Visibility-Enhanced Bicycling Clothes with Flashing LEDs Applied for Biological Motion

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Introduction/Significance. Bicyclists number approximately 39 to 40 million around the world; the U.S. bicyclist population grew by 27 million in 2011 (Formosa, 2012). In 2010, roughly 52,000 bicyclists were injured, and 618 were killed in traffic accidents, which accounted for 2% of all traffic fatalities; the cause was mostly low conspicuity. Eight billion dollars are spent annually in the US to care for bicycle crash victims (NHTSA, 2012). Therefore, researchers have suggested that bicyclists wear visibility aids during at night (Kwan & Mapstone, 2004; Wood et al., 2011). Many studies have suggested using LEDs, but there is a lack of understanding about the appropriate positions for wearing these lights. Previous research (Koo & Dunne, 2011; Koo & Smith, 2010) found effectiveness for using LEDs on joints at nighttime. However, there is no research comparing the effectiveness on differing joints. Thus, the purpose of this study was to develop visibility-enhanced bicycling clothing with flashing LEDs on different configurations, focusing on body joints and evaluating the effects of this clothing design on bicyclists' visibility. This research will provide ideas for apparel designers to develop visibility-aiding bicycling clothing as well as assistance to bicyclists in placing flashing LEDs on the most effective areas of their bodies.

Literature Review/Method. The yellow color of lamps and flashing lights has been shown to enhance detection and recognition by drivers at night (Kwan & Mapstone, 2004). Therefore, in this study, yellow-based flashing LEDs (thatscoolwire.com; MGFL-RB12; a diameter of 10 mm and a height of 13 mm and blinking in 0.2 second intervals) were utilized. The flashing LEDs were positioned on the movement joints (shoulder, elbow, wrist, thigh, knee, and ankle) to increase the bicyclists' visibility in comparison to with previously developed visibility-aiding bicycling wear (Blake & Shiffrar, 2007; Wood et al., 2011). In our study, a female bicyclist wore a black jumper and pants, black shoes, and a black helmet. Black was used to eliminate any potential color factors that might have affected the bicyclist's visibility. Usability tests were conducted to compare vehicle drivers' ability to visually detect moving bicyclists. Previous research of Koo and Dunne (2011) and Koo and Smith (2010) on LEDs for bicycling clothing guided the methods of usability tests in terms of recording videos, and participants answered the questionnaires about their perceptions of bicyclists' visibility. The following eight different configurations of flashing LEDs were recorded on eight videos to conduct usability testing: flashing LEDs located on the top part of the body, including the shoulders, elbows, and wrists (VC1); on the bottom of the body, including the thighs, knees, and ankles (VC2); and on the thigh (VC3), knee (VC4), ankle (VC5), thigh and knee (VC6), thigh and ankle (VC7), and knee and ankle (VC8). The video recordings were obtained using a video camera (Canon IXUS 870 IS) mounted on the driver's forehead in a moving vehicle following the bicyclist. The test involved four steps: introduction to the research; demographic survey; questions about user impressions using a five-point Likert chart for each VC; and post-test questions asking for

selection of one among the VCs in the aspects of visibility, detection, safety, accidents, and suggestions. Each video clip had a total duration of approximately 1 minute, and the total usability testing session lasted roughly 15–20 minutes.

Major Result/Conclusion. The 293 participants consisted of 202 men and 91 women aged 18-65 years old (*M*=29.26, *SD*=8.824). In terms of driving years, the average number was 11.25 (SD =8.86). Differences among the video clips were analyzed with a one-way ANOVA, as well as Duncan's test. Among the identified results, the major results presented significant differences in the observer's detection ($F [7, 2343] = 65.32$, $p<.001$); the recognition of the bicyclist ($F [7, 2343] = 42.72$, $p<.001$); improvement of visibility by the flashing LEDs ($F [7, 2343] = 61.11$, $p<.001$); bicyclists' sense of safety ($F [7, 2343] = 3.84$, $p<.001$); less likelihood of accidents with flashing LEDs ($F [7, 2343] = 5.05$; $p<.001$); and the perceived bicyclist's visibility ($F [7, 2343] = 52.55$, $p<.001$). The flashing LEDs on the bottom of the body (VC2; thigh, knee, and ankle; *M*=4.97, *SD*=1.56); on the thighs and knees (VC6; *M* =4.95, *SD* =1.56); and on the top of the body (VC1: shoulders, elbows, and wrists; *M*=4.84, *SD*=1.56) were the most readily detectable group. Flashing LEDs on the ankle (*M* =2.94, *SD* =1.59) were the least detectable. Similarly, the bicyclist was the most visible when the flashing LEDs were applied on the bottom the body (VC2; *M*=4.95, *SD*=1.38) and on the thigh and knee (VC6; *M*=4.94, *SD*=1.46). The least visible configuration of the flashing LEDs was on the ankles (VC5; *M*=3.03, *SD*=1.72). From the post-test, the most visible bicyclists wore clothing with flashing LEDs on the bottom of the body (VC2=20.8%), followed by thighs and knees (VC6=18.8%), and the top of the body (VC1=18.1%). Thus, when developing visibility-aiding clothing for bicyclists, flashing LEDs on the bottom (thighs, knees, and ankles) is the best option to enhance bicyclists' visibility, and the next best option is on thighs and knees. Future research can experiment with different types of visibility aids and different age groups.

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