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Editorial: Innovative road safety measures

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1. Introduction

The present Special Issue of ATS is dedicated to the 8th Road Safety and Simulation International Conference 2022 (RSS2022) that took place on 08-10 June 2022 at Zappeion Megaron in Athens organized by the National Technical University of Athens (NTUA) and the Hellenic Institute of Transportation Engineers (HITE). The main aim of the Conference was to improve upon the existing scientific knowledge in the area of road safety and contribute to reduce the number of accident fatalities and injuries occurring worldwide, through the promotion of state-of-the-art innovative road safety research and applications in the digital era.

2. Overview of selected papers

This Special Issue on RSS2022 provides a synthesis of thirteen (13) high-quality scientific papers, focusing on innovative road safety measures addressing key research fields, namely roadway infrastructure, safety modelling, human factors, vulnerable road users and automated driving.

2.1. Roadway infrastructure

Roadway infrastructure safety research encompasses geometric design, safety equipment, pavements, roadside and traffic and weather conditions; however, only their co-consideration can lead to the identification of crash and casualty causes and the related countermeasures, which are often costly.

Stamatiadis et al. [1] undertook a research effort to summarize factors which contribute to low-volume roads (LVRs) crashes, identify implemented countermeasures to address LVR safety, and determine how effectively countermeasures address LVR safety. The paper identified best practices and countermeasures agency staff view as being the most effective. Summary sheets were developed which describe each countermeasure, comment on their effectiveness, review installation costs, and list crash types they are used to mitigate.

Bisht et al. [2] evaluated the risk of road crashes on a selected intercity expressway by utilizing an exploratory data analysis technique to ascertain crash characteristics. The results revealed that segments with attributes such as the presence of hazards, presence of access location and underpasses, vertical and horizontal alignment parameters and high AADT have a high risk of fatal crashes. Samandi et al. [3] examined interchange design impacts on traffic emissions and fuel consumption through microsimulation. The paper summarises the case study of an existing service interchange. The results revealed that the existing conventional diamond interchange design provokes much higher emission rates than the single point urban interchange and the diverging diamond interchange. Besides safety and operational performances, emission impacts of interchanges are also significant when assessing the type of interchange design to implement during the planning and designing stages.

The provision of overtaking maneuvers is regarded a key safety priority during the geometric and operational design of two lane rural roads. Matragos at al. [4] studied vehicle's overtaking paths from the road-engineering point of view in order to quantify their trajectories and define potential safety violation imposed from the vehicle acceleration performance. The assessment is based on a driving simulator experiment as well as a vehicle dynamics model. Besides the geometry of the curved overtaking paths, respective critical parameters, such as headway and lateral distances were also investigated.

2.2. Safety modelling

Safety modelling covers all aspects of road safety factors, allowing the identification and prioritization of crash occurrence and severity causes. Although the Road Safety Manual, published in 2010 by AASHTO [5], provides comprehensive guidelines for evaluating highway safety improvements and facilitates decision-making based on safety performance, more research is needed for the identification of sections that should be subject to safety improvements.

Tiberi et al. [6] provide a state-of-practice review of the international literature on methods and applied practices for the identification of hazardous locations based on crash occurrence analysis. The analysis identified and summarized differences and similarities in the various methods and applied practices. In that context, aiming to improve highway safety project ranking, Tanzen et al. [7] introduce a new safety scoring method. The method considers crash severity and incorporates the empirical Bayes (EB) estimates and the excess expected crashes (EEC) metric in a multifactor score. Additionally, it introduces a "goal-driven" EEC, which represents the potential for reaching targets specified in the examined state's (Kentucky) Strategic Highway Safety Plan.

Eustace et al. [8], studied the impacts of raising speed limits by 5mi/h (from 65mi/h to 70mi/h) on rural freeway sections of Ohio. The primary goal of the study was to investigate the safety impacts of the new speed limit using available crash, roadway, and traffic characteristics data. Safety performance functions (SPFs) were developed for both total crashes and fatal and injury (FI) crashes combined. The EB analysis showed a decrease in both total and FI crashes for the two years after the speed limit was changed. However, caution should be taken in drawing conclusions from this study because the after period did not meet the minimum of three years recommended by the Highway Safety Manual.

2.3. Human factors

Human factors (speeding, distracted driving, risky overtaking, driving under the influence of alcohol and other psychoactive substances etc.), are likely to be the most crucial cause of road traffic fatalities and injuries every year and therefore the importance of studying how these factors can affect crash risk is high [9].

Banz et al. [10] explored the relationship between early drinking patterns and vehicle control among sober young adult drivers. A driving simulator experiment was held where vehicle control values were collected on different driving scenarios. The findings offer an initial perspective on how, even while sober, drinking at a younger age is associated with greater variability in vehicle control measures that are linked to increased crash-risk.

Schlichtherle and Hoger [11] also used a driving simulator in order to investigate risky overtaking. Runs with varying levels of oncoming traffic were studied, where each route ended with a traffic situation in which an overtaking manoeuvre would be potentially risky. No clear link could be found between different amounts of oncoming traffic and overtaking intention. Most of the test drivers indicated a positive intention to overtake regardless of the experimental condition.

The results suggest that the cognitive processes during such traffic scenarios and manoeuvres should be examined in more fragmented approaches.

2.4. Vulnerable road users

A vehicular collision event places pedestrians, cyclists and motorcyclists at a high risk of injury. For this reason, these categories of road users are also characterized as Vulnerable Road Users (VRUs). Based on the latest evaluation of road safety level worldwide, the World Health Organization reports that VRUs account for more than 50% of total road fatalities [12].

Wyman et al. [13] investigated how pedestrians search for information at a signalized intersection via a field experiment in which participants crossed an intersection wearing a mobile eye tracker. The results suggest that participants understood how to correctly associate pushbuttons with the corresponding crosswalks at a real-world signalized intersection. Pushbuttons and pushbutton signage were last to be observed, with most fixations occurring less than three seconds to button push. In a similar vein, Juzaafi et al. [14] analysed pedestrian behavior at mid phase of green countdown display in terms of their choices and success with respect to remaining green time at arrival. Results indicated that age group and remaining green time at pedestrian arrival affect pedestrians' choices significantly irrespective their gender.

Nikolaou et al. [15] studied how hand-held cell phone conversation affects the behavior of pedestrians at signalized intersections in terms of both safety and traffic. In order to compare the behavior of distracted and non-distracted pedestrians, an outdoor environment experiment was carried out in real road conditions. The results showed that pedestrian main traffic and safety characteristics were negatively impacted by distraction from hand-held cell phone conversation, as mobile phone use not only reduces pedestrians' speed but also increases the likelihood that they will be involved in a collision with an approaching vehicle.

2.5. Connected and automated driving

Connected and automated vehicles are expected to boost road safety; however, particular attention should be given to the long transition phase of mixed traffic of traditional and automated vehicles, especially in terms of necessary infrastructure adaptations. A key principle for automation safety is the necessity for "Human-Centred Design", in which all possible user profiles should be considered when designing Autonomous Vehicles [16].

Sekadakis et al. [17] aimed to identify and review risk factors that impact road safety and driving performance focusing on three types of users; namely, elderly drivers, truck operators, and office workers. The reviewed risk factors were discussed based on how they can be extended and adapted at the different future autonomous driving levels and what risk factors should be considered in future safety analysis depending on the autonomous driving level at the various road environments.

3. Conclusion

In summary, the present Special Issue collection represents a snapshot of current advancements in innovative road safety measures focussing on roadway infrastructure, safety modelling, human factors, vulnerable road users and automated driving. Road safety is undoubtedly a multidisciplinary scientific field challenging researchers to work together in order to achieve the ultimate goal of reducing the number of accident fatalities and injuries. Some key conclusions arisen from the present Special Issue comprise of the need of co-consideration of all crash factors for accurate results, the importance of digitalisation and technological advancements on boosting road safety, and the significance of implementing innovative and evidence based road safety measures for multiplying the safety benefits.

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A behavioral approach to improving pedestrian infrastructure at signalized intersections

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Abstract

Washington County, Oregon, United States, maintains multiple perpendicular pedestrian crossings at signalized intersections served by two pushbuttons located on a single pushbutton pole. County engineers have observed that pedestrians frequently push both pushbuttons, regardless of the crosswalk they intend to use. This behavior incurs unnecessary delay for all intersection users—particularly at locations operating split phases and where the pedestrian phase controls the time allocated to the concurrent vehicular phase. To address this challenge, the exploratory study presented herein investigates how pedestrians search for information at a signalized intersection via a field experiment in which participants crossed an intersection wearing a mobile eye tracker. Usable eye tracking data for seven participants was collected. The data suggests that participants understood how to associate pushbuttons with corresponding crosswalks and used pedestrian infrastructure at the study location to do so. However, additional information could help participants identify which crosswalks are next to be served and make more efficient crossing decisions. Eye tracking data suggests that participants began observing vehicle traffic earlier and more consistently than other infrastructure elements on their approach to the pushbutton pole. Pushbuttons and pushbutton signage were the last infrastructure elements observed, with most observations occurring less than three seconds to button push. Of traffic signals and traffic, pushbuttons and pushbutton signage, and pedestrian signals, participants fixated on traffic signals and traffic approximately 45% of the time and on pushbuttons and pushbutton signage approximately 51% of the time.

Keywords – pedestrian, intersection, pushbutton, operations, human factors, signals

1. Introduction

Despite advances in automated pedestrian detection, pedestrian pushbuttons are the primary means by which a pedestrian can request a WALK signal at a signalized intersection in the US—and will likely remain so for some time [1, 10]. Multiple signalized intersection corners in Washington County, Oregon, United States (US), have two pushbuttons for perpendicular pedestrian crossings at signalized intersections located on a single pushbutton pole. County engineers have observed that pedestrians frequently push both pushbuttons on the pole, regardless of the crosswalk they intend to use. When the pedestrian phase for the unintended crosswalk activates, it incurs unnecessary delay for all intersection users—particularly at locations where the pedestrian phase controls the time allocated to the concurrent vehicular phase. Delay is exacerbated at intersections with split phasing and coordination, where pedestrian actuations can throw the corridor out of coordination [2, 13]. These behaviors, and the associated consequences, motivated the exploratory study described herein.

Little existing research specifically examines how pedestrians choose a route through an intersection and which pushbutton(s) to push. Most studies on pedestrian pushbutton use focus on accessibility for persons with disabilities and jaywalking, or crossing an intersection against the WALK signal [1]. However, both topics are closely related to this research in that they often 1) seek to understand how and why pedestrians choose to use pushbuttons; and 2) examine potential modifications to existing pedestrian infrastructure, like signals and signage, to provide pedestrians with additional information that encourages better decision-making. Such studies can provide useful insights relevant to the results of this research.

Understanding pedestrian non-compliance with pushbuttons is an initial step towards improving pedestrian safety and efficiency at signalized intersections. Not pushing the pushbutton and jaywalking are frequently-studied forms of non-compliant behavior, perhaps because jaywalking is often cited as a factor in pedestrian crashes. In a study of pedestrian crashes at 1,297 intersections, Zegeer et al. [17] found that 42.7% of pedestrian crashes involved a pedestrian crossing against the WALK signal. In 41.5% of crashes, the driver involved committed no violation [17]. Other common forms of non-compliant pushbutton use include repeatedly pressing the same pushbutton or pushing all pushbuttons available, regardless of the one needed [1]. Repeatedly pressing the same pushbutton is problematic because it decreases the service life of that pushbutton [14]. Pushing all pushbuttons available, regardless of need, can significantly increase delay for all users—especially at intersections with long crossing widths that require long crossing times, coordinated intersections, and intersections with split phasing [2, 13].

There are a variety of reasons why persons might demonstrate non-compliance at crosswalks. Impatience or uncertainty about how a system operates are two factors which may contribute to non-compliance [1, 5]. Prior research on jaywalking shows pedestrians are more likely to cross without the WALK signal the longer they have to wait [4, 15]. Pedestrians may also be more likely to jaywalk when traffic volumes are lower and there are more acceptable crossing gaps, the perceived risk is less, or if they do not believe that their request for service was received [1, 4, 5, 14-16]. If a system does not operate according to a pedestrian's expectations—regardless of whether it is functioning properly—a pedestrian may think the system is malfunctioning [8, 11]. For example, in the cities of Windsor and Toronto, Ontario, Canada, city traffic engineers received repeated complaints that pushbuttons were not working because the WALK signal did not activate quickly after pedestrians activated the pushbutton. In actuality, the pushbuttons were functioning properly—just counter to pedestrians' expectations [8].

When a system is novel to the user, or operates counter to expectations, providing extra information to the user can be important for developing or maintaining the user's trust in the system [11]. A user's trust is critical to the continued use of that system [6, 11]. At signalized intersections, providing visual and audible feedback to pedestrians that their request for the WALK signal has been received has had some success in encouraging pedestrians to use pushbuttons. For example, a before-after study conducted in Miami Beach, Florida examined pushbuttons that provided both visual and audible feedback to pedestrians that their request for the WALK signal had been received [14]. The study found statistically significant evidence that additional feedback increased the proportion of pedestrians who pushed the pushbutton and then waited for the WALK signal to cross [14]. The cities of Windsor and Toronto, Ontario also replaced their conventional pushbuttons with pushbuttons that provided only visual feedback by illuminating when pressed [8]. A before-after study of the system found that installing the illuminating pedestrian push buttons did not significantly affect pedestrian behavior at most sites. However, more pedestrians pushed the pushbuttons after the illuminated pushbuttons were installed and the City of Windsor received fewer

service calls regarding non-functioning pushbuttons [8]. These case studies demonstrate the potential utility of providing pedestrians extra information—especially where the transportation system operates counter to pedestrian expectations.

Finally, understanding where pedestrians look before pressing a pushbutton can be helpful to understanding how pushbuttons are selected—and thus what kind of additional feedback might be most helpful for pedestrians' decision-making. The amount of time a pedestrian spends looking at, or fixating on, various areas of interest (AOIs) often correlates to the cognitive attention given the same AOIs. No previous studies have specifically examined the visual attention of pedestrians for the purpose of understanding pushbutton selection. However, a few eye tracking studies have examined the visual search patterns of pedestrians when making road crossing decisions (e.g., [12]). Few of these studies focus on signalized intersections, most of which have been conducted in a simulator setting (e.g., [12]). The most similar experiments to that presented in this paper are Geruschat et al. [7] and Egan [3]. Both experiments outfitted participants with eye tracking equipment and asked participants to cross a real-world signalized intersection, followed by a researcher who would intervene in dangerous situations [3, 7]. Geruschat et al. [7] conducted real-world crossing experiments at a four-way signalized intersection and a roundabout, examining participants' head movements and fixations during three phases of a street crossing: approaching the curb, waiting at the curb, and crossing the street. AOI categories included vehicles, the roadway, the general environment (trees, sky, billboards), crossing elements (bollards, curbs, crosswalk lines), and traffic controls (traffic signals, pedestrian signals). While approaching the curb, participants fixated most on crossing elements, the general environment, and vehicles. While waiting at the curb, most participants fixated on vehicles [7]. Egan [3] also examined a real-world signalized intersection, specifically evaluating age differences in visual attention between older adults, young adults, and children. AOI categories included the road and vehicles, pedestrians, the walkway, lights and signs, and non-traffic [3]. Egan hypothesized that different age groups would fixate on AOIs based on different approaches to road crossing: compared to younger adults, older adults and children were expected to employ crossing strategies that minimized cognitive demand. Egan also hypothesized that older adults and children would fixate more than young adults on a pedestrian signal, as this source was considered less cognitively demanding compared to the demands of tracking vehicle traffic and assessing gaps. The study found that younger adults tended to focus mostly on the roadway and vehicles (55% of fixation time) and spent little time attending to the traffic signals or signs (8%). Older adults fixated the most on the ground in front of them (38%) and spent more time fixating on signals and signs than younger adults. Children spent most of their time fixating on elements of the environment not relevant to traffic (27% of fixation time). However, children also spent more time fixating on pedestrian signals (18% of fixation time) than young adults (8% of fixation time). There were statistically significant differences between age groups in the time spent fixating on these AOIs, suggesting that visual search pattern varies by age [3].

The study presented herein investigates how pedestrians search for and use information presented at the intersection through a field experiment in which participants performed several intersection crossings wearing a mobile eye tracker. The study addresses the following research questions:

1. Is there a demonstrated need for modifications to existing pedestrian infrastructure at the study intersection that would help pedestrians correctly associate which pushbutton corresponds to which crosswalk and which crosswalk will be served next?

2. Where do pedestrians look for information when choosing between two acceptable crossings?
3. When do pedestrians look for information from specific roadway elements on their approach to the pushbutton pole?

The results of this exploratory study were intended to inform a second study, which involves the development and survey assessment of conceptual design alternatives representing modifications to signals or signage. This paper presents the results of the first study.

2. Methodology

This exploratory study was conducted at the intersection of SW Scholls Ferry Road and SW Nimbus Avenue in Washington County, Oregon with recruited participants. The intersection, shown in Fig. 1a, has marked crosswalks on all intersection approaches activated by pushbuttons at each corner. Pushbuttons for both crosswalks at each corner are located on a single pole, with signage explaining which pushbutton corresponds to which crosswalk (Fig. 1b). The intersection's north and south approaches operate sequentially with split phasing. Depending on time of day, the intersection's east and west approaches operate with a combination of split phasing, concurrent protected east and west left turns, and concurrent east and west through movements with and without permissive flashing left-turn yellow arrows. Pedestrians are not served during the east-west permissive left-turn flashing yellow arrow phase. To receive the WALK indication in the same signal cycle that a pushbutton is activated, the pedestrian must activate the pushbutton prior to the onset of the concurrent vehicular phase. The study location was selected in partnership with transportation engineers at Washington County, who indicated this intersection was of particular interest due to its split-phase operation, high vehicular volume, and the observed prevalence of undesirable pushbutton behaviors.

Participants were recruited within Washington County by Washington County staff and from neighboring communities via email announcement. Some participants were knowledgeable about transportation; others were not. All participants were pre-screened to ensure they were age 18 or older and did not require glasses to participate, as the eye tracker employed is not compatible with glasses (contacts are okay).

Fig. 1a - Aerial image of SW Scholls Ferry Road and SW Nimbus Avenue, Washington County, Oregon, US; Fig. 1b - Pushbuttons and pushbutton signage at study location

Fig. 2 - A researcher follows a participant through the intersection during alpha testing

Participants were asked to arrive at the intersection at a scheduled time, where they were provided a consent form and asked to fill out a brief pre-task survey with demographic questions. Then, the participant was outfitted with Mobile Eye-XG (Applied Science Laboratories) eye tracking glasses and a backpack to carry the eye tracking recorder and instructed in the experimental tasks. The experiment required the participant to travel across the intersection twice, completing two "there-and-back" tours. On one tour, the participant travelled to a corner of the intersection that required crossing only one approach of the intersection. On the second tour, the participant travelled to the diagonal corner of the intersection, requiring them to cross two approaches of the intersection. Half of the participants performed the crossing task in the opposite order, per a crossover study design. As a safety precaution, one researcher followed the participant through the intersection at least six feet behind for all crossings. The participant was informed of this precaution and instructed to disregard the researcher and cross the intersection as they normally would if they were not participating in this experiment. Fig. 2 depicts an example of this experimental setup taken during alpha testing, with a researcher acting the role of a participant. When the participants completed the crossing tasks, they filled out a post-task survey. The post-task survey asked questions about their understanding of pedestrian signage and markings and their typical crossing behavior. The experiment was approved by the OSU IRB Office (Study No. IRB-2020-0511).

In total, each participant experienced six scenarios which required them to select a crossing: three scenarios where only one crosswalk would lead to their desired destination, and three "choice" scenarios where either crosswalk would lead to their destination. Choice scenarios always occurred on the starting (northwest) intersection corner for both diagonal and adjacent tours and on the diagonal (southeast) corner of the diagonal tour. Participants travelled similar distances to the signal pole for the choice scenarios: all participants approached the northwest intersection corner from the temporarily-erected research tent located on the same corner; participants approached the southeast intersection corner after being instructed to first walk to a landmark down the block, then turn around. Eye tracking data was analyzed for the three choice scenarios to determine where and when participants searched for information when they made "reasonably efficient" and "inefficient" crosswalk choices. A reasonably efficient crosswalk choice was defined as a choice consistent with the expectation that the next crosswalk to be served will be the one associated with the vehicular phase which is not currently active. An inefficient crosswalk choice occurred when the participant selected the crosswalk for which the concurrent vehicular phase appeared to already be active. This definition is consistent with common signal timing practices at four-way signalized intersections in Washington County, where the allowable window for a pedestrian activation closes with the onset of the concurrent vehicular phase.

For each participant tour, researchers recorded the participant's route through the intersection and crossing time. Using video data recorded through the mobile eye tracker and detector logs provided by County engineers, researchers extracted data on pushbutton use mapped to participant visual attention. High quality eye tracking data was collected for seven participants. This data was reduced to determine how much time participants spent looking at AOIs, and when they looked at AOIs, consistent with established methods used in similar eye-tracking experiments (e.g., [9]). The following AOIs for both north-south and east-west approaches were considered: pedestrian signal heads, pushbutton signage, pushbuttons, vehicle traffic signals, and vehicle traffic. Elements that a participant looked at for more than 0.10 seconds constituted fixations, a surrogate measure of visual attention. Fixation count, fixation duration, fixation start time, and fixation sequence were extracted for each element during the time between when a participant began approaching the pushbutton pole at each corner and when they made their final button push. When the participant approached a pushbutton pole from a crosswalk, their eye tracking data was recorded from the time they set foot on the next intersection corner to the time they made their final button push on that corner. Time to button push, the time elapsed between when a participant made a fixation on an element and when they pushed the pushbutton, was calculated by subtracting the duration of each eye tracking segment from the fixation start time.

3. Results

3.1. Pre- and post-task survey

Nine total participants completed pre- and post-task surveys, which were merged by participant into one survey dataset. The pre-task survey asked participants to answer basic demographic questions. Seven participants identified as male and two identified as female. There were three participants each in the following age ranges: 25 to 34, 45 to 54, and 55 to 64. When asked about their familiarity with the intersection that they crossed in the field study, five participants indicated that it was their first time at the intersection, three did not use the intersection regularly but remembered using it at least once in the past, and one person indicated that they regularly used the crosswalks at the intersection.

The post-task survey examined participants' understanding of pedestrian pushbutton infrastructure, including signals and signage, and their expectations regarding how pedestrian infrastructure operates in tandem with other intersection elements, like vehicle signal phases. The questions investigated participant understanding of a four-way signalized intersection with two pushbuttons located on a single pole and pedestrian crossings on all four intersection legs; these questions incorporated street-level pedestrian-perspective photographs supplemented by aerial imagery of the field experiment location where necessary.

First, participants were presented with an image of a single signal pole with two pushbuttons and asked to identify which pushbutton corresponded with a specific crosswalk. As shown in Fig. 3a, the image was presented at a distance such that the symbols and text of the supplemental signage above each pushbutton, while present, was not clearly discernible. All participants correctly associated the specified crosswalk with its corresponding pushbutton. Next, participants were presented with an image of a traffic signal showing a green indication for east-west vehicle traffic

and asked which crosswalk, 1 or 2, would most likely be served next (Figure 3b). All participants answered that Crosswalk 1 would be served next, in alignment with typical signal timing practices in Washington County and the definition of a reasonably efficient crossing. These responses suggest that participants approached the survey with pre-existing knowledge about how to associate pushbuttons with crosswalks and reasonably guess which crosswalk would be served next, responses which may have been informed by participation in the field experiment.

When presented a hypothetical crossing scenario in which the participant was given a destination intersection corner that required them to only cross one intersection leg, as shown in Fig. 4a, three of nine participants answered that they would either "Always" or "About half the time" push both pushbuttons on the signal pole to initiate a crossing. When asked to explain, one participant who answered "About half the time" remarked that they would push the pushbuttons "without looking at which direction they were for". When presented with a hypothetical crossing scenario requiring the participant to cross to the diagonal corner of the intersection using two crosswalks, Fig. 4b, six of nine participants indicated that they would push both pushbuttons and cross at whichever crosswalk let them cross first "About half the time" or "Most of the time". Three participants responded that they would "Rarely" check which crosswalk would be first to serve them; the remaining participants answered that they would check "Most of the time" or "About half the time".

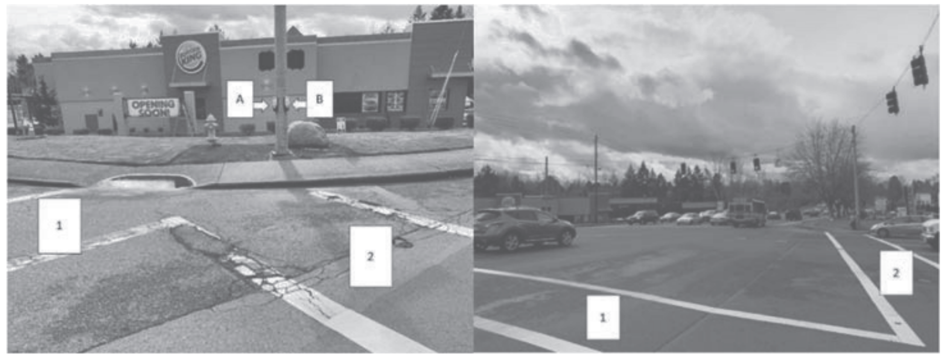

Fig. 3a - Survey graphic assessing pushbutton and crosswalk association; Fig. 3b - Survey graphic assessing participant expectations of which crosswalk would be served next

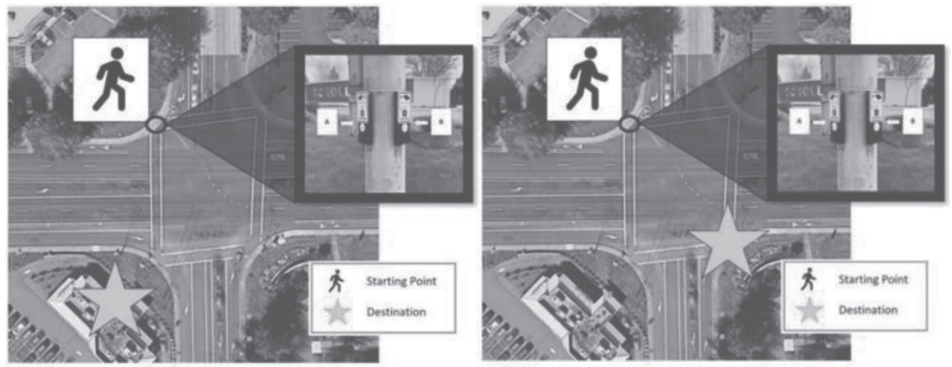

Fig. 4a - Adjacent crossing survey graphic; Fig. 4b - Diagonal crossing survey graphic

Two participants "Agreed" or "Strongly agreed" that additional information to that provided in the survey would help them choose which pushbutton to push. Both participants remarked about efficiency: one said they would "observe streetlights to determine which direction is the most efficient" and the other wrote "I would only push one button if I had an indication which one will come first". Those who "Disagreed" or "Strongly disagreed" made comments including that they would only "cross on the shortest path" and that "directions are simple and clear with both audible and visual information provided".

Participants unanimously responded that they "Agreed" or "Strongly agreed" their pushbutton use impacted other intersection users, including vehicles, pedestrians, and bicyclists. All four participants who elaborated on their agreement mentioned that pushing the pushbutton seemed to impact vehicle phasing. However, when asked whether using a crosswalk inconvenienced other people at the intersection, six participants "Disagreed" or "Strongly disagreed", two participants were "Neutral", and one participant "Agreed". It is possible that participants disliked the negative connotation of associating the term "inconvenienced" with pedestrians in a transportation culture progressively shifting toward de-emphasizing vehicle travel and prioritizing active transportation modes. It is also possible that they approached the statement from the perspective that pedestrian infrastructure cannot be thought of as "inconveniencing" to others because it represents another aspect of normal intersection operation, which deserves as much priority as other modes. While these are two possible explanations, identifying why participants responded as they did warrants additional investigation.

3.2. Field experiment

Of the nine participants who completed the pre- and post-task surveys, seven had usable eye tracking data. Of those with usable eye tracking data, six participants identified as male and one participant identified as female. Three participants were age 25 to 34 years, two were age 45 to 54, and two were age 55 to 64. Four participants wore contacts; three wore no type of corrective eye wear.

Of seven participants, two participants pushed both pushbuttons at an intersection corner at some point during the field experiment. In both instances, participants were completing a choice scenario at the northwest intersection corner. The participants pushed one pushbutton, waited several seconds, remarked that they should have pushed the pushbutton for the other crosswalk because it would be served first, then pushed the second pushbutton. Each participant made a reasonably efficient button push based on common signal timing practices in Washington County. One of these two participants, Participant A, waited approximately 31 seconds between their first and second button push. They received the WALK indication for the crosswalk corresponding to their second button push first and crossed on this indication, per their expectation. The second participant, Participant B, waited approximately 57 seconds between their first and second button push. They received the WALK indication corresponding to their first button push first, yet did not notice the signal had changed until mid-way through the flashing DONT WALK countdown, approximately 40 seconds after making their first button push. Between making their first button push and noticing the countdown, Participant B fixated on the (inactive) pedestrian signal corresponding to their first button push seven times for a total of 1.34 seconds. However, the participant had not fixated on the pedestrian signal for approximately 10 seconds immediately prior to noticing the countdown; they remarked that they had not noticed they had been given the WALK indication. Participant B did not try to cross during the remaining countdown; they waited and crossed with the indication corresponding to their second button push. This participant acted

reasonably for someone with no knowledge of this specific intersection's signal phasing: when they pushed their first pushbutton, they pushed it for a crossing concurrent to an east-west vehicular phase that appeared to already be running. However, the participant actually made the push on a split phase prior to the one that would serve their first-chosen crossing.

Across seven participants, there were 19 choice scenarios with usable eye tracking data in which participants could make a reasonably efficient crossing decision. Of the 19 choice scenarios, 15 scenarios (79%) were reasonably efficient. Of the 4.87 seconds participants spent fixating on AOIs prior to selecting an inefficient crosswalk on their first button push, fixations on traffic and traffic signals accounted for 14% of fixation time on AOIs. Of the 13.24 seconds participants spent fixating on AOIs prior to selecting a reasonably efficient crosswalk on their first button push, fixations on traffic and traffic signals accounted for 56% of fixation time on AOIs. While conclusions are limited by sample size, these results suggest that participants used traffic and traffic signals to choose reasonably efficient crosswalks.

Eye tracking data for all crosswalk choice scenarios was analyzed for information about where and when participants looked at the following roadway elements for both east-west and north-south approach orientations: pushbuttons, pedestrian signals, pushbutton signage, vehicle traffic, and traffic signals. Prior to making their first button push, participants spent 9.03 seconds fixating on AOIs before choosing an east-west-oriented crossing and 9.08 seconds fixating on AOIs before choosing a north-south oriented crossing. Of time spent fixating on AOIs prior to the first button push for an east-west oriented crossing, participants spent the most time fixating on east-west vehicle traffic (34%), followed by the east-west-oriented pushbutton (27%), and north-south vehicle traffic (11%). Of time spent fixating on AOIs prior to the first button push for a north-south oriented crossing, participants spent the most time fixating on the north-south-oriented pushbutton (31%), followed by east-west vehicle traffic and north-south pushbutton signage (21%), then north-south traffic (17%). When data from all approaches is combined, participants spent the most time fixating on vehicle traffic (42%), followed by pedestrian pushbuttons (33%), pushbutton signage (17%), pedestrian signals (4%), and traffic signals (3%). Tab. 1 summarizes the total time spent fixating on each AOI prior to making a first east-west or north-south button push.

For the two participants who selected both pushbuttons at one corner, fixations made before and after the participant's first button push were compared. Participant A made four fixations on AOIs lasting a total of 0.64 seconds prior to selecting a north-south-oriented pushbutton first: one fixation each on the east-west vehicle traffic, north-south-oriented pushbutton, north-south-oriented pushbutton signage, and north-south traffic. Between making their first button push and second button push (on the east-west-oriented pushbutton), Participant A made 26 fixations lasting a total of 5.50 seconds. Time spent fixating on east-west vehicle traffic comprised the majority of the 5.50 seconds (57%), followed by the east-west traffic signal (25%), and north-south traffic (10%). Prior to making their first button push on the east-west-oriented pushbutton, Participant B made five fixations on AOIs lasting a total of 1.00 seconds: three fixations (0.73 seconds) on the east-west-oriented pushbutton and one fixation each on the north-south pushbutton (0.10 seconds) and north-south pushbutton signage (0.17 seconds). Between making their first and second button push (on the north-south oriented pushbutton), Participant B made 45 fixations on AOIs lasting a total of 12.95 seconds. The east-west pedestrian signal comprised the majority of the 12.95 seconds (42%), followed by the east-west traffic signal (25%) and north-south traffic (25%). Participant B was surprised when they received the east-west pedestrian signal indication to cross and noticed it midway through countdown, which potentially explains the relatively large amount of time spent fixating on the east-west pedestrian signal.

Tab. 1 - Fixations by first button push for crosswalk choice scenarios

	East-West Button Push		North-South Button Push	
AOI	**Fixation Duration (s)**	**% of Total Fixation Time on AOIs**	**Fixation Duration (s)**	**% of Total Fixation Time on AOIs**
East-West Pushbutton	2.47	27%	0.13	1%
East-West Pedestrian Signal	0.33	4%	0.00	0%
East-West Pushbutton Signage	0.67	7%	0.10	1%
East-West Traffic	3.07	34%	1.95	21%
East-West Traffic Signal	0.43	5%	0.13	1%
North-South Pushbutton	0.60	7%	2.82	31%
North-South Pedestrian Signal	0.00	0%	0.46	5%
North-South Pushbutton Signage	0.44	5%	1.94	21%
North-South Traffic	1.02	11%	1.55	17%
North-South Traffic Signal	0.00	0%	0.00	0%

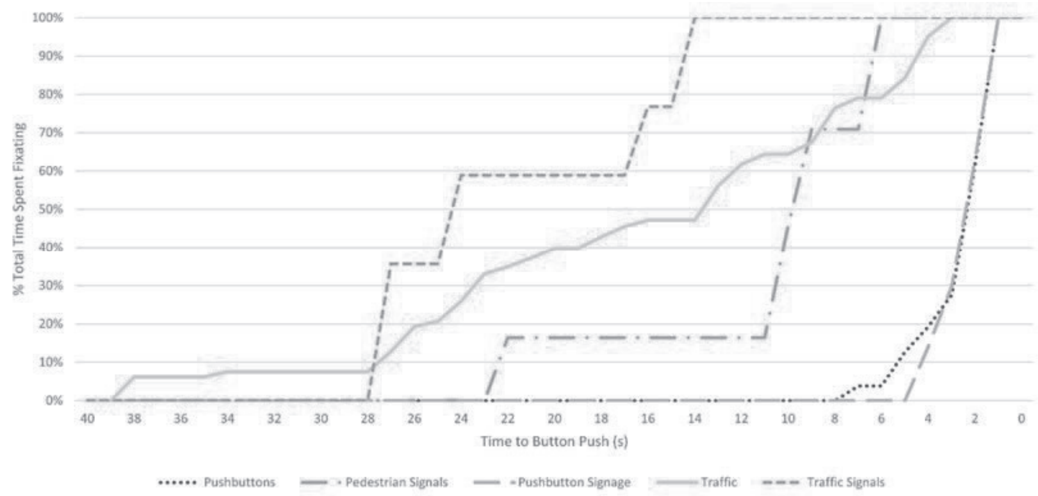

Fig. 5 - Time fixating on AOIs prior to first button push

The order in which participants looked at AOIs was also considered. Fig. 5 summarizes the percent of total time spent looking at each AOI category based on time to button push, where t=0 seconds represents the time at which the participant made their first button push.

Fig. 5 shows that participants began fixating on vehicle traffic and vehicle traffic signal displays earliest on their approach to the pushbutton. Vehicle traffic was the most consistently attended to AOI for the duration of the participants' approaches to the pushbutton, with participants attending to vehicle traffic until approximately 3 seconds to button push. At 3 seconds to button push, fixations on pushbuttons and pushbutton signage rose dramatically, comprising nearly all fixations made between 3 and 0 seconds to button push. Participants attended to traffic signals for a shorter duration than vehicle traffic and relatively early on their approach to the pushbutton, until approximately 14 seconds to button push. Participants fixated on pedestrian signal heads later than vehicular traffic and traffic signal heads, but transitioned from attending to pedestrian signal heads to pushbuttons and pushbutton signage around 7 seconds to button push.

4. Discussion

The survey results suggest study participants seem to understand which pushbutton corresponds to which crosswalk without explicitly needing to view the pushbutton signage or the pushbutton arrow. Regardless of whether this result was influenced by participation in the field experiment or previous experiences with signalized intersections, participants entered the post-task survey with an understanding of how to approach pedestrian infrastructure at the case study location. During the experiment, however, participants fixated more on pushbuttons and pushbutton signage than many other AOIs. Combined, fixations on pushbuttons and pushbutton signage accounted for approximately 51% of total time spent fixating on AOIs, suggesting that study participants used pushbutton markings and signage to identify which crosswalk corresponded to which pushbutton during the field experiment.

Although participants unanimously seemed to understand how to correctly associate pushbuttons with crosswalks, survey responses indicated more variation in how participants would choose a crosswalk. Six of nine participants indicated that they would "Most of the time" or "About half the time" push both pushbuttons when crossing to a diagonal corner and, asked to explain, one participant explicitly mentioned desiring additional information about which crosswalk would be served next. Another participant mentioned using traffic signals to determine the most efficient crosswalk. Field observations support this statement: participants who made inefficient crosswalk choices made fewer fixations on traffic and traffic signals than participants who made reasonably efficient crosswalk choices. However, it can sometimes be difficult to determine which crosswalk will be served next even if one's choice is reasonably efficient—as Participant B experienced. Participant B selected one crosswalk, remarked that the other crosswalk would be served next after making 45 fixations totalling 12.95 seconds on various elements of the intersection environment, and selected the second crosswalk—only to receive the WALK indication for the first crosswalk first. Participant B's experience suggests that pedestrians, particularly at signalized intersections with split-phasing or phasing which varies, could benefit from additional information about which crosswalk is next to be served.

Finally, this study investigated where and when pedestrians look for information in the roadway environment when choosing between two acceptable crosswalks. Participants appeared to begin observing vehicle traffic earliest on their approach to the pushbutton pole, almost as soon as beginning their approach. Observing which vehicles are moving on which approach can provide similar information to that of a traffic signal, as it implies the active vehicular phase. Of all AOIs, participants spent the most time fixating on vehicle traffic (42%), observed vehicle traffic consistently, and observed it for the longest duration. Participants observed vehicle traffic consistently until approximately three seconds to button push, when fixations on pedestrian pushbuttons and pushbutton signage increased dramatically. The relatively large amount of time participants spent fixating on vehicle traffic is consistent with similar eye-tracking studies, like Egan [3] and Geruschat et al. [7], who observed that vehicles were among the most fixated-on category of AOIs they examined among adult participants [3, 7].

This study demonstrates a need to provide pedestrians with additional information about which crosswalk will be served next, and that pedestrians are looking for this information—not always successfully. In future work, the authors will use these results to explore potential modifications to existing pedestrian infrastructure at the study location which communicate which crosswalk will be served next. Conceptual alternatives will be developed and assessed via a large-scale survey study of persons in Washington County, Oregon and the US. Because participants spent a significant amount of time looking at pushbuttons and pushbutton signage just prior to making their pushbutton selection, conceptual alternatives which modify pushbuttons and pushbutton signage will primarily be considered.

The most obvious limitation of this study is its small sample size. The authors acknowledge that this impedes statistical conclusions which might be drawn from the data presented within. However, the exploratory nature of this study sets the stage for future exploration of pedestrian pushbutton interactions with a larger and more diverse sample size. A second limitation is that participant behavior may have been influenced by the presence of the researchers and research equipment. Participants were encouraged to cross the intersection as they would if they were not participating in this experiment. They also walked about wearing the mobile eye tracker before beginning the field experiment to acclimatize themselves to the goggles. While it is the author's experience that the goggles are non-intrusive and forgettable once acclimatized, it is possible that the eye tracker influenced participant behavior. Lastly, a third limitation of this study was the diversity of recruited participants: the sample size was largely comprised of educated persons who identify as male and Caucasian. No persons with prior knowledge of the study participated, however, some persons recruited within Washington County were practicing transportation engineers or had some prior knowledge of transportation engineering.

5. Conclusions

The results of this exploratory study suggest that participants understood how to correctly associate pushbuttons with the corresponding crosswalks at a real-world signalized intersection. However, additional information could help the participants identify which crosswalks are next to be served. Participants explicitly mentioned desiring additional information to determine which crosswalk would be served next. Eye tracking data suggests that participants observed vehicle traffic signals and traffic on both the east-west and north-south approaches to choose which pushbutton to push, often earlier than other infrastructure elements on their approach to the pushbutton pole. Pushbuttons and pushbutton signage were last to be observed, with most fixations occurring less than three seconds to button push. Traffic and traffic signals comprised approximately 45% of total fixations for crosswalk choice scenarios, while fixations on pedestrian pushbuttons and pushbutton signage comprised approximately 51% of total fixations for crosswalk choice scenarios.

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Estimating the safety effects of raising speed limits on rural freeways in Ohio

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Abstract

The impacts of raising speed limits on traffic safety is an area that has generated much research, although a strong consensus has not emerged on the relationship between speed and safety. The Ohio legislature raised speed limits from 65 mi/h to 70 mi/h on 570 miles of rural freeways in Ohio on July 1, 2013 and an additional 398 miles of rural freeways starting on September 29, 2013. The primary goal of the current study was to investigate the safety impacts of this new speed limit using available crash, roadway, and traffic characteristics data. Statewide crash data from January 1, 2010 to December 31, 2015 were obtained from the Highway Safety Information System (HSIS). The study utilized the empirical Bayes (EB) before-after study in the evaluation of the safety effectiveness of the raised speed limit. The intent of the before-after study was to estimate the performance (in terms of crash frequency and severity levels) following the speed limit increase and what the safety performance would have been if there was no increase in speed limit. Safety performance functions (SPFs) were developed for both total crashes and fatal and injury (FI) crashes combined using the negative binomial regression and the SPFs were used to predict the average crash frequency of each of the segments in the observed period. The EB analysis showed that total crashes went down by 24.6% and FI crashes went down by 8.8% for the two years after the speed limit was changed. Therefore, caution should be taken in drawing conclusion from this study because the after period did not meet the minimum of three years recommended by the HSM since the data available for the after period were only for two years. We have received additional 2 years of data and the updated analysis is ongoing.

Keywords – speed limit, Empirical Bayes, before-after study, negative binomial, crash frequency, crash severity

1. Introduction

Historically, speed limit has been used for several purposes such as to conserve fuel, to reduce noise and to promote road safety [1].The increase in the cost of fuel due to oil embargo in the early 1970s caused many states to adopt a lower speed limit with the goal of saving fuel and resources. On January 2, 1974, President Richard M. Nixon signed the Emergency Highway Energy Conservation Act, setting a new National Maximum Speed Limit (NMSL) of 55 mi/h with the expectation of saving $2 million annually in fuel consumption [2]. Most studies [2,3] reported that the actual savings was way less than the estimated amount, which instead attributed to fewer fatalities.