High-precision capture of perceived velocity during passive translations

Joshua H. Siegle[1], Jennifer L. Campos[1], Betty J. Mohler[1], Jack M. Loomis[2], and Heinrich H. Bülthoff[1]

[1]Department of Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics, Tübingen, Germany

[2]Department of Psychology, University of California, Santa Barbara

BACKGROUND

- Our intuitive sense of changing velocity during passive movement in the absence of vision depends on the integration of inertial cues (Mayne, 1974)
- The objective of the current study was to develop a dynamic, intuitive method of measuring passive self-motion perception that circumvents some of the limitations of previous paradigms.

OUR METHOD: CONTINUOUS POINTING

- During passive transport, participants point continuously to a previously viewed target (white ball mounted at shoulder height)
- Intuitive task to perform; less likely to be biased by cognitive influences
- Participants instructed not to attend to their own velocity, only to the perceived location of the external target
- Following analysis, we recover perceived velocity in absolute, real-world units (m/s)
- Requires the assumptions that the initial target location is accurately perceived, and that all pointing errors can be attributed to errors in perceived self-motion (Loomis & Philbeck, in press)
- Continuous pointing has been previously used for:
  - Distance perception (Loomis et al., 1992)
  - Perception of rotation (Ivanenko et al., 1997; Siegler et al., 1999)
- Never used as an explicit measure of instantaneous translational velocity
- Same method used in Campos et al. (2008) to show that the characteristic pointing behavior seen during actual translation is not present when subjects imagine themselves moving

STIMULI AND APPARATUS

Experiment 1: Three trajectory types, 2 speed levels, 4 target-relative start locations. Presented with robotic wheelchair.

Experiment 2: Similar trajectories were used on the MPI Motion Simulator, but scaled to slower speeds (0.74 m/s max), shorter distances (2.5 m long), and for three speed levels.

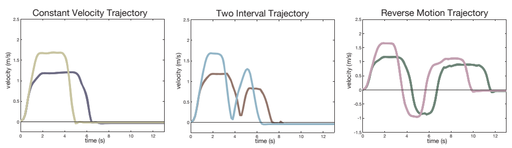


Figure 1. Velocity profiles for three trajectory types and two speeds.

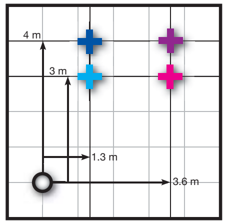
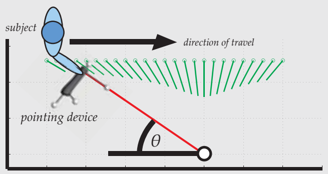


Figure 2. Target-relative start locations for Experiment 1.

DATA ANALYSIS

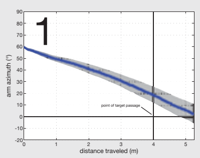


Data Collection

Subjects pointed to the felt location of the target in the absence of vision while being passively transported.

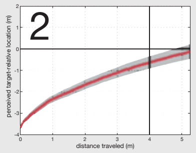
Orientation of hand-held pointing device recorded at 12 Hz throughout the trial (VICON infrared tracking system).

Location and orientation of the head was also tracked.



Average of actual raw data (blue line): rotation of pointer around the z-axis (arm azimuth)

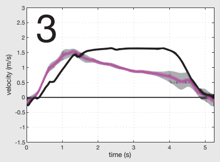
Standard error for all subjects is shown in gray.



Perceived location (red line) was computed with the following equation:

$$y_{subj} = -x \tan \theta_{arm}$$

This equation answers the question: "where must the participant be located along the trajectory, given the indicated location of the target?"



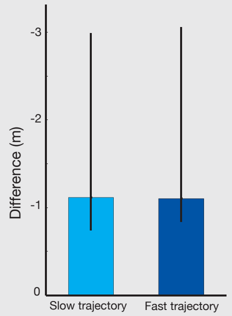
Perceived velocity is simply the derivative of perceived location (pink line).

Actual velocity (as recorded from helmet tracking) is represented by the black line.

EXPERIMENT 1 RESULTS

Figure 4 (left). A subject on the robotic wheelchair. The reflective markers for head and hand tracking can be seen.

Figure 3 (right). Difference between perceived location and actual location at end of constant-velocity trials (inverted scale). Shown with 95% confidence intervals.



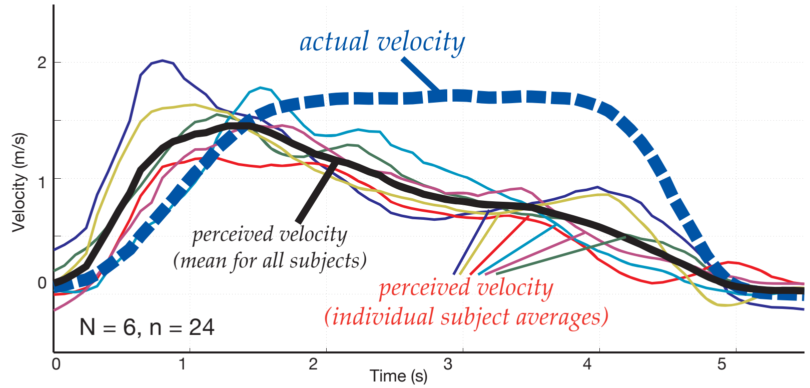


Figure 5 (above). Average perceived velocity for all subjects is well-fit by a leaky integrator function with a time constant of 3.5 s. This plot suggests that the under-perception of distance traveled is due to a steady decay in perceived velocity during periods of constant-velocity travel, rather than a scaled misperception of speed.

Figure 6 (below). Continuous pointing method clearly reveals that three subjects do not perceive movement reversal (highlighted region).

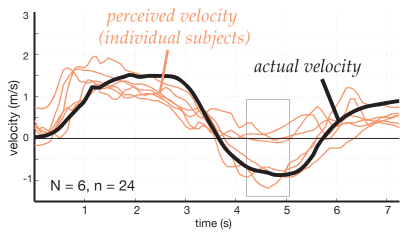
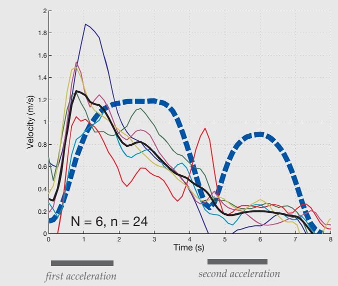


Figure 7 (below). Second acceleration is perceived much less strongly than first acceleration by all subjects, despite the fact that it is well above threshold. Data labeling same as in Figure 5.



EXPERIMENT 2 RESULTS

We performed a similar experiment in which subjects were transported by robotic arm (MPI Motion Simulator). The velocities were slower (max 0.74 m/s), but the conditions were more controlled (e.g., vertical noise masked the vibrations of the machine).

The findings of the wheelchair study were replicated, including underperception of distance and difficulty in perceiving the second acceleration.

Figure 8. A subject on the MPI Motion Simulator.

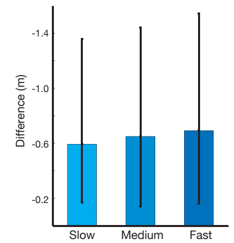


Figure 9 (above). Difference between perceived location and actual location at end of constant-velocity trials (inverted scale). Shown with 95% confidence intervals.

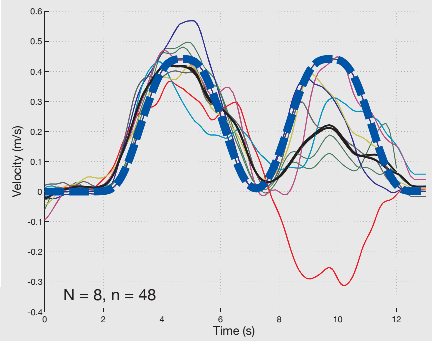
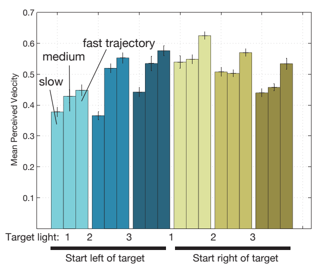


Figure 10. (right). Perceived velocity for two-interval trajectories in Experiment 2. Data labeling same as in Figure 5.

CONCLUSIONS

- The continuous pointing paradigm is a method for measuring the instantaneous perceived velocity of a person who is undergoing a variety of acceleration profiles during passive transport.
- There is a clear decay in perceived velocity during periods of constant, nonzero velocity, an aspect of self-motion perception that other experiments have failed to capture
- Biomechanical constraints on pointing behavior must be taken into account during the design of experiments (see Figure 11).
- Continous pointing can be adapted for use in other research domains, including spatial updating, vection, and visual-vestibular integration

Figure 11. (below). Mean perceived velocity at point of peak actual velocity on the MPI Motion Simulator.



REFERENCES

Campos JL, et al. (2008) Imagined self-motion differs from perceived self-motion. Vision Sciences Society abstract (Naples, Florida: 9-14 May).

Ivanenko YP, et al. (1997) The contribution of otoliths and semicircular canals to the perception of two-dimensional passive whole-body motion in humans. *J Physiol*, **502**: 223-233.

Loomis JM, et al. (1992) Visual space perception and visually directed action. *J Exp Psychol Hum Percept Perform*, **18**: 906-921.

Loomis JM & Philbeck JW (in press). Measuring perception with spatial updating and action. In RL Klatzky, M Behrmann & B. MacWhinney (Eds.), *Embodiment, Ego-Space, and Action* (Mahwah, NJ: Erlbaum).

Mayne R (1974) A systems concept of the vestibular organs. In *Handbook of Sensory Physiology: Vestibular System Part 2*, Ed. H.H. Kornhuber. Berlin: Springer-Verlag, 493-580.

Siegler I, et al. (1999) Role of otoliths in spatial orientation during passive travel in a curve. *Ann NY Acad Sci*, **871**: 447-450.

ACKNOWLEDGEMENTS

Special thanks to Michael Weyel for his help in programming the wheelchair and automating data capture. Thanks to the MPI Motion Simulator Team and Michael Reimann for technical support with the robot arm. Thanks to John Butler and Bernhard Riecke for advice on the experimental design and analysis. We thank Simon Musall and Naima Laharnar for their help running the experiment.

Poster presented at Vision Sciences Society
Naples, Florida (9-14 May 2008)

contact: josh.siegle@tuebingen.mpg.de
poster available at www.kyb.mpg.de/~jsiegle