Optic flow and physical effort as cues for the perception of the rate of self-produced motion in VE

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Understanding how humans perceive their rate of translational locomotion through the world is important for designing virtual environments. People have access to two primary classes of cues that can provide information about their movement through the environment: Visual and auditory cues (e.g. optic flow, optical expansion, Doppler shift) and somatosensory cues (e.g. effort, proprioceptive feedback.) An important research question is the relative weighting of these cues for perceiving the rate of translational movement in a virtual environment.

As walking is the most organic mode of locomotion for humans, it is highly likely that pedestrians have a strong perceptual-motor coupling between the distance covered with each step and the optic flow associated with that motion. Because bicycling is a mechanically mediated mode of locomotion, participants are unlikely to have a pre-existing robust perceptual-motor coupling between the movement of their legs on the pedals and the translational movement of the bicycle. This ambiguous relationship between physical effort and visual motion cues allows for experimental manipulation of these cues to evaluate whether somatosensory or visual cues are favored in speed perception. The purpose of this experiment was to determine whether bicyclists are more attuned to physical effort (i.e., pedal speed) or optic flow when controlling the speed at which they move through a virtual environment.

Thirty-nine participants rode a bicycling simulator through a virtual town. Participants rode through two different segments. In the first segment, the optic flow rate was matched with the rate of pedaling. In the second segment, the optic flow rate was manipulated such that people were moving through the world at ± 15% of their actual pedaling rate. The task was to maintain the same self-selected rate of motion through the environment in both segments. Participants in the experimental manipulation conditions experienced either the optic flow faster (n=15) or optic flow slower (n=12) condition. There was also a control group (n=12), which experienced no manipulation of optic flow rate.

These manipulations of optic flow lead to different predictions for the two conditions in the second segment relative to the first segment. If people are attuned to effort, then in the slower optic flow condition the visual speed in segment two should be slower than in segment one, while pedaling speed should be the same; if people are attuned to optic flow, then in segment two the visual speed should be same, and pedaling speed should be faster. In the faster optic flow condition, if people are attuned to effort then in segment two visual speed should be faster than in segment one, and pedaling speed should be same; if people are attuned to optic flow, then in segment two visual speed should be same, and pedaling speed should be slower.

Results

The dependant variables in this experiment were the *visual speed* at which participants were moving through the virtual environment, and the participants' *pedaling speed*. A repeated-measures ANOVA of the participants' visual speed showed a significant interaction between optic flow rate and segment, $F(2,36)=80.62$, $p<0.001$. Follow-up analyses indicated that participants in the reduced optic flow condition traveled more slowly in the second segment than in the first, while participants in the increased optic flow condition traveled through the second segment faster than the first. These between-segment differences were significant for both optic flow reduced ($F(1,11)=51.4$, $p<0.001$) and optic flow increased conditions ($F(1,14)=76.7$, $p<0.001$). There was no significant between-segment difference for the control condition, $F(1,11)=0.4$, $p=0.55$. The participants' visual speed in each segment and condition is shown in Figure 1.

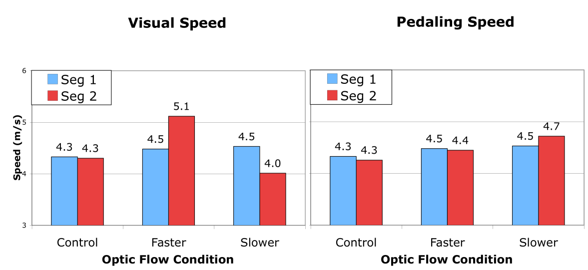

Figure 1. Participants' visual and pedaling speed in each segment.

A repeated-measures ANOVA was also conducted on the participants' pedaling speed. This analysis indicated a significant interaction between optic flow rate and segment, $F(2,36)=4.45$, $p=0.02$. Subsequent testing showed that participants in the reduced optic flow condition pedaled significantly faster in the second segment than in the first, $F(1,11)=7.23$, $p=0.02$. There was no significant between-segment difference in the pedaling speed for participants in the increased optic flow ($F(1,14)=0.23$, $p=0.64$) and control ($F(1,11)=1.54$, $p=0.24$) conditions. The participants' pedaling speed in each segment and condition can be seen in Figure 1.

Participants in the faster optic flow condition did not show a significant change in pedaling speed between segments. This suggests that people are more attuned to effort than optic flow when controlling their rate of speed in the virtual environment. However, participants in the slower optic flow condition increased their rate of pedaling in segment two, but not enough to compensate for the 15% reduction in optic flow. It seems optic flow was driving this increase in effort. This is inconsistent with the idea that participants are exclusively attuned to only one of these sources of information (effort or optic flow). Further, these asymmetric results suggest that the relative weighting of optic flow and effort is directionally dependant when assessing rate of motion in virtual environments.

APGV 2009, Chania, Crete, Greece, September 30 – October 02, 2009.
ISBN 978-1-60558-743-1/09/0009