Auditory Cues in the Perception of Self Motion

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Introduction

Self-Motion Perception

- How do we know we have moved relative to the external world ?
  - Physical cues, sensed by vestibular organ
  - Visual cues: optic flow
  - Auditory cues: changes in intensity and reverberation, Doppler frequency shifts
- Self motion perception is not fully understood → most studies have focused primarily on visual and vestibular cues
  - Self motion is over-estimated → we perceive we travel further than we actually do
  - Accuracy increases with increasing acceleration
- Even less is known about the role of auditory cues
  - Developing a better understanding can lead to more accurate simulations

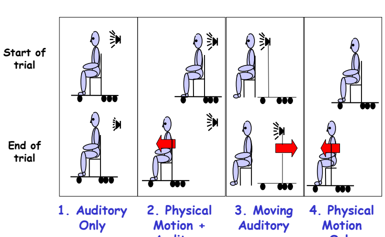
Project Goals

Examine Auditory Self-Motion Perception

- Measure the contribution of auditory cues to self motion perception

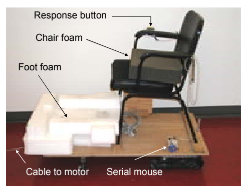
Four Experiments

1. Audio Only → how reliable of a cue is decreasing sound source associated with increasing sound source distance, to self motion perception ?
2. Physical Motion + Auditory → how well can we judge our self motion relative to a stationary sound source ?
3. Moving Auditory → does a sound source physically moving away from the subject provide a more robust cue to self motion perception ?
4. Physical Motion Only → how well can we judge our self motion in the presence of physical motion cues and absence of auditory cues ?



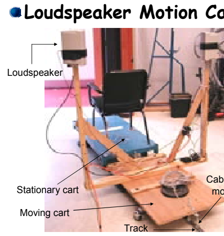
Apparatus

Subject Motion Cart (Conditions 1,2,4)



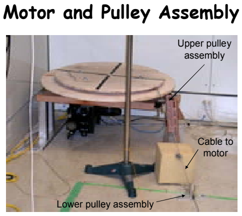
- "Subject response button" on arm rest
- Pulled at constant acceleration with motion profile generated by motor

Loudspeaker Motion Cart (Condition 3 only)



- Two loudspeakers mounted on each side of cart
- Pulled at constant acceleration with motion profile generated by motor

Motor and Pulley Assembly



- EG & G MT-5330 servo motor controlled by a Galil DMC-630 motion controller
- Steel cable connected cart to motor via pulley assembly

Auditory Stimulus → White Noise

- Broadband (200Hz – 10kHz), uniformly distributed
  - Sound source localization generally more accurate with broadband sound source
  - Initial sound source level of each trial randomly chosen from one of: 72dB, 69dB or 66dB

Experimental Procedure

1. Subject at starting position shown visual (physical, "real world") target
   - Target at either 1m, 2m, 3m or 4m away
2. Subject blindfolded (all four experiments)
3. Presented with stimulus - audio and/or physical motion
   - One of five motion profiles
   - → $0.012ms^{-2}$ $0.025ms^{-2}$ $0.05ms^{-2}$ $0.1ms^{-2}$ $0.2ms^{-2}$
3. Subjects indicated when they reached target position by pressing response button on cart
   - Time and distance recorded by computer

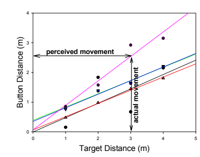
Results

Perceptual Gain (g_p) Measure

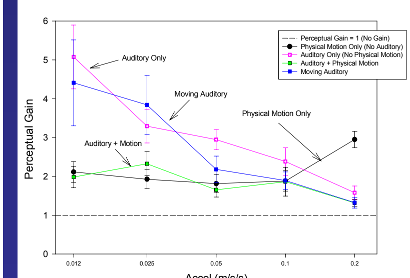
- Subject's perceived distance d_p compared to the actual distance d_a moved

$$g_p = \frac{d_p}{d_a}$$

- $g_p = 1 \rightarrow d_p = d_a$ (ideal scenario)
- $g_p > 1$ then $d_p > d_a \rightarrow$ over-estimate
- $g_p < 1$ then $d_p < d_a \rightarrow$ under-estimate



- Perceptual gain calculated by taking inverse slope of each line and averaged across subjects for each acceleration and each experiment



Discussion/Summary

Over Estimate Self Motion in all Conditions → On Average, 2x – 3x

Least Accurate → Audio Only

- Over-estimation of approx. 5x
  - To be expected – sound source distance estimates made using intensity alone are generally over-estimated

Most Accurate → Motion + Audio

- Sound seems to be effective in making self motion estimation more accurate
- This improvement cannot be attributed to the auditory system alone
  - Perhaps it represents an accurate anchor point to which self motion can be related

No Significant Difference Between Moving Audio and Audio Only

- Increasing accuracy with increasing acceleration observed in both conditions