An Analysis of Visibility Aids for Biomotion Through 3D Eye-tracking Systems

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Introduction and Literature Review. Biological motion, or biomotion, is the perceptual phenomenon in which highlighting the major joints of the body renders recognition of the human form almost immediately (Johansson, 1973). By taking advantage of biomotion, clothing materials and garments can increase visibility of bicyclists through the application of visibility aids on the major joints (Koo & Huang, 2015; Wood et al., 2010; Wood et al., 2012; Wood et al., 2013). The purpose of this research is to compare the effectiveness of biomotion visibility aids for nighttime bicyclists via 3D eye-tracking technology. A literature review of biomotion visibility aids and a between-subjects experiment were conducted in this research. Within the existing literature, there is a lack of research addressing bias of attention and natural driving states when participants receive explicit recognition tasks—by measuring gaze via eye-tracking technology, attention to roadside bicyclist targets can be determined implicitly, without biasing participants.

Methods. Based on the literature review, four visibility aid conditions were tested via videos in a lab setting: *biomotion* (retro-reflective knee and ankle bands), *non-biomotion* (retro-reflective vest), *pseudo-biomotion* (vertical retro-reflective stripes on the back of the legs), and *control* (all-black clothing). In the experiment, a total of 40 participants, who are in the ages of 18 and 35 in the U.S. without any eye health issues, were randomly assigned one video condition and gaze fixations were measured with 3D eye-tracking glasses. Gaze coordinate data were analyzed via a one-way ANOVA using SPSS. Heatmaps exported in the Pupil software displayed location and frequency of gaze averaged over time on a defined surface, marked with Pupil's printable markers placed on the corners of the experiment's monitor. A heatmap is data visualization with an X and Y axis that shows hierarchy through colors and shades (Wilkinson & Friendly, 2012). After then, qualitative assessments of the experiment were measured with a post-experimental questionnaire through color-coding and major theme extractions.

Results and Discussions. After a series of one-way ANOVA and Tukey's post-hoc analyses, significant differences were found between the four reflective clothing design conditions in both X-coordinate values ($p<.01$) and Y-coordinate values ($p<.05$). For the X-coordinate (i.e. left and right eye movement), cases 1 and 2 (*biomotion*: M=70.228, SD=8.376; and *pseudo-biomotion*: M=71.397, SD=6.674) were the most visible group, while case 4 (*control*: M=56.098, SD=13.116) was the less visible group. Case 3 (*non-biomotion*: M=64.795,

SD=8.694) was included in both groups, therefore less visible than cases 1 and 2. Based on the results, *biomotion* and *pseudo-biomotion* configurations of retroreflective visibility aids are significantly more visible than both *control* and *non-biomotion* configurations. X-axis coordinates were more significant due to the nature of scanning roads at night from the perspective of a driver (Sodhi et al., 2002). This confirms that the knee-and-ankle biomotion configuration, as well as the newly introduced pseudo-biomotion configuration, are significantly more visible than a vest configuration or all black-clothing. From the survey, the major results indicated that more than 80% of participants expressed concern about adoptability, to what extent aesthetics should factor into their choice for adoption of visibility aids.

Conclusion. This research has the potential to benefit both drivers and nighttime bicyclists through a better understanding of how biomotion can increase visibility, as well as further inform clothing designers on how to incorporate biomotion to increase bicyclist visibility. The results are expected to guide applications of biomotion into clothing design in the development process. The next stage of this research is to design retroreflective-biomotion bicyclist clothing that incorporate the findings and evaluate the prototypes through surveys and user-tests.

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