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Compensating for failed attention while driving

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ABSTRACT

While operating a motor vehicle, drivers must pay attention to other moving vehicles and the roadside environment in order to detect and process critical information related to the driving task. Using a driving simulator, this study investigated the effects of an unexpected event on driver performance in environments of more or less clutter and under situations of high attentional load. Attentional load was manipulated by varying the number of neighboring vehicles participants tracked for lane changes. After baseline-driving behavior was established, the unexpected event occurred: a pedestrian ran into the driver's path. Tracking-accuracy, brake initiation, swerving, and verbal report of the unexpected pedestrian were used to assess driver performance. All participants verbally reported noticing the pedestrian. However, analyses of driving behavior revealed differences in the reactions to the pedestrian: drivers braked faster and had significantly less deviation in their steering heading with a lower attentional load, and participants in low clutter environments had a larger overall change in velocity. This research advances the understanding of how drivers allocate attention between various stimuli and the trade-offs between a driver's focus on an assigned task and external objects within the roadway environment. Moreover, the results of this research lend insight into how to construct roadway environments that encourage driver attention toward the most immediate and relevant information to reduce both vehicle-to-vehicle and vehicle-to-pedestrian interactions.

1. Introduction

A key factor in the ability to safely and successfully navigate through a roadway environment is driver attention. Attention is critical for locating objects along the roadway and for tracking or following other moving vehicles. When attention is impaired or distracted by other activities or events, driving errors can occur and safety can be diminished. Attention is a limited cognitive resource. Individuals preforming more than one attention-demanding task must divide their attention between multiple tasks while allocating attention to information that is most important and away from other information. This can result in critical information being overlooked, despite the information being clear and directly within an observer's line-of-sight (Hyman, Boss, Wise, McKenzie, & Caggiano, 2009; Simons & Chabris, 1999).

Driving is an attention-demanding task because attention must be allocated to surrounding vehicles, objects near the roadway, and objects inside of the vehicle. "Target detection" is a general term used to describe the process of detecting, finding, or noticing a specific item amidst a variety of distractors, which demand attention (Treisman, 1986). Inattentional

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blindness occurs when individuals fail to detect unexpected events or targets while performing an attention-demanding task (Simons & Chabris, 1999). Inattentional blindness could have severe consequences while driving. For example, the failure to detect a pedestrian entering the roadway could lead to a fatal accident.

The research suggests that inattentional blindness while driving is more likely to occur when drivers are participating in attention demanding tasks (Most & Astur, 2007; Strayer, Drews, & Johnston, 2003). A failure to be attentive to critical targets while driving may account for hundreds of motor vehicle crashes every day. Thus, the need for research into primary driving tasks (e.g. following vehicles) and environmental elements (e.g. ambient roadside density) that engage a driver's attention outside the vehicle is essential for improving highway safety. To date, the focus of most previous driving research on attentional limits has been on distractions that occur inside of the vehicle rather than outside of it (Young & Regan, 2007). The current research investigated the effects of attentional distraction by elements outside of the cockpit to determine when failed attention is present while driving and what compensation driving strategies are utilized when lapses in attention occur.

1.1. Attention is limited

Focused attention is an essential factor in the ability to drive a motor vehicle, and failed attention is a significant contributor to driving errors and motor vehicle crashes (Young & Regan, 2007). Two of the most important attention-demanding tasks while driving are tracking moving objects and detecting items in the roadway environment (Pylyshyn & Storm, 1988; Simons, 2000; Treisman & Gelade, 1980). Errors on these tasks are more likely to occur when attention is diverted or overloaded (Hyman et al., 2009; Simons & Chabris, 1999). Furthermore, due to the relative monotony and repetitive nature of the driving task, drivers often adapt or become habituated to the task (Duncan, Williams, & Brown, 1991; Shinar, Meir, & Ben-Shoman, 1998; Wickens, 2002), making them more susceptible to errors caused by inattention. Therefore, attention failures can occur while driving because attention is not always appropriately allocated to critical information.

Typically, there is a goal associated with a primary task, which provides the parameters for what information will be attended and what information will be ignored. In traditional work on inattentional blindness participants are tasked with counting ball passes (Simons & Chabris, 1999), counting wall bounces (Most, 2010), or some other attentionally engaging task (Most & Astur, 2007; Neisser & Becklen, 1975; Strayer et al., 2003). While performing this attentional engagement task, an unexpected object or event occurs. These unexpected events or objects can be anything ranging from women carrying umbrellas (Becklen & Cervone, 1983), motorcycles veering into a car's path (Most & Astur, 2007), unicycling clowns (Hyman et al., 2009), or a gorilla beating its chest (Simons & Chabris, 1999). What's remarkable is that although participants are generally very good at performing the primary task, nearly half of participants fail to notice the unexpected object (Simons & Chabris, 1999). Therefore, to the extent that driving a car and monitoring the other cars on the roadway is treated as the primary task, a secondary and more incidental task of detecting pedestrians entering the roadway may receive less attentional resources than needed for optimal performance.

There are many tasks that can occur inside the motor vehicle while driving that can serve as a primary attentionally demanding task, leading to decreased performance on other tasks. Specifically, tasks inside the car can lead to attentional distractions, which limit the driver's ability to effectively distribute attention while driving (Wickens, 2002). One area that has been extensively researched is the inclusion of various electronic devices (e.g., cell phones, radio, GPS navigation systems) in vehicles (see Young & Regan, 2007 for a review). The consensus of such research is that the use of these devices by drivers consistently hinders driving performance. For example, talking on a cell phone has been shown to negatively impact driver ability (Nelson, Atchley, & Little, 2009; Strayer & Johnston, 2001; Strayer et al., 2003). These experiments have shown that drivers alter various aspects of their driving behavior to accommodate these secondary tasks, such as reducing speed/acceleration, increasing inter-vehicle distance, or altering the allocation of attention toward other variables (Alm, 1995; Brookhuis, De Vries, & De Waard, 1991; Horberry, Anderson, Regan, Triggs, & Brown, 2006; Strayer et al., 2003). It should be noted that most research has focused on attention distractions that occur inside of the vehicle rather than outside of it (Young & Regan, 2007). However, attention directed outside of vehicle could also result in drivers missing critical road- and driving-related events (Most & Astur, 2007). Therefore, understanding how and when tasks and environmental elements outside of the vehicle affect critical target detection is essential for improving driver safety.

Much of the relevant information and events that occur during driving are located outside of the vehicle (Charlton & Starkey, 2013; Pammer & Blink, 2013). Two of the most important attentionally demanding tasks required outside-of-the-vehicle are (1) target detection and (2) neighboring-car monitoring. A driver's ability to quickly detect important targets (e.g. traffic signs, pavement marking, pedestrians, etc.) while ignoring irrelevant distractors (e.g., advertisements) is a key component to maintaining a safe driving environment (Borowsky, Shinar, & Parmet, 2008). Therefore, the current study will examine the effects of target detection while monitoring the number of lane changes of neighboring cars. As an analog to the inattentional blindness research, we are treating the neighboring-car monitoring task as the primary task because participants are directly instructed to do this task, and the target detection task as secondary because although pedestrian detection is incidental to the driving task, it was not explicitly described as a task of interest to the participants.

Target detection performance is not only affected by other ongoing tasks that distract attention, but also by the amount of competing information in the visual environment. Specifically, as the number of distractors or the level of clutter increases, the amount of time needed to find the target also increases (Beck, Lohrenz, & Trafton, 2010; for reviews see Eckstein, 2011;

Wolfe, 1998). A visual environment can be defined as highly cluttered when there is a large amount of variable visual information (Rosenholtz, Li, Mansfield, & Jin, 2005; Rosenholtz, Li, & Nakano, 2007). Within a cluttered environment some information may be missed due to attention being spread across items (Stinchcombe & Gagnon, 2010). Previous research suggests that target detection while driving is impaired in driving environments cluttered with roadway signs and advertisements (Borowsky et al., 2008). However, in high clutter environments more glances are made to the left and right sides of the roadway, suggesting that despite these glances critical targets may not be detected within high clutter roadway environments (Perez & Bertola, 2010). Furthermore, driver expectations (Pammer & Blink, 2013) and familiarity with a roadway (Charlton & Starkey, 2013) both have been shown to impair target detection. Therefore, in order to determine the effects of clutter in the driving environment on the ability to detect critical targets, the current study will examine reactions to a pedestrian entering the roadway in high and low cluttered driving environments.

1.2. The primary task: multiple vehicle tracking

Given that the goal of the current study is to examine the effects of a primary driving task that requires attention on the ability to detect a critical target, a primary driving task that is known to tax attentional resources was chosen for the current study. Specifically, the primary task in the current study is a multiple vehicle-tracking (MVT) task. This task requires individuals to follow a number of identical moving vehicles on a roadway and to monitor the vehicles as they exchange lanes and row positions (Lochner & Trick, 2014). Generally, a subset of the vehicles is cued at the start of the task, and then, at the end of the task, participants identify the vehicles that were cued at the start of a trial. Participants may be asked to track zero, one, three or four cars, while acting as the driver of the simulator or while acting as a passenger in the simulator (Lochner & Trick, 2014). As expected from traditional multiple object tracking literature (Pylyshyn & Storm, 1988), performance decreased as the number of vehicles to track increased. Additionally, MVT performance decreased when participants were acting as the driver rather than a passenger, suggesting that attention resources were expended not only on tracking the cars but also on operating the vehicle. Increasing the tracking load resulted in a significant increase in lane deviations as well as a significant increase in the amount of headway afforded to the vehicles. This research demonstrates that increasing the number of cars to be tracked increases the attentional resources needed to complete the task and provides an ecologically valid manipulation of the attentional load imposed by the primary task.

Another factor that may also influence the attentional load of a driving task is the amount of "clutter" in the driving environment. In prior research drivers have been observed looking at non-critical items within roadway environments including scenery or various features of the road (Land & Lee, 1994). For example, advertisements attract attention, and can cause attention to be directed away from other objects which are critical to the driving task (Crundall, Vanloon, & Underwood, 2006; Edquist, Horberry, Hosking, & Johnston, 2011). The complexity of many roadways may be one reason why drivers miss critical information, in particular during a peripheral detection task (Stinchcombe & Gagnon, 2010). This demonstrate that as the complexity of the visual environment increased, performance in a peripheral detection task decreases, suggesting that the complexity of the visual environment plays a role in the ease of target detection (Stinchcombe & Gagnon, 2010).

1.3. Current research

The goal of this research was to examine the effect of MVT on safe driving in the presence of clutter. The research focused not only on the visual complexity of the environment, but also on the dynamic relation of the moving vehicles on attention. By measuring target detection in a visual complex environment while completing a MVT task, the influence of outside vehicle factors on a driver's ability to detect critical targets was assessed. Like other work on texting-while-driving, this research suggests that *any* task that distracts a driver's attention away from detecting a critical target may significantly increase the potential for vehicle crashes (Alosco et al., 2012; Cook & Jones, 2011), even if that task is part of normal driving behavior.

Using a full-scale driving simulator and accompanying simulation software, participants were assigned two primary tasks: (1) operate the motor vehicle safely; while performing (2) counting the number of lane changes made by the surrounding vehicles (i.e. MVT). A third target detection task, unannounced to the participants, was to detect and react to a pedestrian running into the roadway. The independent variables in the study included the number of vehicles tracked in the MVT task (1 out of 2 or 2 out of 4) and the amount of visual cutter in the environment (low or high). The effects of these independent variables on target detection were assessed by examining several dependent variables. Pedestrian detection was measured by verbal reporting. Driving reactions to the pedestrian were assed with various quantitative driving measures including brake reaction time, velocity change, and steering deviation were recorded to measure driver's reactions to the pedestrian.

Within this experimental framework, several hypotheses were proposed, specifically that: (1) MVT performance would be impaired when there were more vehicles to track; (2) a higher MVT load would impair pedestrian detection either through lower rates of verbal report of the pedestrian or through driving reactions to the pedestrian; (3) high clutter environments would impair pedestrian detection either through lower rates of verbal report of the pedestrian or through driving reactions to the pedestrian.

2. Method

Participants performed a MVT tracking task for high or low tracking loads and for high and low clutter. Driving performance was measured in terms of braking reaction time, velocity change and steering deviation in response to a pedestrian entering the roadway.

2.1. Experimental design and test configurations

To assess these hypotheses, this study was conducted using the Louisiana State University driving simulator, which is a full-sized passenger car (a Ford Fusion with no wheels) combined with a series of cameras, projectors and screens to provide a high fidelity virtual environment. Realtime Technology Inc. manufactured the simulator. Environments were constructed using the Internet Scene Assembler and the experiments were run through the SimVista control interface. Examples of the simulator setup are shown in Fig. 1A and B. A 2 × 2 multivariate between participants analysis was used in which the number of vehicles tracked (track 1-out-of-2, or 2-out-of-4 vehicles) and amount of "environmental clutter" (low or high) were varied between participants to form a set of eight experimental groups.

To maintain consistent stimulus control between individual experiments, the simulation followed an identical path for all trials. The driving path had common roadway features such as the number and design of intersections, curves/bends, and driveways. The general driving scene consisted of a four-lane (two-lanes on each side of a midline) road with a path leading through an S-curve then a straight path between two, two-way stop controlled intersections. Participants traveled on the major street and were not required to stop at the two intersections, ensuring that they maintained a steady pace, minimizing stops and accelerations. The simulator automatically ended when participants reached a flagpole just before a T-intersection downstream of the second of the two two-way stop intersections.

In this experiment, a pedestrian entered the road at a point between the first and second intersections. The critical detection sequence, during which the dependent variables were recorded, also occurred between the two intersections. The tracked vehicles were coded to perform specific maneuvers along the experimental route (e.g. accelerate, pass, brake, change lanes, etc.).

2.2. Participants

166 students (males = 40, females = 126) from Louisiana State University, with a mean age of 20.28 years (SD = 1.93), voluntarily participated in this study and were compensated with course credit for their time. Ten participants were removed from the dataset 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. To be included in this study each participant was required to present a valid state issued driver's license prior to the start of the experiment. No additional information was collected regarding a participant's previous driving history.

2.3. Stimuli and procedure

Participants first completed a pre-trial run to establish comfort with the driving environment and to gain familiarity with the driving simulator equipment. The pre-trial run used the same driving path and design as the test trials with no localized environmental clutter, such that all features and objects within close proximity to the driving path were removed.

Following the pre-trial run, each participant completed two runs. The pre-test run had no pedestrian entering the road while the test run had the critical target pedestrian entering the roadway. The MVT task was similar to those previously used (Lochner & Trick, 2014), where participants tracked either one (low load) or two (high load) vehicles in the simulated environment as they drove.

In the low-load trials, participants were asked to track one vehicle in the presence of a separate, identical vehicle as a distractor. Under the high-load condition, participants were asked to 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 (low-load = 4–6 changes, high-load = 6–8 changes). To ensure continual attention, participants were also asked 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 experimental 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 adjust the amount of ambient "clutter," the experimenters varied the number of objects in the local (i.e. the immediate roadside) environment. This was accomplished using the Internet Scene Assembler within which, individual road path tiles (100 m × 100 m) contained objects. A low-clutter environment had relatively few trees, buildings, and signs, (Fig. 1C) while the high-clutter environment incorporating many more trees, buildings, and signs (Fig. 1D). Low clutter environments were created such that each tile contained zero to one building on each side of the road and no more than three vegetation features. High-clutter environments utilized the identical environment as the low-clutter scenarios, but included two to three

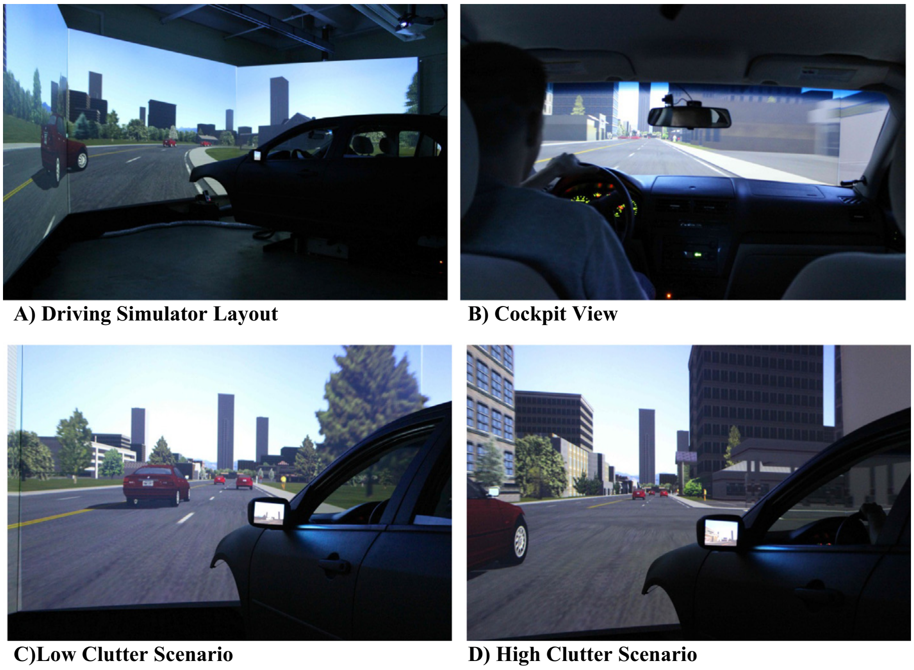

Fig. 1. Driving simulator configuration and various scenario alternatives. (A) Simulator layout from outside the cockpit, (B) layout from inside the cockpit, (C) low clutter scenario and (D) high clutter scenario.

additional buildings and up to five additional vegetation features per tile on each side of the road. Participants were randomly assigned to low- and high-clutter conditions, while an identical level of clutter was maintained between the pre-test and test runs.

The unexpected pedestrian crossing event was used in all test runs, but was not used during either the pre-trial or pre-test runs. The location of the crossing pedestrian was placed between the two two-way stop controlled intersections in the route. In addition to the ambient environmental information and the to-be-tracked vehicles, the environment also included background pedestrians, none of which crossed the driver's path. These additional pedestrians made it such that the participants could not predict if, when, or where the unexpected pedestrian crossing instance would occur. An example location of the critical target pedestrian within the environment can be seen in Fig. 2.

In the test run in which the pedestrian entered the roadway, the virtual pedestrian ran into the road after the driver passed an unidentifiable trigger point. The distance between the participant vehicle and pedestrian entry was 72 ft. (22 m). At the end of the test run, participants were asked if they saw a pedestrian enter the roadway. Participants were randomly assigned to one of the four experimental groups (low load – low clutter; low load – high clutter; high load – low clutter; high load –high clutter) that varied between the two dependent variables (tracking load, environmental clutter).

3. Results

Comparisons were made between the various experimental trial groups to determine how tracking load and environmental clutter affected driving performance. An analysis between the various sets of experimental groups was conducted to determine if the independent variables (tracking load, environmental clutter) had a significant effect on task performance. Groups were created based on the tracking load and the amount of environmental clutter. MVT/attentional load was evaluated by tracking accuracy (i.e. did the participant count the correct number of lane changes?). Driving performance was evaluated using brake reaction time, velocity change and steering deviation.

The two dichotomous variables (tracking accuracy and pedestrian detection) were evaluated using a chi-square test, whereas the three driving performance variables were evaluated using a 2×2 multivariate analysis of variance (ANOVA) with an $\alpha = 0.05$.

3.1. Vehicle tracking load check

MVT attentional load data for the test runs are summarized in Fig. 3. Analysis showed that more participants accurately counted the number of lane changes when only tracking one vehicle (low load: $M = .91$) than when tracking two vehicles (high load: $M = .46$), $x^2(1, n = 155) = 35.90$, $p < .001$. This finding is consistent with other findings regarding multiple object

Fig. 2. Example target pedestrian within the environment.

tracking and MVT, which demonstrated that as the number of items to track increases, accuracy subsequently decreases (Lochner & Trick, 2014; Pylyshyn & Storm, 1988).

To evaluate how discrepant the accuracy was on tracking, an analysis was conducted to examine how the number of observed lane changes deviated from the actual number of lane changes. The high-load tracking group witnessed more lane changes compared to the low-load group, having the opportunity for a greater deviation in the number of observed lane changes from the actual number of presented lane changes. To evaluate this, the average squared difference for inaccurate participants from both groups was examined (Fig. 4). A subsequent independent samples *t*-test was conducted demonstrating no differences between the groups $t(6) = .823$, $p = .44$.

3.2. Pedestrian detection

Unexpected pedestrian detection was 100% in all conditions; with all participants reporting seeing the pedestrian in the roadway after the test run was complete. Interestingly, although the pedestrian was always detected, the speed of the detection and reaction time of drivers varied between the experimental groups. Despite perfect reporting of the unexpected pedestrian, the results showed that 17 participants failed to react, without ever having braked or altered their heading, to the pedestrian.

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 high clutter environments ($M = .14$), $x^2(1, n = 155) = 1.31$, $p < .25$. Participants who failed to react were removed from the multivariate ANOVA analysis for brake reaction time, as these participants would have skewed the results because a participant "failing to react" would have created infinite brake reaction times.

3.3. Brake reaction time

No significant interaction was observed between tracking load and environmental clutter for brake reaction time (Fig. 5), however, brake time was faster for fewer vehicles were tracked (low load, $M = 765$ ms; high load, $M = 812$ ms), $F(1,130) = 5.49$, $p = .02$, $\eta_p^2 = .64$. In addition there was small, non-significant effect of environmental clutter (low $M = 768$ ms, high $M = 810$ ms), $F(1,134) = 2.94$, $p = .09$, $\eta_p^2 = .02$ on brake reaction time.

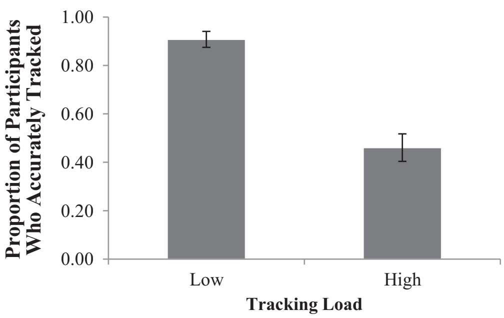

Fig. 3. Proportion of participants who accurately tracked in the low load and high load conditions.

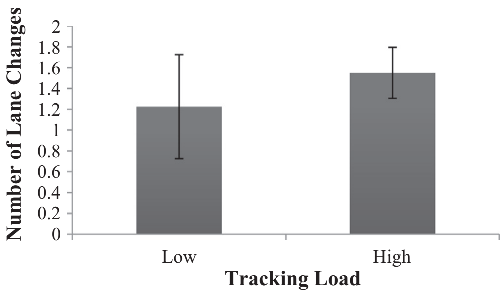

Fig. 4. Average squared deviation of reported lane changes from actual lanes changes.

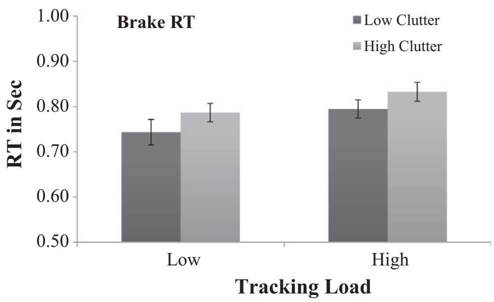

Fig. 5. Average brake reaction time for the experimental groups.

3.4. Change in velocity

No significant interaction was observed for change in velocity, (Fig. 6), as well as no effects of tracking load (low, $M = 2.84$ mph; high, $M = 2.93$ mph). However, low clutter environments produced a larger change in velocity than high clutter environments (low, $M = 3.35$ mph; high, $M = 2.43$ mph), $F(1,130) = 4.40$, $p = .04$, $\eta_p^2 = .55$.

3.5. Steering deviation

Steering deviation (i.e. the degree of change in steering wheel rotation) was calculated from the initial heading at the moment the pedestrian entered the roadway to the heading of the vehicle when the car reached the location of the pedestrian. A positive value indicates a change in steering to the left and a negative value indicates a change to the right. Study participants tended to change heading more when tracking load was high (low, $M = -16.45°$; high, $M = -66.43°$), $F(1,151) = 5.92$, $p = .02$, $\eta_p^2 = .04$, as shown in Fig. 7. Whereas, there were no differences in steering deviation based on environmental clutter and no interaction.

The effect for number of vehicles tracked on steering deviation combined with the effect of the number of vehicles tracked on braking reaction time suggests that participants who were tracking fewer vehicles were more likely to rely on their braking rather than steering for collision avoidance. Alternatively, when tracking more vehicles, participants used steering avoidance. It is also important to note that the direction of the steering change was in the opposite direction from the side from which the pedestrian entered the roadway (i.e., the pedestrian was entering from the right heading to the drivers left and the drivers steered to the right of the pedestrian).

4. General discussion

Based on the results of this research, there are a number of general and specific conclusions that could be reached. First, the results indicated that tracking accuracy was better when fewer vehicles were to be tracked. This finding was not surprising and coincides with previous literature on multiple object tracking (Alvarez & Franconeri, 2007; Pylyshyn & Storm, 1988; Tombu & Seiffert, 2008) and MVT (Lochner & Trick, 2014).

The results showed that none of the participants failed to detect (or report) the presence of a pedestrian running into the road, demonstrating a lack of inattentional blindness. This suggests that participants were not actually blind to the participant but may have instead been attentionally misdirected (Memmert, 2010). This would demonstrate a mechanistically different form of inattentional blindness while driving (Most, 2010). While another potential reason for this difference is that

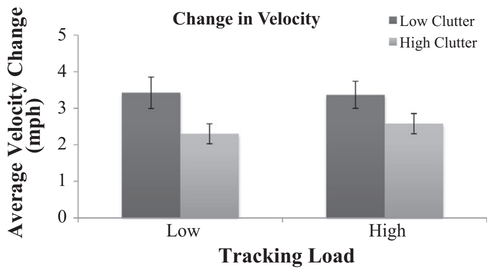

Fig. 6. Average change in velocity for the experimental groups.

although there were other pedestrians present in each driving scenario, the unexpected pedestrian was markedly different from the tracked vehicles (Most, 2013).

Another likely cause for a lack of inattentional blindness may have been that the pedestrian impeded the path of the driver. In other words, to maintain their operating speed, participants would have collided with the pedestrian, making detection of the pedestrian almost unavoidable. Despite perfect detection, nearly 11% of all participants in this study failed to react to striking the pedestrian. Therefore, future research in this area may seek to include more participants in each design group, as a sample size of 30–50 drivers may be able to show inattentional blindness with higher statistical certainty.

A higher tracking load was the only factor that contributed to braking onset reaction time and steering deviations. When tracking fewer vehicles, participants reacted significantly faster to the pedestrian, while simultaneously demonstrating less of a steering deviation. This increase in steering deviation for the high load group may have been a compensation strategy for failing to brake quickly when reacting to the unexpected pedestrian. This suggests that the slow braking reaction required drivers to swerve quickly in order to safely avoid the pedestrian. This is potentially problematic because when tracking load is high, there are likely more cars on the roadway within the vicinity of the driver. Therefore, because a steering deviation is more likely during an unexpected event, the likelihood of a collision with another car concurrently increases.

One plausible explanation for this lack of inattentional blindness and the greater likelihood to adjust steering instead of braking may be a cause of the inability to detect peripheral information within complex environments (Stinchcombe & Gagnon, 2010). Meaning that in the high clutter environments the participant may have missed the ambient environmental information. Work on multiple object tracking has shown similar deficits, such that participants actively suppress distracting information while tracking (Pylyshyn, 2006). This suppression of supposed irrelevant information may be the critical factor that exposes individuals to dangerous situations or parameters while driving.

The amount of clutter in the environment was the factor that caused the greatest discrepancy in overall change in vehicle velocity. This suggests that although drivers in low clutter environments were able to react faster via braking, they also pressed down on the brakes with greater intensity, resulting in an overall larger decrease in velocity. While the complexity of the visual environment plays a role in the ability to detect information, the current experiences and situations of the driver may also play a factor in tracking ability and target detection. Differences have been found between urban and rural landscapes when making driving judgments (Pammer & Blink, 2013). Road familiarity may also play a pivotal role in driving ability (Charlton & Starkey, 2013). Specifically, driving the same route repeatedly (e.g. commuting to and from work) may eventually cause a driver to withdraw attention from their immediate task (Charlton & Starkey, 2013).

Although the load of the MVT task and a high level of environmental clutter may have increased the attentional load of the driving task leading to impaired responses to a critical target, cues in the environment may be able to mitigate these effects. For example, a crosswalk sign could act as a cue to guide attention toward the location of upcoming pedestrians. These cues have been shown to affect the attentional set or expectations of the driver and could thus improve the driver's ability to locate a target quickly (Most & Astur, 2007). Cues could also alert drivers to the time and location of potential

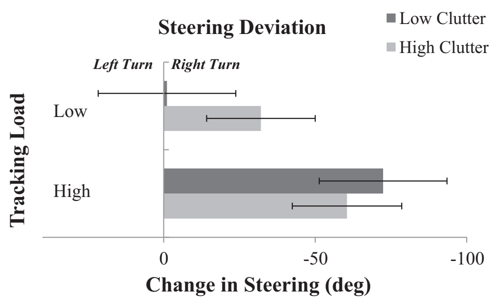

Fig. 7. Average steering deviation in degrees for the experimental groups.

targets, which would aide in improving response time (Posner, 1980; Beck, Hong, van Lamsweerde, & Ericson, 2014). Previous experiences can also serve as cues that alter observers' expectations about the stability of visual information over time and greatly influence their ability to detect a change (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. However, despite the effective use and placement of cues, unexpected events are still potentially likely to occur away from these cues.

When all combined, the data suggests that to increase safety while driving, the roadway environment should take a minimalist approach toward the attentional demands for the driver. This is not a novel concept as it has been well recognized 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 suggests that drivers routinely suppress visual information (Pylyshyn, 2006) when driving and 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 concepts and results presented here should be considered in designing driving environments, particularly paying consideration to the amount of ambient traffic in combination to the amount of irrelevant ambient clutter. However, since it is also recognized that roadway environments are difficult to alter, this type of information can be used to encourage larger headway to promote safe driving behavior.

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