Optimizing Signal Parameters to Enhance Echoacoustic Perception of Objects in Humans

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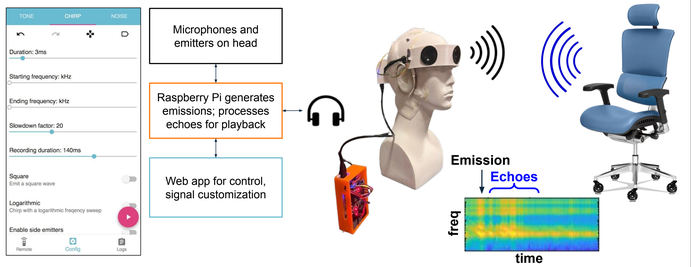
Introduction

- Some blind humans echolocate using tongue-clicks to sense, interact with, and navigate in the world without vision [1,2].
- Bats echolocate at ultrasonic frequencies that carry higher-resolution information but are inaudible to humans [3].
- Some echolocation aids produce ultrasonic echoes, slowed down to aid spatial localization at audible frequencies [4,5].

Research Questions

1. Can novices discriminate slowed ultrasonic object echoes?
2. Does echoacoustic perception benefit from slower echoes?
3. Does perceptual discriminability match acoustic dissimilarity?

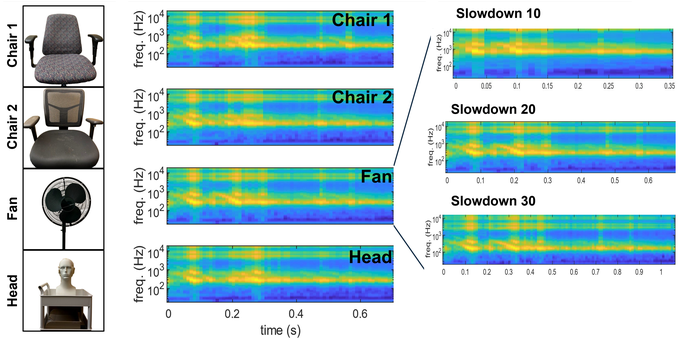
"Robin" - A Wearable Echolocation Aid



Methods

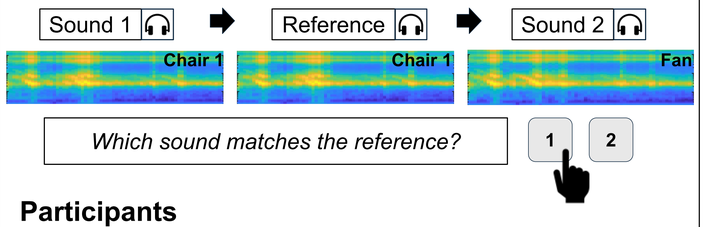
Stimuli

4 objects | 12 echo recordings per object | 3 slowdown factors



Task

3-Interval 2AFC match-to-reference task (adapted from [6])

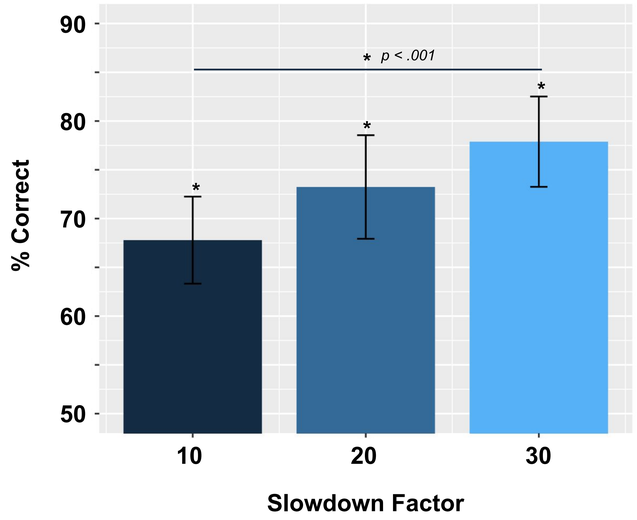


Participants

- N = 13 sighted adults (6 male; 32.5y ± 13.1)
- 6 object pairs, repeated 4x per slowdown block

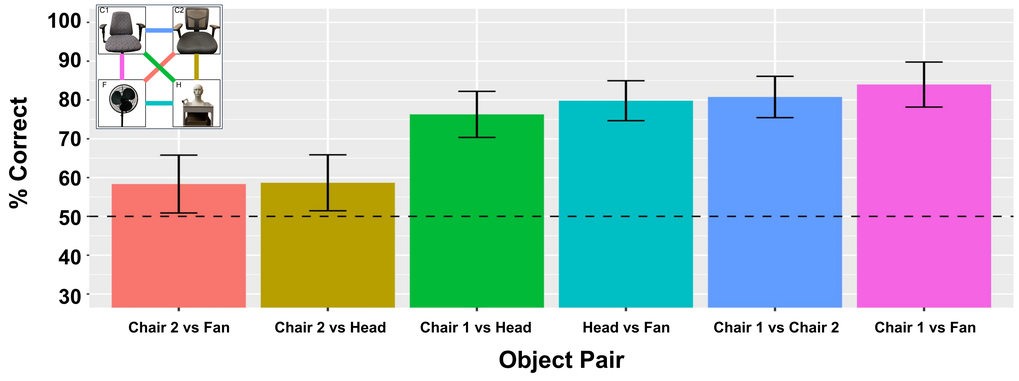
Results

Increasing the slowdown factor improves performance



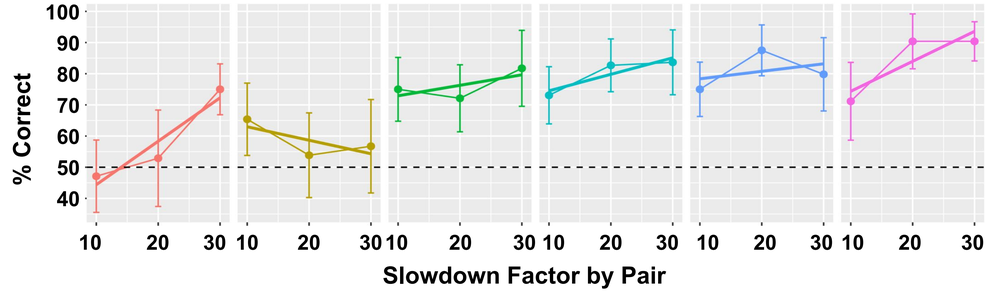
- Performance was significantly above chance overall (M=72.97%; 95% CI[70.18%,75,76%]; t=16.22, p<.001) and for each slowdown factor separately (M_{10}=67.8%; M_{20}=73.2%; M_{30}=77.9%; all p<.001, corrected).
- Performance varied significantly by Slowdown (F=7.83, p < .001).
- Post-hoc tests revealed a significant difference between performance at Slowdowns of 10 and 30 (p < .001).

Discrimination performance depends on object pairs



Performance varied significantly across object pairs (F=16.48, p<.001).

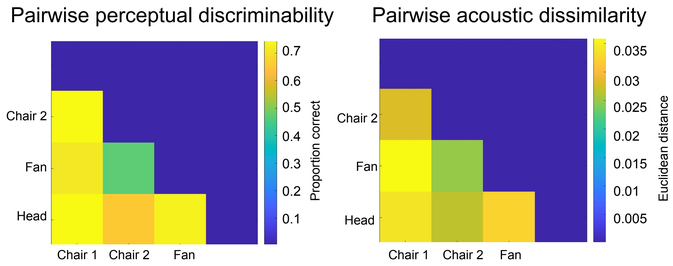
Slowdown effect varies across object pairs

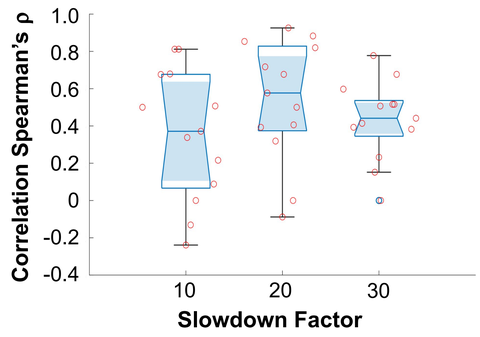


Significant interaction between slowdown factor and object pair (F=3.77, p<.001).

Results

Perception reflects acoustic pairwise dissimilarity





Pairwise behavioral discrimination correlated with acoustic dissimilarity (Spearman's ρ_{10}= 0.4121 (p = 0.013), ρ_{20}=0.6216 (p = 0.001), ρ_{30}= 0.4545 (p<0.001), Bonferroni corrected).

Summary/Conclusions

- Consistent above-chance discrimination of object echoes.
- Performance modulated by Slowdown and Object Pairs.
- Behavioral discrimination correlated with acoustic differences.
- Our task probes discrimination, not direct object perception.
- Performance was likely driven by feature comparison, not top-down object knowledge.
- Perception may differ in blind listeners vs our sighted sample.
- Customizable echo signal parameters are instrumental in making assisted echolocation useful and practical.

References

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Acknowledgments

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