Influence of Taillight Brightness on the Ability to Recognize Closing Speed, Closing Distance, and Closing vs. Separating

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Rear-end crashes contribute to a large percentage of fatal collisions in the United States. However, every rear-end collision cannot be classified as a single type of crash. Some crashes may be caused due to human error while some crashes may be attributed to a human inability to recognize closing speed well. Observers were shown two 4-second video clips of a commercial vehicle closing on a slow-moving vehicle on an unlit highway. The lead vehicle was depicted at distances of 91m (300 ft), 128m (420 ft) and 152m (500 ft). Closing speeds of 40 km/h (25 mph) and 105 km/h (65 mph) were depicted. The taillights on the lead vehicle were randomly shown as bright, or 80% dimmer which is typical of older taillights or aged retroreflective materials. Results showed that observers' ability to recognize closing from separating worsened with increased distance, dimmer taillights and lower closing speeds. Observers perceived brighter taillights to be closer. Also, at greater distances, observers did not recognize closing speeds as well.

INTRODUCTION

A term used when describing the ability to recognize the rate of moving closer to an object is looming. Looming is the rapid expansion of the size of any given object being perceived. This rapid enlargement of the objects triggers an automatic psychological response and one would perceive that they are closing or approaching the object at a certain speed (Gibson, 2014). When driving, if a driver is closing on another vehicle, the size of this vehicle would enlarge or expand in the drivers' field of view. Hence, giving the perception of closing.

According to the Fatal Analysis Reporting System (FARS), there were 9,633 fatal crashes involving a front-to-rear impact between 2011 and 2015 [https://rspcb.safety.fhwa.dot.gov/Dashboard/]. Of these crashes, 2,142 crashes were at or near intersections 3,073 crashes were on interstates. While younger and older drivers account for a greater percent of intersection crashes, their number decreased in interstate crashes. As research has shown young and old drivers to be more prone to making errors (slips, lapses, and mistakes) (Reason, 2000), and they may be more prone to missing important cues that could provide them with more information, predominantly present at intersections.

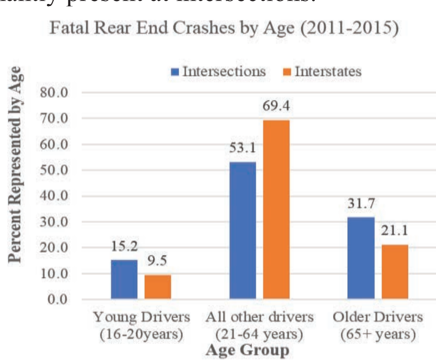

Figure 1: Fatal rear-end crashes classified by age at intersections and interstates

More noticeable was that drivers ages 21-64, who are frequently associated with reduced crash risk, were involved in 16% more interstate crashes compared to intersection crashes. Admittedly, some of the increased number of crashes might be due to different highway use by each age group. However, during high speed closing crashes, environmental cues are limited, which leaves drivers of any age with little more than looming information to learn about the speed of a vehicle ahead.

Young drivers, and old drivers, had similar numbers of fatal crashes at intersections and interstates. Drivers ages 16-20 were involved in 326 fatal intersection crashes compared to 292 fatal interstate crashes. Drivers over 65 were involved in 678 intersection fatal crashes compared to 646 interstate fatal crashes. However, the age group 21-64 had nearly twice as many interstate fatal crashes as intersection fatal crashes (2135 compared to 1138). These data imply that interstate rear end might strain drivers' perceptual abilities.

Several studies have shown that stopped vehicle are comparatively at much greater risk of a crash than are decelerating vehicles. (Knipling et al, 1993; McGehee et al., 1997; Sorock et al., 1996; Dingus et al., 2006). The occurs much later in the event when a lead vehicle is stopped.

When there was a wealth of information to drivers, they responded faster than when there was limited information available to the driver (Muttart, 2003). A stopped vehicle on an interstate might be easily identifiable, but its closing speed is not, particularly when the lead vehicle is stopped (Dingus et al., 2006, Markkula et al., 2016)

Stopped lead vehicles (LV) events involve instances where the following vehicle approaches a stopped vehicle from a long distance. These incidents are different from ones where a constant following distance was maintained until the lead vehicle suddenly decelerates. This lack of ability to recognize closing at larger distances is a key factor in these rear-end collisions (Markkula et al., 2016; Muttart, et al., 2005; Hoffman & Mortimer, Knipling, 1996; Mortimer, 1972, 1990; Summala et al., 1998; Lamble et al., 1999). Humans in general inapt for judging longitudinal distance, velocity, or acceleration of vehicles moving in the same direction at longer distances necessary for safe driving (Gray & Regan, 2000; Markkula et al., 2016).

Drivers have not been able to recognize closing from separating when they were closing on the lead vehicle dangerously fast until at shorter distances (Victor et al., 2015; Lee et al., 2002; Markkula et al., 2016; Terry et al., 2008). To test this, in this paper two different speeds will be used to quantify the effect of relative velocity in drivers' ability to recognize closing speed and distance.

Naturalistic studies were able to amass drivers' on-road behavior in crashes and near crash scenarios when closing on slow moving or stopped lead vehicles (Braunstein & Laughery, 1964; Victor et al., 2015; Markkula et al., 2016; Dingus et al., 2006). Simulator and laboratory studies have also been able to measure closing threshold and looming effect (Muttart, et. al, 2017; Muttart, et al., 2005; Hoffman & Mortimer, 1996; Mortimer, 1972, 1990; Janssen et al., 1976,1977; Fisher & Hall, 1976; Venkatraman, 2017).

The threshold of closing on a vehicle is measured by visual expansion threshold θ. Visual expansion threshold is the rate of growth of a size of an object in an individual's view which may trigger no response, a routine response (lane change), or an emergency response. The subtended angle of an object in a drivers' view is the angular size of an object from the observers' perspectives. The rate change of the subtended angle is used to measure visual expansion. It can be calculated with the following formula:

$$\theta = \frac{w \times V_R}{d^2} \qquad [1]$$

In equation 1, θ is the subtended angular velocity or looming threshold at detection; w is discernible width of the LV; V_R is the relative velocity (speed of the following vehicle minus speed of the LV), and d is the distance between the LV and approaching vehicle at the moment of interest. When discussing discernable width *w*, it is the maximum width of an object that can be easily identifiable and associated with the correct object. At night, if the entire rear of the vehicle is not recognizable, the only cues the driver receives are taillights or any conspicuity enhancing materials.

Other research has reported that presence of lights (running lights) did not result in a significant difference in detection of a change of headway (Fisher and Hall, 1976). While some studies have relied on width of the vehicle, other studies have measured the angular width of the LV, in a term referred to as inverse Tau which is defined as the subtended angle of the LV divided by the change of the angle of the LV (Markkula et al., 2016; Lee et al., 2002).

All other studies indicated that a combination of distance, closing speed and observation time influenced the ability to discriminate closing from separating (Janssen et al., 1976, 1977; Hoffman and Mortimer, 1996; Muttart et al., 2005).

The following experiment is a part of a two-part study to understand how different taillight configurations influence the ability to recognize closing on slower moving vehicles. In the first experiment (Muttart, et. al., 2017) the influence of taillight width on the ability to identify closing from separating and distance was evaluated. The results showed that a wider taillight configuration was more likely perceived to be closer even when the taillight was at the same distance or when as much as 60 m (200 ft) farther away. That study also showed that drivers' ability to discriminate closing from separating decreased with increasing distance.

The main aim of this experiment was to build on the results from the first experiment and obtain a deeper understanding on drivers' ability to recognize both closing distance and closing speed. Again, two different taillight configurations were tested (bright vs. dim) and two different approach speeds (40 kmph vs. 105 kmph) were compared.

Studies in the past have shown higher brightness and higher contrast have aided in depth perception. Relative brightness aided in depth perception but its effect reduced at larger distances (Surdick, 1997). Contrast has been an important cue in depth perception. Objects with higher contrast were perceived to be closer as compared to objects with lower contrast (O'Shea, 1994). Lighter objects when placed farther away appeared to be the same distance as darker objects placed nearer (Farne, 1997). In nighttime driving scenarios, brighter taillights have greater contrast with the dark background as compared to dimmer taillights and can provide better visual cues to an approaching driver. Brighter taillights might also be associated with greater saliency and urgency to respond.

Brightness of taillights can be of concern on older vehicles and vehicles that are prone to pick up dirt which lead to reduced brightness. With the average age of vehicles being driven on the roads increasing every year, there is a large percentage of older vehicles on the roads.

In the current study observers were shown stop motion video clips of closing to final distances of 91 m (300 ft), 128 m (420 ft), and 152 m (500 ft). Two different taillight configurations were used, differentiated by their brightness. One set of the videos had unaltered taillight brightness at all distances and speeds and the second set of videos had taillights that were 80% dimmer than the original taillights. The main goal was to evaluate the effect of taillight brightness on ability to recognize closing distance and speed.

The current experiment builds previously published results. In particular, the methodology and results reported by Hoffman and Mortimer (1996). Hoffman and Mortimer also showed two 4-second video clips in which the observers were closing on a lead vehicle. The study showed closing on lead vehicles at relatively small headways and relative velocities of only 0.54 to 7.23 m/s (1.2 to 16.2 mph). Each of the closing scenarios utilized by Hoffman and Mortimer was typical of an avoidable scenario by the approaching driver.

Lee, Olsen, Wierwille (2003) measured eye glances of drivers closing on slower moving vehicles in a naturalistic study. These glances were recorded for 3 seconds before the participants started to move laterally. Drivers made between 1-2 glances per second and made periodic fixations to the vehicle in front of them. On the other hand, in video studies, drivers are more likely stare and constantly fixate on the lead vehicle and stare, a behavior seldom seen in drivers while driving in a naturalistic setting. In comparison, naturalistic driving exhibits periodic sampling (fixations) and drivers are able to recognize closing speed without direct observation. This is referred to as motion extrapolation (Delucia & Mather, 2006).

To account for periodic fixations typical of drivers when closing on a lead vehicle (Lee, Olsen, Wierwille, 2003), the current study entailed showing the observers eight still images, which are meant to depict fixations timed one half second apart. This methodology forced the observers to make fixations that were not common of observers when watching a video. Periodic still images helped provide a surrogate for these periodic fixations.

In the first part of this study (Muttart, et. al., 2017) the results were similar to those of previous studies for cars with typical taillight separation (Lamble, et al.,1999; Markkula, et al., 2017). The subtended angular velocity threshold for those looking only directly forward at the LV was 0.0044 rad/sec and an inverse Tau of 0.22. These findings suggested that the stop motion styled videos (frame-by-frame) methodology was a good surrogate for real life driving. When applying this methodology, it is important to consider that most drivers are sampling mirrors and the environment periodically during this critical time (Lee et al., 2003) which causes the real-life closing speed recognition threshold to be close to approximately 0.006 rad/sec (Lamble et al, 2000; Muttart et al, 2005).

Hypotheses

1. Observers will recognize closing better at closer distances, brighter taillights, and higher approach velocities
2. Brighter taillights will be perceived to be closer and dimmer taillights will be perceived to be farther away
3. Drivers will be able to discern closing speed better at closer distances than farther

METHOD

Participants

The study had a total of 54 participants. The participants belonged to ages between 20 years and 68 years (Mean= 40.94 years; Std. Dev =12.58 years). All participants held a valid driver license for 1 to 51 years (Mean= 23.8 years; Std. Dev = 13years). 7 of the 54 participants either currently hold or have held a commercial driver license in the past. All participants had normal or corrected to normal visual acuity.

Equipment

A 1994 GMC 1500 4x4 SL pickup was used as the LV. Two lead vehicle conditions were used: 1) The vehicle was equipped with the pickup's original taillights and the were 1.7 m (5.43 ft) apart. 2) The taillights displayed were at the same width but at a lower level of brightness. Post-processing the photographs was performed to display 80% lower luminance value. This was achieved by applying a 50% transparency filter around the taillights and the headlight bloom of the lead vehicle. The retroreflective license plate was left unaltered.

Photographs were taken from drivers' eye position from within a 2006 Kenworth tractor to represent the observer's vehicle. Headlight aim was adjusted in accordance with manufacturer specifications.

A full-frame Nikon DSLR was tethered to a color and luminance calibrated laptop so the photographs would accurately represent the test site. The area was completely dark with no measurable illumination to the test area other than the subject drivers' vehicle headlights.

To best mimic the information offered to a driver, video clips were compiled using the still photographs displayed every 0.5 seconds. These video clips closed to final distances of 91 m (300 ft), 128 m (420 ft), 152 m (500 ft). The distances were chosen based on results from Muttart et. al (2017) which showed reduced ability for drivers to recognize closing beyond these distances. Two relative velocities were used to show approach to the lead car. The slower speed video clips closed at 40 km/h (25 mph) and the faster closing speed was 105 km/h (65 mph). A 105 km/h (65 mph) closing scenario is usually an unavoidable event for most drivers while a 40 km/h (25 mph) event is typically avoidable.

Procedure

The treatments used in the study were two taillight configurations, two speeds and 3 total distances. Hence, a Latin Square Design was incorporated to test every combination of distance and taillight configuration.

Figure 2. Bright Taillights (top) and Dim Taillights (bottom) from same distance of 128 m.

Each participant was shown 24 trials and each trial comprised of two 4-second video clips shown in quick succession. The monitor to eye distance was calculated to represent correct visual angles for their respective distances. The two video clips were separated by a black slide. At the end of each trial the participant would be asked four questions.

1. In the first clip, were you closing (getting closer to) or separating (getting farther apart)?
2. In the second clip, were you closing (getting closer to) or separating (getting farther apart)?
3. In which clip was the lead vehicle closer? (Or were they at the same distance.)

4. In which clip was the closing/separating speed the quickest? (Or were they closing or separating at the same speed.)

For questions 3 and 4, the options were Clip 1, Clip 2, or Same. The participants were then presented with a training video to familiarize them with the videos and questions. Participants were unaware but, in all clips, participants were closing on the lead vehicle. The accuracy of all answers was compared. When correct, the answer was scored a 1 and when incorrect a 0. P(x) is the probability of x outcomes in n independent trials. Binomial comparisons were made utilizing equation 2:

$$P(x) = \frac{n!}{(n-x)!x!} P^2 (1-P)^{n-x} \qquad [2]$$

RESULTS AND DISCUSSION

The ability of participants to recognize closing decreased with respect to all three independent variables. Participants accuracy for questions 1 and 2 decreased with increased distance from the lead vehicle. Similarly, reduced brightness and dimmer taillights decreased the accuracy of recognizing closing. Figure 3 represents the percentage of all participants who recognized they were closing on the lead vehicle.

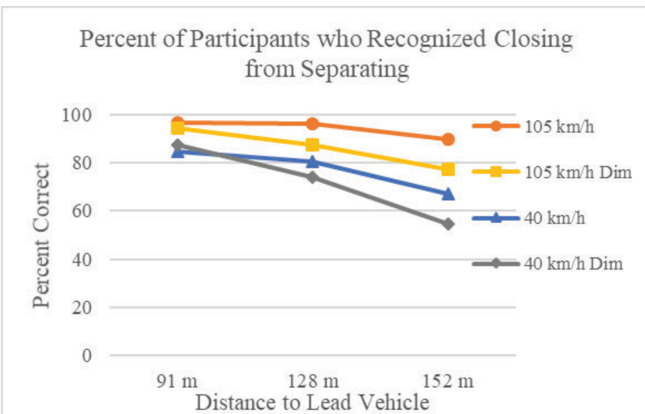

Figure 3. Closing versus separating accuracy when observing closing at different speeds and different taillight brightness levels

The pairwise comparative analysis part of this experiment was conducted to examine participants' perception of distance and speed (Questions 3 and 4). All combinations of distance and speed were compared and the results are as follows. Regarding Question 3 of the experiment, participants were asked to estimate which lead vehicle was closer of the two clips shown in each trial. Participants were accurate when they selected the closer of the two vehicles to be closest to them. With three possible answers, a guess would have a likely accuracy of 33%.

Table 1 represents the results from study where participants perceived the configuration on the left (rows) to be closer than the configurations on top (columns). When comparing trials where both clips were at the same speeds, similar results were represented across these speeds. Indicating that the drivers relied less on the rate of increase in the subtended angle of the vehicle. Participants' accuracy to identify the closer clip was significantly high when comparing clips of the same lighting configuration.

Table 1. Probability of observers who selected clips on the left (rows) to be closer when compared corresponding combinations (with columns) (Significance P < .05 indicated in bold)

				40 kmph			
		91	*128*	*152*	*91 Dim*	*128 Dim*	*152 Dim*
40 kmph	*91*	**0.57**	**0.7**	**0.78**	**0.56**	**0.66**	**0.77**
	128		0.42	**0.62**	**0.58**	0.5	**0.75**
	152			0.31	**0.15**	0.37	**0.76**
	91 Dim				0.31	0.5	**0.68**
	128 Dim					0.42	**0.52**
	152 Dim						0.5
				40 kmph			
105 kmph	*91*	0.31	**0.66**	**0.78**	0.47	**0.93**	**0.87**
	128	**0.21**	0.375	**0.732**	**0.1**	**0.55**	**0.68**
	152	**0.05**	**0.11**	0.43	**0.18**	**0.22**	**0.625**
	91 Dim	0.36	**0.57**	0.29	0.43	**0.66**	**0.75**
	128 Dim	**0.06**	0.35	**0.22**	0.26	0.44	**0.64**
	152 Dim	**0.17**	0.37	**0.12**	**0.05**	0.23	0.43
				105 kmph			
105 kmph	*91*	0.43	**0.85**	**0.82**	0.5	**0.81**	**0.77**
	128		**0.53**	**0.72**	**0.23**	**0.58**	**0.7**
	152			0.35	0.25	0.21	0.44
	91 Dim				0.43	**0.64**	**0.73**
	128 Dim					0.47	**0.55**
	152 Dim						**0.78**

Table 2. Probability of observers who selected clips on the left (rows) to be faster when compared corresponding combinations (with columns) (Significance P < .05 indicated in bold)

				40 kmph			
	(m)	*91*	*128*	*152*	*91 Dim*	*128 Dim*	*152 Dim*
40 kmph	*91*	0.42	0.29	**0.64**	0.37	0.44	**0.72**
	128		**0.05**	0.375	**0.14**	0.33	**0.56**
	152			0.43	0.4	0.25	0.29
	91 Dim				**0.125**	0.31	**0.68**
	128 Dim					0.31	0.36
	152 Dim						0.25
				40 kmph			
105 kmph	*91*	**0.63**	0.46	0.42	0.41	**0.62**	0.375
	128	**0.78**	0.25	0.38	**0.72**	**0.55**	0.31
	152	**0.94**	**0.64**	0.375	**0.75**	**0.55**	0.375
	91 Dim	**0.78**	**0.57**	0.35	**0.56**	0.44	0.5
	128 Dim	**0.87**	0.41	**0.61**	**0.73**	0.44	0.47
	152 Dim	**0.82**	**0.68**	**0.625**	**1**	**0.61**	0.43
				105 kmph			
105 kmph	*91*	**0.13**	**0.21**	**0.76**	0.43	0.5	**0.77**
	128		0.33	0.5	0.41	**0.58**	**0.64**
	152			**0.14**	**0.625**	0.4	0.375
	91 Dim				0.375	**0.21**	**0.59**
	128 Dim					**0.11**	0.52
	152 Dim						0.35

When comparing taillights of different configurations, a significant percentage of participants selected brighter taillights be closer than dimmer taillights even though brighter taillights were at the same distance or at a greater distance then dimmer taillight. Interestingly, when trials consisted of clips at different speeds and different taillight configuration participants' accuracy to recognize the closer vehicle increased across most comparisons. The only deviation from this result was when both clips were at the same distance, where participants did not favor one choice over the other (chance response).

Question 4 of the experiment, participants were asked to estimate which clip they perceived to be closing/separating at a faster rate of the two clips shown in each trial. Table 2 represents the results where participants perceived the configuration on the left (rows) to be faster than the configurations on top (columns). When comparing the trials where both clips shown were at the same speed, clips at 91 m (300 feet) were significantly perceived as moving faster than clips at 152 m (500 feet). This effect was even greater when brighter taillights were at 128 m (420 feet) and dimmer taillights at 152 m (500 feet) away. In other trials participants were equally likely to perceive either clip to be moving faster and resulted in statistically insignificant choices, or chance responses.

When comparing clips at different speeds, participants significantly selected the faster video clip (105 km/h) to be faster than the slower video clip (40 km/h). However, driver's responses had no significance when clips were being compared at greater distances and were reduced to chance probability.

From these results, observers clearly had a difficult time recognizing closing from separating at the lesser closing speed and longer distances. When combined with dimmer taillights, this made the task of recognizing more difficult for the observers. Observers also showed a bias towards brighter taillights being perceived as closer when compared to dimmer taillights. While recognizing closing speed observers perceived themselves to be closing faster in clips where they were closer to the lead vehicle. This is an intriguing result given the large speed difference (65 km/h; 40 mph) between the speeds shown. Observers ability to recognize closing speed also reduced at distances of 152 m (500 feet) and beyond. These results are consistent with those obtained in the first experiment (Mutttart et. al, 2017) and are consistent with the literature. Specifically, observers recognized closing at 0.001 to 0.003 radians/second but did not recognize closing speed until approximately 0.006 radians/second. Furthermore, scenarios where typical taillight information is not available to an approaching driver might further increase the difficulty in recognizing dangerous closing speeds. Future scope of this study includes integrating naturalistic data with these results. It will also aid in recognizing better conspicuity increasing designs and equipment for vehicles, especially under low lighting conditions.

ACKNOWLEDGEMENTS

I wish to thank the following people who assisted in this research:Thomas Vadnais, Ted Perryman, Thomas Schafer.

REFERENCES

Braunstein, M. L., Laughery, K. R., (1964). Detection of vehicle velocity changes during expressway driving, Human Factors, 6, 327-331.

Delucia, P. R., Mather, R. D. (2006). Motion extrapolation of car-following scenes in younger and older drivers, Human factors, 48(4), 666-674.

Dingus, T. A., Klauer, S. G., Neale, V. L., Petersen, A., Lee, S. E., Sudweeks, J., Perez, M. A., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z. R., Jermeland, J., and Knipling, R. R. (2006). The 100-Car Naturalistic Driving Study, Phase II - Results of the 100-Car Field Experiment DOT HS 810 593. NHTSA, USDOT.

Farnè, M. (1977). Brightness as an indicator to distance: relative brightness per se or contrast with the background? Perception, 6(3), 287-293.

Fatality Analysis Reporting System [FARS]. (2012). (National Highway Traffic Safety Administration) Retrieved March 11, 2017, from http://www.nhtsa.gov/people/ncsa/fars.html

Fisher, A. J., & Hall, R. R., (1978). The effect of presence lights on the detection of change of headway, Australian Road Research, 8, 13-16.

Gray, R., & Regan, D. (2000). Risky driving behavior: A consequence of motion adaptation for visually guided motor action, Journal of Experimental Psychology: Human Perception and Performance, 26, 1721 – 1732.

Gibson, J. J. (2014). The ecological approach to visual perception: classic edition. Psychology Press.

Hoffmann, E. R. & Mortimer, R. G. (1996). Scaling of relative velocity between vehicles. Accident Analysis and Prevention, 28, 415-421.

Janssen, W. H. (1977). Driver's inability to judge important parameters of leading vehicle movement at night. (Technical paper # 770129). Warrendale, PA: Society of Automotive Engineers.

Janssen W H, Michon J A, Harvey L. O. Jr. (1976). The perception of lead vehicle movement in darkness. Accident Analysis and Prevention, 8, 151–166.

Knipling, R., Mironer, M., Hendricks, D., Allen, J., Tijerina, L., Everson, J., & Wilson, C. (1993, May) Assessment of IVHS countermeasures for collision avoidance: Rear-end crashes. Final Report (Report No. DOT HS 807 995). Washington, DC: NHTSA

Lamble, D., Laasko, M., & Summala, H. (1999). Detection thresholds in car following situations and peripheral vision: implications for positioning of visual demanding in-car displays, Ergonomics, 42, 807-815.

Lee, S. E., Olsen, E. C. B., Wierwille, W. W. (2003). A comprehensive examination of naturalistic lane-changes. (Technical paper DOT HS 809 702). Washington, DC: NHTSA.

Lee, J. D., McGehee, D. V., Brown, T. L., Reyes, M. L. (2002). Collision warning timing, driver distraction, and driver response to imminent rear-end collisions in a high fidelity driving simulator, Human Factors, 44, 314-344.

Markkula et al., (2016). A farewell to brake reaction times? Kinematics-dependent brake response in naturalistic rear-end emergencies, Accident Analysis and Prevention, 95, 209-226.

McGehee, D.V., T. Brown, and T. Wilson (1997). Examination of drivers' collision avoidance behavior in a stationary lead vehicle situation using a front-to-rear-end collision warning system. USDOT/NHTSA Office of Crash Avoidance Research Technical Report.

Mortimer, R. G. (1972). Weber's Law and Rear End Collisions, Michigan Academian, 4, 99-105.

Mortimer, R., G. (1990). Perceptual factors in rear end crashes, Human Factors Society 34th Annual Meeting, (pp.591-594). Santa Monica, CA: Human Factors & Ergonomics Society.

Muttart, J. W., Dinakar, S., Suway, J., Kuzel, M., Gernhard, S., Rackers, M., Schafer, T., Vadnais T., & Fischer, J. (2017, September). Influence of Taillight Width on the Ability to Recognize Closing Speed, Closing Distance, and Closing versus Separating. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting

Muttart, J. W. (2003). Development and evaluation of driver perception-response equations based upon meta-analysis, (Technical paper no. 2003-01-0885). Warrendale, PA: Society of Automotive Engineers.

Muttart, J. W., Messerschmidt, W., & Gillen, L. (2005). Relationship between Relative Velocity Detection and Driver Response Times in Vehicle Following Situations (Technical paper No. 2005-01-0427). Warrendale, PA: Society of Automotive Engineers.

O'Shea, R. P., Blackburn, S. G., & Ono, H. (1994). Contrast as a depth cue. Vision research, 34(12), 1595-1604.

Reason, J. Human Error: Models and management, Western Journal of Medicine. 2000 Jun; 172(6): 393–396.

Sorock, G. S., Ranney, T. A., Lehto, M. R. (1996). Motor vehicle crashes in roadway construction workzones: an analysis using narrative text from insurance claims, Accident Analysis and Prevention, 28, 131-138.

Summala, H., Lamble, D., & Laakso, M. (1998). Driving experience and perception of the lead car's braking when looking at in-car targets, Accident Analysis & Prevention, 30, 401-407.

Terry, H. R., Charlton, S.G. and Perrone, J.A. (2008). The role of looming and attention capture in drivers' braking responses. Accident Analysis and Prevention, 40(4), 1375-1382.

Victor, T., Dozza, M., Bärgman, J., Boda, C.-N., Engström, J., Flannagan, C., Lee, J. D., Markkula, G. (2015). Analysis of Naturalistic Driving Study Data: Safer Glances, Driver Inattention, and Crash Risk SHRP 2 safety project SO8. Washington, D.C.: Transportation Research Board of the National Academy of Sciences. ISBN: 97

Surdick, R. T., Davis, E. T., King, R. A., & Hodges, L. F. (1997). The perception of distance in simulated visual displays: A comparison of the effectiveness and accuracy of multiple depth cues across viewing distances. Presence: Teleoperators & Virtual Environments, 6(5), 513-531