Assessing the Impact of Three Intersection Treatments on Bicyclist Safety Using a Bicycling Simulator

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Extended Abstract

Bicyclist safety at urban intersections is a critical element for encouraging an increase in the bicycle commuting. With cyclist injury and fatality rates rising due to collisions with vehicles at signalized intersections, increasing the safety of riders continues to be an important consideration when promoting this mode of transportation. The present study performed human subjects testing in the Oregon State University (OSU) Bicycling Simulator to expose study participants to a combination of three different intersection treatments and various types of conflicts with passenger cars to better understand which treatment is most effective at mitigating turning vehicle-bicycle collisions at signalized intersections. Previous research has addressed crash causality with these types of conflicts and helped to develop several roadway treatments to improve bicyclist safety, but little has been done to compare and contrast the benefits of the various treatment types. This bicycling simulator study examined the impacts of three intersection treatments (i.e., bike box, mixing zone, and bicycle signals) to better understand their influence on the performance measures of bicyclists' comfort, levels of stress, and riding behaviors. This improved understanding allowed researchers to make recommendations for which of the three designs proved to be most effective for reducing the risk of vehicle-bicycle collisions at intersections. The three treatments examined are currently being used to improve bicyclists' safety in the as-built environment and 3-D renderings of the designs used in the simulated environment are shown in Figure 1.

Figure 1: Bike Box, Mixing Zone, Bicycle Signal Treatments (from left to right)

These designs take different approaches for reducing the risk of right/left- hook crashes, a type of conflict where a turning vehicle collides with a through moving bicyclist. Crash causality for these types of collisions may be attributed to both vehicles and bicycles, but this study used the OSU Bicycling Simulator to assess only the bicyclist's response to the intersection treatments. Figure 2 displays a participants view when approaching an

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intersection treatment while riding in the OSU Bicycling Simulator. With bicyclist response being the primary focus, turning vehicle movements were programmed by researchers and were kept constant throughout each participant's exposure in the study. There may be room to further advance this study by including future work that examines vehicle responses to these treatments to understand how driver response varies as a result of these intersection treatments.

Figure 2: OSU Bicycling Simulator Rider Perspective

Forty participants from the area surrounding Corvallis, OR completed the study by responding to twenty-four scenarios while riding in the simulated environment. Recruitment of participants was conducted through flyers posted in bike shops and common areas in the surrounding area, through social media, and from various email listservs. An effort was made to incorporate participants between the ages of 18 to 75 years, with one additional exclusionary criterion being that participants must not require the use of glasses while riding a bicycle. Participants had to read and acknowledge the IRB-approved consent form (Study Number IRB-2020-0531) prior to participating and were compensated $20 for their time. To avoid any potential bias effects on participant's responses, they were not provided with the research hypothesis or specific details regarding the experimental design in advance of their participation. Survey results indicated that the participant sample to be well distributed in terms of age, gender, biking experience, and frequency of riding; Indicating the sample is representative of biking demographic in Oregon based on past survey results. To ensure accurate collection of data, equipment was adjusted and calibrated for each participant individually prior to any of the riding tasks. Calibration procedures allowed participants the opportunity to get acclimated to the simulated environment while wearing the equipment necessary for recording biometric feedback such as eye-tracking and galvanic skin response sensors. These calibration procedures also provided researchers the opportunity to assess if the participant was at risk of experiencing simulator sickness and did not include any of the independent variables to avoid inference of study motivations. COVID-19 protocols were followed throughout the study duration and implementation of safety precautions were taken throughout the data collection phase.

A 4x3x2 factorial design of independent variables resulted in 24 scenarios being presented to each participant. The scenarios were separated into four different grids, each with six intersections of interest where all scenarios were fully counterbalanced and presented in a randomized order to reduce the chance of order effects from occurring. The testing procedure was designed to mitigate the chances that participants experienced fatigue or simulator sickness and short breaks between the grids along with limited turning maneuvers helped to accomplish this. The scenarios presented to each participant featured a cross between the different levels of the three explanatory variables which include: Presence of conflict vehicle, Treatment applied, and Stopping requirement. The conflict vehicle variable allowed researchers to evaluate bicyclist response to various positions of a turning vehicle to answer the research objectives. The stopping requirement included two levels - whether bicyclists were allowed to proceed through or whether they were required to stop at the intersection, as dictated by a red or green signal indication displayed upon arrival. Data for each participant was collected in three phases: pre-ride survey questionnaire, experimental ride, and post-ride survey questionnaire where the pre- and post-ride surveys were used to gather demographic information and direct responses from participants regarding the scenarios. During the experimental ride portion of the study, researchers collected data related to the dependent variables of interest which include lateral position in lane, eye-tracking fixations, and level of stress. Instantaneous time-space measurements output from the bicycling simulator allowed researchers to segment the lateral position of participants across the scenarios of interest while eye-tracking fixations and levels of stress were assessed using the external programs ET Analysis and iMotions. The ET Analysis software allowed researchers to evaluate visual attention data by manually coding polygons for certain areas of interest (AOI), where the visual attention allocated towards the conflict vehicle by the bicyclists on approach was the main AOI. Stress levels of participants was recorded using biometric feedback from their skin conductance and assessed using the iMotions software. This is known as the galvanic skin response and was gathered throughout the study duration to understand how stress levels vary in real-time and how the different scenarios impacted participants level of stress.

The experimental design exposed each participant to all combinations of independent variables; Thus, a repeated measures analysis of variance (ANOVA) test was used to assess for differences in the dependent measurements. This ANOVA test is common for designs where each participant generates multiple measurements and when a statistically significant result was found, Mauchly's test of sphericity and a Bonferroni pairwise comparison test was conducted to further analyze the comparisons. Time-space measurements for the lateral position on intersection approach revealed statistically significant results, where more sporadic riding behaviors were associated with the mixing zone treatment. Participants tended to deviate furthest from center of lane when traversing the mixing zone, riding approximately 0.80 meters (2.6 ft) further to the left of lane center when compared with the other treatments. Visual attention has been shown to be an accepted method for assessing shifts in attention and was measured as the amount of time allocated to viewing the conflict vehicle by participants. The measurements revealed that participants tended to focus more visual attention on the conflicting vehicle when traversing the mixing zone treatment as compared to the bike box and bicycle signals. In addition, analysis of the participants' eye-movements revealed a lower rate of recognizing the conflict vehicle when traversing the bicycle signal treatment. Statistical analysis of the visual attention data found a statistically significant difference when comparing across all treatment types using the Bonferroni Pairwise Comparison Test. Galvanic Skin Response measurements were used to measure participants stress levels but found no statistically significant results, although it was found that the mixing zone elicited slightly larger stress responses.

Overall recommendations conclude that the bike box design was found to be the most versatile treatment out of the three evaluated, providing a balance of increased safety while also requiring the participant to perceive potential danger and be ready to respond accordingly. In scenarios where there is a large frequency of crashes, the bicycle signal may prove most effective as its design restrict conflicting vehicle movements with the bicyclists. The mixing zone may be best fit in scenarios where crashes tend to occur with a pre-existing bike lane, as the positioning data shows that bicyclists are willing to merge with the traffic and the provided right-of-way may allow safer movements between the two modes. Despite these recommendations, all treatments were found to have a positive and negative effect on the riding habits of participants; Therefore, it has been recommended that implementation of the various treatments to be situational. Using a treatment too frequently may influence bicyclists to adopt negative riding habits that reduce their safety and the safety of others on the roadway. The tradeoff between safety and bicyclists' comfort and convenience must be considered, as the present study showed how participants were most comfortable traversing the bicycle signal but saw reduced searching for potential conflicts on approach. To add on to this, the mixing zone treatment brought participants out of their comfort zone and was indicated to create the most discomfort but required participants to be alert of potential conflicts when claiming lane. The results of this research can provide a better understanding of how to best implement these treatments to increase bicyclists' safety at signalized intersections when operating around conflicting vehicles. Considerations should be taken surrounding additional treatment alternatives that could outperform the bicycle box that were not assessed in the present study.