Gulf Coast Research Center for Evacuation and Transportation Resiliency

LSU / UNO University Transportation Center

Minimizing Driver Errors: Examining Factors Leading to Failed Target Tracking and Detection

Final Report

Melissa R. Beck & Justin M. Ericson

Performing Organization
Gulf Coast Research Center for Evacuation and Transportation Resiliency
Louisiana State University Psychology Department

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GULF COAST RESEARCH CENTER FOR EVACUATION AND TRANSPORTATION RESILIENCY

The Gulf Coast Research Center for Evacuation and Transportation Resiliency is a collaborative effort between the Louisiana State University Department of Civil and Environmental Engineering and the University of New Orleans' Department of Planning and Urban Studies. The theme of the LSU-UNO Center is focused on Evacuation and Transportation Resiliency in an effort to address the multitude of issues that impact transportation processes under emergency conditions such as evacuation and other types of major events. This area of research also addresses the need to develop and maintain the ability of transportation systems to economically, efficiently, and safely respond to the changing demands that may be placed upon them.

Research

The Center focuses on addressing the multitude of issues that impact transportation processes under emergency conditions such as evacuation and other types of major events as well as the need to develop and maintain the ability of transportation systems to economically, efficiently, and safely respond to the changing conditions and demands that may be placed upon them. Work in this area include the development of modeling and analysis techniques; innovative design and control strategies; and travel demand estimation and planning methods that can be used to predict and improve travel under periods of immediate and overwhelming demand. In addition to detailed analysis of emergency transportation processes, The Center provides support for the broader study of transportation resiliency. This includes work on the key components of redundant transportation systems, analysis of congestion in relation to resiliency, impact of climate change and peak oil, provision of transportation options, and transportation finance. The scope of the work stretches over several different modes including auto, transit, maritime, and non-motorized.

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16. Abstract:

Driving a motor vehicle is a common practice for many individuals. Although driving becomes repetitive and a very habitual task, errors can occur that lead to accidents. One factor that can be a cause for such errors is a lapse in attention or a failure to notice critical information. When driving, individuals must not only attend to the other moving vehicles, but they must also remain aware of and detect critical information that is in the surrounding environment. As the environment becomes more complex however, the ease of detecting these critical targets becomes hindered. Because of these failures in attention, this research focuses not only on the visual complexity of the environment but also on the dynamic relation of the moving vehicles on attention. By incorporating a dual task paradigm of vehicle tracking and target detection in a visually complex environment, a direct examination for the influence of outside vehicle factors on a driver's ability to detect critical targets was measured. Furthermore, driver reactions such as brake onset, steering deviations, and changes in velocity were examined. This research found that overall improvements in driver reactions are observed when the environment has low clutter and there were fewer vehicles to be tracked.

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Executive Summary

Introduction

Driving a motor vehicle is a preferred method of transportation for many individuals. However, drivers can make errors resulting in a traffic violation and/or an accident. A variety of factors can contribute to driver errors; attention is one of these factors. For example, a lapse in attending to important information in the driving environment presents a likely scenario in which an accident is likely to occur.

This study examines how failures in attention can affect driver performance in detecting important target information (e.g. pedestrians). Specifically we are interested in how tracking ambient traffic and the amount of visual clutter in the surrounding environment can influence the ability for drivers to successfully detect targets. This research investigates not only under what circumstances is target detection successful, but what sacrifices (e.g. time to brake, steering deviations, etc.) are afforded to other aspects of the driving task in order to warrant successful target detection.

Review of the Literature

This study's literature review serviced two main goals 1) to demonstrate situations that are likely to outstrip attentional resources while driving and 2) how these situations may influence driver performance.

Attention is a key factor in a driver's ability to safely and successfully navigate through the environment. A driver uses attention to locate items in the environment and to track/follow other moving vehicles. Accomplishing these two tasks simultaneously is an important facet for safe driving. If attention is not directed to these tasks or if attention is spread between too many different items errors can occur.

Attention is Limited

This review examined factors that, in laboratory settings, have lead to lapses in attention and therefore, failed target detection. Specifically, research has shown that when attention is directed to tracking moving objects, failing to detect another object can occur frequently (about 50% of the time). This situation is analogous to the driving situation of tracking the locations of cars in front of you while also needing to detect pedestrians in the roadway. The engagement of attention by the tracking task could lead to a failure to detect the pedestrian and would be a case of what is referred to in the visual attention literature as inattentional blindness.

Attention is a limited cognitive resource, thus, when an environment is littered with an extensive amount of visual clutter, attention becomes spread thin, resulting in individuals missing vital information. Inattentional blindness is a phenomenon where an individual can be looking directly towards the location of an item, but fail to recognize important information.

Failures in attention associated with inattentional blindness can be broken down into two components of the task, counting the changes in the moving objects and noticing the unexpected event. We therefore chose to focus on these two tasks 1) target detection and 2) multiple-object tracking to further investigate the nature of these errors and their effects on driving performance.

Target detection is the ability to detect an item in the visual environment that is relevant to the current task. The ability to detect a target can vary based on the amount of attentional resources available to devote to detecting the target, the amount of other visual information that is within the area, and whether or not the target is expected to be present or not.

Multiple-object tracking (MOT) is the ability to follow and correctly identify multiple moving items in the environment amidst several other moving distractors. MOT while driving is referred to as Multiple-vehicle tracking (MVT). In a MVT task individuals must track a subset of cars in the road. Research examining MVT performance has shown that as the number of items to track increases, MVT accuracy decreases and other driver factors change (e.g. braking, headway, lane deviations).

Factors potentially affecting target detection and MVT

A focus was placed on research that was used primarily in driving situations or was directly relatable to the driving task. With the two tasks, target detection and multiple-object tracking, and discuss relevant applications and factors associated with the driving task. We promote three factors that are to be investigated in the study 1) clutter, 2) cues, and 3) a dual task combination of these factors.

Previous research has shown that environmental factors (e.g. scenery, billboards) influence driver performance. This suggests that attention may be pulled away from the two critical facets of driving we discussed, vehicle tracking and target detection. From this evidence it can be assumed that in more cluttered environments target detection would be worse compared to uncluttered environments.

In addition to the amount of clutter that can exist in the surrounding environment, we investigated how the use of cues can aide in target detection. Specifically when cues are present it becomes substantially easier to identify targets amidst distractors. For use in driving scenarios it can then be inferred that the presence of a cue (e.g. a crosswalk sign) would aid in the detection of targets (e.g. a pedestrian).

While driving, an individual must monitor the other moving vehicles that are traveling on the roadway. In this respect, monitoring the other surrounding vehicles requires a significant amount of the driver’s attention. Based on previous research on dual task performance, we suggest that tracking vehicles while driving may cause failures in target detection.

Study Design and Results

The study is conducted in a Realtime Technologies Inc. driving simulator utilizing the SimVista driving simulator software. We manipulated three independent variables (i.e., number of vehicles to track, clutter, and pedestrian expectation), while measuring various factors of driving performance (e.g., tracking accuracy, breaking RT, changes in velocity, steering deviation, verbal report of pedestrian detection) to determine the effect of these variables on driving performance.

Participants completed a tracking task and a detection task while driving. For the tracking task, participants counted the number of vehicle lane changes in front of them. For the detection task, a pedestrian walked into the driver's path on the route once the driver passed an invisible marker. Pedestrian detection was measured by verbal report at the end of the experiment and by various driving performance measures.

Participants were directed to track 1 (out of 2) or 2 (out of 4), cars in front of them. The tracking task was conducted by having participants follow the target vehicles along the designated driving course. We assessed participants' ability to accurately count the total number of lane changes that occurred for the target vehicles during the route. Participants reported the count at the end of the driving route.

To manipulate clutter, the driving route varied regarding the amount of objects that were placed throughout the environment. Ambient environment features, global (i.e. distant, horizon) features remained constant for all trial runs. However, local (i.e. close, roadside) features varied across conditions, with low clutter trials having few local features, and high clutter trials having many more local features in the environment.

Pedestrian expectations were manipulated by placing a crosswalk sign at the location where the pedestrian would appear. A pedestrian was present at the crosswalk sign location, and the pedestrian may or may not unexpectedly enter the roadway regardless of the presence of the sign.

Along with measures of performance accuracy in the tracking task and the pedestrian detection task, we also examined measures of driver performance such as braking onset, speed changes, and steering deviations. Broadly speaking, the results of this study help to determine the driving circumstances under which attention is taxed leading to driving errors. Specific hypothesis are as follows: In regards to MVT performance, tracking performance will be impaired when there are more vehicles to track and there is more high visual clutter. In regards to the ability to notice and react to the pedestrian, a higher tracking load, higher visual clutter, and the lack of pedestrian expectation will impair pedestrian detection either through rates of noticing or driving reactions to the pedestrian (i.e., break RT, change in velocity, or steering deviations).

The data indicate that tracking accuracy is better when fewer vehicles are to be tracked. However, tracking accuracy is better in the high clutter conditions, but only when tracking 2 out of 4 vehicles. Furthermore, contrary to many studies demonstrating inattentional blindness, in the current study, none of the participants failed to detect (or report) the presence of the critical pedestrian running into the road. However, various conditions did lead to slowed reactions and reduced evasive maneuvers. First, when tracking few vehicles participants were significantly faster at reacting to the pedestrian, although they had less of a steering deviation. Second, the amount of visual clutter in the environment was the factor that caused the greatest discrepancy in overall change in vehicle velocity. Finally, pedestrian expectations actually *increased* the proportion of participants who failed to react with either a breaking response or a steering deviation.

Conclusion

These results give new insight into how drivers allocate attention between various stimuli (e.g., other cars, signs, and pedestrians), and under what circumstances attention is too taxed to be able to complete the driving task effectively. Furthermore, this research demonstrates that limiting the attentional load on drivers can improve driver reactions to critical targets. Although drivers routinely noticed salient targets, visual environments should be limited when trying to improve reactions to these targets.

Abstract

Driving a motor vehicle is a common practice for many individuals. Although, for most, driving is a repetitive task and can become mostly habitual, errors can occur that lead to accidents. One factor that can be a cause for such errors is a lapse in attention or a failure to notice critical information. When driving, individuals must not only attend to the other moving vehicles, but they must also remain aware of and detect critical information that is in the surrounding environment (e.g., pedestrians). As the environment and the driving task become more complex however, the ease of detecting these critical targets may be hindered. This research focuses the effects of the visual complexity of the driving environment, the attentional load of the driving task, and pedestrian expectation on driving performance. Specifically, a dual task paradigm of vehicle tracking and target detection was used to examine the influence of outside vehicle factors on a driver's ability to detect critical targets. Furthermore, driver reactions such as brake onset, steering deviations, and changes in velocity were examined. This research found that overall improvements in driver reactions are observed when the environment has low clutter and fewer vehicles to be tracked.

1.0 Introduction

Driving a motor vehicle is an everyday task for many individuals. Risks associated with driving include vehicle-to-vehicle accidents and vehicle-to-pedestrian accidents that are often the result of violating a traffic law (i.e., speeding, missing a sign, illegal turns, etc.). A critical factor in many of these scenarios is the driver not noticing or not attending to the posted traffic notifications in their surroundings. Sometimes individuals may explicitly choose to not follow the posted information, in other situations, the cited driver may have been paying attention to something other than the posted signs; such as talking on a cell phone, talking to fellow passengers, listening to the radio, or tracking the locations of the vehicles around them. This failure of attending to relevant and important information is a key reason for the traffic violation and accidents.

2.0 Review of the Literature

Attention is an essential factor in the ability to drive a motor vehicle, with failed attention being a likely cause for most errors (Young & Regan, 2007). Two of the key attentionally demanding tasks while driving are tracking moving objects (Pylyshyn & Storm, 1988) and the ability to detect items in the environment (Simons, 2000; Treisman, 1980). These two tasks are important for effectively navigating our environment and errors occur when drivers miss vital information because attention is directed away or overloaded by these tasks, (Hyman, Boss, Wise, McKenzie, & Caggiano, 2009; Simons & Chabris, 1999). Due to the repetitive nature of performing a driving task, individuals become adapted or habituated to the task (Duncan et al., 1991; Shinar et al., 1998; Wickens, 2002), making them more susceptible to errors caused by inattention.

2.1 Attention is Limited

Attention is a limited cognitive resource, therefore individuals can miss critical information even when the information occurs directly where they are looking, a phenomenon known as inattentional blindness (Hyman et al., 2009; Simons & Chabris, 1999). Because attention is a limited resource, when there is a cluttered environment, some information must be attended while other information is ignored. Typically, there is a goal associated with the current task, which provides the parameters for what information will be attended and what information will be ignored. In a now classic study, Simons and Chabris (1999) had observers watch a video of several individuals, each wearing either a white or black t-shirt, moving about each other while passing basketballs. Each team, of either white or black shirts, could only pass the basketball to individuals on the same team. Observers were tasked with monitoring one of the teams and counting the number of passes that team made with the basketball. As expected, performance for counting the number of passes was near perfect. However, without warning to the observer, during the motion sequence an unexpected event would occur; a Gorilla walked into the middle of the ball game turned toward the viewer bounded its chest and then walk out of view. Surprisingly, when participants were counting the passes of the team wearing white shirts, nearly half of the participants failed to notice the unexpected event. In a similar fashion a driver could potentially miss an unexpected event, a pedestrian in the roadway, if they are focusing attention on the task of monitoring the locations of moving vehicles in the driving environment. This finding clearly demonstrates the importance of attention when performing a task; specifically as we monitor the environment there is a high probability that we will miss critical information, even if it is directly in front of us.

As demonstrated by inattentional blindness, when attention is directed onto particular aspects of the environment or tasks, other visual information may be missed. Therefore, when additional components are included inside a motor vehicle (e.g., steering wheel, gauges, pedals, and checking the mirrors) the ability to effectively distribute attention while driving becomes diminished (Wickens, 2002). One area of research that has been investigated extensively is the use of additional electronic devices (e.g., cell phone, radio, GPS navigation systems) while driving (see (Young & Regan, 2007) for a review). The consensus from this research is that usage of such devices consistently hinders driving performance. Many evaluations of performance in driving situations has found that drivers alter various aspects of their driving strategy in order to accommodate these secondary tasks, such as reducing speed/acceleration (Horberry, Anderson, Regan, Triggs, & Brown, 2006), increasing inter-vehicle distance (Alm, 1995; Strayer, Drews, & W. A. Johnston, 2003), or by altering the allocation of attention towards other variables (i.e. checking mirrors and traffic patterns) (Brookhuis, Vries, & Ward, 1991). As noted by Young and Regen (2007) in most driving research a focus has been on attentional distractions that occur inside of the vehicle rather than outside the vehicle. However, attention does not need to be directed inside the vehicle for information outside the vehicle to be missed. As we see with inattentional blindness, information can be missed even when the eyes are directed to the location where the information is occurring. Therefore, a focus on research for tasks and environmental elements that engage attention outside the vehicle while driving is essential for improving driver safety.

Much of the relevant information for driving is occurring outside of the vehicle. Two of the tasks that require distributing attention outside of the vehicle while driving are (1) target detection and (2) vehicle tracking. A driver’s ability to quickly detect important targets (e.g., roadway signs or pedestrians) while ignoring irrelevant distractors (e.g., advertisements) is a key component to safely driving a motor vehicle. Target detection or visual search is the task that individuals are performing when examining the environment for a specific item amidst a variety of distractors (Treisman, 1986). In a traditional visual search experiment participants must examine an image filled with various objects (distractors) while trying to locate a designated target within that image as quickly as possible. The number of distractors and the similarity of features jointly associated with the target item and the distractors determines how quickly an observer can detect the target; with more distractors that share features with the target resulting in slower reaction times (Treisman, 1986). Therefore, it is expected that when the driving environment is cluttered with roadway signs and advertisements, it will be more difficult to detect information important to the driving task (e.g. a pedestrian entering the roadway). However, Perez and Bertola (2010) reported that more glances were made to the left and right sides of the roadway when there was high roadway clutter. Therefore, it is possible that a pedestrian would be detected just as well or more when there is high roadway clutter.

Monitoring and tracking other moving vehicles or pedestrians in the environment is another critical facet of driving a motor vehicle that requires attentional resources. Luckily, individuals have the ability to track several (approximately four) independently moving objects simultaneously (Pylyshyn & Storm, 1988), and can maintain attention on these items over extended periods of time (Wolfe, Place & Horowitz; 2007). Experimental tasks, that examine performance on this ability, have been collectively called multiple object tracking (MOT). The MOT paradigm usually consists of visually following a subset of independently moving items amidst a field of identical (Pylyshyn & Storm, 1988) or unique objects (Makovski & Jiang, 2009). In a typical MOT task the target items are identified via cues, or distinguished in some fashion, from the distractor counterparts at the start of the trial, after which all the items begin moving about the display; following the motion sequence the objects stop and the observer is asked to report which item(s) were the previously indicated targets. Typically, an individual can track approximately four targets accurately (Pylyshyn & Storm, 1988), although this number can fluctuate depending on variable display properties (e.g., object speed) or individual differences (Alvarez & Franconeri, 2007).

Multiple vehicle tracking (MVT) is a paradigm currently in development that uses driving simulation to examine the ability of individuals to follow a number of moving vehicles on a roadway (Lochner, 2011). Similar to a standard MOT task, in MVT participants are seated in a driving simulator and asked to follow a subset of target vehicles amidst a field of nine identical vehicles as they travel down a highway. These nine cars are placed on a 3-lane highway, and are positioned in three rows, with three cars within a row each occupying one lane of the highway. The cars then exchange lane and row position as they travel down the simulated highway. After a period of time, the cars stop moving and participants are asked to identify the target cars that were cued at the start of a trial. Lochner and Trick (2011) had participants sit in a driving simulator and track either zero, one, three or four cars, while they were in control of the simulator cockpit or simply sat in the cockpit and observed the vehicle as the simulator was running. As expected from traditional MOT literature, they found that performance decreased as the number of vehicles to track increased. Additionally, performance accuracy for tracking the vehicles decreased when participants were in control of the driving simulator, suggesting that attentional resources were expended not only on tracking the cars but also on operating the vehicle. Further evidence for the expenditure of attention onto the vehicle being driven was demonstrated by the number of lane deviations as well as the amount of headway given to the surrounding traffic. By simply adding one vehicle to explicitly track while in control of the simulator, participants had a significant increase in lane deviations as well as a significant increase in the amount of headway afforded to the vehicles.

2.2 Factors potentially affecting target detection and MVT while driving

Target detection and MVT are essential attentionally demanding tasks required while driving for which performance will likely decline if needed attentional resources are not available. Attention may be distracted by roadway factors that also engage attentional resources or by simply performing both tasks at the same time. One roadway factor that may influence target detection performance is the amount of clutter in the driving environment. In addition, cues in the driving environment can influence target detection because they change expectations for the target. Finally, as inattentional blindness research has demonstrated, performing both a MVT task (counting the ball passes) and a target detection task (detecting the gorilla) can lead to impaired performance on one or both tasks. These three factors (clutter, cues, and dual task) will each be discussed in more detail below.

Drivers have been known to look at non-critical items within the environment, such as scenery or aspects of the roadway (Land & Lee, 1994). For example, advertisements serve the goal of attracting attention towards them so that they are easily noticed, however they inadvertently cause attention to be directed away from other information that is critical to the driving task, target detection and MVT (Crundall, Vanloon, & Underwood, 2006; Edquist, Horberry, Hosking, & I. Johnston, 2011). As such the complexity of the visual environment may acts as a reason for why drivers miss critical information while driving (Stinchcombe & Gagnon, 2010). Stinchcombe and Gagnon (2010) manipulated the amount of visual information in a driving simulator environment while having participants perform a peripheral detection task. They found that as the complexity of the visual environment increased performance in the peripheral detection task decreases, suggesting that the complexity of the visual environment plays a role in the ease of target detection.

Other research using visual search tasks not directly related to driving has demonstrated the detrimental effects of clutter on target detection. Beck, Lohrenz, and Trafton (2010) had participants search through complex visual maps for a target items. The maps varied in the amount of global clutter (the clutter of the whole chart) and the amount of local clutter (the amount of clutter surrounding the target). Search reaction time (RT) was slower as the amount of global clutter increased, with the effect being strongest when the target was in a high local clutter region. In addition, eye movements were measured and indicated that the increase in RT for higher levels of clutter was caused by an increase in the number of fixations that occurred before the target was found. This indicates that increasing global and local clutter increases the number of areas in the charts that will compete with the target for attention. This could easily be applied to the situation of using a moving map display while driving. It may also generalize to clutter outside of the vehicle. Therefore, target detection while driving may be improved by minimizing clutter (e.g., billboards).

An important factor that can influence target detection is cues (i.e., signs, prior driving experience). Cues are important because they affect the attentional set or expectations of the driver which can improve the driver's ability to locate targets quickly (Most & Astur, 2007). Cues can help alert observers to the time and location for a target and response time to a target is quicker when observers know when and where a target will appear (Posner, 1980; Beck, Hong, van Lamsweerde, & Ericson in prep). In addition, previous experiences can serve as cues that alter observers' expectations about the stability of visual information over time and greatly influence their ability to detect a change in the visual world from one glance to the next (Beck, Angelone, & Levin, 2004). Drivers' target detection performance may be improved by changing expectations with visual cues (Beck, & van Lamsweerde, 2011) and/or previous driving experiences.

Not only can factors such as roadway clutter and cues influence target detection performance, but attentionally demanding tasks completed while driving can interfere with each other. For example, MOT/MVT performance is affected if another attentionally demanding task is performed simultaneously (Tombu & Seiffert, 2008). Tombu and Seiffert (2008) paired an auditory tone discrimination task with the MOT paradigm; analogous to driving situations, this would resemble your cell phone ringing while driving and tracking the locations of the cars around you. Tombu and Seiffert (2008) found that when the auditory discrimination task was performed at the same time as when the dots for the MOT task moved closer to each other, MOT accuracy suffered more so then if the auditory discrimination task happened after the dot had moved further away from each other. When the MOT task required more attentional resources (when the dots are close to each other) and a concurrent task also requires attentional resources (auditory discrimination), performance declines. This result indicates that attentional resources are distributed between the two tasks, and there are not enough resources to complete both tasks accurately at the same time.

Further evidence for dual task interference in MOT/MVT situations has been demonstrated via self motion; with self motion inhibiting tracking performance (Thomas & Seiffert, 2011; Thomas & Seiffert, 2010). Specifically, Thomas and Seiffert (2010) asked participants to track moving objects in a virtual environment, meanwhile participants either stayed stationary, walked in place, or moved about the virtual world. They found that performance accuracy suffered in the tracking task when the participant either walked about the environment or was pushed in a wheelchair. They concluded that individuals must update representations of the not only the moving objects, but of themselves in this dynamic environment. This suggests that attention while driving may be deployed not only on the moving vehicles and pedestrians in the environment but also on the spatial location of the vehicle that is being driven. Luckily however, an individual spatial representation of oneself or vehicle represents only one item (Thomas & Seiffert, 2011) and therefore, the added attentional load should be minimal.

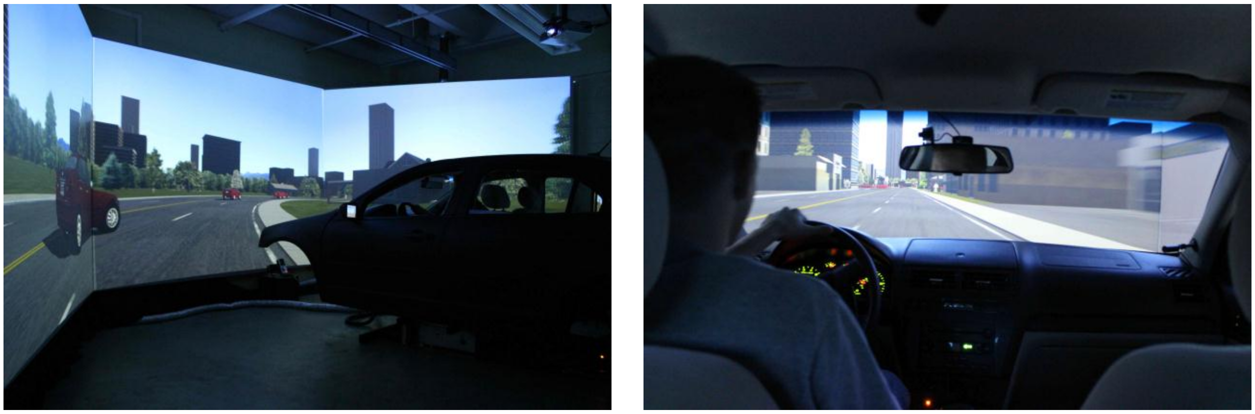
Previous research on driver attention has focused on distractions that occur within the vehicle (e.g., cell phones, radio, GPS navigation) or on static items that occur outside the vehicle, (e.g., advertisements or scenery). Tracking non-static objects in the environment offers a new direction for research on driver safety and accident prevention. Due to the nature of the MOT/MVT task, it can be inferred that individuals sustain attention within one specific area of the visual field. However, because of this dedicated level of attention to the task, it could be further assumed that drivers would then miss critical information that is not only located in peripheral areas but also located directly in front of the driver, resulting in instances of inattentional blindness. The research proposed here focuses not only on the visual complexity of the environment but also on the dynamic relation of the moving vehicles on attention. By incorporating a dual task paradigm of visual search in a visual complex environment and MVT we can directly examine the influence of outside vehicle factors on a driver's ability to detect critical targets. This research allows for us to investigate ways to improve driver safety and to improve methods for having relevant signs and markings stand out to drivers in order to effectively grab attention without causing a substantial loss of attention to other important aspects of the driving task.

Though still in its infancy, research on explicitly tracking moving vehicles provides advantages that can be easily measured in safe simulator environments. For instance, manipulating target vehicle driving activity or distractor vehicle activity (i.e., accelerating, braking, weaving) while measuring the effect it has on a driver can offer valuable insight into key factors that diminish driving performance. By using MVT we will investigate how and when drivers miss vital visual information due to inattentional blindness. Furthermore, by directing attention to the vehicles in the MVT task, we can focus on how to have relevant stimuli (i.e., a crosswalk signs) attract attention.

3.0 Study Design and Results

Attention is a limited resource. Focusing attention on a task goal and filtering out information that is not directly task related increases the probability of an instance of inattentional blindness. Therefore, a driver primarily focusing attention on MVT may fail to notice information (e.g. a pedestrian walking into the road) that is not directly related to the MVT task. This should become more probable as the number of vehicles to be tracked increases. In addition, ambient clutter in the surrounding environment may negatively affect MVT performance, while also increasing instances of inattentional blindness (i.e. more instances of missing critical information). In the current study, participants performed a MVT tracking task of high or low load and we measured tracking performance and reactions to a pedestrian entering the roadway. The amount of visual clutter and the presence of a pedestrian sign to cue attention toward the pedestrian were also manipulated. Several hypotheses were examined in the current study. First we examined two hypotheses in regards to MVT performance. 1) Tracking performance will be impaired when there are more vehicles to track. 2) If the areas surrounding the roadway have high visual clutter, fewer vehicles will be successfully tracked, compared to an environment with low visual clutter. Second, several hypotheses in regards to the ability to notice and react to the pedestrian were examined. 1) A higher tracking load will impair pedestrian detection either through rates of noticing or driving reactions to the pedestrian (i.e., break RT, change in velocity, or steering deviations) 2) High clutter environments will impair pedestrian detection either through rates of noticing or driving reactions to the pedestrian. 3) A cue indicating an upcoming critical target (e.g. a crosswalk sign), will improve pedestrian detection either through rates of noticing or driving reactions to the pedestrian.

To assess these hypotheses, the study was conducted in a Realtime Technologies Inc. driving simulator utilizing the SimVista driving simulator software; see Figure 1 for an example. We manipulated three independent variables (i.e., number of vehicles to track, pedestrian expectation, and clutter), while measuring tracking performance, target detection performance and various factors of driving performance (e.g., braking, changes in velocity, and steering deviations). As such a 2 x 2 x 2 between participants design was used. The number of vehicles tracked (track 1 out of 2 or 2 out of 4 vehicles), pedestrian expectation (crosswalk sign – present or absent), and amount of environmental clutter (low or high) were between subjects variables, resulting in eight experimental conditions.



a) **b)**

Figure 1: Example a) layout of the Realtime Technologies Inc. driving simulator utilizing the SimVista driving simulator software and a view b) from inside the simulator.

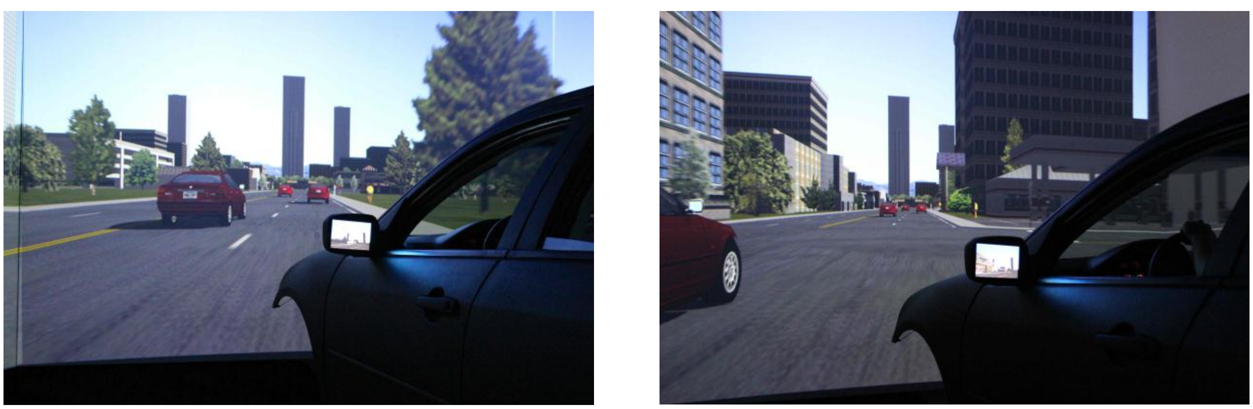
To maintain stimulus control for the task, a roadway that follows a singular path was constructed for all trials. The roadway has common roadway features such as intersections, curves/bends, and driveways. The driving path was constructed using the Internet Scene Assembler provided by Real Time technologies for use in the driving simulator. The driving scene that was designed consists of a two-lane road that proceeds through an S-curve bend and then moves in a straight path towards two intersections. Both intersections are controlled by 2-way stop signs, but do not impede the driver’s path, and only stops the crossing traffic, ensuring that the driver follows a steady pace throughout the path without any stops or accelerations. The simulator environment automatically ends when the participant comes to a flagpole just before a T-intersection following the second 2-way stop sign intersection. A pedestrian enters the roadway at a predetermined point between the first and second intersection. The critical detection sequence, during which we record our driving reaction dependent variables, occurs between the two stop sign intersections. The standard, automatically coded from Real Time Technologies, driving behavior is used for all ambient traffic, whereas the to be tracked cars are coded to maintain a particular driving path along the designated route.

Participants in this task were 166 students (males = 40, females = 126) from Louisiana State University, with a mean age of 20.28 years (SD = 1.93). Ten participants were removed from the data set due to poor data recording (n = 6), overtaking vehicles during the critical test trial (n = 3), or withdrawing from the task prior to completion of the experiment (n = 1), resulting in 156 participants total for the experiment. All participants gave informed consent prior to participation and reported normal or corrected-to normal vision. In addition each participant had to have acquired a state issued drivers license before beginning the task.

Participants first completed a pre-trial to establish comfort with the driving environment to insure our measures were not suspect to the potential simulator sickness or the novelty of use in the driving simulator environment. This pre-trial used the driving path with a simulator template that matched the road design in the critical test trial with no localized environmental clutter (removed all features and objects within close proximity to the driving path).

Each participant completed two runs, the pre-test run had no pedestrian entering the road while the test run always had the critical target pedestrian entering the roadway. For each participant, one level of each between subjects variable was selected for each run. Such that each participant would perform MVT with either a low or high load, have either low or high environmental clutter, or have the pedestrian crosswalk sign be present or absent on each run. The MVT task was similar to that of Lochner and Trick (2011), see above, where participants track either one (low load) or two (high load) vehicles in the simulated environment as they drive down the roadway. For the low load trials participants tracked one vehicle with one other identical vehicle distractor. In the high load condition participants track two identical vehicles in the presence of two identical distractor vehicles. These target and distractor vehicles traveled along the route at approximately 33.5 mph (15 m/s) and changed lanes a predetermined number of times. To ensure that participants maintained attention on these vehicles, we asked them to count the total number of lane changes that occurred for the target vehicle(s). Participants were also instructed to not overtake any of the vehicles, and if they did, the run was terminated and then repeated; except if an overtaking maneuver occurred during the critical trial in which case the data was removed from analysis. At the end of each trial run, participants reported the number of lane changes that occurred for the target vehicles.

To manipulate clutter, the route varied regarding the amount of objects that were placed throughout the local (i.e., immediate roadside) environment. A low clutter environment had very few trees, buildings, and signs, (see Figure 2a) whereas a high clutter environment had many more trees, buildings, and signs (see Figure 2b). Each participant was randomly assigned to low clutter or high clutter, and both the pre-test and test run contained the same level of clutter.



a) **b)**

Figure 2: Examples the a) low clutter environment and the b) high clutter environment.

For all participants, the pedestrian was within the environment but refrained from entering the road during the pre-test run, and then the pedestrian was present and entered the roadway during the test run. To manipulate pedestrian expectations, crosswalk signs were either present or absent at the critical pedestrian crossing point in the path (see Figure 3). The location of the crosswalk sign and the target roadway pedestrian varied between the stop sign intersections in the route such that participants could not easily predict when or where the critical pedestrian crossing instance would occur. For trials where the pedestrian entered the roadway, when the driver passed an invisible marker point, the virtual pedestrian ran into the road. The critical distance between the participant driving the vehicle and the location of the pedestrian entering the roadway was 22 m. For expectation present trials, a pedestrian crossing sign was placed to signify within close proximity (2 m) of where the target pedestrian, if entering the roadway, would enter the roadway. Participants were randomly assigned to one of each of the three between groups variables, (track 1 or 2 vehicles; high or low clutter, and presence or absence of crosswalk signs) resulting in eight conditional groups between participants, with each participant participating in both a roadway pedestrian absent (pre-test) and present (test) runs.

a)

b)

Figure 3: Example scenes of the a) unexpected (no crosswalk sign) and the b) expected (crosswalk sign) conditions.

3.1 Tracking Results

The proportion of participants accurately counting the number of lane changes in the MVT task can be seen in Figure 4. Because tracking accuracy was measured dichotomously (either correct or incorrect) a chi-square analysis was conducted for each of our independent variables; number of vehicles tracked, amount of clutter, and pedestrian expectation. More participants accurately counted the number of lane changes when only tracking 1 vehicle (M = .91) compared to when tracking 2 vehicles (M = .46), x^2(1, n = 155) = 35.90, p < .001. More participants accurately tracked in the high clutter environments (M = .78) compared to the low clutter environments (M = .58), x^2(1, n = 155) = 8.21. Additional analysis revealed no differences in the proportion of participants who tracked accurately between the high and low clutter environments when tracking 1 of 2 vehicles x^2(1, n = 78) = .26, p = .61, however there were significantly more participants who tracked accurately in the high clutter condition when tracking 2 of 4 vehicles x^2(1, n = 78) = 11.73, p = .001. Finally, the proportion of participants to accurately track was not lower when a pedestrian was expected (M = .72) compared to when there was no expectation for a pedestrian (M = .65), x^2(1, n = 155) = .84, p = .36.

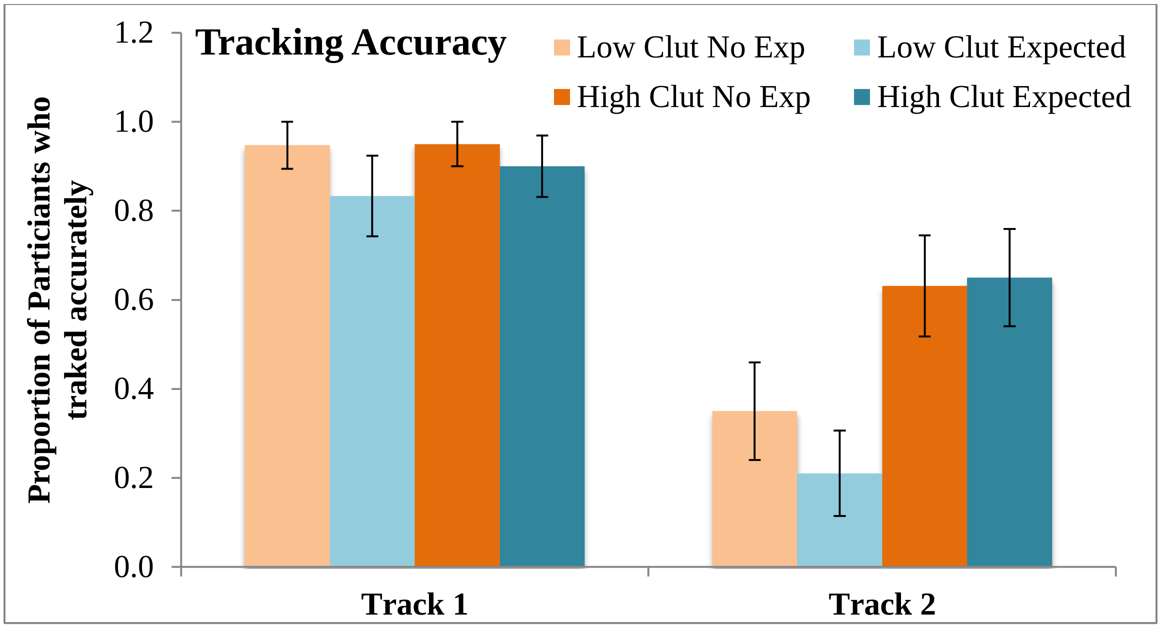


Figure 4: Proportion of participants who accurately counted the number of lane changes for the target vehicle(s) in the MVT task. Conditions displayed are unexpected or expected pedestrian (crosswalk sign present or absent), number of vehicles to track (1 of 2 or 2 of 4 cars), and low or high local environmental clutter. Error bars represent standard errors of the mean.

The effect of number of vehicles tracked agrees with previous research regarding tracking ability, in that tracking is easier with fewer items to track (Pylyshyn & Storm, 1988). Meanwhile the effect of environmental clutter suggests the active use of cognitive inhibition of irrelevant information in order to aide tracking (Pylyshyn, 2006) in the high clutter environment. Specifically, when the tracking load was high and there was more environmental clutter, selection to the tracked cars appears to have been enhanced due to greater use of selective attention under highly distracting conditions (more distractors – non tracked cars and more clutter) leading to better tracking performance.

3.2 Target Detection Results

Pedestrian road crossing detection was 100% in all conditions, with no participant ever stating that they did not see the target pedestrian in the roadway. Though the pedestrian was always detected crossing the roadway, how quickly or what driving reactions occurred differed between conditions.

Although detection, as measured by verbal report, was 100%, 17 participants failed to react to the target pedestrian (no breaking and/or steering deviation) within the range of time from when the pedestrian entered the road until the car reached the plane of movement of the pedestrian's location. The proportion of participants who failed to react within each condition is presented in Figure 5. A Chi-square analysis was used to determine significant differences for failures to react. The proportion of participants who failed to react when asked to track 1 of 2 vehicles (M = .13) did not differ from the proportion of participants tracking 2 of 4 vehicles (M = .09), x^2(1, n = 155) = .64, p = .42. Low clutter environments produced a similar proportion of participants who failed to react (M = .08) compared to those in high clutter environments (M = .14), $x^2(1, n = 155) = 1.31$, p = .25. There were more failures to react when a pedestrian was expected (M = .17) than when the pedestrian was not expected (M = .05), $x^2(1, n = 155) = 5.48$, p = .02.

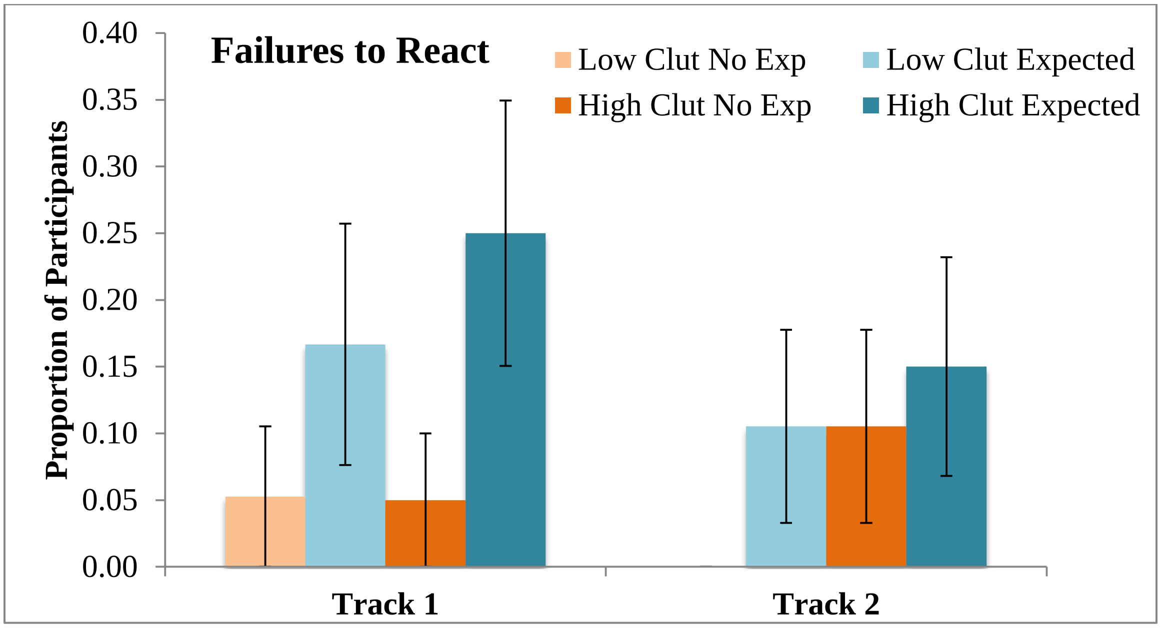


Figure 5: Proportion of participants who failed to react to the target pedestrian by condition. Conditions displayed are unexpected or expected pedestrian (crosswalk sign present or absent), number of vehicles to track (1 of 2 or 2 of 4 cars), and low or high local environmental clutter. Error bars represent standard errors of the mean.

The effect of pedestrian expectation on the failure to react is surprising because the expectation (a crosswalk sign) resulted in more failures to react than when there was no expectation. This result may have occurred because attending to the crosswalk sign could have delayed or prevented attention to the pedestrian (i.e., an attentional blink, Raymond, Shapiro, & Arnell, 1992).

For the participants who did react to the pedestrian, a 2 x 2 x 2 multivariate ANOVA was performed on brake RT, change in vehicle velocity, and steering deviations with number of vehicles tracked, amount of clutter, and pedestrian expectation as between subjects variables.

Across all conditions average vehicle speed was 33.82 mph, with a SD = 2.48 mph, matching the approximate speed of the target vehicles in the MVT task. The time participants took to perform a brake onset from the moment the pedestrian enters the roadway are presented in Figure 6. Brake time was faster for fewer tracked vehicles (2 cars, M = 765 ms; 4 cars, M = 812 ms), $F(1,130) = 5.49$, p = .02, η_p^2 = .64. However, there was no effect of environmental clutter (low M = 774 ms, high M = 810 ms), $F(1,130) = 3.06$, p = .08, η_p^2 = .41, or pedestrian expectation (unexpected M = 803 ms; expected M = 779ms), $F(1,130) = 1.53$, p = .22, η_p^2 = 23, on brake RT. In addition no significant interactions were found.

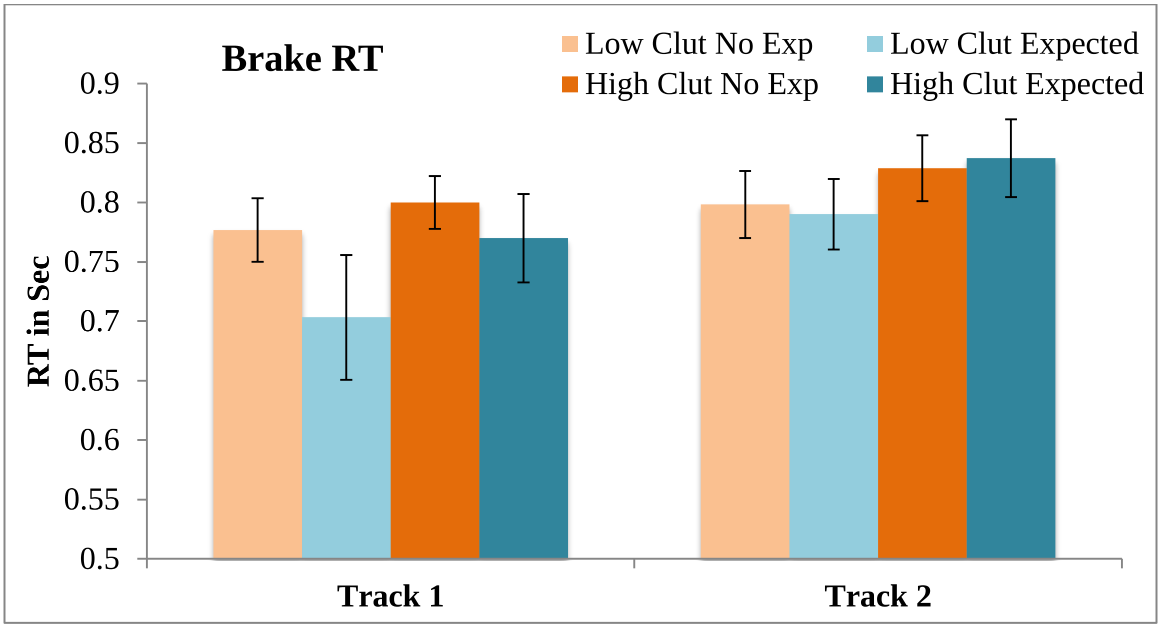


Figure 6: Time for brake onset for the test condition when the pedestrian enters the road. Conditions displayed are unexpected or expected pedestrian (crosswalk sign present or absent), number of vehicles to track (1 of 2 or 2 of 4 cars), and low or high local environmental clutter. Error bars represent standard errors of the mean.

Data for the average change in velocity from the moment the pedestrian enters the road to when the vehicle reaches the coordinate of where the pedestrian is located in the road is presented in Figure 7. There was no significant effect of number of vehicles tracked (1 car, *M* = 2.84 mph; 2 cars, *M* = 2.93 mph), $F(1,130) = 0.83$, $p = .77$, $\eta_p^2 = .06$. However, low clutter environments produce a larger change in velocity than high clutter environments (low, *M* = 3.35 mph; high, *M* = 2.43 mph), $F(1,130) = 4.40$, $p = .04$, $\eta_p^2 = .55$. Finally, there was no significant effect of pedestrian expectation (unexpected, *M* = 3.09 mph; expected, *M* = 2.66 mph), $F(1,130) = .44$, $p = .51$, $\eta_p^2 = .10$.

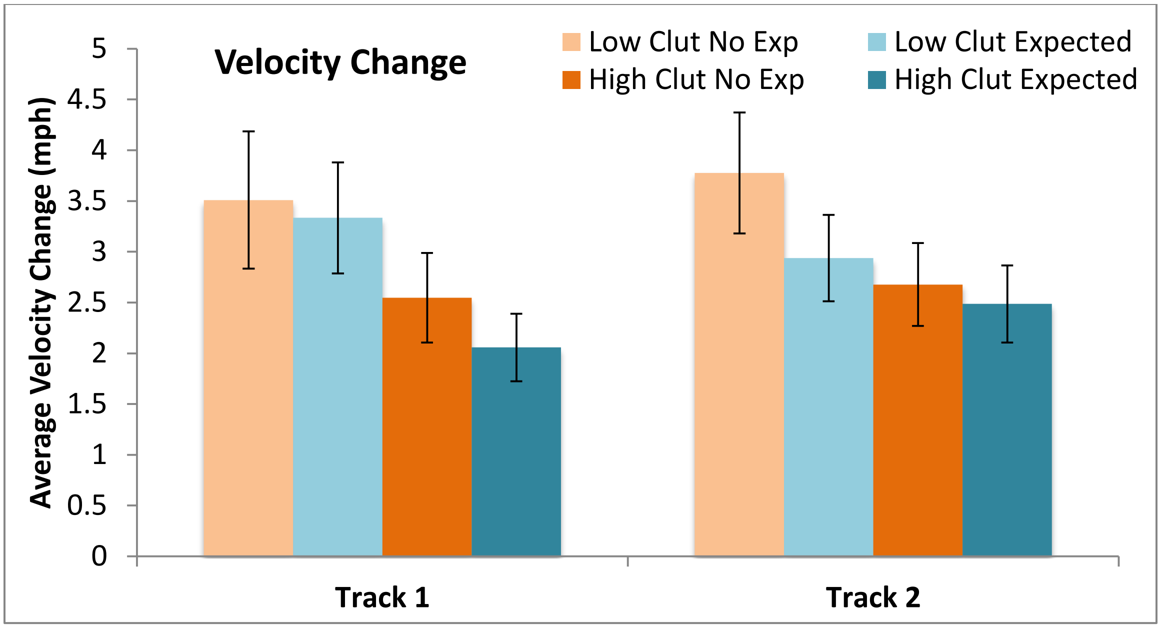


Figure 7: Average change in vehicle velocity from onset of the pedestrian entering the roadway to the location of the pedestrian in the road. Conditions displayed are unexpected or expected pedestrian (crosswalk sign present or absent), number of vehicles to track (1 of 2 or 2 of 4 cars), and low or high local environmental clutter. Error bars represent standard errors of the mean.

The main effect of clutter indicates that in high clutter environments participants may take a more precautious approach to driving, or that individuals are less likely to alter their vehicle speed in cluttered visual worlds. However, closer examination of the data shows that the maximum test run velocity of the vehicle was approximately equal for both levels of visual clutter in the environment (low clutter M = 33.67 mph; high clutter M = 33.74 mph; t(153) = .22, p = .81), suggesting that the later proposition is the case.

Data from the change in steering wheel direction are presented in Figure 8. Change in steering wheel rotation (degrees) is calculated from the initial heading at the moment the pedestrian enters the roadway to the heading of the vehicle when reaching the location of the pedestrian. Note that positive values indicate changes in steering direction to the right, while negative values are to the left. Participants deviated more when tracking more vehicles (1 car, M = -17.19°; 2 cars, M = -66.03°), $F(1,130) = 6.10$, p = .02, η_p^2 = .69. The amount of deviation was similar across levels of environmental clutter (low, M = -37.32°; high, M = -46.29°), $F(1,130) = .04$, p = .85, η_p^2 = .05, and pedestrian expectation (unexpected, M = -41.71°; unexpected, M = -42.13°), $F(1,130) = .02$, p = .89, η_p^2 = .05. In addition, there were no significant interactions.

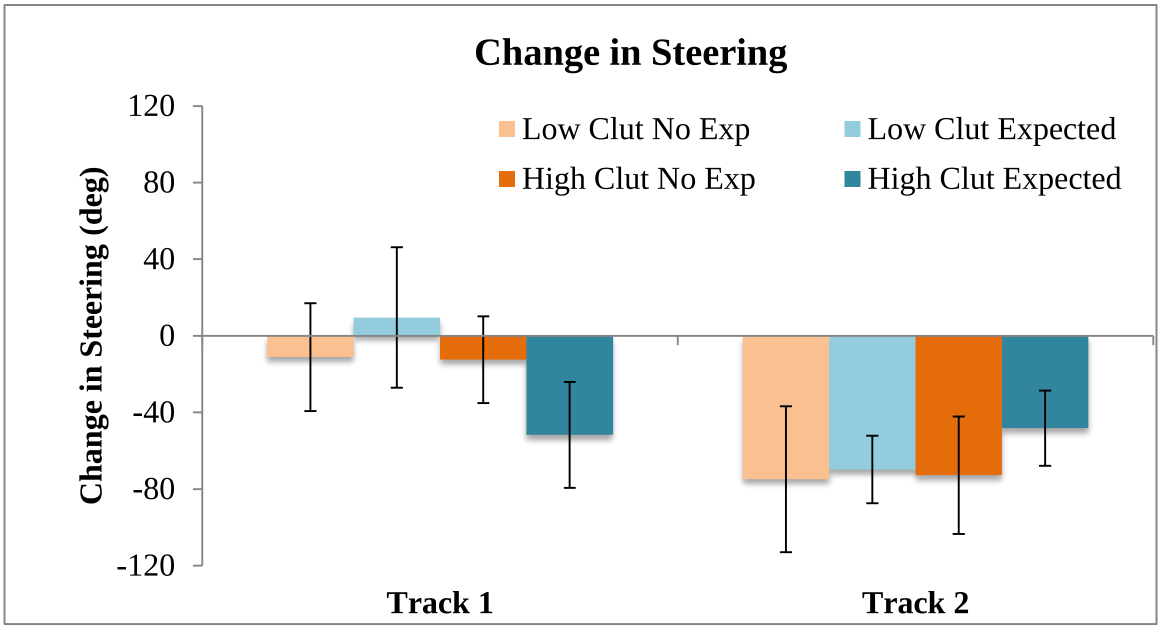


Figure 8: Positive values indicate changes to the left while negative values indicate changes to the right. Conditions displayed are unexpected or expected pedestrian (crosswalk sign present or absent), number of vehicles to track (1 of 2 or 2 of 4 cars), and low or high local environmental clutter. Error bars represent standard errors of the mean.

The main effect for number of vehicles tracked on steering deviation combined with the main effect for number of vehicles tracked on breaking RT demonstrates that when tracking fewer vehicles participants are more likely to rely on their braking ability rather than deviating the direction of the steering wheel. Alternatively, when tracking more vehicles, participants are more likely to deviate steering. It is also important to note that the direction of the steering change was opposite of the direction from which the target pedestrian entered the roadway (the pedestrian was entering from the right and drivers deviated to the left).

4.0 Conclusion

To briefly summarize, we predicted that in regards to MVT, performance would decline during high environmental clutter and during a greater tracking load. In addition, in regards to target detection, we predicted that detection and driving reactions to the target would be impaired under a higher tracking load, high clutter, and without the expectation of a pedestrian.

The data indicate that tracking accuracy is better when fewer vehicles are to be tracked. This finding coincides with much of the previous literature on MOT (Alvarez & Franconeri, 2007; Pylyshyn & Storm, 1988; Tombu & Seiffert, 2008) and MVT (Lochner & Trick, 2011), as fewer objects are consistently easier to track. However, in contrast to the predictions the results indicated that tracking accuracy is better in the high clutter conditions but only when tracking 2 out of 4 vehicles. This suggests that the drivers may be suppressing the surrounding environment (Pylyshyn, 2006), but only when the ambient visual environment is complex and tracking load is high. In particular it is possible that in the low clutter environments, because the amount of visual information is not complex, that the environmental information may be attracting attention; much like an advertisement (Crundall, Vanloon, & Underwood, 2006; Edquist, Horberry, Hosking, & Johnston, 2011).

Contrary to many studies demonstrating inattentional blindness, in the current study, none of the participants failed to detect (or report) the presence of the critical pedestrian running into the road. This contradicts the hypothesis that an increased tracking load or a high clutter environment would reduce target detection, as seen with other inattentional blindness tasks (Hyman et al., 2009; Simons & Chabris, 1999). Potential reasons for this difference is likely due to the fact that the pedestrian was markedly different from the to be tracked vehicles, and that the pedestrian moved in such a manner that it impeded the path of the driver. Meaning that in order for the participant to complete the task of maintaining their current speed, the participant would have had to drive through the pedestrian to continue along the route. This result is a positive demonstration of driver awareness, however, it does not exclude the possibility of slowed reactions or lack of evasive maneuvers.

A higher tracking load is the only factor that contributed to braking onset RT and steering deviations. When tracking few vehicles participants were significantly faster at reacting to the sudden onset of the pedestrian, although they had less of a steering deviation. The possibility remains then that due to the failure to brake quickly in the high tracking load, drivers compensate for their failure to brake by quickly swerving out of the way from the pedestrian. This is potentially problematic because there are more cars on the roadway when tracking load is high and a steering deviation may be more likely than breaking to result in a collision with another car.

The amount of visual clutter in the environment was the factor that caused the greatest discrepancy in overall change in vehicle velocity. This suggests, that drivers in low clutter environments were able to slow the vehicle faster than those in high clutter environments.

The presence of cues (crosswalk signs) in the driving environment did not influence critical target detection. The failure to react data actually contradicted the initial predictions of the study, in that pedestrian expectations actually *increased* the proportion of participants who failed to react. One possible explanation of this result is that attending to the crosswalk sign could have delayed or prevented attention to the pedestrian (i.e., an attentional blink, Raymond, Shapiro, & Arnell, 1992). Alternatively, the crosswalk sign may not have been salient enough to capture attention.

Overall, the data presented here represents a new way of investigating inattentional blindness (Simons & Chabris, 1999) in a real world scenario and demonstrate that responses to unexpected targets can be impaired when there is a high attention demand from the driving task. Although there were no failures to detect the target pedestrian in the road during the task it is possible that if an even greater tracking load were used, for example track 4 out of 8 vehicles, that instances of inattentional blindness may have been observed. However, the differences seen within the driving reaction measures of participants lend new insights in roadway and evacuation design.

For example, the data suggest that to provide the safest scenarios, a driving environment should take a minimalist approach towards the attentional demands for the driver. Meaning that increasing the number of opposing vehicles in the roadway ultimately decreases the ability of the driver to effectively react to critical target items. In addition, this study found that observers are potentially suppressing visual information (Pylyshyn, 2006) when driving, such that increases in ambient clutter do not necessarily distract the driver away from targets (Stinchcombe & Gagnon, 2010), but rather can serve as a catalyst to ignoring other potentially relevant information (the crosswalk signs). The data presented here should be taken into consideration when designing safe driving environments, with special consideration towards the amount of ambient traffic and towards the amount of irrelevant ambient clutter. In addition, for situations where driving environments are difficult to alter, additional information about safe headway should be given to drivers in order to promote safe driving behavior.

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