ABSTRACT

CLARK, RALPH OWEN. Exploring How Driver's Training and Crosswalk Warning Apparatus Can Improve Pedestrian Safety at Roundabouts (Under the direction of Christopher B. Mayhorn.)

The purpose of this study was to improve pedestrian safety at roundabouts. The three experiments examined driver's training about roundabouts and the use of warning apparatus to increase the saliency of pedestrians crossing at roundabouts. All the participants were recruited from the North Carolina State University (NCSU) undergraduate population. The first experiment was a 2 (training) X 6 (driving situation entering or exiting) mixed factorial design. Fifty-five participants used a computer interface to decide if they must stop or if they may proceed in the roundabout. Both correctness of answer and decision time was evaluated. The anxiety of the participants and attentional ability were also measured. Results indicated that the training manipulation was ineffective yet there were differences within the six driving situations such that entering without right of way due to a vehicle was the most difficult (i.e., fewer correct answers, slower decision time). The second experiment utilized a 2 (warning apparatus) X 2 (Pedestrian presence/nonpresence) within participants design. Forty-two participants encountered two warning apparatus: the Rectangular Rapid-Flashing Beacon (RRFB) and the High Intensity Activated Crosswalk (HAWK). As with the first experiment, participants used a computer interface to decide if they must stop or if they may proceed in the roundabout. Eyesight acuity, anxiety, attention, and cognitive load were measured. Results indicated that the RRFB produced lower cognitive workload than the HAWK as measured by the NASA-TLX and that participants were more accurate and faster when making decisions about roundabout navigation when the RRFB was present. Given the results from the first two experiments, experiment three used the RRFB as the traffic signaling device and again, assessed training. This experiment was a 2

(training/nontraining) X 9 (trial type) between participants design using the RRFB from experiment 2 that proved most effective. Forty-two participants completed measures of roundabout navigation response accuracy, decision time, anxiety, attention, and cognitive load. Again, the level of training was not found to be significant. While the presence of the RRFB did not increase the correct answers in the driving task, it did reduce driver decision time and reduced driver frustration levels likely making the pedestrian crossing a safer experience for both the pedestrian and the driver. Findings from the three experiments are discussed to inform future roundabout design and training.

Keywords: roundabouts, road safety, pedestrian, driver training

Exploring How Driver's Training and Crosswalk Warning Apparatus Can Improve Pedestrian Safety at Roundabouts

by
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DEDICATION

I dedicate this work to several people who have helped me achieve this milestone in my life. To Dr. Jerry Powell, Dr. Ken Duffy, and Dr. Barry Trunk, thank you for believing in me and spurring me forward, even when I did not believe in myself. To my father, I still remember our last conversation, I finished high school like you asked, I did a little more too. Thank you for instilling in me the value of education.

And lastly, to my wife and beloved, thank you for putting up with me and plying me with coffee and having a discerning eye and listening ear as I rambled on about things you probably really did not care about, but you did it anyway. This is one of the many reasons I love you.

BIOGRAPHY

Ralph O. Clark earned a B.A. from The Citadel (1987), an M.Div. from the University of the South (2001), and an M.A. from Webster University (2013). He began his PhD in Psychology concentrating in Human Factors and Applied Cognition at North Carolina State University in 2018. Mr. Clark's research interests include training and safety. His research on pedestrian safety at roundabouts has been published. His nonprofessional interests include backpacking and traveling with his wife, Vikki.

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Exploring How Driver's Training and Crosswalk Warning Apparatus Can Improve Pedestrian Safety at Roundabouts

Circular intersections have been a part of the United States (U.S.) road milieu since the early days of the 20th century (Robinson et al., 2000). These early circular intersections were characteristically large circles designed to facilitate traffic flow at high speeds. Traditionally, the traffic entering the circle had right-of-way over the traffic already in the circle to facilitate traffic flow. Given the large variety of traffic patterns, several terms have been used to describe different types of circular intersections (National Cooperative Highway Research Program, 2010; Robinson et al., 2000) and these are listed below:

Roundabout

Roundabouts are the modern circles as designed in the UK in the 1960s. Roundabouts include yielding entering traffic (different from the traditional circular intersections described earlier), smaller circles to encourage slower speeds, and channelized entry.

Rotaries

Rotaries are the large circular intersections that were popular in the early part of the 20th century. Their large diameter facilitates higher speeds, and their lack of channelized entries require a non-controlled lane change within the circle.

Signalized Traffic Circles

To address the dangers of some rotaries, traffic control signals have been installed to control entry into the circle. These circles develop different traffic characteristics than the yield-controlled entry of rotaries, so they have been given their own category.

Neighborhood Traffic Circles

In some cities in the US, residential intersections have been converted to circular intersections by adding a small island in the middle and changing traffic control signage.

The different types of circular intersections all present challenges to drivers. The current research is concerned exclusively with roundabouts and this term will be used for the duration of this manuscript. Roundabouts are an improvement over the older rotaries as indicated by Robinson et al. (2000) and the National Cooperative Highway Research Program (2010). However, there are negative attributes concerning roundabouts that will also be addressed.

From a historical perspective, the design of circular intersections remained largely unchanged until the 1950s when traffic volumes increased during the post Second World War years (Robinson et al., 2000). The increased volumes of traffic were blamed for the increase in crashes and congestion in circular intersections and these types of intersections became less popular. Additionally, the speed of travel also increased during these years. The American Safety Council (2018) points out that in the first decade of the 20th century states were posting 15 miles per hour (MPH) speed limits on open road whereas the national speed limit was increased during the Second World War to 35 MPH (The National WWII Museum, 2015). The developing problems of circular intersections were not limited to the US. The crash rate and traffic jams in these intersections were seen internationally as well (Robinson et al., 2000). The increase of traffic speed and volume found fewer and fewer circular intersections being built and existing ones being removed.

The circular intersection had a different fate in the United Kingdom (UK) according to the 2010 report of the National Cooperative Highway Research Program of the Transportation Research Board. Where the US rejected the circular intersection, the UK addressed the issues of crashes and traffic jams by altering the driving rules and design of the circular intersection. The

National Cooperative Highway Research Program (2010) states the UK changed the driving rules such that the right-of-way in the circular intersection changed from those entering the circle to those vehicles already in the circle. This change prevented the circle from becoming overloaded with traffic. The UK also made the circle a smaller diameter that required traffic to slow down to safely negotiate the tighter curvature of the circle. These changes improved safety based on the reduced number of severe crashes (National Cooperative Highway Research Program, 2010). This modern circular intersection has led to increased popularity of the roundabout both internationally and in the US.

Statement of the Problem

The redesign of the roundabout was engineered with the focus on increased traffic flow and vehicular safety. Early research suggests significant decreases in vehicle accidents and accident-related injuries when four-way intersections were changed to roundabouts (Flannery & Datta, 1997; Persaud et al., 2001; Retting et al., 2001). However, these studies did not consider pedestrians and bicycles. Burdett and his colleagues (2016, 2017) call into question the early findings and suggest roundabouts are responsible for a 12% increase in vehicular accidents but with a 38% decrease in injuries. The supposition is roundabouts have successfully slowed traffic leading to the reduction of injuries but drivers' unfamiliarity with roundabouts has caused the increase in accidents. Two issues that must be considered alongside the development of roundabouts are pedestrian safety and the training of drivers on the rules of roundabouts.

Pedestrian safety has been lacking in the discussions of increased roundabout installations (Perdomo et al., 2014; Stone et al., 2002). Pratelli et al. (2009) suggest pedestrian crossings with warning beacons are safer than crossings without such apparatus. These results are supported by Giuffre and Grana (2012) and Salamati et al. (2013). Salamati et al. (2012)

suggest that the most effective form of crossing warning apparatus is a beacon that flashes. They also found pedestrians crossing at an exit leg of a roundabout were overlooked by drivers even more than at entrance legs; this finding was replicated by Clark and Mayhorn (2022).

Both Moller and Hels (2008) and Giuffre and Grana (2012) identified the need to increase driver's training concerning roundabouts. While there is no national training program for drivers in the U.S., the State of North Carolina recently introduced a section in the driver handbook concerning roundabouts with the 2022 edition (North Carolina Department of Motor Vehicles [NCDMV], 2022). The limited coverage of the driving task at roundabouts leaves drivers unsure of the rules. Chen and Ulsoy (2001) suggest that uncertainty in the human/machine interface, in this case a vehicle, greatly degrades system performance. As more of the cognitive load of the driver is filled with the uncertainty of action, less cognitive assets are available to search for visual cues of environmental dangers, such as other traffic and pedestrians. The research of Barrett and Bliss-Moreau (2009) suggest environmental stimuli may even look different depending on how the perceiver feels.

Environmental Stimuli Associated with Roundabouts

Previous research has focused on how environmental stimuli have changed as roundabout design has evolved over time. For instance, Sadeq and Sayed (2016) identified several positive changes that have accompanied the evolution of the modern roundabout. Primary among them is the ability to increase the flow of vehicular traffic while reducing the vehicular conflict points from 32 found in a standard intersection to eight found in a roundabout (Vignali, et al., 2020). However, Stone and his colleagues (2002) suggest the effects of roundabout usage on pedestrian safety is mostly unknown. The 2008 study by Møller and Hels suggests an underestimation of risk and lack of knowledge about relevant traffic rules may contribute to car–pedestrian/bicycle

collisions in roundabouts. Salamati and her colleagues (2013) suggest drivers are less likely to comply with the "Yield to Pedestrians" sign at roundabouts than at other types of controlled intersections. Clark and Mayhorn (2022) suggest an attention capture dynamic where the driver becomes fixated on opposing vehicular traffic within the circle on the left side of the field of vision and consequently never looks to the right for pedestrian traffic when entering a roundabout. This finding supports Tumber (1997) who found 45% of crashes at roundabouts involving pedestrians occurred at the entrance into roundabouts and 27% occurred at the exit from roundabouts (as cited in Giuffre & Grana, 2012). These findings certainly warrant additional study to increase the safety of pedestrian crossings.

Observed Safety Benefits of Roundabouts

Given these potential safety concerns, it is also important to recognize that there are several positive qualities to the modern roundabout. Roundabouts are often cited as reducing the number of severe accidents; the 2010 report of the National Cooperative Highway Research Program is a case in point. This report suggests roundabouts are safer than other forms of intersections as indicated by lower crash rates. Robinson et al. (2000) suggests that the crash rate in U.S. roundabouts was reduced by 37% for all crashes and 51% for injury producing crashes. A meta-analysis conducted in 2017 by Elvik supports this position as well. He reviewed 44 studies from 10 countries conducted from 1975 through 2014 concerning the implementation of roundabouts and found a 65% reduction of fatal accidents and a 40% reduction of accidents producing injuries. Likewise, Stone et al. (2002) also supports this assertion of greater safety. However, not all the research supports these claims.

Burdett et al. (2016) reports that roundabouts reduced fatal and injury inducing accidents by 38% but there was an overall 12% increase in total accidents. Burdett and his colleagues

(2016) found the most common form of non-injury producing accident was rear-end collisions and the demographic that was most represented in this increase was drivers 16 to 24 years of age. Burdett and his colleagues (2016) suggest this overrepresentation of the youngest drivers is indicative of the complexity of the driving task at roundabouts. The improvement numbers of crashes are much lower than found by Persaud and his colleagues (2001) where their findings are roundabouts produce a 90% reduction in fatal crashes and a 76% reduction in injury crashes. It is important to note that in the same study, Persaud et al. (2001) found the reduction of pedestrian accidents was only 30-40%. Even with the reduction of crashes, the underlying complexity of the driving task at roundabouts is evident given the presence of pedestrians and nonmotorized conveyances such as bicycles.

Tracking Pedestrian and Bicycle Injuries

Roundabouts, particularly in urban areas, are often found with pedestrian crosswalks located at the entry and exit points of the roundabout. This placement of crosswalks can be traced back to the UK redesign of the modern roundabout in the 1960s (Robinson et al., 2000). According to the National Cooperative Highway Research Program (2010), no substantial safety problems exist for pedestrians and bicyclists based on the number of crash reports involving either pedestrians or bicyclists. Stone and his colleagues (2002) had a different opinion of the lack of data involving pedestrians and bicyclists and called for a study of the safety of pedestrians and bicyclists in and around roundabouts. They suggest that the likelihood of pedestrian and bicycle versus vehicle accidents was reduced because of the fewer number of interaction points on the direction of travel for each moving entity (Stone et al., 2002). Grana (2011) identified the following disadvantages of roundabouts for pedestrians:

- Entering traffic does not necessarily stop causing hesitation by pedestrians in the crosswalk
- Anxiety increases for pedestrians who are not confident judging gaps in traffic
- Crossing locations and setbacks from the yield line often raise travel distances for pedestrians

However, roundabouts have improved the pedestrian crossing experience in some ways including the split island between traffic lanes. This safety island reduces the complexity of the crossing task for the pedestrian or bicyclist, in effect making the crossing task into two tasks. The crossing person only has to look in one direction to reach the dividing island and a separate task of looking in only one direction to reach the other side instead of the crossing person having to focus attention on opposite directions to cross both lanes of traffic. The concept of reducing the cognitive load of the pedestrian and bicyclist certainly seems to have face validity but it does not consider driving behavior and the cognitive load of drivers entering and exiting the roundabout.

Salamati, et al. (2012) studied crosswalk placement and the use of signaling devices to alert drivers to persons in the crosswalk. The study illustrated that the installation of any kind of beacon, with or without relocating the crosswalk, increases driver yielding rates significantly. However, just relocating the crosswalk without a signaling device does not provide a significant increase in the driver yielding rate. Also, in 2012, Schroeder et al. suggested that increases in pedestrian traffic at roundabouts can result in impeded traffic flow in the roundabout. Schroeder and his colleagues (2012) found that the use of a pedestrian flow signal reduces the traffic impediment for the same flow rate of both pedestrians and vehicles when compared to a non-controlled pedestrian crosswalk. The placement of crosswalks at the entry and exit points of

roundabouts may require additional signaling to make the roundabout a more effective intersection.

Information Processing During Roundabout Driving

Cognitive load is defined by Sweller (2011) as the amount of information that a person can process in working memory. Working memory is defined by Cowan (2008) as the cognitive process that uses attention to manage short-term memory. Miller (1956) identified the amount of information processed at any given time as seven different items. Moreover, Cowan (1999) suggested that the amount of information processed is dependent on the complexity of the information. Such an observation on cognitive load is pertinent because drivers must manage a high volume of information when navigating a roundabout. In addition to the high potential cognitive load of the driver while traversing a roundabout, the attention of the driver is also a factor in pedestrian safety.

Attention. Another cognitive construct that potentially reduces safe crossing of pedestrians at roundabout crosswalks is attention capture. Anderson and Yantis (2013) define this construct by assigning a value to visual stimuli that is in line with reward potential of the goal of the observer. Attention capture establishes an attentional bias at the expense of other stimuli in the field of vision. Luck et al. (2021) and Theeuwes (2010) agree that physically salient stimuli are captured in an automatic manner during the first visual sweep of the visual area. The only way to prevent the capture of attention on this salient stimulus is through a top-down process that incorporates expectancy and priority of the signal being received. These findings are also supported by Tay and his colleagues (2022). In the case of driving through a roundabout, the oncoming traffic that is already in the roundabout presents a salient stimulus. One approach to overcoming the capture of attention and teaching drivers to actively scan for

pedestrians may require increasing driver's training to increase the saliency of the signal when pedestrians are attempting to cross at the crosswalk.

Environmental Interventions: Signage, Pavement Markings, and Signaling Devices

Another approach to implementing pedestrian safety interventions includes crosswalk placement and the use of signaling devices to alert drivers to persons in the crosswalk (Salamai et al, 2012). While the presence of signaling devices and crosswalks are meant to facilitate pedestrian safety, it should be noted that increases in pedestrian traffic at roundabouts could result in impeded traffic flow in the roundabout (Schroeder et al., 2012). They found that the use of a pedestrian flow signal reduces the traffic impediment for the same flow rate of both pedestrians and vehicles when compared to a non-controlled pedestrian crosswalk. The placement of crosswalks at the entry and exit points of roundabouts may require additional signaling to make the roundabout a more effective intersection. All these measures are important factors in making pedestrians safer while crossing at roundabouts.

In the United States, crosswalks have in the past been marked on the pavement with two parallel lines. Vignali and her colleagues (2020) found zebra pavement markings, as seen in Figure 1, are the most glanced at element of roundabout crossings being seen by 93.75% of the drivers in their study. This study also suggests that the least seen element of crossings without warning apparatus was the "Yield here to pedestrians" vertical sign. With the inclusion of zebra stripe crossings, the mean distance of first fixation of the crosswalk increases from 21.98 meters before the intervention, to 40.69 meters after it. Steps to increase the saliency of signage have included the addition of beacons and rectangular rapid-flashing beacons (RRFB). Shurbutt and his colleagues (2009) find the addition of round beacons added to the side of the sign or overhead had a minimal increase in yielding behavior of drivers whereas the RRFB system

produced a marked increase in yielding behavior. The findings of Vanwagner and her colleagues (2011) and Fitzpatrick and her colleagues (2014) support the increased saliency of RRFBs in the use of speed control.

Figure 1

Typical Zebra Stripped Crosswalk

Another crossing safety measure is the High Intensity Activated Crosswalk (HAWK). This system consists of overhead lights, two red lenses above a single yellow lens, that control vehicular traffic when activated by a pedestrian and was developed by the city of Tucson, Arizona in the 1990s (Nassi & Barton, 2008). The initial study of the HAWK system by Nassi and Barton (2008) included 21 systems installed at traditional, 90-degree intersections that were previously pedestrian crossings without warning apparatus and found a 69% reduction in pedestrian accidents. The HAWK system is included for use by the Manual of Uniform Traffic Control Devices (MUTCD) as of 2009. These systems increase the signal saliency of pedestrians who are attempting to cross the street but the training of drivers in the rules of the road at roundabouts and regarding pedestrians is also important.

Behavioral Intervention: The Role of Training

There is no national training program for drivers in the U.S. However, there are national guidelines published by the National Highway Traffic Safety Administration that were most

recently updated in 2013. These guidelines specify that "Each State shall have a highway safety program…, that is designed to reduce traffic accidents and the resulting deaths, injuries, and property damage" (402(a)(1)). The federal guideline names driver's training specifically as a part of the highway safety program. The inclusion of drivers training enumerates,

"(i) driver education;

(ii) driver testing to determine proficiency to operate motor vehicles; and

(iii) driver examinations (physical, mental, and driver licensing)" (402(a)(2)(B))

However, there are no specifications as to how each state will comply with these guidelines.

Unfortunately, driver's training concerning roundabouts has not kept pace with the increased use of these intersection transitions. The North Carolina Driver's Handbook was only updated in 2022 to include equal treatment of roundabouts and conventional intersections (North Carolina Department of Motor Vehicles [NCDMV], 2022). Prior to this update the manual for driving was last updated in 2012 and roundabouts were mentioned only three times compared to other intersections that were mentioned 61 times (NCDMV, 2018). In the North Carolina Commercial Driver's Manual roundabouts are not mentioned at all (American Association of Motor Vehicle Administrators, 2017). This is a stark contrast to the states of Idaho, Virginia, Nevada, and Wisconsin that all have a section in their respective driver's handbook covering roundabouts (Idaho Division of Motor Vehicles, 2019; Nevada Department of Motor Vehicles, 2018; Virginia Department of Motor Vehicles, 2019; Wisconsin Department of Motor Vehicles, 2018). The Town of Davidson, North Carolina published a brochure concerning the negotiation of roundabouts in their town possibly as an attempt to address the lack of driver's training at the state level. However, the brochure does not include the possibility of crossing pedestrians (Town of Davidson, N.D.). The limited coverage of the driving task at roundabouts leaves drivers

unsure of the rules. This lack of instruction is suspected to be a source of anxiety and frustration due to the lack of driver confidence concerning the rules and responsibilities when confronted with a roundabout. Such uncertainty concerning the rules of a roundabout could lead to increased accidents and decreased efficiency of the roundabout.

Purpose of the Study

The current research study should answer three empirical questions (each associated with particular hypotheses listed below) about roundabout safety. First, how does the training of drivers on the function of roundabouts affect driver performance?

H_1A: Driver training on roundabouts will increase the correct responses in roundabout driving situations. This hypothesis will be tested by comparing the number of correct answers in the trained group to the number of correct answers in the untrained group.

H_1B: Driver training on roundabouts will decrease the response time in roundabout driving situations. The Decision time (DT) of the trained group with the DT of the untrained group will be compared to test this hypothesis. Only the DT of correct answers will be used.

The second question addressed by this study considers the comparative utility of the Rectangular Rapid Flashing Beacon (RRFB) and the High intensity Activated Crosswalk Beacon (HAWK). Which warning apparatus is the most effective at raising the signal of pedestrians with the lowest increase of cognitive load on the driver?

H_2A: The RRFB will significantly raise driver awareness of pedestrians attempting to cross defined as having more correct responses. Comparing the total correct answers of the HAWK and the RRFB will inform this hypothesis.

H_2B: The RRFB will significantly raise driver awareness of pedestrians attempting to cross as defined as having the quicker DT. This hypothesis will be assessed by comparing the total DT for each apparatus.

H_2C: The RRFB will not significantly raise the cognitive demands of the driver. This hypothesis will be evaluated by comparing the NASA-TLX scale scores for each apparatus.

The third question considers whether the addition of driver training in the presence of a flashing beacon at a roundabout will increase the conspicuity of pedestrians attempting to cross.

H_3A: The presence of driver training will increase the correct responses by drivers in roundabout driving situations that use flashing beacons making pedestrians safer. This hypothesis will be tested by comparing the number of correct answers in the trained group to the number of correct answers in the untrained group.

H_3B: The presence of driver training will decrease the response time as measured by DT in roundabout driving situations that use flashing beacons making pedestrians safer. Comparing the DT of the trained group with the DT of the untrained group will test this hypothesis. Only the DT of correct answers will be used.

Significance of the Study

This study will not only identify the importance of proper driver training but will also produce results that could be used to increase pedestrian safety at roundabouts. Three separate studies explored the factors contributing to safe roundabout navigation.

EXPERIMENT 1

The first study examined the effects of driver training on the speed and accuracy of roundabout navigation using a 2(training/nontraining) X 6(Trial Type) mixed factorial design. Additionally, anxiety was measured both before and after completing the task using the five-

question version of the Spielberger State-Trait Anxiety Inventory (STAIS-5). This study used the Qualtrics platform to interface with the participants (Qualtrics, Provo, UT).

Method

Participants

The fifty-five participants were undergraduates, 23 male and 32 female, recruited from NCSU who were at least 18 years of age and had a valid driver's license. Age ranged from 18 to 28 years old (M = 19) and 70% (n = 39) of them reported that they received roundabout training when they took their driving test for licensure. Ninety-six percent (n = 54) reported having normal color vision. A power analysis using the G*Power program, indicates the proposed design will require 27 participants to achieve an 80% statistical power (Faul et al., 2009) so the sample was sufficient.

Design

Experiment 1 utilized a 2 (training/no training) X 6 (trial type shown in Table 1) mixed factorial design. Driver training (between groups) in six different driving tasks (manipulated within subjects) were the independent variables while the accuracy and the speed of decisions to drive through the roundabout were the dependent variables. The signal detection approach was not considered as there were no trial types that incorporated either the false alarm or correct rejection quadrants of possible outcomes (Green & Swets, 1966).

Instrumentation

The instruments used for this study were the Qualtrics online survey platform, the STAIS-5, two videos from NCDOT, a map of a roundabout identifying the vehicle/pedestrian meeting points, and 86 pictures of roundabout driving situations. Additionally, a driving knowledge test was used as well as a reaction time test. The 21-question driving test was

developed by the researcher using the NCDOT driving manual. The STAIS-5 popularized by Zsido et al. (2020) has high internal consistency and test reliability with the long form of the Spielberger State-Trait Anxiety Inventory ($\alpha = .91$). The quality of the instrument and the short form make it a good measure of anxiety generated during the study.

The CRSD-ANT is a widely used and accepted instrument for measuring the attentional network. The shorter version of the instrument requires 10 minutes for completion, half the time of the standard version. According to Weaver et al. (2013), the validity of the reaction time scores is equivalent to that of the standard version based on the Median RT scores ($r = .92$). The CRSD-ANT produces three calculated attentional effects from the raw data of the participants known as the Posner attention networks, the Alert Effect, the Orienting Effect, and the Conflict Effect (Posner et al., 1987). The Alert Effect is associated with achieving and maintaining alertness and is calculated by subtracting the $RT_{no\ cue}$ from the $RT_{double\ cue}$ (Alerting = $RT_{double\ cue}$ - $RT_{no\ cue}$). The Orienting Effect represents the orienting of attention towards a specific location in the visual search area and is calculated by subtracting $RT_{center\ cue}$ from $RT_{spatial\ cue}$ (Orienting = $RT_{spatial\ cue}$ - $RT_{center\ cue}$). The Conflict Effect involves resolving conflict between several possible focal points in the search field and is calculated by subtracting $RT_{congruent\ cue}$ from $RT_{incongruent\ cue}$ (Conflict = $RT_{incongruent\ cue}$ - $RT_{congruent\ cue}$). With all of these effects the larger the number the slower the RT and, therefore, the worse performance by the participant. Due to the nature of roundabout driving and the driver attentional tasks in roundabouts, all three attentional networks were evaluated.

Videos from the NCDOT were used to provide driver training to the participants. The experimental group viewed a 2 minute and 12 second video on how to drive through roundabouts (North Carolina Department of Transportation [NCDOT], 2019). The experimental group also

viewed a diagram of a roundabout that highlights the meeting points between vehicles and pedestrians (Figure 2). The control group viewed the roundabout driving video but also viewed a 33 second long second video that addressed the safety consequences of texting while driving (NCDOT, 2013).

Figure 2

Roundabout Diagram Used with the Experimental Group

The computerized driving task used picture stimuli, taken from the driver's perspective by the researcher that included 86 still pictures presented randomly with a written prompt. These images were presented one at a time in Qualtrics and do not advance until the participant manually selects the next button. The pictures depict a driving situation at a roundabout and the participant was prompted to respond if it is safe to either enter or exit the roundabout depending on the situation. Participants responded by selecting radio buttons next to the action that they thought was correct.

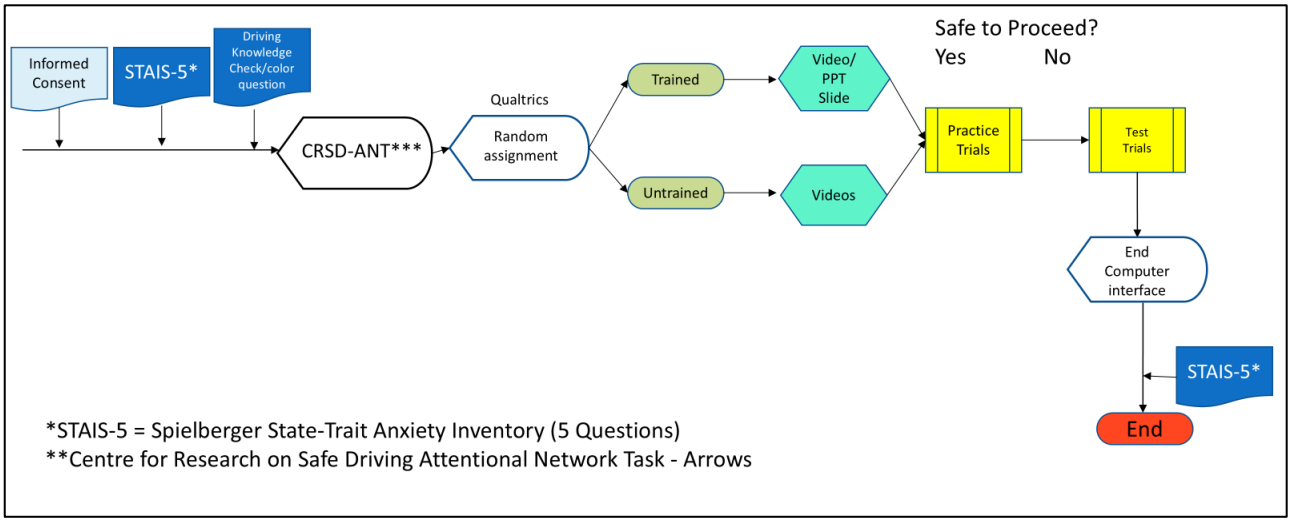
Procedure

Participants completed informed consent and were randomly assigned to either the experimental training group (n = 28) or the control training group (n = 27) once they started the

Qualtrics program. The first task for all participants was to complete the Spielberger State-Trait Anxiety Inventory, five question form (STAIS-5; Zsido et al., 2020). After this, all participants completed a 21-question driving knowledge, multiple choice test based on the North Carolina driving manual (NCDMV, 2018) to measure their current knowledge of basic driving tasks including roundabouts. This test asked the participants to report whether they have normal color vision. Following the driving knowledge test, participants completed a reaction time task using the Centre for Research on Safe Driving Attentional Network Task (CRSD-ANT). Following the attentional task, participants watched training videos produced by the North Carolina Department of Transportation (NCDOT, 2019). However, the experimental training group also viewed a roundabout map identifying the watch points for pedestrians while the control training group watched a second video about the dangers of texting while driving (NCDOT, 2013). The total time for each group was the same. This procedure is visually represented in Figure 3.

Figure 3

Experiment 1 Participant Flow



After watching the appropriate videos, all participants were presented with the following task prompt: *You will now be presented with a series of images of driving situations. You will be*

asked to determine if you have the right-of-way or not. The first two will be practice trials. The participants were presented with a still image of a roundabout driving situation photographed in Raleigh, North Carolina on Pullen Road and Hillsborough Street, and in Fayetteville, North Carolina on Hay Street (Figure 4). The photographs were taken from the back seat of a vehicle over the right shoulder of the driver. The participants responded to the questions, "it is safe to proceed" and "it is not safe to proceed" by selecting the corresponding radio button next to each statement. After making their decisions in the first two practice trials, participants received feedback on the correct answer and the rationale for the answer's correctness.

Figure 4

Sample Depicting a Driving Situation at a Roundabout

○ it is safe to proceed

○ it is not safe to proceed

For the test trials that followed practice, each participant was presented with this prompt: *The following images will be presented in the same manner as the practice images. However, you will not receive feedback after each image. Please address each question as quickly as*

possible as if you were driving with traffic behind you. Then the participants were presented with 84 randomized images, one at a time that coincided with the conditions in Table 1. The correctness of the answer and the time to respond were recorded.

Table 1

Trial Types of Experiment 1

Condition	Vehicle Present	Pedestrian Present
Enter with right-of-way		
Enter without right-of-way	X	
Enter without right-of-way		X
Enter without right-of-way	X	X
Exit with right-of-way		
Exit without right-of-way		X

After the trials were complete the second STAIS-5 was administered (Zsido et al., 2020). Following the STAIS-5, demographic questions were asked including age and identifying gender using binary gender identifiers, and whether their original driver's training included roundabouts. In total, the procedure for each participant lasted approximately 45 minutes.

Results

Differences by Training Condition

The results of the STAIS-5, the driving knowledge test, and the CRSD-ANT are reported in Table 2.

Table 2

Results of the Individual Differences in Experiment 1

Instruments	Trained		Untrained	
	Mean	SD	Mean	SD
STAIS-5				
Before	6.61	1.62	5.96	1.32
After	5.96	0.92	5.56	1.12
Knowledge Test	15.79	1.69	15.44	1.85
CRSD-ANT				
Alerting Effect	46.39	29.73	38.94	26.38
Orienting Effect	19.73	16.89	24.58	30.07
Conflict Effect	71.45	18.21	71.52	33.80

Note. For all measures, a higher score indicates more of the construct. Such as the higher the number on the STAIS-5 the greater the anxiety felt by the participant.

The Spielberger State-Trait Anxiety Inventory, Short Form, (STAIS-5) was analyzed to measure any increased anxiety after interacting with the stimuli. There was no significant difference between the trained group, (M = 6.61, SE = 0.31) and the untrained group (M = 5.96, SE = 0.25) before the participants participated in the experiment, [t (53) = -1.62, p = .13]. There continued to be no significant difference after the experiment between the trained group (M = 5.96, SE = 0.17) and the untrained group (M = 5.56, SE = 0.22). Comparing the STAIS-5 Before (M = 6.29, SE = 0.20) with the STAIS-5 After (M = 5.76, SE = 0.14) indicated that the anxiety of all participants went down significantly, [t (53) = 41.27, p < .01] after the experiment was over.

Comparison of the trained and untrained groups on the other instruments revealed no significant differences between the two groups, indicating the groups were not different from one another prior to completing the driving task.

Behavioral Data from Driving Task

Correct Answers. The data in all three experiments was trimmed, removing responses that were more than three standard deviations from the mean, and checked for normalcy. To test Hypothesis 1A, a 2-way analysis of variance (ANOVA) was conducted to examine the percentage of correctly answered driving trials. When comparing the trained group (M = 8.55, SE = 0.12) and the untrained group (M = 8.44, SE = 0.12) there was no significant difference in the results, F (1, 53) = .40, MSE= .16, p = .53, η = .01, thus Hypothesis 1A was not supported.

Analysis by Trial Type. To analyze the performance on individual trial types (listed in Table 1) by training condition, the same 2-way ANOVA revealed that the interaction between training and trial type was not significant, F (5, 50) = .80, MSE= 1.07, p = .55, η = .02. While the main effect for training was not significant, F (1,53) = .40, MSE = .99, p = .53, η = .01, there was a significant main effect for trial type, F (5, 50) = 49.40, MSE= 66.10, $p < .001$, η = .48. The mean and standard error (SE) for each type by training condition are listed in Table 3 below. To guard against familywise error in all three experiments, pairwise comparisons for each trial type were avoided for ANOVA analyses in lieu of the correlation and regression analyses below.

Table 3

Means and Standard Error of Each Trial Type, Correct Answer in Experiment 1

Trial Type	Trained		Untrained	
	Mean	SE	Mean	SE
Enter with right-of-way	8.86	.23	8.85	.13
Enter without right-of-way, Vehicle	6.57	.35	6.70	.40
Enter without right-of-way, Pedestrian	8.82	.20	8.44	.27

Table 3

Means and Standard Error of Each Trial Type, Correct Answer in Experiment 1 (continued)

Exit with right-of-way	9.89	.06	9.81	.12
Exit without right-of-way, Pedestrian	8.93	.18	9.11	.19

Note. The larger the mean indicates more correct answers given. The range of 0-14 was the same for all trial types.

Correlations and Regressions. All the individual differences and driving task performance (correct answers) measures were loaded into a correlation matrix with the results listed in Table 4.

Table 4

Correlation Matrix for Individual differences and Correct Answers in Experiment 1

Variable	Entering W/O ROW Vehicle & PED	Entering W/O ROW PED	Entering W ROW	Entering W/O ROW Vehicle	Exiting W ROW	Exiting WO ROW	Alerting Effect	Orienting Effect	Conflict Effect	STAIS-5 Before	STAIS-5 After	Knowledge Test
Entering W/O ROW Vehicle & PED	1											
Entering W/O ROW PED	-.03	1										
Entering W ROW	.59**	-.07	1									
Entering W/O ROW Vehicle	.12	.23	-.04	1								
Exiting W ROW	.20	.25	-.08	.16	1							
Exiting WO ROW	.00	.43**	-.06	.20	.25	1						
Alerting Effect	-.62	.01	-.17	-.13	.30*	.07	1					

Table 4

Correlation Matrix for Individual differences and Correct Answers in Experiment 1 (continued)

Orienting Effect	.08	-.02	-.24	.11	.24	.10	.03	1				
Conflict Effect	-.11	.17	-.27*	.06	.30*	.11	-.04	.30*	1			
STAIS-5 Before	-.07	.05	-.27*	-.05	.14	-.12	.05	.08	.15	1		
STAIS-5 After	-.05	.02	-.14	.08	-.22	-.11	-.10	.09	-.10	.56**	1	
Knowledge Test	-.10	.04	.05	.21	.06	.06	.04	.02	-.13	-.01	.09	1

** Correlation is significant at the .01 level
* Correlation is significant at the .05 level

Correlations. There were several significant correlations among the individual differences and the trial types. The entering with right-of-way condition and the entering without right-of-way due to a vehicle and pedestrian condition were positively correlated, r (55) = .59, p < .01. The exiting without right-of-way due to a pedestrian condition was positively correlated with the entering without right-of-way due to a pedestrian condition, r (55) = .43, p < .01.

Among the individual differences there were also significant correlations. The Conflict Effect was positively correlated with the Orienting Effect, r (55) = .30, p < .05. Additionally, the STAIS-5 Before and the STAIS-5 After were positively correlated, r (55) = .56, p < .01.

Regressions. Regressions were conducted where predictor and outcome variables were significantly correlated. The correlations between the Alerting Effect, the Conflict Effect, and the exiting with right-of-way were significant. The regression model significantly predicted scores on the exiting with right-of-way, F (1, 53) = 5.03, p < .05, with the Conflict Effect contributing positively (B = 0.01, p < .05). This model explained 9% of the variance in the exiting with right-of-way scores (R^2 = .09). When the Alerting Effect was added, the equation still significantly predicted scores on the exiting with right-of-way, F (2, 52) = 5.64, p < .05, with both the

Conflict Effect (B = 0.01, $p < .05$) and the Alerting Effect (B = 0.01, $p < .05$) contributing positively. This model explained 18% of the variance in the exiting with right-of-way scores ($R^2 = .18$). When participants had faster Alerting RT and Conflict RT, they answered correctly more often on exiting with right-of-way trials.

Another relationship that was significantly correlated was between entering with right-of-way and the Conflict Effect. The regression model significantly predicted scores on the entering with right-of-way, F (1, 53) = 4.04, $p < .05$, with the Conflict Effect contributing negatively (B = -0.01, $p < .05$). This model explained 7% of the variance in the exiting with right-of-way scores ($R^2 = .07$). When participants had faster Conflict RT, they answered correctly fewer times on entering with right-of-way trials.

Decision Time. The time-based data did not follow a normal distribution (Figure 5). Therefore, all the time data was logarithmically transformed to increase the linearity and decrease the potential for positive skew. Additionally, only the DT data in cases where the correct answer was given were considered in the DT calculations. DT data can be found in Figure 5. DT data is expressed in milliseconds (MS) and was derived from the Qualtrics timing mechanism.

Figure 5

Frequency Distribution of Decision Times in Experiment 1

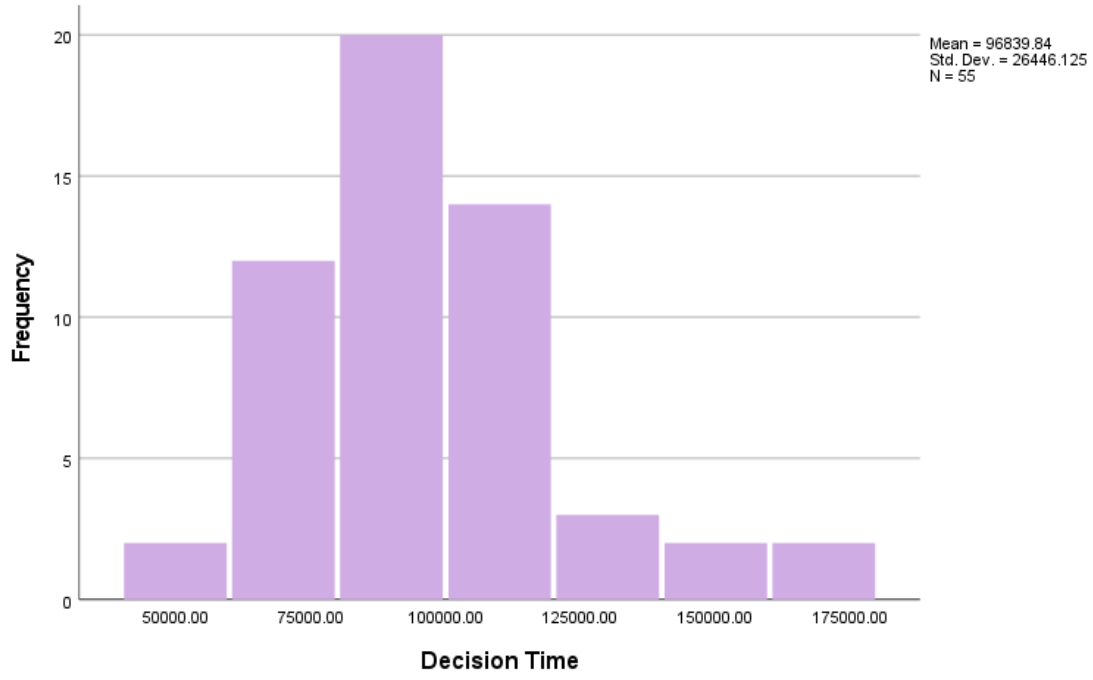


Table 5

DT Means and Standard Error in Experiment 1

Trial Type	Trained		Untrained	
	Mean	SE	Mean	SE
CRSD-ANT Mean RT	2.69	.01	2.70	.01
DT Entering without Right-of-way, Vehicle and Pedestrian	6.08	.03	6.07	.04
DT Entering without Right-of-way, Pedestrian	6.10	.03	6.10	.03

Table 5

DT Means and Standard Error in Experiment 1 (continued)

DT Entering with Right-of-way	6.10	.03	6.11	.02
DT Entering without Right-of-way, Vehicle	6.03	.03	6.06	.05
DT Exiting with Right-of-way	6.16	.03	6.16	.03
DT Exiting without Right-of-way	6.04	.03	6.05	.03
Total DT Across Conditions	36.51	.15	36.57	.15

Note. The lower the mean represents faster response times.

To test Hypothesis 1B, a 2-way ANOVA was conducted to examine the DT of the trained group and the untrained group using the total DT across all trial types. When comparing the trained group (M = 6.09, SE = 0.24) and the untrained group (M = 6.09, SE = 0.03) responses averaged across trial types, there was no significant difference in the results, F (1, 53) = .07, MSE= .00, p = .79, η = .00, thus Hypothesis 1B was not supported.

DT Analysis by Trial Type. To analyze the DT in the individual trial types (as depicted in Table 1), the same 2-way ANOVA revealed that the interaction between training and trial type was not significant, F (5, 50) = .19, MSE= .00, p = .97, η = .00. While the main effect for training was not significant, F (1,53) = .07, MSE = .01, p = .79, η = .00, there was a significant main effect for trial type, F (5, 50) = 8.88, MSE= .11, p < .001, η = .14. The mean and standard error (SE) for each type were listed in Table 5.

DT Correlations and Regressions. All the DT of the conditions along with CRSD-ANT mean RT and the individual differences were loaded into a correlation matrix with the results listed in Table 6.

Table 6

Correlation Matrix for Individual Differences and Decision Time in Experiment 1

Variable	Alerting Effect	Orienting Effect	Conflict Effect	STAIS-5 Before	STAIS-5 After	Knowledge Test	ANT Mean RT	Entering W/O ROW Vehicle & PED	Entering W/O ROW PED	Entering W ROW	Entering W/O ROW Vehicle	Exiting W ROW	Exiting WO ROW
Alerting Effect	1												
Orienting Effect	.03	1											
Conflict Effect	-.04	.30*	1										
STAIS-5 Before	.05	.08	.15	1									
STAIS-5 After	-.10	.09	-.10	.56**	1								
Knowledge Test	.04	.02	-.13	-.01	.09	1							
ANT Mean RT	.15	-.05	.05	.03	-.18	-.39**	1						
Entering W/O ROW Vehicle & PED	-.08	.09	-.02	-.09	-.13	-.00	-.03	1					
Entering W/O ROW PED	-.16	.06	-.10	-.00	.01	.16	.15	.47**	1				
Entering W ROW	-.07	-.09	-.19	-.22	-.23	.09	.11	.72**	.47**	1			
Entering W/O ROW Vehicle	-.27*	.18	-.01	-.19	.06	.19	-.24	.58**	.49**	.44**	1		
Exiting W ROW	.00	.13	.03	-.08	-.11	.04	-.10	.71**	.49**	.71**	.42**	1	

Table 6

Correlation Matrix for Individual Differences and Decision Time in Experiment 1 (continued)

Exiting WO ROW	-.08	.30*	.02	-.12	-.08	.28*	-.08	.64**	.60**	.62**	.57**	.62**	1

** Correlation is significant at the .01 level
* Correlation is significant at the .05 level

DT Correlations. There were several significant correlations found. As before, the Orienting Effect and Conflict Effect were positively correlated, r (55) = .30, $p < .05$ and the STAIS-5s were positively correlated, r (55) = .56, $p < .01$. The Knowledge Test and the Mean RT from the CRSD-ANT were negatively correlated, r (55) = - .39, $p < .01$. All of the DT data for each trial type were correlated with every other trial type. These 15 correlations were represented in Table 6.

DT Regressions. The correlation between the DT for entering without right-of-way with a vehicle and the Alerting Effect was significant. The regression model significantly predicted scores on the DT for entering without right-of-way, F (1, 53) = 4.04, $p < .05$, with the Alerting Effect contributing negatively (B = .00, $p < .05$). This model explained 7% of the variance in the DT for entering without right-of-way with a vehicle scores ($R^2 = .07$). Participants with a fast DT on the Alerting Effect responded quicker on the entering without right-of-way due to a vehicle trials.

The correlation between the DT for exiting without right-of-way and the Orienting Effect was significant. However, the regression equation was not significant.

The correlation between the DT for exiting without right-of-way and the Knowledge Test was significant yet, the regression equation was not significant.

Discussion

The additional training of the trained group produced no significant difference in the accuracy of the roundabout navigation responses. Therefore, Hypothesis 1A was not supported. The lack of a robust training manipulation that differentiated the trained groups was evident. Both the trained and the untrained groups watched the roundabout video but only the trained group was shown the diagram of the pedestrian/vehicle intersection points. The significant decline in the STAIS-5 scores after the experiment suggests the participants were experiencing some level of heightened anxiety, similar to performance anxiety, before the experiment that was relieved afterward, but the training manipulation did not account for this change.

From the regression analyses, the Conflict Effect calculated from the CRSD-ANT predicted outcomes on both the exiting with right-of-way trial type and the entering with right-of-way trial type. The need for drivers to visually find driving conflicts while navigating roundabouts would explain the relationship in the Conflict Effect and these two trial types. When entering the roundabout, the faster the driver can visually deconflict vehicles in the roundabout and pedestrians trying to cross the road the quicker the response time for the driver to decide they have right-of-way and proceed. The Alerting Effect also predicted outcomes on the exiting with right-of-way trial type. Again, the Alerting Effect represents the driver's ability to acquire a target visually and maintain vigilance on that target. That is the task of drivers exiting a roundabout because the only potential conflict is a possible pedestrian or bicycle attempting to cross the road.

DT Data

The DT data did not support Hypothesis 1B because there was no significant difference between the DT of the trained group and the untrained group. The only regression that proved to

be significant was the Alerting Effect predicting the outcomes on the DT for entering without right-of-way due to a vehicle. The faster a driver acquires a visual target such as a vehicle in the roundabout the faster the DT of that driver will be in responding to that vehicle.

EXPERIMENT 2

The second study examined the cognitive load effects on drivers when presented with approved apparatus for providing a warning for crosswalks from the MUTCD (Federal Highway Administration, 2009). The two warning apparatus studied are the HAWK device and the RRFB in a 2(HAWK/RRFB) X 2(pedestrian/no pedestrian) design. The National Aeronautics and Space Administration Task Load Index (NASA-TLX) measured the cognitive load placed on the driver as they encountered each warning apparatus. This study was conducted in a laboratory setting using the Qualtrics platform to interface with the participants for some of the measures but also involved measures not on Qualtrics (Qualtrics, Provo, UT).

Method

Participants

The participants were undergraduates from NCSU, 27 males and 14 females (one participant did not provide an answer to the gender query), who were at least 18 years of age, had a valid driver's license, and did not participate in Experiment 1 (N = 42). The age range was 18 to 25 (M = 19.9). Ninety-three percent (n = 39) of the participants reported normal color vision. Given the 2 (warning apparatus) X 2 (Pedestrian presence/non presence) within groups design, G*Power results indicated that the current design required 24 participants to achieve an 80% statistical power (Faul et al., 2009) thus the sample was sufficient.

Instrumentation

The Qualtrics online survey platform and the CRSD-ANT are the same as in the first experiment. Experiment 2 also included the NASA-TLX.

The NASA-TLX was developed by Hart and Staveland (1988) to measure the perceived workload of tasks. This instrument has been used in previous studies to measure perceived workload of driving tasks (Jeon et al., 2014; Sugiono et al., 2017).

Procedure

This study evaluated the effectiveness of two different types of crosswalk warning apparatus at roundabouts. One type of crosswalk warning apparatus was the High Intensity Activated Crosswalk (HAWK; Figure 6). Like in the first experiment the trial types did not include two of the four quadrants in signal detection theory (Green & Swets, 1966).

Figure 6

HAWK Device

The other type of apparatus was the rectangular rapid-flashing beacons (RRFB; Figure 7). There were two conditions for each apparatus, with pedestrians present and without pedestrians present. The presentation of each apparatus was counterbalanced.

Figure 7

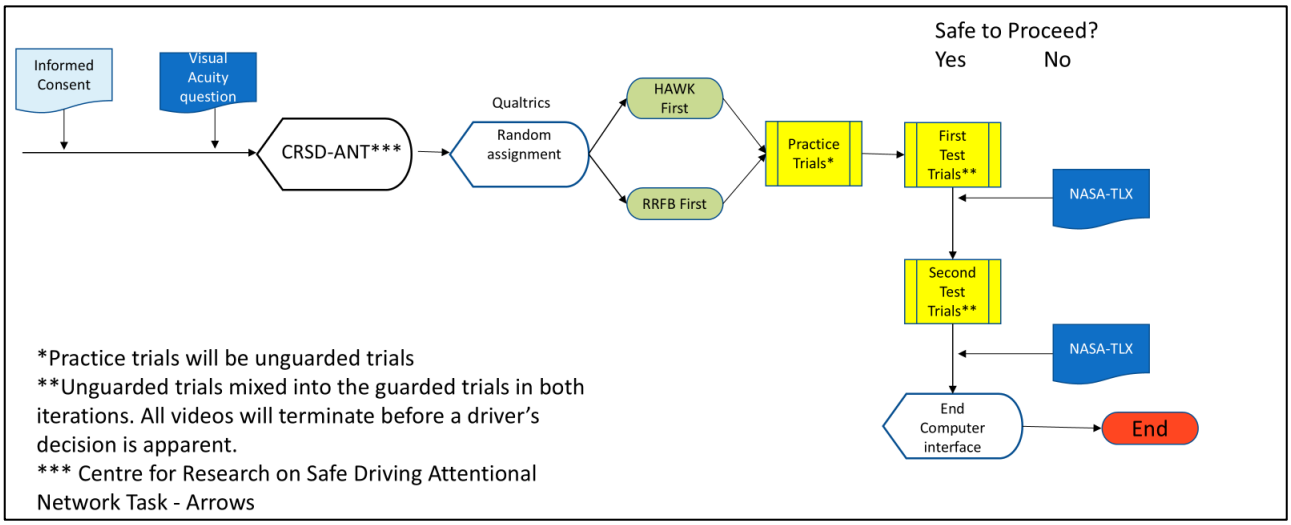
RRFB

The first task for all participants was to complete the CRSD-ANT instrument. Following this the participants completed the Qualtrics survey where they received the following prompt: *The following videos will show you different driving situations. You will be required to decide what you should do as the driver. Make your decisions quickly as if there was traffic behind you but accuracy is also very important. The first two videos will be practice.* When the participant manually advanced the screen, the first practice trial was started. During the video each participant selected the radio button that was next to the action they believed was correct; either "it is not safe to proceed" or "it is safe to proceed". The video stopped short of the decision point so waiting to respond did not provide an advantage. The two practice trials were videos of crossings without beacons collected in Durham, NC in the same manner as in experiment 1. The

participants received feedback at the end of each practice trial. The flow of the experiment is represented in Figure 8.

Figure 8

Experiment 2 Participant Flow



After the practice trials, each participant received instructions that the next series of videos were not practice and there would be no feedback after them. An additional reminder of the need for accuracy and speed was given at this time. When the participant manually advances Qualtrics, the participant was randomly presented either the HAWK apparatus block first or the RRFB block first. The HAWK videos were taken on Duke Street in Durham, North Carolina in the same manner as in experiment 1. During each video, the participant selected the radio button that corresponds with the action they believed was correct; either *it is not safe to proceed,* or *it is safe to proceed*. The measurement of the response time began when the video started and ended when a selection was made. The participant then selected the next button to advance to the next video. The HAWK block of videos was a series of eight videos taken on Duke Street in Durham, North Carolina and show each of the six aspects of the HAWK apparatus including when the

HAWK was not activated with the presence of pedestrians and without the presence of pedestrians (Table 7).

Table 7

Conditions of HAWK Stimuli

Condition	Pedestrian Present
Not Activated	
Not Activated	X
Flashing Yellow	X
Flashing Red	
Solid Red	X
Solid Yellow	X

The RRFB block contained eight videos of each of the three aspects of the RRFB including the RRFB not active with pedestrians present and not present (Table 8). These videos were taken on Pullen Road in Raleigh, North Carolina in the same manner as in experiment 1. At the end of the block of videos, the participants completed the National Aeronautics and Space Administration Task Load Index (NASA-TLX; Hart & Staveland, 1988) to measure the cognitive load for that warning apparatus.

Table 8

Conditions of RRFB Stimuli

Condition	Pedestrian Present
Activated	X
Not Activated	X
Not Activated	

The participants then began the second iteration/block with the other warning apparatus. This iteration presents the warning apparatus not shown in the first block proceeding in the same manner as the first iteration except there were no additional practice trials. The NASA-TLX was administered at the end of this iteration as well. In total, the procedure for each participant lasted approximately 45 minutes.

Results

Descriptives

The descriptive results of the CRSD-ANT and the NASA-TLX by order (HAWK first/RRFB first) as well as by the total for each signaling apparatus are reported in Table 9.

Table 9

Results of the Descriptive Instruments in Experiment 2

Instrument	HAWK First		RRFB First	
	Mean	SD	Mean	SD
CRSD-ANT				
Alerting Effect	41.17	24.77	7.85	120.68
Orienting Effect	23.98	27.31	35.96	41.40
Conflict Effect	75.68	41.91	79.99	38.74
NASA-TLX HAWK				
Mental Demand	7.82	4.01	8.80	5.46
Physical Demand	2.64	2.57	3.00	3.01
Temporal Demand	10.95	5.05	8.95	5.24
Performance	7.00	4.73	7.15	3.91
Effort	9.05	4.57	9.10	5.90
Frustration	5.82	4.17	3.55	3.24
NASA-TLX RRFB				

Table 9

Results of the Descriptive Instruments in Experiment 2 (continued)

Mental Demand	5.95	3.75	8.75	4.05
Physical Demand	2.64	2.30	1.95	1.43
Temporal Demand	8.77	4.72	8.95	4.56
Performance	6.32	4.16	5.80	3.56
Effort	5.91	3.62	9.45	5.33
Frustration	4.41	3.51	4.10	3.84

Note. Higher means denote more of the construct present. For example, a higher mean for the Mental Demand means the participants found the task more mentally demanding.

The HAWK first and the RRFB first groups were compared on the three attentional constructs and the NASA-TLX scales for both devices using *t*-tests. There were no significant differences between the two groups, indicating that the order of presentation was not an issue.

Looking at the NASA-TLX for both the HAWK and RRFB paired sample *t*-tests were used for each of the six scales with the descriptive statistics shown in Table 10.

Table 10

Descriptives for the Comparison of NASA-TLX in Experiment 2

TLX Aspect	HAWK		RRFB	
	Mean	SE	Mean	SE
Mental Demand	8.29	.73	7.29	.63
Physical Demand	2.81	.43	2.31	.30
Temporal Demand	10.00	.80	8.86	.71
Performance	7.07	.67	6.07	.59
Effort	9.07	.80	7.60	.74
Frustration	4.74	.60	4.26	.56

Note. Higher means denote more of the construct present. For example, a higher mean for the Mental Demand means the participants found the task more mentally demanding.

The physical demand and frustration aspects did not vary significantly by apparatus. However, significant differences were observed for the other four aspects of the NASA TLX. Comparing the Mental scale of the HAWK (M = 8.29, SE = 0.73) to the Mental scale of the RRFB (M = 7.29, SE = 0.63), the RRFB was significantly less mentally demanding, [t (41) = 1.78, $p < .05$, $d = 0.28$]. On the Temporal scale, the participants felt significantly less rushed with the RRFB (M = 8.86, SE = 0.71) than with the HAWK (M = 10.00, SE = 0.80), [t (41) = 1.74, $p = .05$, $d = 0.27$]. Again, on the Performance scale, participants believed they performed better with the RRFB (M = 6.07, SE = 0.59) than with the HAWK (M = 7.07, SE = 0.66), [t (41) = 1.80, $p < .05$, $d = 0.28$]. The Effort scale measures how hard the participant felt the task was and the RRFB (M = 7.60, SE = 0.74) seemed to significantly require less effort than the HAWK (M = 9.07, SE = 0.80), [t (41) = 2.50, $p < .01$, d = 0.38]. Although effect sizes were generally small, these NASA TLX results (such as reduced mental demand and reduced perceived effort) support Hypothesis 2C.

Behavioral Data from Driving Task

Correct Answers. Consistent with the first experiment, the data was trimmed, removing responses that were more than three standard deviations from the mean, and checked for normalcy. To allow for the direct comparison of the correct answers provided when participants encountered the HAWK and RRFB, Table 11 below collapses the four different classes of HAWK activation (i.e., Flashing Yellow, Flashing Red, Solid Yellow, Solid Red) as shown in Table 7 into one “Activated” classification below. Thus, correct performance on the HAWK and the RRFB can be calculated for each of the three response types (i.e., Activated, Not Activated, Not Activated, Ped).

To test Hypothesis 2A, a *t*-test was used to compare the total correct answers on the HAWK device (M = 13.46, SE = 0.29) with the total correct answers of the RRFB (M = 14.50, SE = 0.33). Participants responded to the RRFB correctly more often than they responded to the HAWK, t (41) = 43.37, $p < .001$, CI (13.82, 15.18). This finding supports Hypothesis 2A.

Analysis by Trial Type. The correct answer descriptives for the trial types of the two types of apparatus are depicted in Table 11. A 2 X 3 ANOVA revealed that the interaction between the order of presentation and the trial types was not significant, F (5, 37) = .44, MSE= .58, p = .82, η = .01. While the main effect for order of presentation was not significant, F (1,40) = 2.15, MSE = .33, p = .15, η = .05, there was a significant main effect for trial type, F (5, 37) = 61.99, MSE= 81.60, $p < .001$, η = .61.

Table 11

Correct Answer Descriptives for HAWK and RRFB

Trial Type	Mean	SE
HAWK		
Activated	4.15	.13
Not Activated	5.90	.06
Not Activated, PED	3.40	.24
Flashing Yellow	3.52	.37
Flashing Red	1.86	.31
Solid Yellow	4.93	.22
Solid Red	6.29	.09
RRFB		
Activated	5.64	.24
Not Activated	6.05	.08
Not Activated, PED	2.81	.20

Note. The larger the mean the greater number of correct answers for that condition.

Correlations and Regressions. All the descriptive data and the correct answers by trial types for each of the warning apparatus were loaded into two correlation matrixes with the results for the HAWK listed in Table 12 and the results for the RRFB listed in Table 13.

Table 12

Correlation Matrix for Descriptive Data and Correct Answers by HAWK Trial Types in Experiment 2

Variable	Alerting Effect	Orienting Effect	Conflict Effect	HAWK Mental	HAWK Physical	HAWK Temporal	HAWK Performance	HAWK Effort	HAWK Frustration	HAWK Inactive No PED	HAWK Inactive W PED	HAWK Active
Alerting Effect	1											
Orienting Effect	-.70**	1										
Conflict Effect	.06	.06	1									
HAWK Mental	-.09	-.06	-.04	1								
HAWK Physical	-.08	.14	-.29	.32	1							
HAWK Temporal	.06	-.21	.08	.59**	.23	1						
HAWK Performance	.07	.02	-.26	.07	.14	.12	1					
HAWK Effort	-.16	.18	-.05	.60**	.43**	.35*	.18	1				
HAWK Frustration	-.01-	.05	.01	.44**	.39**	.46**	.02	.51**	1			
HAWK Inactive No PED	-.00	-.24	.09	-.12	-.21	.01	-.09	-.47**	-.05	1		
HAWK Inactive W PED	-.02	-.13	.05	-.07	-.07	.15	-.03	.11	.31*	-.2	1	
HAWK Active	-.25	.30	-.04	.22	.23	.21	-.07	.31*	.33*	-.36*	.23	1

** Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

HAWK Correlations. Several significant correlations emerged. The Alerting Effect and the Orienting Effect were positively correlated, (r (42) = .70, p < .01). Within the individual differences the NASA-TLX Mental scale for the HAWK was positively correlated with the NASA-TLX Temporal scale for the HAWK (r (42) = .59, p < .01), the NASA-TLX Effort scale for the HAWK (r (42) = .60, p < .01), and the NASA-TLX Frustration scale for the HAWK (r (42) = .44, p < .01). The NASA-TLX Physical scale for the HAWK was positively correlated with the NASA-TLX Effort scale for the HAWK (r (42) = .43, p < .01) and the NASA-TLX Frustration scale for the HAWK (r (42) = .39, p < .01). The NASA-TLX Temporal scale for the HAWK was positively correlated with the NASA-TLX Effort scale for the HAWK (r (42) = .35, p < .05) and the NASA-TLX Frustration scale for the HAWK (r (42) = .46, p < .01). The NASA-TLX Effort scale for the HAWK was positively correlated with the NASA-TLX Frustration scale for the HAWK (r (42) = .51, p < .01). Finally, the active HAWK was negatively correlated to the inactive HAWK without a pedestrian, (r (42) = -.36, p < .05).

Within the HAWK trial conditions, several significant correlations were observed. The inactive no pedestrian was negatively correlated with the NASA-TLX Effort scale for the HAWK, (r (42) = -.47, p < .01). The inactive with pedestrian was positively correlated with the NASA-TLX Frustration scale for the HAWK, (r (42) = .31, p < .05). The active HAWK was positively correlated to both the NASA-TLX Effort scale for the HAWK (r (42) = .31, p < .05) and the NASA-TLX Frustration scale for the HAWK (r (42) = .33, p < .05)

HAWK Regressions. Regressions were conducted on significant correlations when detected between predictor and outcome variables. The correlation between the inactive HAWK with no pedestrian and the NASA-TLX Effort scale for the HAWK was significant. The regression model significantly predicted scores on the inactive no pedestrian HAWK, F (1, 40) =

11.15, $p < .05$, with the NASA-TLX Effort scale for the HAWK contributing negatively (B = -0.03, $p < .05$). This model explains 22% of the variance in the HAWK inactive condition ($R^2 = .22$). Participants who perceived greater effort on the inactive HAWK without pedestrian trial type answered incorrectly more often.

The correlation between the inactive HAWK with a pedestrian and the NASA-TLX Frustration scale for the HAWK was significant. The regression model significantly predicted scores on the inactive with a pedestrian condition, F (1, 40) = 4.37, $p < .05$, with the NASA-TLX Frustration scale contributing positively (B = 0.12, $p < .05$). This model explains 10% of the variance in the inactive with a pedestrian condition ($R^2 = .10$). Participants who found the inactive HAWK with a pedestrian trial type more frustrating answered correctly more often.

The correlation between the active HAWK, the NASA-TLX Effort and Frustration scales was significant. The regression model significantly predicted scores on the active HAWK, F (1, 40) = 4.75, $p < .05$, with the NASA-TLX Frustration scale contributing positively (B = 0.07, $p < .05$). This model explains 11% of the variance in the inactive with a pedestrian condition ($R^2 = .11$). The regression analysis showed that the relationship between the active HAWK and the NASA-TLX Effort scale (B = .20, $p = .74$) was not statistically significant. Participants who found the active HAWK trial type more frustrating answered correctly more often.

Table 13

Correlation Matrix for Descriptive Data and Correct Answers by RRFB Trial Types in Experiment 2

Variable	Alerting Effect	Orienting Effect	Conflict Effect	RRFB Mental	RRFB Physical	RRFB Temporal	RRFB Performance	RRFB Effort	RRFB Frustration	RRFB Active	RRFB Inactive No PED	RRFB Inactive W PED
Alerting Effect	1											
Orienting Effect	-.70**	1										

Table 13

Correlation Matrix for Descriptive Data and Correct Answers by RRFB Trial Types in Experiment 2 (continued)

Conflict Effect	.06	.06	1									
RRFB Mental	-.11	-.05	.05	1								
RRFB Physical	.06	.04	-.10	.23	1							
RRFB Temporal	-.06	-.09	.23	.46**	.30	1						
RRFB Performance	-.07	.33*	-.09	-.03	.31*	.10	1					
RRFB Effort	-.23	.28	.04	.54**	.24	.42**	.16	1				
RRFB Frustration	-.04	.15	-.16	.25	.24	.27	.16	.50**	1			
RRFB Active	.33*	-.23	-.11	.01	.01	-.09	-.32*	-.24	.05	1		
RRFB Inactive No PED	.03	.06	.22	-.09	-.17	.05	.21	-.00	-.23	-.20	1	
RRFB Inactive W PED	.10	.04	-.26	.14	.09	.18	-.08	.10	.00	.20	-.06	1

** Correlation is significant at the .01 level
* Correlation is significant at the .05 level

RRFB Correlations. Much like the results between the NASA-TLX and the HAWK, several of the NASA-TLX scales were significantly correlated. The NASA-TLX Temporal scale for the RRFB was positively correlated with the NASA-TLX Mental scale for the RRFB, r (42) = .46, $p < .01$. The NASA-TLX Performance scale for the RRFB was positively correlated with the NASA-TLX Physical scale for the RRFB, r (42) = .31, $p < .05$. The NASA-TLX Effort scale was positively correlated with both the NASA-TLX Mental scale for the RRFB (r (42) = .54, $p < .01$) and the NASA-TLX Temporal scale (r (42) = .42, $p < .01$). Finally, the NASA-TLX Frustration scale was positively correlated with the NASA-TLX Effort scale, r (42) = .50, $p < .01$).

RRFB Regressions. Regressions were conducted where significant correlations were detected between predictor and outcome variables. The correlation between the active RRFB and both the Alerting Effect and the NASA-TLX Performance scale for the RRFB was significant. The regression model significantly predicted scores on the RRFB active condition, F (1, 40) = 4.96, $p < .05$, with the Alerting Effect contributing positively (B = 0.01, $p < .05$). This model explained 11% of the variance in the active RRFB condition ($R^2 = .11$). When the NASA-TLX Performance scale was added to the equation the regression continued to significantly predict scores on the RRFB active condition, F (2, 39) = 4.80, $p < .05$, with the Alerting Effect contributing positively (B = 0.01, $p < .05$) and the NASA-TLX Performance scale contributing negatively (B = - 0.12, $p < .05$). This model explained 20% of the variance in the active RRFB condition ($R^2 = .20$). Participants whose Alerting Effect score was high indicating a faster DT to acquiring a visual target and who had a more positive perception of their performance answered the active RRFB correctly more often. Because the Performance scale is an inverse scale, a negative correlation is actually a positive effect.

Decision Time

Similar to Experiment 1, the time-based data was not normally distributed. Therefore, all time data was trimmed and transformed consistent with the process described in Experiment 1. Additionally, only the DT data in cases where the correct answer was given were considered in the DT and calculations. The video lengths were not the same across trial types, so a relative DT was calculated by multiplying the video length with the raw DT (Relative DT = Video Length x Raw DT). The DT is expressed in milliseconds (MS). The means and standard errors for presentation order and apparatus type totals are listed in Table 14 below.

Table 14

Relative Decision Time Means and Standard Error in Experiment 2

Group	Mean	SE
HAWK First	4.90	.10
RRFB First	4.73	.10
HAWK Total	13.60	.27
RRFB Total	15.20	.36

Note. The lower the mean the faster the decision time. Totals were the sum of the DT for correct answers for the three trial types for that apparatus (such as, HAWK active $_{correct}$ + HAWK inactive $_{correct}$ + HAWK active, Ped $_{correct}$ = HAWK Total)

A 2-way ANOVA was conducted to examine the relative DT of the HAWK first group and the relative DT of the RRFB first group using the relative DT across all conditions. When comparing the HAWK first group (M = 4.90, SE = .10) and the RRFB first group (M = 4.73, SE = .10; Table 14) there was no significant difference in the results, F (1, 38) = 1.50, MSE= .24, p = .23, η = .04, indicating the counter balanced presentation was successful.

To test Hypothesis 2B, a t-test compared the total relative DT of the HAWK (M = 13.60, SE = .27) and the total relative DT of the RRFB (M = 15.20, SE = .36; Table 14). Participants responded significantly more quickly to the HAWK than to the RRFB, t (41) = 51.14, p < .001, CI (13.06, 14.14), thus Hypothesis 2B is not supported.

Table 15

Relative Decision Time Means and Standard Error by Trial Type in Experiment 2

Trial Type	HAWK First		RRFB First	
	Mean	SE	Mean	SE
HAWK				
Relative DT Active	5.04	.16	4.93	.17
Relative DT Not Activated	5.24	.09	5.26	.10

Table 15

Relative Decision Time Means and Standard Error by Trial Type in Experiment 2 (continued)

Relative DT Not Activated PED	3.84	.29	3.22	.30
Relative DT Flashing Yellow	4.77	.40	4.12	.50
Relative DT Flashing Red	4.63	.47	3.76	.58
Relative DT Solid Yellow	4.28	.28	4.41	.26
Relative DT Solid Red	6.22	.09	6.21	.07
RRFB				
Relative DT Inactive PED	3.82	.28	4.00	.29
Relative DT Inactive No PED	5.70	.16	5.38	.17
Relative DT Active	5.70	.34	5.55	.36

Note. The lower the mean the faster the decision time. DT for correct responses only

DT Analysis by Trial Type. The descriptives for the trial types in each apparatus are depicted in Table 15. To analyze the individual trial types, the active presentations of the HAWK were combined producing the active HAWK trial type as previously explained. This was necessary to establish parity with the trial types for the RRFB. The individual trial types were compared using the same 2-way ANOVA that revealed the interaction between presentation order and trial type was not significant, F (5, 36) = .61, MSE= .74, p = .69, η = .02. There was a

significant main effect for trial type, F (5, 36) = 25.16, MSE= 30.50, $p < .001$, $\eta = .40$. The six trial types for Experiment 2 are listed in Table 16.

Table 16

Relative Decision Time Means and Standard Error by Collapsed Trial Type in Experiment 2

Trial Type	HAWK First		RRFB First	
	Mean	SE	Mean	SE
HAWK				
Relative DT Active	5.04	.16	4.93	.17
Relative DT Not Activated	5.24	.09	5.26	.10
Relative DT Not Activated PED	3.84	.29	3.22	.30
RRFB				
Relative DT Active	5.70	.34	5.55	.36
Relative DT Not Activated	5.70	.16	5.38	.17
Relative DT Not Activated PED	3.82	.28	4.00	.29

Note. The lower the mean the faster the decision time.

DT Correlations and Regressions. All the DT for the three response types (i.e., Active, Inactive, Inactive with PED), the three attention effects from the CRSD-ANT, and the Mean RT also from the CRSD-ANT were loaded into correlation matrixes for each signaling apparatus. The results for the HAWK are found in Table 17 and the results for the RRFB are listed in Table 18.

Table 17

Correlation Matrix for Individual Differences and Decision Time of HAWK Trial Types in Experiment 2

Variable	Alerting Effect	Orienting Effect	Conflict Effect	Mean RT	Inactive No PED DT	Inactive W PED DT	Active DT
Alerting Effect	1						
Orienting Effect	-.70**	1					
Conflict Effect	.06	.06	1				
Mean RT	-.02	.33*	.19	1			
Inactive No PED DT	.06	-.20	-.08	-.16	1		
Inactive W PED DT	-.01	-.18	.10	-.27	-.12	1	
Active DT	-.24	.32*	-.02	.09	-.19	.22	1

HAWK DT Correlations. As previously identified, the Alerting Effect and the Orienting Effect were negatively correlated, r (42) = -.70, $p < .01$. The Orienting Effect was positively correlated with the Mean RT from the CRSD-ANT, r (42) = .33, $p < .05$.

There was only one HAWK trial type that was significantly correlated. The DT for the active HAWK trial type was positively correlated with the Orienting Effect, r (42) = .32, $p < .05$.

HAWK DT Regressions. Regressions were conducted on the significant correlations when detected between predictor and outcome variables. The correlation between the DT for active HAWK and the Orienting Effect was significant. The regression model significantly predicted scores on the DT for the active HAWK, F (1, 40) = 4.42, $p < .05$, with the Orienting

Effect contributing positively (B = 0.24, $p < .05$). This model explained 10% of the variance in the mean RT scores ($R^2 = .10$). Participants who had faster response time with the Orienting Effect were faster responding to the active HAWK trial type.

RRFB DT Correlations. The correlations between the predictors have been identified previously.

Table 18

Correlation Matrix for Individual differences and Decision Time of RRFB Trial Types in Experiment 2

Variable	Alerting Effect	Orienting Effect	Conflict Effect	Mean RT	RRFB Inactive W PED DT	RRFB Inactive No PED DT	RRFB Active DT
Alerting Effect	1						
Orienting Effect	-.70**	1					
Conflict Effect	.06	.06	1				
Mean RT	-.02	.33*	.19	1			
RRFB Inactive W PED DT	.08	.05	-.27	-.01	1		
RRFB Inactive No PED DT	.05	.07	.07	.10	.07	1	
RRFB Active DT	.34*	-.21	-.09	-.18	-.12	-.12	1

** Correlation is significant at the .01 level
* Correlation is significant at the .05 level

RRFB DT Regressions. The correlation between the DT for the active RRFB and the Alerting Effect was significant. The regression model significantly predicted scores on the DT

for the active RRFB, F (1, 40) = 5.10, $p < .05$, with the Alerting Effect contributing positively (B = 0.02, $p < .05$). This model explained 11% of the variance in the DT for the active RRFB scores ($R^2 = .11$). Participants who had faster response times with the Alerting Effect had quicker response times to the active RRFB trial type.

Discussion

The second experiment compared the HAWK and the RRFB in both the driver's ability to respond correctly when presented with the different aspects of each device and the level of additional cognitive load placed on the drivers.

Behavioral Data from Driving Task.

Participants responded to the RRFB correctly more often than the HAWK. Therefore, Hypothesis 2A was supported. The flashing red signal in the HAWK proved to be the hardest presentation of the HAWK for participants to get correct. It is speculated that the unfamiliarity with a flashing red light and the HAWK apparatus were the reasons this was the hardest condition for participants. In the U.S., a flashing red light is not common and could cause the participant to not know what to do when confronted with one. The correct action for a flashing red light at a HAWK is to proceed if the crosswalk is clear. Again, the unfamiliarity of drivers with the HAWK and the drastically different message the flashing red light signals compared to most red lights in our environment would cause drivers to incorrectly interpret the signal.

The presentation of the RRFB most missed trial type was when the RRFB was not flashing but there was a pedestrian present. One potential explanation for this finding is that the participant did not see the pedestrian because there was a search satisfaction effect (also known as subsequent search miss errors) when the RRFB was not active (Cain et al., 2013). In such a scenario, the participant may have assumed there was no pedestrian and stopped searching.

Differences by Condition.

Using the NASA-TLX to evaluate the amount of cognitive load placed on the driver it was found that the HAWK presented a higher cognitive load as defined by the lower scores on the Mental, Temporal, Performance, and Effort scales for the RRFB. Participants thought the RRFB was less mentally taxing and required less mental effort to engage. Moreover, the participants felt less rushed and believed they performed better with the RRFB. There was also a lower level of frustration with the RRFB, but this difference was not significant. Therefore, Hypothesis 2C was supported.

HAWK Regressions. The correlation between the inactive HAWK with no pedestrian and the NASA-TLX Effort scale for the HAWK was significant. The Effort scale was negatively correlated indicating that higher Effort scales scores predicted lower correct answers on the HAWK when it was inactive with no pedestrian. This relationship supports the previous finding that participants found the HAWK required greater effort to negotiate than the RRFB. This was also found in the relationship between the inactive HAWK with a pedestrian and the Frustration scale where a higher frustration score predicts more correct answers on that trial type. This was the same relationship observed between the Frustration scale and the active HAWK.

Focusing on the individual active trial types indicated the NASA-TLX Effort scale contributed to both the Flashing Yellow condition and the Inactive condition. It is possible that a flashing yellow light was unknown to the participants and that uncertainty of what to do was perceived as needing greater effort by the participants. The relationship between the NASA-TLX Effort scale and the presentation of an inactive HAWK device without a pedestrian present was a negative relationship. This relationship possibly suggests that drivers scanned for pedestrians and completely disregarded the HAWK or did not scan for pedestrians at all making this condition

require less effort. This idea is supported by the positive correlation between the inactive HAWK with a pedestrian present and the NASA-TLX Frustration scale. Assuming drivers are disregarding the inactive HAWK and not scanning for pedestrians, pedestrians when present would increase the frustration of the driver.

RRFB Regressions. The Active RRFB was correlated with both the Alerting Effect and the NASA-TLX Performance scale for the RRFB was significant. The Alerting Effect was positively correlated, meaning the higher scores on the Alerting Effect indicated higher scores on the active RRFB. The basis of the Alerting Effect is the driver's ability to acquire visual focus on a target. The ability to see and visually monitor an active RRFB indicates leads to more correct answers on that trial type. Interestingly, the NASA-TLX Performance scale appears to be negatively correlated with the active RRFB. However, the performance scale was an inverse scale on the NASA-TLX so the lower value on the Performance scale actually indicates a greater sense of performance by the participants. Considering that this is an inverse scale the relationship between the Performance scale and the active RRFB indicates that greater perceived performance by the participants coincides with more correct responses on the active RRFB trial type. This relationship suggests that participants found the active RRFB easy to interpret and they responded with a high level of certainty.

Decision Time (DT) Data.

A quicker DT by the driver could suggest increased awareness of the driver to the presence of a pedestrian. When comparing the HAWK and the RRFB, the RRFB DT was significantly faster than the HAWK, thus Hypothesis 2B was supported.

DT Regressions. The Orienting Effect successfully predicted scores on the DT for the HAWK Active trial type. The Orienting Effect indicates the ability to focus attention at a specific

target. This relationship suggests that the faster a driver can orient their focus on the active HAWK the faster they can respond to the information being conveyed by the HAWK.

In similar fashion, the Alerting Effect that indicates the ability to acquire attention on a target positively predicted scores on the active RRFB.

The RRFB was found to produce less cognitive load and faster decision times than the HAWK. Moreover, the RRFB produced more correct answers than the HAWK and faster decision times more often than not. These findings and the lower cognitive load made the RRFB the apparatus adopted for use in Experiment 3.

EXPERIMENT 3

The third study combined the findings of the first two studies in a 2 (trained/untrained) X 9 (Trial Type in Table 19) mixed factorial design. The effect of training along with the addition of RRFB at the entry and exits of roundabouts were the main manipulations explored. Data collection was conducted in a laboratory setting using the STAIS-5 and the NASA-TLX to measure anxiety and task load of the participants. This study also used the Qualtrics platform to interface with the participants (Qualtrics, Provo, UT).

Table 19

Order of Experiment 3 Stimuli

Condition	Vehicle Present	Pedestrian Present
Enter with RRFB		X
Exit with RRFB		X
Enter without RRFB	X	X
Exit without RRFB		X
Enter without RRFB	X	
Enter without RRFB		X

Table 19

Order of Experiment 3 Stimuli (continued)

Enter with RRFB	X	X
Exit with RRFB	X	X
Exit without RRFB	X	X

Method

Participants

The participants were undergraduates, 26 males and 16 females, from NCSU who were at least 18 years of age, have a valid driver's license, and did not participate in either of the previous two experiments (N = 42). The age range was 18 to 31 (M = 19.6) and 76% (n = 32) received roundabout training when they tested for licensure. Normal color vision was reported by 95% (n = 40) of participants. According to the G*Power program, a mixed groups, repeating measures design requires 30 participants to achieve 80% statistical power (Faul et al., 2009) such that the sample was sufficient.

Instrumentation

The instruments for this study were the Qualtrics online survey platform, the STAIS-5, the 21-question driver knowledge test, the CRSD-ANT, the two videos from NCDOT, and the map of a roundabout pointing out the vehicle/pedestrian meeting points from the first experiment and the NASA-TLX from the second experiment. Nine videos of roundabout driving situations were made by the researcher.

The video stimuli, taken from the driver's perspective, included each of the nine scenarios in Table 19. These videos were presented one at a time and were not advanced until the participant selected the next button. The videos depict a driving situation at a roundabout and the

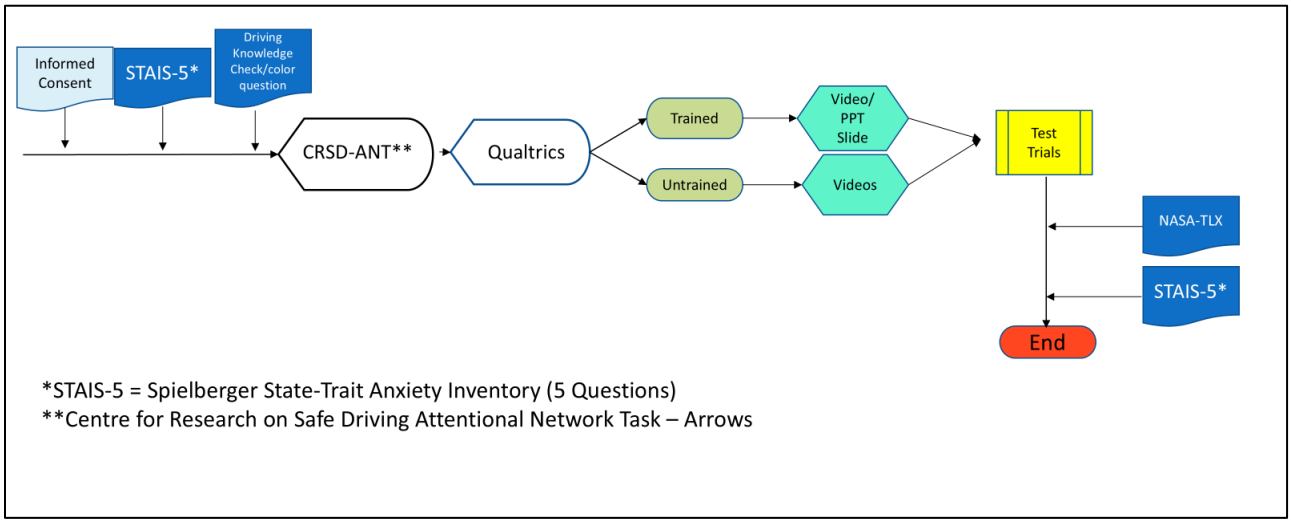
participant responded by selecting the radio button that corresponds to the action the participant believes is correct; either it is safe to proceed, or it is not safe to proceed. The sequence of videos is repeated four times providing 36 total stimuli.

Procedure

This study manipulated the training of the participants (between groups) in driving tasks and the use of warning apparatus for the crosswalks at roundabouts. The participants were randomly assigned to either the trained group (n = 21) or the untrained group (n = 21) when they visited Qualtrics to complete the trials. See Figure 9 for a workflow chart for experiment 3. The training was not changed from the first experiment because the potential for colluding the results of the warning apparatus effect. Signal detection theory was not considered in this experiment as in the previous two experiments.

Figure 9

Experiment3 Participant Flow



During a single visit to the laboratory, the participant completed the STAIS-5, the driving knowledge test from the first experiment, and the CRSD-ANT. Later, they started the Qualtrics survey where they were randomly assigned to either the experimental group or the control group.

Both groups viewed the same 2 minute and 12 second video on how to drive through roundabouts from experiment 1 (NCDOT, 2019). The trained group then viewed the same diagram of a roundabout with pedestrian crossing points highlighted from experiment 1 (Figure 2). The untrained group viewed the same second video about the dangers of texting while driving from experiment 1 (NCDOT, 2013).

Following this procedure, the participants completed the Qualtrics survey where they received the following prompt: *The following videos will show you different driving situations. You will be required to decide what you should do as the driver. Make your decisions quickly as if there was traffic behind you but accuracy is also very important. The first two videos will be practice.* When the participant manually advanced the screen, they were able to start the first practice video. During the video each participant selected the correct radio button to indicate their choice: not safe to proceed, safe to proceed. Each video stopped short of the decision point so waiting to respond did not provide an advantage. The two practice trials were crossings without beacons, and the participants received feedback at the end of each practice trial.

After the practice trials, each participant received instructions that the next series of videos were not practice and there would be no feedback. An additional reminder of the need for accuracy and speed was given at this time. When the participant manually advanced Qualtrics, the first video was started by the participant. The videos were taken in Raleigh, North Carolina on Pullen Road and Hillsborough Street, and in Fayetteville, North Carolina on Hay Street in the same manner as in experiment 1.

Qualtrics presented the vignettes in a predetermined order (Table 19). This sequence was repeated four times for each participant giving a total of 36 presentations. During each video the participant selected a radio button at the bottom of the video. Each button corresponded to either

the not safe to proceed response or the safe to proceed response. The measurement of the response time began when the video started and ended when a selection was made. The participant was required to advance the program to the next video each time. Limited demographic information was collected after the video series was complete.

The participants completed the second NASA-TLX and the STAIS-5 after completing the series of videos. In total, the procedure for each participant lasted approximately 45 minutes.

Results

Differences by Condition

The results of the Spielberger State-Trait Anxiety Inventory, Short form, (STAIS-5), the driving knowledge test, and the CRSD-ANT are reported in Table 20.

Table 20

Results of the Individual Differences in Experiment 3

Instruments	Trained		Untrained	
	Mean	SE	Mean	SE
STAIS-5				
Before	6.33	.30	6.30	.42
After	6.33	.25	6.00	.25
Knowledge Test	15.05	.39	14.40	.55
CRSD-ANT				
Alerting Effect	36.24	4.18	54.11	13.82
Orienting Effect	22.00	4.62	38.63	7.36
Conflict Effect	80.33	5.96	76.48	7.34
NASA-TLX				
Mental Demand	8.85	.86	7.21	1.04
Physical Demand	2.80	.48	2.47	.59
Temporal Demand	9.85	.99	7.00	1.06
Performance	13.55	.87	14.16	1.20

Table 20

Results of the Individual Differences in Experiment 3 (continued)

Effort	8.15	.90	6.11	.89
Frustration	8.40	.73	7.47	1.17

Note. Higher means denote more of the construct present. For example, a higher mean for the Mental Demand means the participants found the task more mentally demanding.

The STAIS-5 was analyzed to measure any increased anxiety after interacting with the stimuli. There was no significant difference between the trained group, (M = 6.33, SE = 0.30) and the untrained group (M = 6.30, SE = 0.42) before the participants participated in the experiment, t (39) = -.07, p = .82. There continued to be no significant difference between the trained group (M = 6.33, SE = 0.25) and the untrained group (M = 5.95, SE = 0.25) after the experiment, t (39) = -1.09, p = .38. Comparing the STAIS-5 Before (M = 6.32, SE = 0.25) with the STAIS-5 After (M = 6.15, SE = 0.18) indicated that the anxiety of all participants went down significantly, t (40) = 34.81, p < .001 after the experiment was over: a finding consistent with Experiment 1.

Comparing the trained and untrained groups on the other instruments there were no significant differences between the two groups, indicating the groups were equal in the beginning.

Behavioral Data from Driving Task

Correct Answers. All the data was trimmed, removing responses that were more than three standard deviations from the mean, and checked for normalcy as in Experiment 1. To test Hypothesis 3A, a 2-way ANOVA was conducted to examine the percentage of correctly answered driving trials. The descriptives can be found in Table 21. When comparing the correct answers provided by the trained group (M = 30.48, SE = 1.14) and the untrained group (M =

31.30, SE = 1.17) there was no significant difference in the results, F (1, 39) = .11, MSE= .05, p = .74, η = .00, thus Hypothesis 3A was not supported.

Table 21

Means and Standard Error of Trial Type Totals for Correct Answer in Experiment 3

Trial Type	Trained		Untrained	
	Mean	SE	Mean	SE
Total Correct	30.48	1.14	31.30	1.17
Enter active RRFB, PED Present	2.95	.24	2.85	.23
Exit active RRFB, PED Present	2.52	.16	2.70	.18
Enter inactive RRFB, Vehicle and PED Present	1.90	.30	2.55	.31
Exit inactive RRFB, PED Present	3.43	.21	3.55	.25
Enter inactive RRFB, Vehicle Present	2.62	.34	2.75	.37
Enter inactive RRFB, PED Present	3.57	.24	3.80	.16
Enter active RRFB, Vehicle and PED Present	3.38	.27	3.05	.30
Exiting active RRFB, Vehicle and PED Present	3.67	.21	3.45	.26
Exiting inactive RRFB, Vehicle and PED Present	3.43	.25	3.40	.27

Note. The higher the mean the more correct answers for that condition.

Analysis by Trial Type. To analyze the performance on individual trial types the same 2-way ANOVA revealed that the interaction between training and trial type was not significant, F (8, 33) = .81, MSE= .84, p = .60, η = .02. While the main effect for training was not significant, F (1, 39) = .11, MSE = .44, p = .74, η = .00, there was a significant main effect for

trial type, F (8, 33) = 9.99, MSE= 10.38, $p < .001$, $\eta = .20$. The nine trial types for Experiment 3 were listed in Table 19 while the mean and standard error (SE) for each type are listed in Table 21 above.

To compare the effectiveness of the RRFB, the conditions were grouped by those conditions with an active RRFB and those conditions with an inactive RRFB without considering the training/no training bifurcation. The descriptives are found in Table 22. The difference between the total correct answers in trial types with an active RRFB (M = 9.98, SE = .38) and the total correct answers in conditions with an inactive RRFB present (M = 10.07, SE = .40) was significant, t (40) = 25.46, $p < .001$. Participants answered correctly more often when the RRFB was inactive.

Table 22

Means and Standard Error of RRFB, non RRFB Totals for Correct Answer in Experiment 3

Condition	Mean	SE
All trials with active RRFB	9.98	.38
All trials with inactive RRFB	10.07	.40

Note. The higher the mean the more correct answers for that condition. Trial types were collapsed based on an active or inactive RRFB (such as, Enter active RRFB, Ped + Exit active RRFB, Ped + Enter active RRFB, vehicle and Ped + Exiting active RRFB, vehicle and Ped = All trials with active RRFB)

Correlations and Regressions. All the correct answer descriptives and trial types were loaded into a correlation matrix with the results listed in Table 23.

Table 23

Correlation Matrix for Descriptives and Correct Answer Trial Types in Experiment 3

Variable	STAIS-5 Before	STAIS-5 After	Knowledge Test	NASA-TLX Mental	NASA-TLX Physical	NASA-TLX Temporal	NASA-TLX Performance	NASA-TLX Effort	NASA-TLX Frustration	Alerting Effect	Orienting Effect	Conflict Effect	EnterWFBWPED	ExitWFBWPED	EnterW/OFBWVEH&PED	ExitW/OFBWPED	EnterW/OFBWVEH	EnterW/OFBWPED	EnterWFB,VEH,&PED	ExitWFB,VEH&PED	ExitW/OFBWVEH&PED
STAIS-5 Before	1																				
STAIS-5 After	.53**	1																			
Knowledge Test	.05	.32*	1																		
NASA-TLX Mental	.17	.29	.15	1																	
NASA-TLX Physical	.02	.31	.16	.52**	1																
NASA-TLX Temporal	.01	.42**	.23	.42**	.50**	1															
NASA-TLX Performance	.16	.06	.20	.15	.04	.06	1														

Table 23

Correlation Matrix for Descriptives and Correct Answer Trial Types in Experiment 3 (continued)

NASA-TLX Effort	-.06	-.09	.11	.66**	.44**	.33*	.20	1								
NASA-TLX Frustration	.19	.37*	.17	.16	.32	.25	-.08	-.01	1							
Alerting Effect	-.06	-.09	.00	-.16	-.30	-.24	.01	-.11	.02	1						
Orienting Effect	-.02	.03	-.14	.08	-.07	-.08	-.17	-.11	-.12	.29	1					
Conflict Effect	-.02	-.13	-.10	.01	-.14	-.08	.04	.19	-.09	-.21	-.41**	1				
Enter W FB W PED	.13	.14	.31*	.03	-.17	.06	.34*	-.12	.03	.12	.17	-.26	1			
Exit W FB W PED	.12	-.11	-.26	-.28	-.54**	-.53**	.01	-.39*	-.04	.24	-.03	.06	.07	1		
Enter W/O FB W VEH & PED	.20	.04	.15	.03	.36*	-.12	.08	-.05	-.09	.15	.29	-.22	.50**	.20	1	
Exit W/O FB W PED	.10	-.15	-.13	-.22	-.49*	-.54**	.02	-.35*	-.07	.11	-.13	.29	-.07	.82***	.18	1
Enter W/O FB W VEH	.13	.12	-.12	.09	.03	.20	-.03	-.09	.01	-.10	-.09	.15	-.06	-.02	.20	.01	1

Table 23

Correlation Matrix for Descriptives and Correct Answer Trial Types in Experiment 3 (continued)

Enter W/O FB W PED	-.12	-.30	.18	-.04	-.25	-.18	.26	.05	-.22	.17	.00	.09	.10	.07	.31*	.39*	-.04	1		
Enter W FB W VEH & PED	.03	.18	.21	.03	-.23	.06	.24	.04	.01	.17	.22	-.08	.76**	.21	.40**	.05	-.05	.17	1	
Exit W FB W VEH & PEN	.10	-.03	-.07	-.23	-.52**	-.42**	.08	-.35*	.09	.21	-.15	.21	.14	.86**	.14	.83**	.11	.09	.24	1
Exit W/O FB W VEH & PED	.05	-.05	.06	-.14	-.38*	-.39*	.08	-.24	-.02	.16	-.26	.29	.03	.69**	.22	.83**	.22	.32*	.15	.83**	1

** Correlation is significant at the .01 level
* Correlation is significant at the .05 level

Correlations. There were many significant correlations among the predictor instruments. As identified in the previous studies the STAIS-5 Before and the STAIS-5 After were positively correlated [r (41) = .53, $p < .001$] as were the Conflict Effect and the Orienting Effect [r (41) = .41, $p < .001$]. The Knowledge Test was positively correlated with the STAIS-5 After, r (41) = .32, $p < .05$.

Several of the NASA-TLX scales were correlated with each other. The Physical scale was positively correlated with the Mental scale, r (39) = .52, $p < .001$. The Temporal scale was positively correlated with the STAIS-5 After [r (39) = .42, $p < .001$], the Mental scale, [r (39) = .42, $p < .001$], and the Physical scale [r (39) = .50, $p < .001$]. The NASA-TLX Effort scale was

positively correlated with the Mental scale [r (39) = .66, p < .001], the Physical scale [r (39) = .44, p < .001], and the Temporal scale [r (39) = .33, p < .05]. Finally, the NASA-TLX Frustration scale was positively correlated with the STAIS-5 After, r (39) = .37, p < .05.

Several of the trial type conditions were significantly correlated as well. The entering without a RRFB with a vehicle and a pedestrian was positively correlated with the entering with a RRFB and a pedestrian, r (41) = .50, p < .001. The exiting without a RRFB with a pedestrian was positively correlated with exiting with a RRFB and a pedestrian, r (41) = .82, p < .001. The entering without a RRFB with a pedestrian was positively correlated with the entering without a RRFB with both a vehicle and a pedestrian [r (41) = .31, p < .05] and the exiting without a RRFB with a pedestrian [r (41) = .39, p < .05]. The entering with a RRFB and with both a vehicle and a pedestrian was positively correlated with both the entering with a RRFB and a pedestrian [r (41) = .76, p < .001] and the entering without a RRFB with both a vehicle and a pedestrian [r (41) = .40, p < .001]. The exiting with a RRFB and both a vehicle and a pedestrian was positively correlated with the exiting with a RRFB and a pedestrian [r (41) = .86, p < .001] and the exiting without a RRFB with a pedestrian [r (41) = .83, p < .001]. Finally, the exiting without a RRFB with both a vehicle and a pedestrian was positively correlated with the exiting with a RRFB and a pedestrian [r (41) = .69, p < .001], the exiting without a RRFB with a pedestrian [r (41) = .83, p < .001], the entering without a RRFB with a pedestrian [r (41) = .32, p < .05], and the exiting with a RRFB and both a vehicle and pedestrian [r (41) = .83, p < .001].

Regressions. Regressions were conducted on all significant correlations between predictor and outcome variables. The correlation between entering with an active RRFB and a pedestrian, the Knowledge Test, and the NASA-TLX Performance scale was significant. The regression model significantly predicted scores on entering with an active RRFB and a

pedestrian, F (1, 37) = 4.80, $p < .05$, with the NASA-TLX Performance scale contributing positively (B = 0.07, $p < .05$) and the Knowledge Test proved to not contribute (B = .13, $p = .41$). This model explained 12% of the variance in entering with a RRFB and a pedestrian scores ($R^2 = .12$). The NASA-TLX Performance scale is reverse coded so participants who did not think they performed well actually answered correctly more often.

The correlation between exiting with an active RRFB and a pedestrian, the NASA-TLX Physical scale, the NASA-TLX Temporal scale, and the NASA-TLX Effort scale was significant. The regression model significantly predicted scores on exiting with an active RRFB and a pedestrian, F (1, 37) = 14.98, $p < .001$, with the NASA-TLX Physical scale contributing negatively (B = - 0.18, $p < .001$). This model explained 29% of the variance in the exiting with an active RRFB and a pedestrian scores ($R^2 = .29$). When the NASA-TLX Temporal scale was added to the equation the regression model continued to significantly predict scores on the exiting with an active RRFB and a pedestrian, F (2, 36) = 11.15, $p < .001$, with the NASA-TLX Physical scale contributing negatively (B = - 0.12, $p < .05$) and the NASA-TLX Temporal scale contributing negatively (B = - 0.06, $p < .05$). This model explained 38% of the variance in the exiting with an active RRFB and a pedestrian scores ($R^2 = .38$). The regression analysis showed that the relationship between the NASA-TLX Effort scale and the exiting with an active RRFB and a pedestrian was not statistically significant (B = -.14, $p = .34$). Participants who found the exiting with an active RRFB trial type less physically challenging and felt less rushed answered correctly more often.

The correlation between entering with an inactive RRFB with both a vehicle and a pedestrian and the NASA-TLX Physical scale was significant. The regression model significantly predicted scores on entering with an inactive RRFB with both a vehicle and a

pedestrian, F (1, 37) = 5.43, $p < .05$, with the NASA-TLX Physical scale contributing negatively (B = - 0.21, $p < .05$). This model explained 13% of the variance in entering with an inactive RRFB with both a vehicle and a pedestrian scores ($R^2 = .13$). Participants who found the entering with an inactive RRFB less physically challenging answered correctly more often.

The correlation between exiting with an inactive RRFB with a pedestrian, the NASA-TLX Physical scale, the NASA-TLX Temporal scale, and the NASA-TLX Effort scale was significant. The regression model significantly predicted scores on exiting with an inactive RRFB with a pedestrian, F (1, 37) = 15.13, $p < .001$, with the NASA-TLX Temporal scale contributing negatively (B = - 0.12, $p < .001$). This model explained 29% of the variance in the exiting with an inactive RRFB with a pedestrian scores ($R^2 = .29$). The regression analysis showed that the relationship between the NASA-TLX Physical scale (B = -.29, $p = .75$) and the NASA-TLX Effort scale (B = -.19, $p = .89$) were not statistically significant. Participants who felt rushed answered correctly less often.

The correlations between exiting with an active RRFB where both a vehicle and a pedestrian are present, the NASA-TLX Physical scale, the NASA-TLX Temporal scale, and the NASA-TLX Effort scale were significant. The regression model significantly predicted scores on exiting with an active RRFB and both a vehicle and a pedestrian, F (1, 37) = 13.37, $p < .001$, with the NASA-TLX Physical scale contributing negatively (B = - 0.23, $p < .001$). This model explained 27% of the variance in the exiting with an active RRFB and both a vehicle and a pedestrian scores ($R^2 = .27$). The regression analysis showed that the relationship between the exiting with an active RRFB and both a vehicle and a pedestrian and the NASA-TLX Temporal scale (B = -.21, $p = .19$) and the NASA-TLX Effort scale (B = -.15, $p = .81$) were not statistically

significant. Participants who found the exiting with an active RRFB and both a vehicle and a pedestrian trial type less physically demanding answered correctly more often.

The correlation between exiting with an inactive RRFB with both a vehicle and a pedestrian, the NASA-TLX Physical scale, and the NASA-TLX Temporal scale was significant. The regression model significantly predict scores on exiting with an inactive RRFB with both a vehicle and a pedestrian, F (1, 37) = 6.61, $p < .05$, with the NASA-TLX Temporal scale contributing negatively (B = - 0.10, $p < .05$). This model explained 15% of the variance in the exiting with an inactive RRFB with both a vehicle and a pedestrian scores ($R^2 = .15$). The regression analysis showed that the relationship between exiting with an inactive RRFB with both a vehicle and a pedestrian and the NASA-TLX Physical scale was not statistically significant (B = -.25, $p = .75$). Participants who felt less rushed on the exiting with an inactive RRFB trial type answered correctly more often.

Decision Time. Like the preceding experiments, the time-based data was not normally distributed. Therefore, all time data was trimmed and transformed consistent with the process described in Experiment 1. Additionally, only the DT data in cases where the correct answer was given were considered in the DT calculations. The video lengths were not the same across trial types, so a relative DT was calculated by multiplying the video length with the raw DT (Relative DT = Video Length x Raw DT). The Relative DT data can be found in Table 24. DT data is expressed in milliseconds (MS).

Table 24

Relative Decision Time Means and Standard Error by Trial Type in Experiment 3

Trial Type	Trained		Untrained	
	Mean	SE	Mean	SE
CRSD-ANT Mean RT	2.69	.01	2.70	.01

Table 24

Relative Decision Time Means and Standard Error by Trial Type in Experiment 3 (continued)

Relative DT Enter active RRFB, PED present	4.67	.19	4.24	.27
Relative DT Exit active RRFB, PED present	11.50	.40	12.04	.53
Relative DT Enter inactive RRFB, Vehicle and PED present	4.31	.30	4.51	.45
Relative DT Exit inactive RRFB, PED present	12.18	.45	12.56	.58
Relative DT Enter inactive RRFB, Vehicle present	4.15	.44	4.98	.35
Relative DT Enter inactive RRFB, PED present	6.75	.29	6.75	.28
Relative DT Enter active RRFB, Vehicle and PED present	4.99	.31	4.49	.38
Relative DT Exit active RRFB, Vehicle and PED present	13.05	.37	12.11	.65
Relative DT Exit inactive RRFB, Vehicle and PED present	12.67	.21	11.82	.57

Table 24

Relative Decision Time Means and Standard Error by Trial Type in Experiment 3 (continued)

Relative DT Total Across Conditions	70.14	2.60	70.01	3.21

Note. The lower the mean the faster the response time. DT for correct answers only.

To test Hypothesis 3B, a 2-way ANOVA was conducted to compare the relative DT of the trained group and the untrained group using the total relative DT across all conditions. When comparing the trained group (M = 70.14, SE = 2.60) and the untrained group (M = 70.01, SE = 3.21) there was no significant difference in the results, F (1, 25) = .02, MSE= .01, p = .90, η = .00, thus Hypothesis 3B was not supported.

DT Analysis by Trial Type. To analyze the DT in the individual trial types the same 2-way ANOVA revealed that the interaction between training and trial type was not significant, F (8, 19) = .97, MSE= 1.82, p = .46, η = .04. While the main effect for training was not significant, F (1, 25) = .02, MSE = .01, p = .90, η = .00, there was a significant main effect for trial type, F (8, 19) = 242.23, MSE= 451.73, p < .001, η = .91. The nine trial types for Experiment 3 were listed in Table 19 while the mean and standard error (SE) for decision time by each type were listed in Table 24.

An interesting relative DT result came when comparing all the trial types with active RRFB (M = 32.05, SE = 1.19) to all of the trial types with inactive RRFB (M = 38.03, SE = 1.05). When there was an active RRFB present the participants responded significantly quicker to the situation, t (40) = 26.94, p < .001, CI (29.64, 34.45).

Table 25

Means and Standard Error of RRFB, non RRFB Totals for DT in Experiment 3

Condition	Mean	SE
All trials with active RRFB	32.05	1.19
All trials with inactive RRFB	38.03	1.05

Note. The higher the mean the slower the DT for that condition.

***Correlations and Regressions*.** All the DT of the conditions along with CRSD-ANT mean RT and the predictive instruments were loaded into a correlation matrix with the results listed in Table 26.

Table 26

Correlation Matrix for Descriptives and Decision Time in Experiment 3

Variable	Alerting Effect	Orienting Effect	Conflict Effect	STAIS-5 Before	STAIS-5 After	Knowledge Test	ANT Mean RT	DT Enter W FBW PED	DT Exit W FBW PED	DT Enter W/O FBW VEH & PED	DT Exit W/O FBW PED	DT Enter W/O FBW VEH	DT Enter W/O FBW PED	DT Enter FBW VEH & PED	DT Exit W FBW VEH & PED	DT Exit W/O FBW VEH & PED
Alerting Effect	1															
Orienting Effect	.29	1														
Conflict Effect	-.21	-.41**	1													
STAIS-5 Before	-.06	-.02	-.02	1												
STAIS-5 After	-.09	.03	-.13	.53**	1											
Knowledge Test	.00	-.14	-.10	.05	.32*	1										
ANT Mean RT	-.21	.29	.22	-.26	-.38*	-.30	1									

Table 26

Correlation Matrix for Descriptives and Decision Time in Experiment 3 (continued)

DT Enter W FB W PED	.15	.03	.10	.25	.12	.23	-.34*	1							
DT Exit W FB W PED	.38*	.03	.05	.01	-.14	-.12	-.21	.34*	1						
DT Enter W/O FB W VEH & PED	.09	.15	-.20	.36*	.16	.20	-.33	.40*	.26	1					
DT Exit W/O FB W PED	.13	-.10	.35*	-.08	-.22	.07	.00	.28	.67**	.15	1				
DT Enter W/O FB W VEH	-.11	.01	.10	-.09	.07	.10	-.14	-.03	-.23	.14	-.01	1			
DT Enter W/O FB W PED	.31	-.03	.09	-.08	-.26	.16	-.22	.38*	.44**	-.13	.65**	-.14	1		
DT Enter W FB W VEH & PED	.15	.20	-.05	.05	.23	.25	-.38*	.50**	.50**	.20	.23	.03	.28	1	
DT Exit W FB W VEH & PED	.27	-.10	.27	-.07	-.03	.20	-.18	.65**	.66**	.30	.56**	-.01	.37*	.52**	1
DT Exit W/O FB W VEH & PED	.18	-.18	-.10	-.06	.19	.02	-.41**	.24	.39*	-.07	.26	-.04	.33*	.25	.27	1

** Correlation is significant at the .01 level
* Correlation is significant at the .05 level

DT Correlations. There were many correlations among the predictor instruments. As identified in the previous studies, the STAIS-5 Before and the STAIS-5 After were positively correlated [r (41) = 0.53, $p < .001$] as were the Conflict Effect and the Orienting Effect [r (41) = 0.41, $p < .001$]. The Knowledge Test was positively correlated with the STAIS-5 After, r (41) =

0.32, $p < .05$, and the Mean RT was negatively correlated with STAIS-5 After, r (41) = - 0.38, $p < .05$.

There were also several correlations among the DT of the difference trial types. The DT for exiting with an active RRFB and a pedestrian was positively correlated with the DT for entering with an active RRFB and a pedestrian, r (36) = 0.34, $p < .05$. The DT for entering with an inactive RRFB with both a vehicle and a pedestrian was positively correlated with the DT for entering with an active RRFB and a pedestrian, r (33) = 0.40, $p < .05$. The DT for exiting with an inactive RRFB with a pedestrian was positively correlated with the DT for exiting with an active RRFB and a pedestrian, r (39) = 0.67, $p < .001$. The DT for entering with an inactive RRFB with a pedestrian was positively correlated with the DT for entering with an active RRFB and a pedestrian [r (37) = 0.38, $p < .05$], the DT for exiting with an active RRFB and a pedestrian [r (38) = 0.44, $p < .01$], and the DT for exiting with an inactive RRFB with a pedestrian [r (38) = 0.65, $p < .001$].

The DT for entering with an active RRFB and both a vehicle and a pedestrian was positively correlated with the DT for entering with an active RRFB and a pedestrian [r (38) = 0.50, $p < .01$], and the DT for exiting with an active RRFB and a pedestrian [r (39) = 0.50, $p < .01$]. The DT for exiting with an active RRFB and both a vehicle and a pedestrian was positively correlated with the DT for entering with an active RRFB and a pedestrian [r (36) = 0.65, $p < .001$], the DT for exiting with an active RRFB and a pedestrian [r (39) = 0.66, $p < .001$], the DT for exiting with an inactive RRFB with a pedestrian [r (39) = 0.56, $p < .001$], the DT for entering with an inactive RRFB with a pedestrian [r (38) = 0.78, $p < .05$], and the DT for entering with an active RRFB and both a vehicle and a pedestrian [r (39) = 0.52, $p < .001$].

Finally, the DT for exiting with an inactive RRFB with both a vehicle and a pedestrian was positively correlated with the DT for exiting with an active RRFB and with a pedestrian [r (39) = 0.39, $p < .05$] and the DT for entering with an inactive RRFB with a pedestrian [r (40) = 0.33, $p < .05$].

DT Regressions. Regressions were performed to explore all significant correlations between predictor and outcome variables. The correlation between the DT for entering with an active RRFB and a pedestrian and ANT Mean RT was significant. The regression model significantly predicted scores on the DT for entering with an active RRFB and a pedestrian, F (1, 36) = 4.59, $p < .05$, with the Mean RT contributing negatively (B = - 20.44, $p < .05$). This model explained 11% of the variance in the DT for entering with an active RRFB and a pedestrian scores ($R^2 = .11$). Participants with quicker RT on the CRSD-ANT had slower DT on the entering with an active RRFB and a pedestrian trial type.

The correlation between the DT for exiting with an active RRFB and a pedestrian and the Alerting Effect was significant. The regression model significantly predicted scores on the DT for exiting with an active RRFB and a pedestrian, F (1, 37) = 6.04, $p < .05$, with the Alerting Effect contributing positively (B = 0.02, $p < .05$). This model explained 14% of the variance in the DT for exiting with an active RRFB and a pedestrian scores ($R^2 = .14$). Participants who had fast RT in the Alerting Effect had faster DT on the exiting with and active RRFB trial type.

The correlation between the DT for entering with an inactive RRFB with both a vehicle and a pedestrian and the STAIS-5 Before was significant. The regression model significantly predicted scores on the DT for entering with an inactive RRFB with both a vehicle and a pedestrian, F (1, 31) = 4.61, $p < .05$, with the STAIS-5 Before contributing positively (B = 0.84, $p < .05$). This model explained 13% of the variance in the DT for entering with an inactive

RRFB with both a vehicle and a pedestrian scores (R^2 = .13). Participants who reported higher anxiety before the experiment started had slower DT on the entering with an inactive RRFB with both a vehicle and pedestrian.

The correlation between the DT for exiting with an inactive RRFB with a pedestrian and the Conflict Effect was significant. The regression model significantly predicted scores on the DT for exiting with an inactive RRFB with a pedestrian, F (1, 37) = 5.26, p < .05, with the Conflict Effect contributing positively (B = 0.03, p < .05). This model explained 12% of the variance in the DT for exiting with an inactive RRFB with a pedestrian scores (R^2 = .12). Participants who responded faster on the Conflict Effect also responded faster on the exiting with an inactive RRFB with a pedestrian trial type.

The correlation between the DT for entering with an active RRFB and both a vehicle and a pedestrian and the Mean RT was significant. The regression model significantly predicted scores on the DT for entering with an active RRFB and both a vehicle and a pedestrian, F (1, 39) = 6.65, p < .05, with the Mean RT contributing negatively (B = - 33.92, p < .05). This model explained 15% of the variance in the DT for entering with a RRFB and both a vehicle and a pedestrian scores (R^2 = .15). Participants whose RT was fast in the CRSD-ANT, as defined using the Mean RT, were slower on the entering with an active RRFB and both a vehicle and a pedestrian trial type.

The correlation between the DT for exiting with an inactive RRFB with both a vehicle and a pedestrian and the Mean RT was significant. The regression model significantly predicted scores on the DT for exiting with an inactive RRFB with both a vehicle and a pedestrian, F (1, 39) = 7.83, p < .01, with the Mean RT contributing negatively (B = - 21.16, p < .01). This model explained 17% of the variance in the DT for exiting without a RRFB with both a vehicle and a

pedestrian scores (R^2 = .17). Again, participants whose RT was fast in the CRSD-ANT, as defined using the Mean RT, were slower on the exiting without a RRFB with both a vehicle and a pedestrian trial type.

Discussion

Similar to the results for Experiment 1, additional training produced no significant difference in the accuracy of the response. Therefore, Hypnosis 3A was not supported. It is likely that the lack of robust training manipulation failed to differentiate the trained group from the untrained group. Both groups watched the roundabout safety video but only the trained group was shown the diagram of the pedestrian/vehicle intersection points. Although effects did not vary by training condition, comparing the STAIS-5 Before with the STAIS-5 After the driving task revealed that the anxiety of the participants went down significantly following the roundabout navigation task. It is suspected that this change was a function of either performance or test anxiety that was elevated prior to the experimental driving task.

Differences By Trial Types.

The comparison of trial types with a RRFB to those without a RRFB found that more correct answers were given when there was not a RRFB present. However, an interesting DT result was observed when comparing the DT for all the trial types with RRFB to the DT for all of the trial types that did not have a RRFB. When there was a RRFB present, the participants responded significantly quicker to the situation suggesting that even though the RRFB did not increase awareness of the pedestrian, the presence of an active RRFB shortened the decision time of the driver making the pedestrian safer.

Correlations and Regressions

Three of the scales on the NASA-TLX predicted the outcomes on trial types. The Performance scale negatively predicted scores on the entering with RRFB and a pedestrian. The Performance scale is inverted meaning the lower the score on the Performance scale the greater the sense of success by the participant. Therefore, the greater sense of success a participant feels the more correct answers on the entering with RRFB and a pedestrian trial type. Again showing the perceived proficiency participants felt with the RRFB.

The NASA-TLX Physical scale negatively correlated with the exiting with a RRFB and a pedestrian trial type, the entering without a RRFB with both a vehicle and a pedestrian trial type, and the exiting with a RRFB and both a vehicle and a pedestrian trial type. It is possible that the presence of two or more visual targets gave the participants a greater sense of effort that was translated onto the Physical scale.

The NASA-TLX Temporal scale was negatively correlated with the exiting with a RRFB and with a pedestrian trial type, the exiting without a RRFB with a pedestrian trial type, the exiting without a RRFB with both a vehicle and a pedestrian trial type. The common denominator with these three trial types is exiting a roundabout. These relationships suggest that the less rushed a participant felt, the more correct answers would occur on these trial types.

Decision Time (DT) Data.

Training did not decrease decision time when participants encountered pedestrian and vehicle interaction points in roundabouts. When comparing the trained group and the untrained group there was no significant difference in the results, thus Hypothesis 3B was not supported.

DT Regressions. There were some instruments that predicted outcomes on some of the nine trial types. The CRSD-ANT produced a Mean RT calculation in addition to the three construct values. The Mean RT score was negatively correlated with the DT for entering with a RRFB and a pedestrian, the DT for entering with a RRFB and both a vehicle and a pedestrian, and the DT for exiting without a RRFB with both a vehicle and a pedestrian. This relationship suggests that the faster the Mean RT time would predict slower response times in these particular trial types.

The Alerting Effect positively predicted the outcome of the DT for exiting with a RRFB and a pedestrian. As before, the Alerting Effect indicates the ability to acquire and maintain attention on a visual target. The exiting task requires a driver to monitor only one area, that being the RRFB to the right side of the road.

The Conflict Effect was positively correlated with the DT for exiting without a RRFB with a pedestrian trial type. The need to resolve the visual conflict of two different draws on the attention of the driver, that being traffic in the roundabout and pedestrians trying to cross, is exactly the conditions that the Conflict Affect is based on. The better able a participant is to visually manage two or more points of attention the greater the Conflict score will be and the faster the DT will be.

Finally, the STAIS-5 was found to positively predict times on the DT for entering without a RRFB with both a vehicle and a pedestrian. This relationship suggests that highly anxious individuals are faster when entering without a RRFB when there is both a vehicle and a pedestrian present; Further research should explore whether negative outcomes such as crashes might be more likely to occur when anxious drivers are faster at entering roundabouts where vehicles and pedestrians are present when a flashing beacon is not present to warn them.

GENERAL DISCUSSION

One goal of this series of studies was to make pedestrians safer while crossing the street at roundabouts. The first experiment studied the effects of driver knowledge. The hypotheses were that increased training would increase the number of correct responses in the trial conditions and the DT to make those decisions would decrease. The additional training of the trained group produced no significant difference in the accuracy of the response. Therefore, Hypnosis 1A was not supported. Moreover, there was no difference in the DT of the trained group and the untrained group. Therefore, Hypnosis 1B was also not supported.

The second experiment explored the effectiveness of two types of pedestrian warning apparatus: the HAWK and RRFB. There were three hypotheses in the second experiment. The first hypothesis was that the RRFB would increase driver awareness of the presence of a pedestrian at least as well as the HAWK. The second hypothesis was that the DT for the RRFB would be quicker than the HAWK. Finally, the third hypothesis was that the RRFB would not significantly raise the driver's cognitive load.

Participants responded to the RRFB correctly more often than the HAWK. Therefore, Hypothesis 2A was supported. The flashing red signal in the HAWK proved to be the hardest presentation of the HAWK for participants to get correct. It is possible that the unfamiliarity with a flashing red light in the HAWK apparatus is the reason this was the hardest condition for participants. In the U.S., a flashing red light is not common at all (unless used to signify a four-way stop) and could cause the participant to not know what to do when confronted with one. The correct action for a flashing red light at a HAWK is to proceed if the crosswalk is clear, much like a yield sign. Again, the unfamiliarity of drivers with the HAWK and the drastically different

message the flashing red light signals compared to most red lights in our environment would cause drivers to incorrectly interpret the signal.

A quicker decision time by the driver could suggest increased awareness of the driver to the presence of a pedestrian. When comparing the DT of the HAWK and the RRFB, the RRFB DT was significantly faster than the HAWK, thus Hypothesis 2B was supported. The slowest response time for the RRFB was when the apparatus was flashing. It is speculated that the flashing beacon caused the driver to continue to search for a pedestrian before responding to the situation.

The NASA-TLX was used to evaluate the amount of cognitive load placed on the driver. It was found that the HAWK presented a higher cognitive load as defined by the RRFB receiving better scores on the Mental, Temporal, Performance, and Effort scales. Participants thought the RRFB was less mentally taxing and required less mental effort to engage. Moreover, the participants felt less rushed and believed they performed better with the RRFB. There was also a lower level of frustration with the RRFB, but this difference was not significant. Therefore, Hypothesis 2C was supported.

The third experiment studied the effectiveness of driver knowledge and the effectiveness of adding a warning apparatus to the entrances and exits of roundabouts. The two hypotheses for the third experiment were that training in the presence of the RRFB would increase the number of correct answers in the trial conditions and the DT would be decreased with the RRFB present. As found in the first experiment, additional training produced no significant difference in the accuracy of the response. Therefore, Hypothesis 3A was not supported. When comparing the decision times of the trained group and the untrained group there was no significant difference in the results, thus Hypothesis 3B was not supported. However, an interesting DT result came when

comparing all the trial types with a RRFB to all of the trial types that did not have a RRFB. When there was an RRFB present, the participants responded significantly quicker to the situation. This suggests that even though the RRFB did not increase the number of correct responses when pedestrians and vehicles were present, the presence of an active RRFB shortened the decision time of the driver.

The lack of training effect in the first and third experiments might be the result of a lack of robust training that differentiated the trained group. Both the trained and the untrained groups watched the roundabout video but only the trained group was shown the diagram of the pedestrian/vehicle intersection points. This lack of training effect was also present when comparing participants whose initial driver training included roundabouts with participants whose driver training did not include roundabouts. The incorporation of attentional training in driver training programs may provide future drivers the practice needed to improve their attentional skills to react to roundabout situations. So much of the current driver training relies on cognitive understanding of situational driving that unless a driving situation is practiced until it is held in long-term memory the knowledge and skills necessary will degrade over time. The attentional skills necessary for successful driving are less susceptible to transience than solely relying on memory. The use of simulators and eye tracking as an integral part of driver training would be a good addition to a driver training program. Future studies should test the lasting training effects of attentional training via retention rather than assessing immediate memory following driving situations. Additionally, the development of a training protocol for attentional training that could be deployed to the states would be a meaningful way forward for research in this area culminating with epidemiological studies showing the effectiveness of new training methods in reducing accidents and injuries.

One of the most meaningful parts of this study includes the implications it has for driver training. The operator focus of driver training seems to be lacking a cognitive level of training that, if applied, might improve the quality of driver training, the retention of that training, and ultimately lead to better drivers. The use of apparatus like the RRFB during training scenarios could provide a cueing effect as found in Fuentes and Campoy (2008) that would facilitate training the Alerting Effect. Moreover, the training of attentional networks was shown by Kim and Jang-(2022) using driving tasks in virtual reality. The ability of the three constructs from the CRSD-ANT, the Alerting Effect, the Orienting Effect, and the Conflict Effect, to predict successful completion of driving task makes the addition of attentional network training into driving training an important option.

The Alerting Effect indicated the ability to focus attention on a target and that construct predicted outcomes across the three experiments. Using the Alerting Effect as a driver training construct may increase the driver's speed for acquiring salient targets in the environment. This is particularly salient when entering a roundabout where there is a pedestrian present. As seen in the third experiment, the Alerting Effect predicted outcomes in this driving situation. The Orienting Effect is similar to the Alerting Effect but also includes the ability to focus attention on a specific target and maintain attention on that target. Finally, the Conflict Effect indicates the ability to visually manage two or more points of attention. This effect proved important in exiting roundabout situations. The ability to manage the attentional task of navigating a vehicle through a turn while exiting a roundabout and check for pedestrians is a visual conflict that the Conflict Effect can predict.

Each of these attentional networks are used by drivers when driving through roundabouts and this study suggests improving these attentional abilities in drivers should make both drivers and pedestrians safer at roundabouts.

Limitations

As with all experiments, there were several limitations with this research. First, the sample sizes were relatively small though the power analyses suggested they were appropriate. Larger sample sizes could produce significance that was not apparent with the smaller sample sizes in this study. All the participants were college age and were not far removed from their driver training. A population more diverse in age might have produced different results in the training measures as some older drivers have not experienced driving training in many years. Roundabouts would make an excellent addition to the Drive Aware task (Yuan et al., 2021).

The lack of eye tracking was also a limitation. Eye tracking could provide additional data about the warning apparatus' effectiveness in capturing the attention of the driver. Another limitation was the static nature of the scenarios presented to the participants. Using a more realistic driver interface to present the driving scenarios does increase the realism of the scenarios and does provide better data. The small sample sizes, age of the participants, lack of eye tracking, and driving simulators were all limitations to this research that could be ameliorated in future work.

The training provided to the trained group was not robust enough to establish a training effect. The measure of the training effect was not significant in either of the experiments that measured training. This suggests more robust training for the trained group was necessary.

Future Directions

The safety of pedestrians when they interact with vehicles is very important. Future research on improving the retention of driver knowledge, driver attentional skills, and driver awareness is an important part of increasing the safety of pedestrians. The further study of traffic flow at signaled roundabouts and incorporating pedestrian signals as well seems logical to study the maximized traffic flow while ensuring maximum pedestrian safety. It is also possible that a new pedestrian warning apparatus specifically designed for roundabouts might be the answer to making both the pedestrian and the driver safer in those meeting points. The streets of our urban areas are becoming more crowded with the addition of electrified scooters to the pedestrian and bicycle traffic. These scooters can achieve speeds up to 25 miles per hour making them capable of achieving the speed limit on most urban roads. Education of pedestrians, nonmotorized, and motorized vehicles as to the proper way to interact with traffic and transverse roundabouts is also important to their safety. This education should include the use of the warning apparatus provided. Recreating this research by addressing these methodological limitations could provide knowledge that will also increase the safety of pedestrians.

CONCLUSION

Roundabouts are an increasingly popular intersection in the modern road network. Though the benefits of roundabouts for vehicles traffic are apparent, the pedestrian interaction with vehicles is not as apparent. This research explored how driver training and the use of pedestrian warning apparatus at roundabouts to increase pedestrian safety.

Results indicated that a driver's training and a driver's knowledge had no influence on the driving performance in roundabouts. Moreover, pedestrian warning apparatus (including flashing beacons) did not improve driver awareness of the presence of pedestrians, but the

apparatus allowed drivers to respond quicker when the apparatus was active. An active warning apparatus also reduced the frustration (when the apparatus was not the HAWK) of the driver, making both the pedestrian and the driver safer in the crosswalk encounters at roundabouts.

It is also possible that a new pedestrian warning apparatus specifically designed for roundabouts might be the answer to making the pedestrian, nonmotorized conveyances, motorized conveyances, and the automobile driver safer in those meeting points in a roundabout. In conjunction with more effective training manipulations as described above, public safety could be enhanced through careful manipulation and iterative assessment.

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