

Cycling Rate Is Modulated by Optic Flow in a Virtual Bicycle Environment

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Abstract—Manipulation of optic flow using virtual environments (VE) is known to modulate walking speed. We developed a virtual reality augmented cycling system and sought to determine if manipulation of optic flow modified cycling rate. We tested three groups of healthy subjects ($n = 5:5:3$) as they cycled in a virtual park environment while we modified the gain for optic flow (gain at equal, and higher than comfortable cycling speed) using three protocols: 1) bike uncoupled with the VE and perceived gain, 2) bike coupled with VE and perceived gain and 3) bike coupled with VE and constant gain. We found that cycling speed increases were greatest when the bike was coupled with the VE and the gain was constant ($F=5.207$, $p=0.028$). Cycling rate increased with optic flow, which differs from the inverse relationship of optic flow and walking. To our knowledge this is the first study to provide preliminary evidence on cycling rate responses to optic flow.

Keywords- virtual reality, cycling, optic flow

I. INTRODUCTION

Manipulation of virtual environment (VE) features affects the performance of the user in the real world. Manipulating VE variables and measuring real world responses have mainly been studied through the effect of optic flow speed on gait parameters. Many studies demonstrated that gait parameters are modulated by manipulations of optic flow speed [1]. When optic flow speed decreases, walking speed, stride length and stride frequency increase, while optic flow speed increases produce the opposite effect. When flow speeds are either faster or slower than the comfortable walking speed, participants modulate locomotion to maintain a comfortable walking speed [1-5].

One explanation for the response to gait speed modulation by optic flow is that visual signals are acting on the central pattern generators by changing the timing or amplitude of muscle activation in the legs [6]. An alternative explanation is that control of this locomotor activity is based on the perception of speed of self-motion that arises from a combination of body-based and visual senses. The optic flow speed changes the perception of speed, which in turn affects gait speed [3].

We developed a virtual reality cycling system (Fig. 1) that allows manipulation of optic flow. To date the influence of optic flow on cycling has not been studied. Therefore, the purpose of this study was to determine if manipulation optic flow modified cycling rate.

II. METHOD

A. Instrumentation and Hardware



The virtual reality augmented cycling kit (VRACK) is described in detail elsewhere [7]. Briefly the sensorized handle-bars, pedals and heart rate monitor are inputs into a VE to drive the behavior of the rider and a pacer. Neither the handlebars nor the heart-rate monitor were

Fig. 1: VRACK © Rivers Lab

used in this experiment so only the pedals will be described. The pedals are instrumented with a single axis load cell and an inertial measurement unit (IMU). The IMU is mounted in line with the pedal to detect rotation of the pedal, crank velocity (revolutions per minute), and crank position. To insure good signal clarity and low drift of the IMU, infrared interrupters were positioned on the pedal and the bike chassis to dead reckon the IMU with known positions. The data from the sensing systems were sorted and streamlined into a User Datagram Protocol signal used to drive the VE.

B. Subjects

Thirteen healthy adults (6 male and 7 female) divided into three groups voluntarily participated in this study. Institutional approval was obtained from UMDNJ. All subjects were consented. Gain manipulation was tested with independent groups using three different protocols 1: pedals decoupled and gain self-selected 2: pedals coupled and gain self-selected and 3: pedals coupled and gain constant. Group 1 ($n=5$): Subjects were tested with the pedals decoupled from the cyclist in the VE. Gains (exact and high) were set while subjects cycled at their comfortable speed, based on their perception of the rider's pace in the VE. Exact gain was established when subjects indicated they perceived the rider to be in pace with them. High gain was set as participants reported their perceived an increase in the rider's speed. A single gain (exact or high) was applied for the entire trial. Group 2 ($n=5$): Subjects cycled with the pedals coupled to the VE. Gain (exact, high) was changed from exact to

high within the trial after 30 seconds. Group 3 (n=3): Subjects cycled with the pedals coupled to the VE. Exact gain was set as described above, while high gain was set with a constant known increment from the self-selected gain. The gain was changed from exact to high within the trial after 30 seconds.

Following an orientation to the protocol, subjects were seated on the bicycle (pedal at bottom dead center and parallel to the ground, knee in 50 degrees of flexion). The virtual environment was projected on a television screen located approximately 1.5 meters from the subject. Cycle was set on the “constant” mode with a power of 20 Watts. Subjects warmed up on the bicycle between two and five minutes. During the testing subjects were instructed to cycle in response to the virtual scene with the manipulations described above. Revolutions per minute (rpm) were collected from the bike pedal at 100Hz.

C. Data Extraction and Analysis

RPM were obtained from the IMU in the bike pedal. The rpm were counted as the crank crossed the top-dead center of cycling circumference. Data were analyzed using a 2 (Gain) X 3 (group) RM ANOVA with paired t-test for the post hoc analysis.

III. RESULTS

There was a significant interaction between the gain and the group ($F=5.207$, $p=0.028$). Post-hoc analysis showed a significant increase in the cycling speed between exact and high gain only for the group-3 when the pedals were coupled and a constant gain was applied $p=0.04$ (Fig. 2).

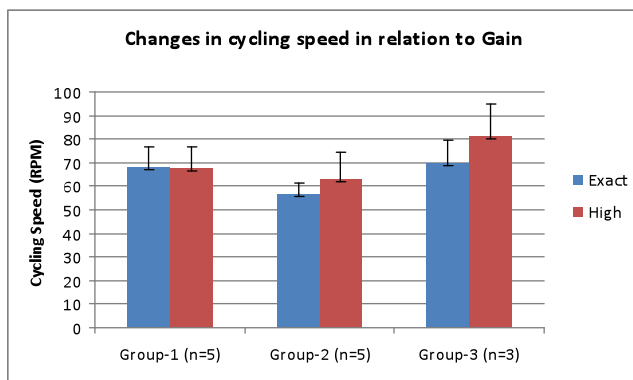


Figure 2: RPM during three gain manipulations

III. DISCUSSION

Cycling rate was affected by the optic flow when cycling was coupled to the VE rider and there was enough contrast in the gain (Group 3). In contrast to walking as gain increased so did cycling rate. When the gain contrast was low or the rider’s movements were not coupled with the environment, the cycling rate wasn’t

affected by the optic flow. These findings can be related to the experimental set up in which users were on a stationary bike and may have lacked the self-perception of motion. Another explanation is that complexity of the visual environment with curves and additional elements in the scene may have diminished the impact of visual flow speed. These results support Rossignol’s hypothesis that there is an interaction of body based and visual senses that affects the speed of motion [6]. Unlike Mohler and colleagues, who used a similar experimental paradigm and found that when a person is instructed to walk at a comfortable speed, their actual walking speed decreased as the rate of visual flow increased[2]; we found that subjects increased their speed as gain increased. This contradiction can be related to decrease in balance threats and increased confidence during cycling on a stationary bike compared to walking on a treadmill.

While this is the first study to our knowledge to report on the effects of optic flow on cycling speed, the findings are only preliminary and represent responses of only thirteen subjects. Nonetheless, modulation of the cycling rate was supported when cycling was coupled to the VE and there was a high degree of contrast in the gain.

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