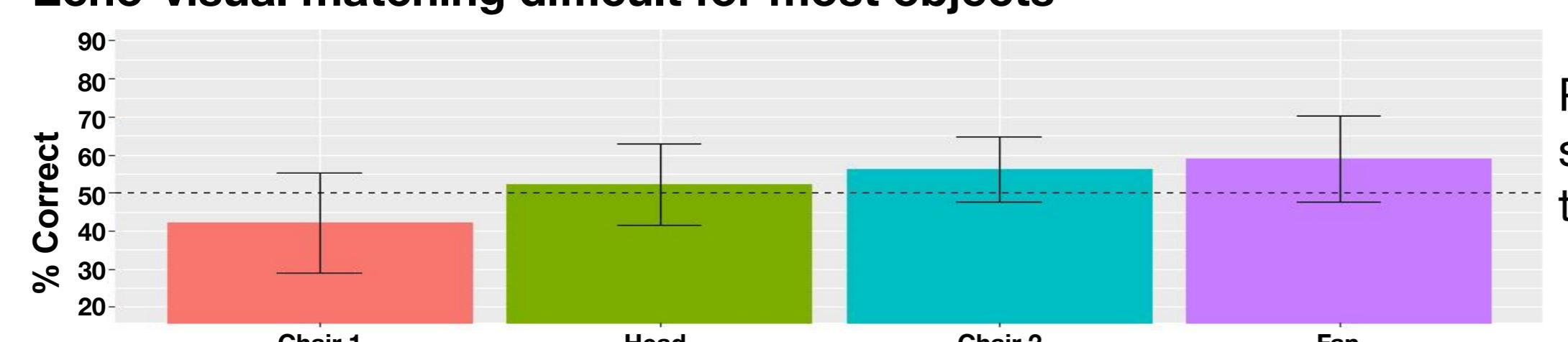
Performance not significantly modulated by target object (p=.144)

Slowdown effect on performance varies across objects
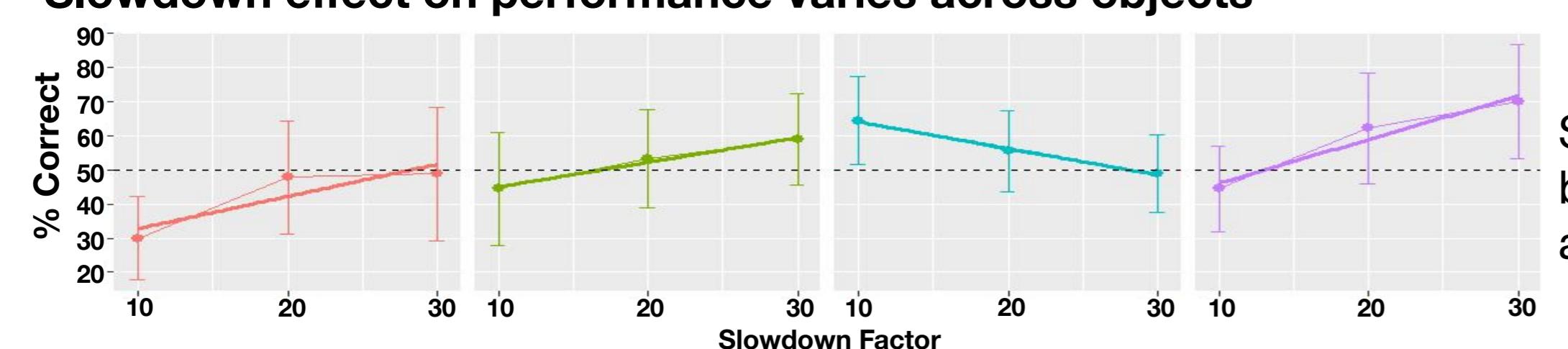
Significant interaction between slowdown factor and target object (p=.021)

Scenes

Echo-visual matching easier for scenes than for objects

Participants: 20 sighted adults (10 male; 25.5y ± 7.49)
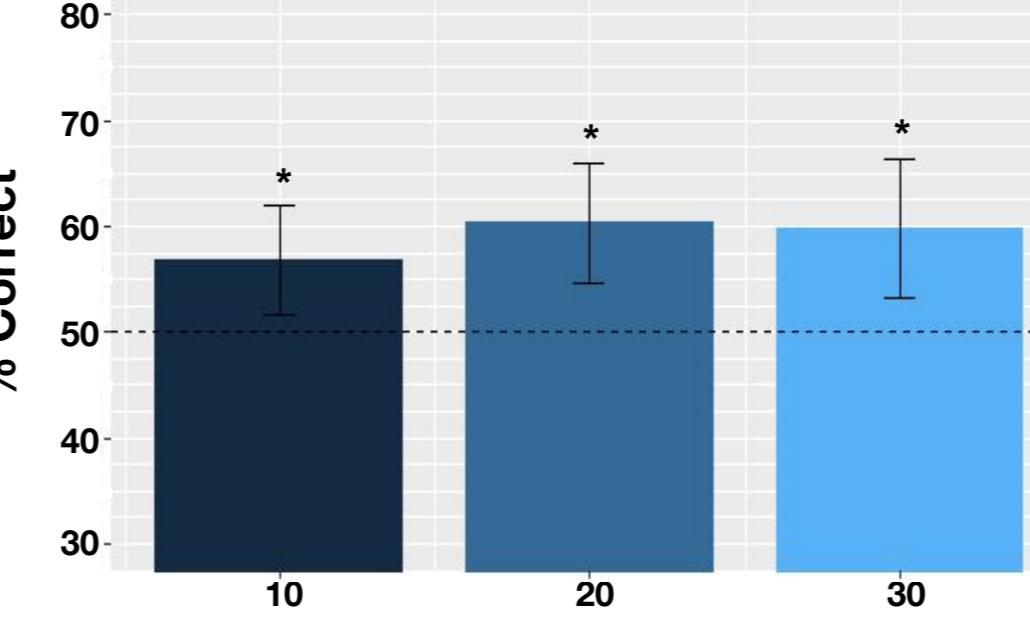
- Above-chance performance overall (M=59.3%, p<.001).
- Moderate slowdown effect on performance (p=.049)

Echo-visual matching easier for some scenes than others
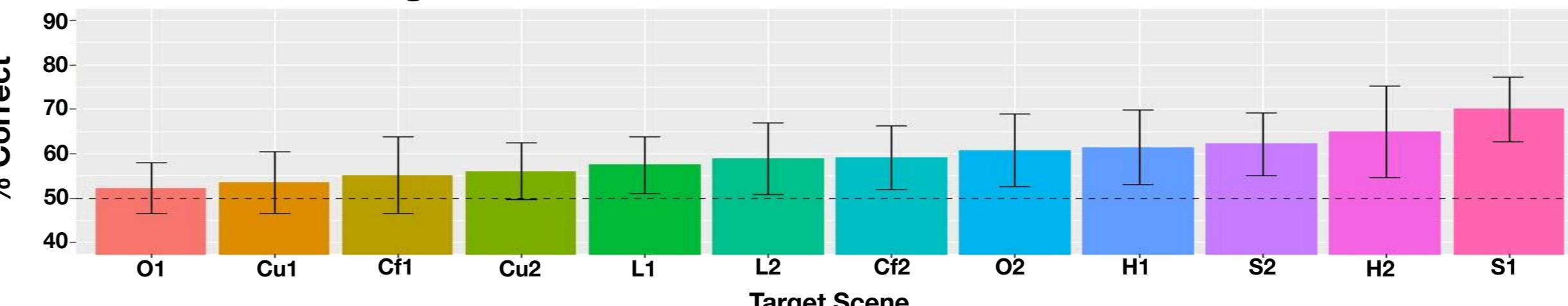
Performance varied across scenes (p<.001)

Slowdown effect on performance varies across scenes
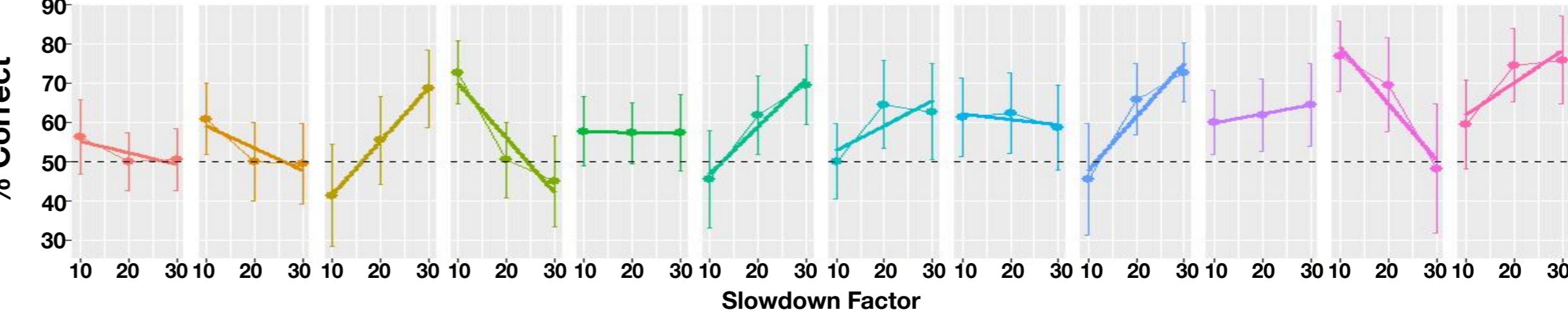
Significant interaction effect for target scenes (p<.001)

Summary/Conclusions

- Slowed ultrasonic echoes were perceptually discriminable for both objects and scenes, modulated by slowdown factor and stimulus pair.
- Echo discriminability improved monotonically with slowdown for objects, but peaked at slowdown 20 for scenes.
- Greater slowdown improved echo-visual matching performance for objects overall. For scenes, the slowdown effect was strongly modulated by the target stimulus.
- Perception may differ in blind listeners vs our sighted sample.
- Customizable echo signal parameters are instrumental in making assisted echolocation useful and practical.

References

1. Teng S, Puri A, Whitney D. Ultrafine spatial acuity of blind expert human echolocators. Exp Brain Res. 2012 Feb;216(4):483-8. doi: 10.1007/s00221-011-2951-1.
2. Thaler L, Goodale MA. Echolocation in humans: an overview. Wiley Interdisciplinary Reviews: Cognitive Science. 2016 Nov;7(6):382-93.
3. Sohl-Dickstein J, Teng S, Gaub BM, Rodgers CC, Li C, DeWeese MR, Harper NS. A Device for Human Ultrasonic Echolocation. IEEE Trans Biomed Eng. 2015 Jun;62(6):1526-1534. Doi: 10.1109/TBME.2015.2393371.
4. Reynolds, I, & Teng, S (2024). Design and optimization of assistive ultrasonic echolocation. The Journal on Technology & Persons With Disabilities, 12. 20.500.12680/vq27zw052
5. Miwa S., Kaoru A., Kazuki Y., Masaki G., Yoshiki H., Kohta I.K., Yoshiaki W., Shizuko H. Bat-inspired signal design for target discrimination in human echolocation. J. Acoust. Soc. Am. 1 April 2019; 145 (4): 2221–2236. https://doi.org/10.1121/1.5097166

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