

Investigating redundant multimodal speedometer displays for a concurrent lane tracking and speed tracking task

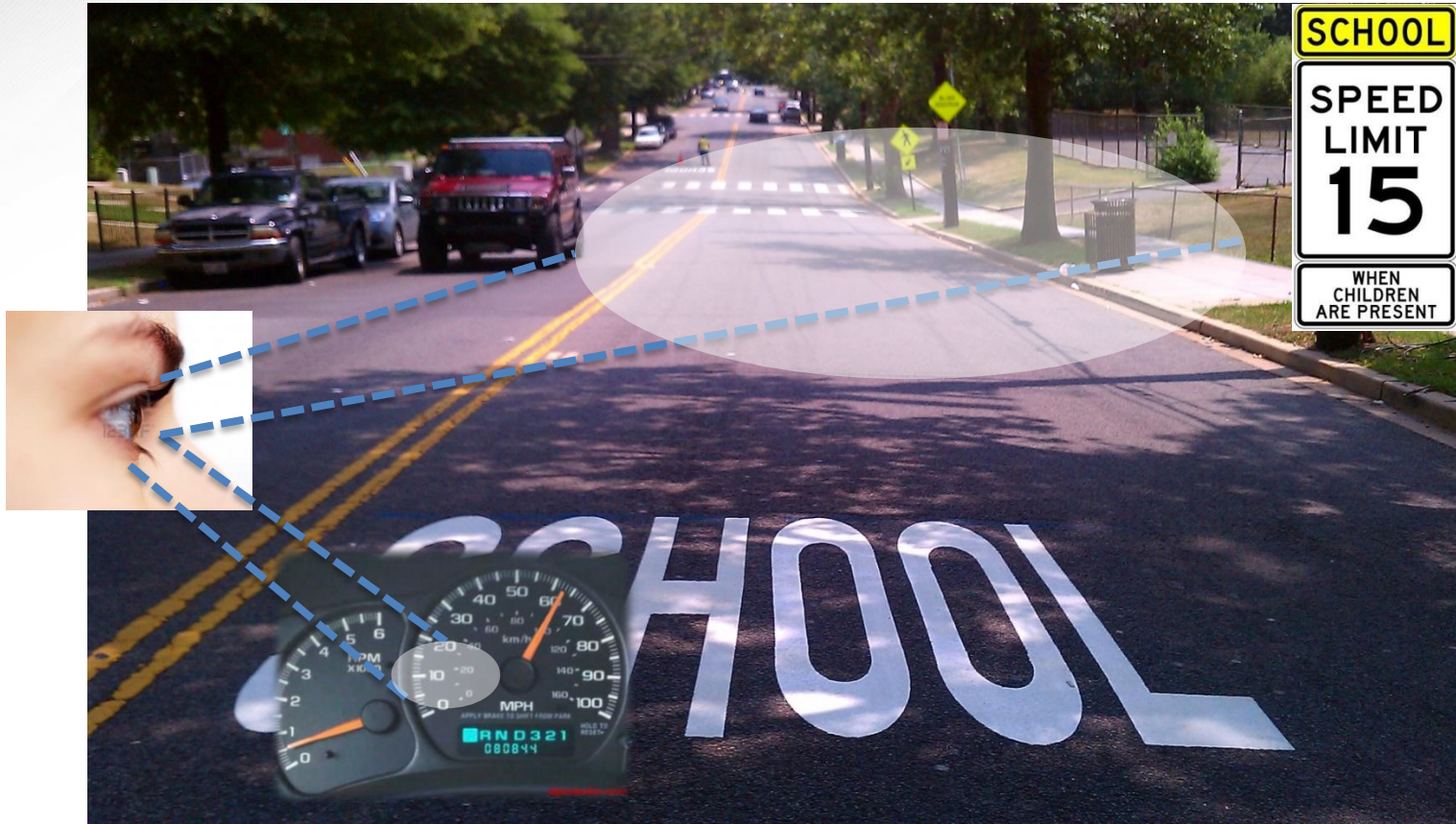
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Multi-tracking Task





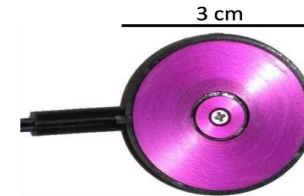
Research Question

How do encoded display dimensions affect multitask performance?

1) Whether spatial dimension encoding improves multi-tracking performance?

2) Whether redundant beat dimension encoding further improves multi-tracking performance?

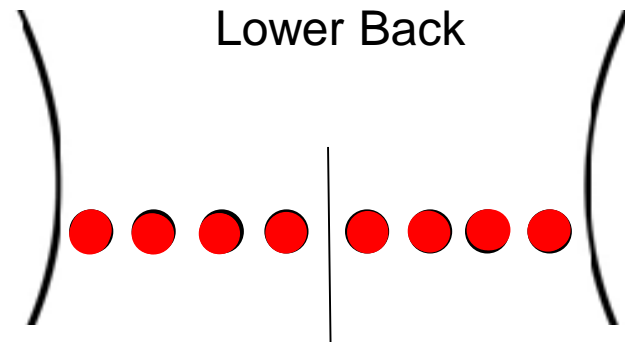
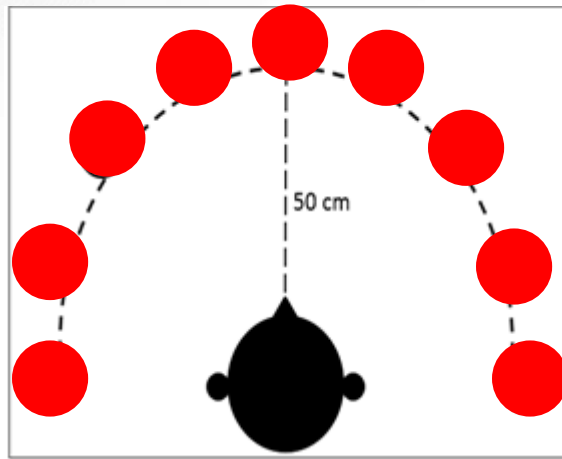
Lane-tracking task & Speed-tracking task



- Five 5-minute scenarios developed in STISIM Drive®
 - Baseline, Auditory-Spatial, Auditory-Beat, Tactile-Spatial, Tactile-Beat
 - Number, angle, and distance between road curves
 - Longitudinal wind effects
- Within-subject study
 - N = 15
 - Performance measures and subjective ratings



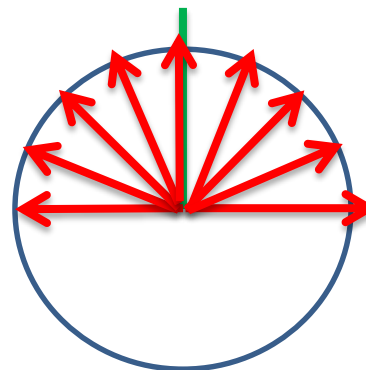
Spatial Dimension Encoding



Created by SLAB, combined with pitch

Target Speed

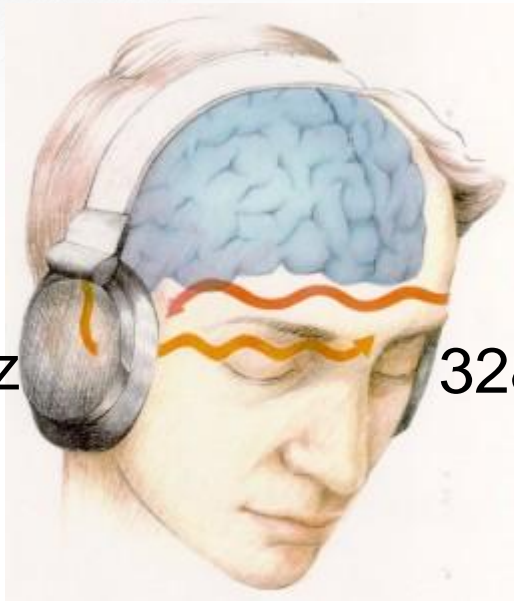
Low Speed



High Speed

Beat Dimension Encoding

Binaural Beats

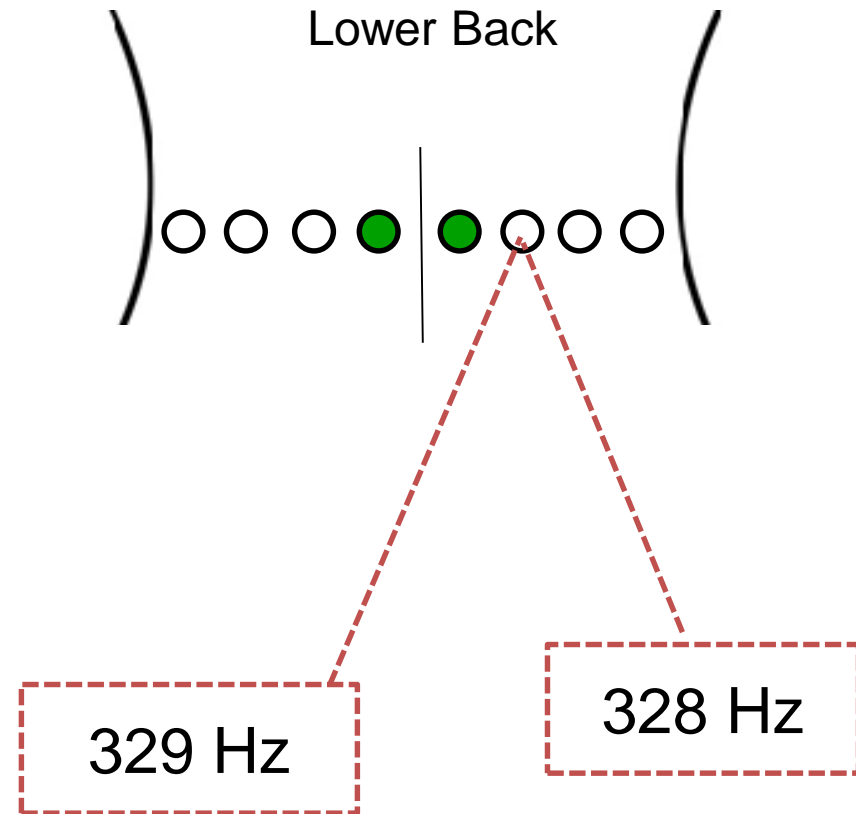


329 Hz

328 Hz

1 Hz beats

Haptic Beats



Lower Back

329 Hz

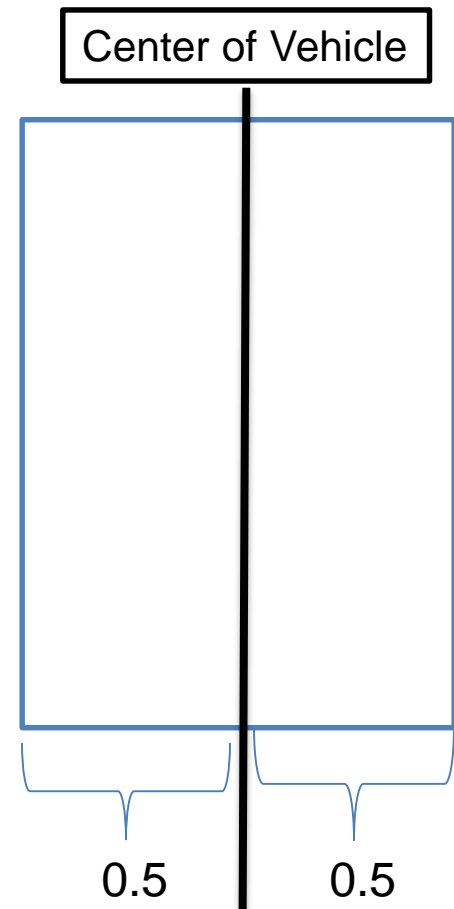
328 Hz

Speed Mapping

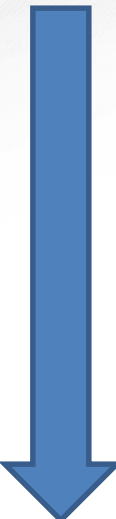
| Speed (mph) | Auditory-Spatial (Location & Hz) | Auditory-Beat (Location & Hz) | Tactile-Spatial (Location & Hz) | Tactile- Beat (Location & Hz) |
|-------------|----------------------------------|-------------------------------|---------------------------------|-------------------------------|
| 54> | 1; 690 | 1; 690+12 | 8 ; 262 | 8 ; 250+12 |
| 53 - 54 | 2; 587 | 2; 587+8 | 7, 8; 258 | 7, 8; 250+8 |
| 52 - 53 | 3; 493 | 3; 493+4 | 6, 7; 254 | 6, 7; 250+4 |
| 51 - 52 | 4; 392 | 4; 392+1 | 5, 6; 251 | 5, 6; 250+1 |
| Accepted | 49 - 51 | 5; 349 | 4, 5; 250 | 4, 5; 250 |
| 48 - 49 | 6; 329 | 6; 329-1 | 3, 4; 249 | 3, 4; 250-1 |
| 47 - 48 | 7; 261 | 7; 261-4 | 2, 3; 246 | 2, 3; 250-4 |
| 46 - 47 | 8; 220 | 8; 220-8 | 1, 2; 242 | 1, 2; 250-8 |
| >46 | 9; 174 | 9; 174-12 | 1 ; 238 | 1 ; 250-12 |



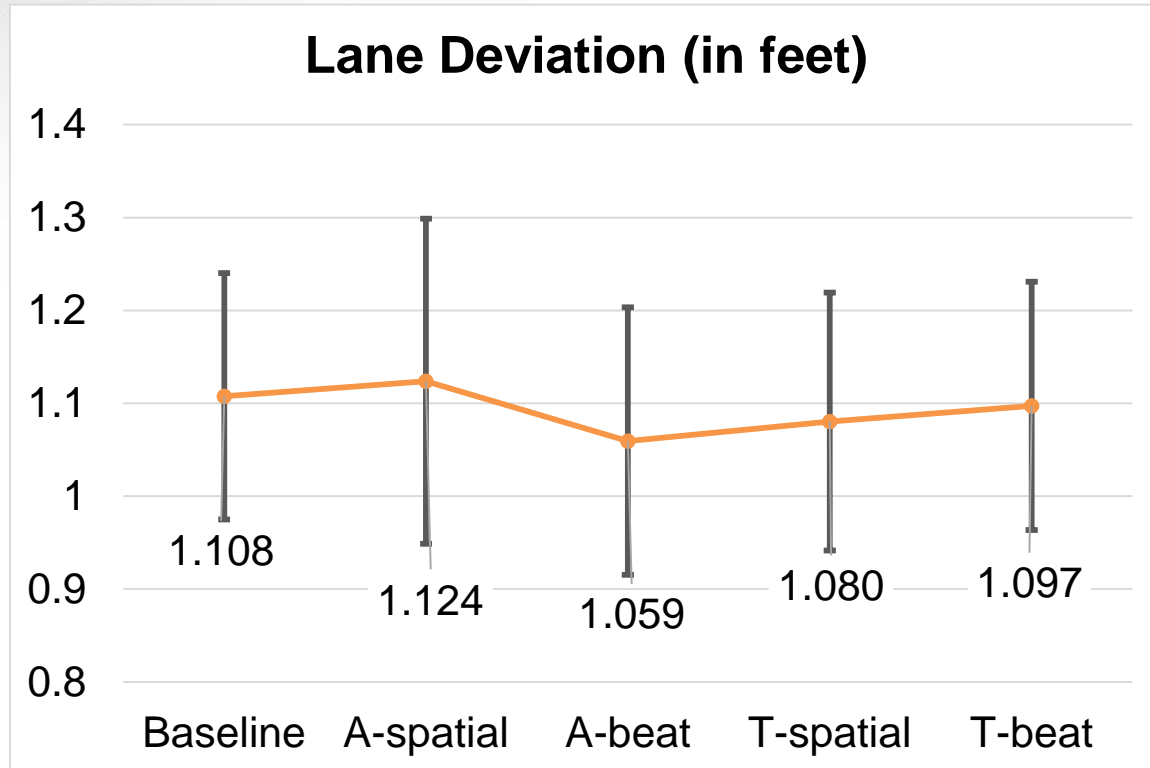
- Speed deviation, Lane deviation,
Acceptance Performance % (AP %)



Results : Lane Deviation

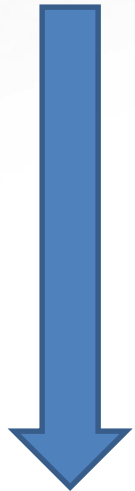


Better

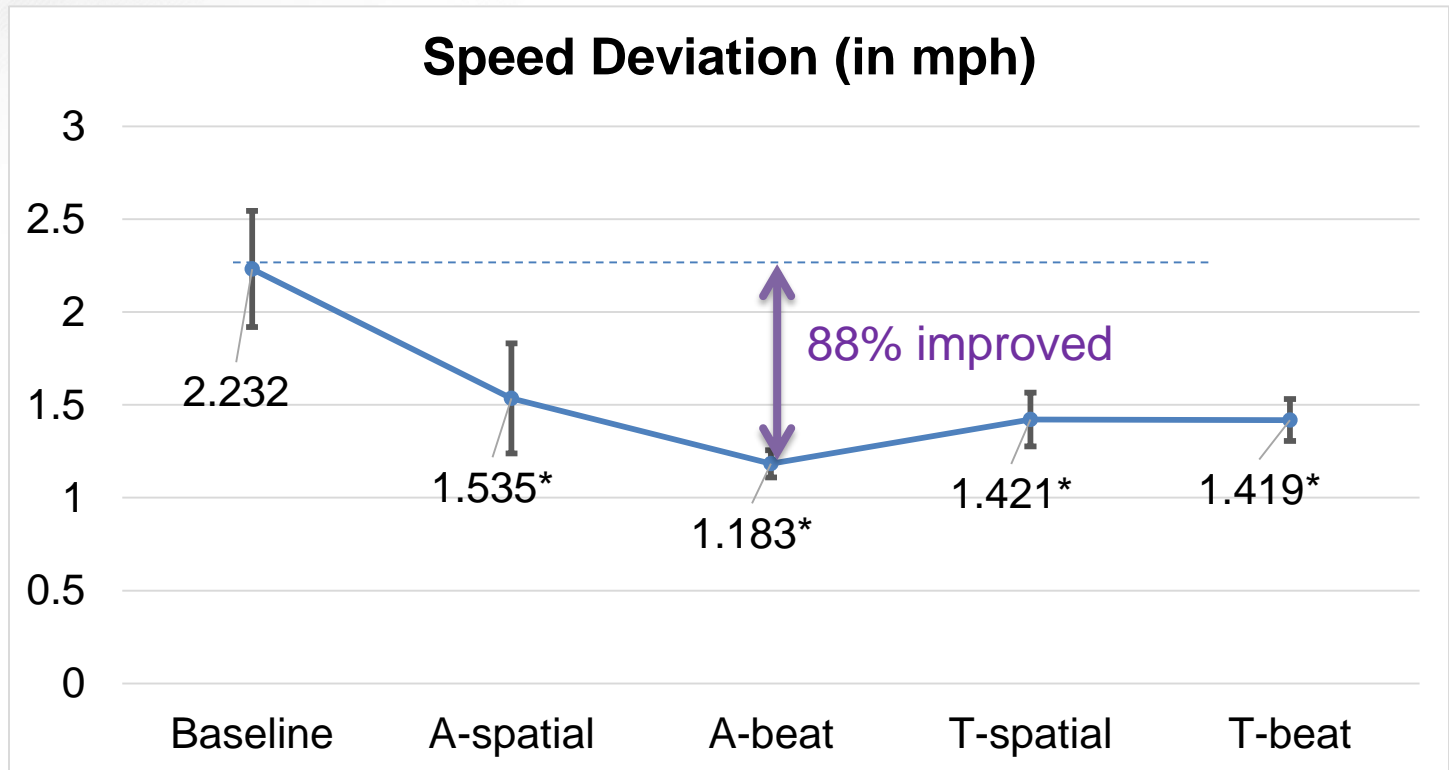


No statistical difference

Speedometer displays do not cause **trade off**



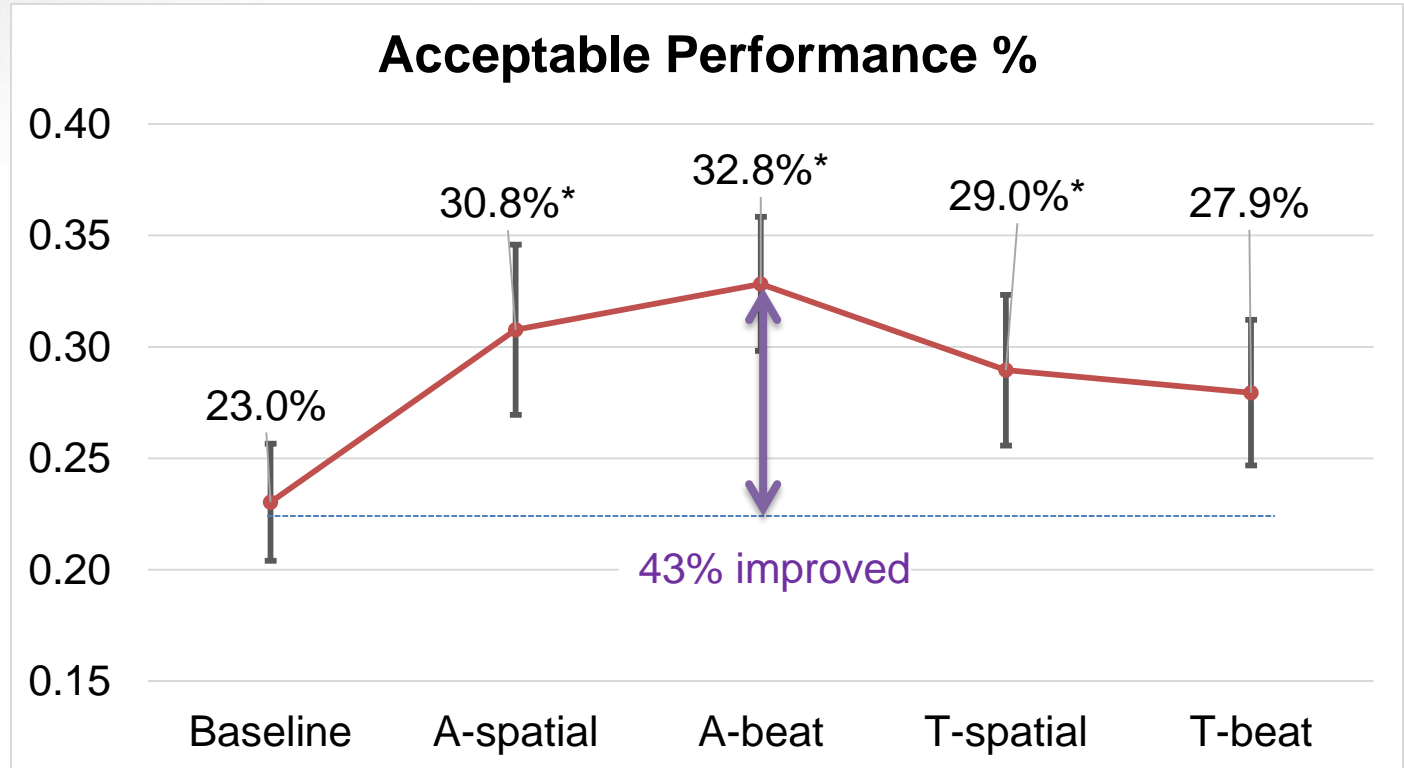
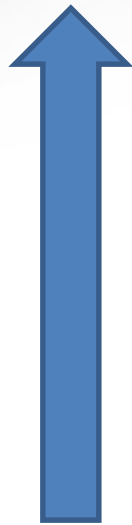
Better



A-spatial>B, A-beat>B, T-spatial>B, T-beat>B

Results: Acceptance Performance%

Better



A-spatial > B, A-beat > B, T-spatial > B



Results: Subjective Preference

| Attribute | Ratings | Sig. |
|----------------|--|---------|
| Satisfaction | A-beat: 8.00 ; T-spatial: 7.73 ; T-beat: 7.27; A-spatial: 6.93; B: 5.87 | 0.0618 |
| Reliance | A-beat:7.93; T-spatial: 7.93; T-beat: 7.86; A-spatial: 7 | N.S. |
| Interpretation | A-beat: 6.67; T-beat: 6.27; T-spatial: 6.2; B: 5.86; A-spatial: 5.6 | N.S. |
| Distraction | T-spatial: 7.33 ; T-beat: 6.80; A-beat: 6.60; A-spatial: 6.27; B: 3.80 | < 0.001 |
| Annoyance | B:8.00; T-spatial: 6.00; A-spatial: 5.47; A-beat: 5.33; T-beat: 5.20 | 0.0387 |

Note: A value of “10” represented the best rating (satisfied; rely on display; extremely easy to interpret; not distracting; not annoying)

Auditory display:

- Spatial + Pitch improve performance (redundancy gain)
- Redundant beat encoding fails to further improve the performance
 - Beat encoding may be important for those who are not good at detecting absolute pitch
 - Perhaps beat encoding reduces the mental effort

Tactile display:

- Spatial encoding improves the performance
 - Prominent tactile spatial perception
 - Inhibition effect at tactors 4 and 5, generating an “anti-signal”

- Redundant beat encoding fails to further improve the performance
 - Most annoying, especially at two sides of lower back
 - Lower AP% (redundancy cost)



Conclusion

- Spatial location could be a prominent feature to encode information in both auditory and tactile modality
- Adding redundant beat dimension fails to further improve the multi-tracking performance



Next Step

- Further study on the beat dimension encoding
- Other display dimensions



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<http://ise.tamu.edu/HF&CS/People.html>