SPEED AND GAP CONTROL DURING SIMULATED CAR FOLLOWING: EFFECTS OF DISPLAYS AND FOLLOWING DISTANCE

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Authorization to Submit Thesis

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Abstract

In a single experiment, I investigated the effects of displays, following distance, and lead vehicle size on a following driver's ability to detect and efficiently respond to decelerations of a leading vehicle. My aim was to compare a novel deceleration display to traditional brake lights in aiding following drivers in responding safely and efficiently to non-constant lead vehicle decelerations. The experiment found that both brake lights and a deceleration display improve the initial detection of lead vehicle deceleration as compared to no display or brake lights, but that the deceleration display also improved magnitude scaling of deceleration, as evidenced by higher correlations between lead and following vehicle trajectories, less extreme braking behavior, and higher minimum speeds. Theoretically, these improvements in the scaling of deceleration responses could increase the efficiency of traffic flow by reducing the tendency to over-react to lead vehicle decelerations, while still allowing drivers to maintain a safe gap. These results suggest that a deceleration display can afford more regulated deceleration responses in following vehicles, increasing both safety and efficiency of traffic flow.

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I would like to first thank Brian Dyre for his continuing guidance over me in this project and his patience with my many questions. His high standard for me and my research made me work harder and more thorough then I ever have before and has made me the researcher I am today. I would also like to thank beyond words Roger Lew for his hours and hours of help with me on the protocol and data reduction. Roger made the ungraspable seem understandable to me. I would also like to thank my committee members Steffen Werner and Ahmed Abdel-Rahim for their continued support and interest. Special thanks go out to Katrina Colby, Connor Hoover, Nolan Boyle, and Soul Teng for their help with data collection and literature work. A solemn thanks goes out to Nash Stanton and the late Ernesto Bustamante for getting me starting with this work that Dr. Dyre and I have taken to amazing new focuses and findings.

Dedication

I would like to dedicate this manuscript and my time here at the University of Idaho to my close immediate family. My big sister Sheldy, you have always been a great role model for me in my work ethic and always having an end goal in sight. I could not have the will power and determination I do without your unwavering example. To my amazingly strong-hearted father Shelby, you are the best friend I could ever imagine. You have set the standards I am as a man and for that I am forever indebted to you. You have molded me into the person that lives and breathes today, one that works with 110% of what I have to offer, holding nothing back. And finally to my late mother Vicki, I love you mom. You are what gets me through the times when I think I should quit trying. Making you proud is my #1 priority in life. I would be nowhere if it weren't for you three. You define who I am and how I carry myself. You have built in me the undeniable lesson that prompts my every thought and action: **Hope Guides Us**!!

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CHAPTER 1: Introduction

Speed and Gap Control During Simulated Car Following: Effects of Displays and Following Distance

Rear-end collisions account for between 25% (Gilling, 1997) and 40% (McKnight, Shinar, & Reizes, 1989) of highway traffic accidents. These collisions likely result from drivers following too closely to accommodate emergency decelerations, drivers not correctly perceiving the deceleration of the vehicle ahead, or some combination of these factors. Most motoring authorities advise a minimal following distance of one to two seconds between lead and following vehicles (Young & Stanton, 2007). Given that brake reaction times can be as short as 384 ms, including *lift time*—the time to lift the foot from the accelerator—a one-to-two second following distance should generally provide ample time to stop safely, but *only if* drivers can reliably detect the deceleration of a lead vehicle (Lei et al., 2007). The high rate of rear-end collisions suggests that either drivers are not maintaining a safe following distance or are not reliably detecting lead vehicle deceleration. Anderson, Cisneros, Atchley and Saidpour,(1999) concluded that errors in detection and scaling of the magnitude of a leading vehicle’s deceleration are likely the most important factors causing rear-end collisions.

Safe and efficient car following requires the driver to not only detect the onset of deceleration but also to scale that deceleration in order to respond optimally. The most fundamental form of optical information for detecting and scaling decelerations is the expansion pattern created as a one moves toward a decelerating vehicle. Lee (1976) suggested that the time to contact (TTC) for an approaching object is directly specified by the size-scaled rate of optical expansion of the object, an optical invariant he referred to as tau. However, while in theory tau specifies the time until contact, the human visual system does not appear to perceive tau reliably (Swanston & Gogel, 1986). Moreover, TTC information such as optical expansion, relative size, static optical flow cues does not always accurately indicate vehicle deceleration and closing distance (Morita, Sekine & Okada, 2006). Indeed, our inability to perceive a vehicle in front of us decelerating based on its optical expansion rate is why supplemental information from brake light displays is required for reliable braking (Surdick & Davis, 1997).

Brake lights have served as a reliable aid to detection of lead vehicle braking since the early 1900s and have become even more effective in reducing the incidence of rear-end collisions since the implementation of the high mounted display in 1974 (Morita, Sekine & Okada, 2006). Standard brake light displays have two-states: on or off. Such displays inform drivers that the vehicle in front of them is braking, but because they do not convey how quickly the lead vehicle is decelerating, drivers must rely solely on optical expansion information for controlling the magnitude of their own braking response (Hoffman & Mortimer, 1996). Misperceiving a high-magnitude deceleration may therefore result in inadequate braking and a rear-end collision. On the other hand, over-braking to low magnitude decelerations leads to inefficient traffic flow and increases congestion. There are even cases where the brake lights provide inaccurate information. For example, consider a case where, rather than braking, a driver lifts his or her foot from accelerator. Wind and rolling resistance decelerate the vehicle but no brake lights are illuminated. Alternatively, a drivers might “ride the brake” with their left foot while depressing the accelerator with their right foot. For both of these situations the brake lights are providing erroneous information.

Clearly, employing the proper magnitude of deceleration is essential to safe and efficient motoring, yet currently we have no vehicle displays that aid in perception of this critical information. The need for an improved deceleration display is evidenced by the 157 million vehicle hours of delay caused by crashing incidents (Lee, McGehee, Brown, & Reyes, 2002; Chung, Song, Hong, Kho, 2005). The purpose of this thesis was to examine the potential of a deceleration display in a car following task for improving safety and efficiency. To this end, I will first review previous research on braking control that has identified different braking strategies. Following this review I will discuss some factors that affect how humans can use optical expansion to estimate deceleration rates. Finally, I will describe a novel deceleration display. At the conclusion of this introductory information I will describe a single experiment that compared the safety and efficiency of our deceleration display to traditional brake lights.

Common Braking Strategies

Yilmaz and Warren (1995) identified three braking strategies used by drivers in simulations of stopping short of a stationary obstacle. Some drivers appeared to minimize approach time by using a *slam-on-the-brakes* control strategy where a zero or low initial deceleration is followed by a rapid increase to maximum deceleration. Other drivers used a *bang-bang* strategy which minimizes collision risk by initially over-estimating the required deceleration and then letting off the brake to a lower magnitude. A third *regulated* strategy was also identified in which moderate and frequent braking adjustments are made. Of the three strategies, the regulated strategy comes closest to maintaining a constant magnitude of deceleration. Using a similar obstacle approach task, Fajen (2005) found that braking strategies are influenced by an interaction between optical factors and control dynamics suggesting that solely using optical information is inadequate for efficient following.

Braking in response to a brake light display has been shown to be more accurate than that responding based on optical expansion alone (Morita et al., 2006). In general, brake displays afford earlier deceleration detection and a more regulated (constant deceleration) braking strategy, which is critical for both safety and efficiency to be optimized. Hope, Lew, Colby and Dyre (2012) found that when brake displays are omitted, drivers more often use a slam-on-the-brakes (technically, *monotonically increasing deceleration*) strategy rather than a regulated (*near constant deceleration*) or a bang-bang strategy (initial high deceleration followed by decreasing deceleration) in response to variable decelerations of a vehicle (see Figure 1). They found higher cross correlations between lead and follow vehicle trajectories occurred when the lead vehicle monotonically increased its deceleration magnitude over time, as compared to constant or decreasing decelerations.

Though brake lights reduce the need for emergency braking, at times they can also induce braking that is more urgent than necessary. The phenomenon of traffic compression waves on busy highways illustrates that when dense traffic slows, a chain reaction occurs where each succeeding following vehicle brakes just a little more than is needed for safe gap maintenance, until eventually traffic is brought to a full stop. If this over-reaction could be mitigated by quick detection of the magnitude of deceleration of a leading vehicle, following vehicles should be able to slow just enough to maintain a safe gap and therefore maintain a higher minimum speed and improving traffic flow.

Factors that Complicate Detection and Scaling of Deceleration

The perception of lead vehicle deceleration from optical information can be complicated by vehicle size and shape, which have been shown to affect our ability to estimate TTC. At times a lead vehicle may partially block a following driver’s view and in turn removes cues that help in deceleration estimation (Harb, Radwan, Yan, & Abdel-Aty, 2007). Judgments are influenced by varying non-tau sources of information, such as vehicle size, and how that size change is perceived. (DeLucia, 2005). Specifically, such judgments are influenced by the pictorial depth cue of relative size (DeLucia, 1991a; DeLucia & Novak, 1997). The considerable variation in vehicle size undermines our ability to reliably estimate TTC and the magnitude of vehicle deceleration.

Further, driving behaviors of consecutive drivers are not independent, the behavior of the following driver has been shown to depend on characteristics of the lead vehicle (Ossen & Hoogendoorn, 2011). For example, trucks and sport utility vehicles are less likely to be hit in a rear end collision due to their increased size over smaller sedans (Harb, Radwan, Yan, & Abdel-Aty, 2007).

The very act of moving makes detecting the optical information for lead vehicle decelerations more difficult (DeLucia & Meyer, 1999). Compared to a stationary observer, such as a person standing on a sidewalk, observers in motion, such as someone driving a car, have greater difficulty in detecting object motion (DeLucia & Meyer, 1999). Ironically, the self-motion cues that allow drivers to accurately control their own vehicle (Reymond & Kemeny, 2000) can mask the motion defining a lead vehicle's deceleration and interfere with a driver's ability to detect and scale the deceleration.

Another critical issue in detection and scaling of lead vehicle deceleration is following distance. Wang, Chen, and Hu (2012) found that depending on the driving environment, drivers varied their following distance around the "rule of thumb" two seconds, following more closely in familiar environments/situations and much further away in riskier or abnormal driving environments/situations (Wang, Chen, & Hu, 2012). Cho and Lo (2002) concluded that velocity, traffic flow and motion all affect the choice of following distance. Hope et al. (2012) presented drivers a simulation of following a car with no brake lights undergoing a series of non-constant decelerations and found that even though participants were instructed to follow at a two second following distance, they chose to follow more closely. This result was unexpected since following at a further distance would afford a greater margin of safety. Hope et al. (2012) suggested that the decreased following distance could be due to the fact that following more closely increases the saliency of optical information for detection and scaling of deceleration. Thus, drivers may have been following more closely to amplify the optical information indicating deceleration of the lead vehicle.

Deceleration Displays

The primary goal of this thesis is to determine if displays specifically designed to communicate vehicle deceleration rates to following drivers afford better scaling of lead vehicle deceleration than traditional two-state brake lights and thus promote safer and more efficient traffic flow. There are a two important differences between brake lights and a deceleration display. First, deceleration displays are based on the magnitude of vehicle deceleration, as measured through an accelerometer, rather than the state of the brake pedal, that may or may not be accompanied by actual vehicle deceleration. Second brake lights have only two states, on or off, while a deceleration display could have many states to more accurately provide information about the magnitude of deceleration. The Idaho Visual Performance Laboratory (IVPL) has developed a prototype deceleration display comprised of a horizontal row of 22 lights mounted across the rear of the vehicle that convey 10 levels of deceleration magnitude (Hope, Lew, Boyle, Stanton, Dyre & Bustamante, 2011; Stanton, Lew, Boyle, Hope, Dyre, & Bustamante, 2011; See Figures 2 and 3). When a car begins to slightly decelerate the brake lights illuminate along with the middle and extreme left and right lights in the deceleration display. As deceleration increases, additional lights in the deceleration display illuminate, spreading from the center of the vehicle out to the corners (See Figure 4). This spreading creates a symmetrical expansion similar to the optical looming effect of an approaching object (Li & Milgram, 2008). We expect the looming effect may help capture attention more efficiently than the onset of brake lights alone. By coding 10 increasing rates of deceleration, the display is designed to provide following drivers with a more accurate sense of how urgent a response is needed so they can better scale their response. When only a few elements of the deceleration display are illuminated a following driver will know that only a slight deceleration is occurring. When a following driver sees all the deceleration display lights illuminate, they know the car ahead of them is slowing rapidly in an emergency stop. Two-state brake light displays (see Figure5) do not convey such deceleration information, leaving following drivers to judge the magnitude of deceleration based on the movements of the vehicle, which can be difficult to detect.

Experimental Rationale

To determine whether the deceleration display actually does allow more accurate and efficient braking performance in a car following task I conducted a simulation experiment. The experiment used a low-fidelity simulation of driving down a straight highway following a single car undergoing a series of non-constant decelerations. To account for differences in optical information resulting from larger and smaller vehicles, I varied the size of the lead vehicle by simulating following a sedan (Figure 2) or a pick-up truck (Figure 3). To examine how following distance affects our ability to use optical information for detecting deceleration I varied the initial following distance (and instructions) to induce drivers to maintain either a one- or two-second gap. In addition to these variables, I varied the type of display carried by the lead vehicle: a) no display (neither brake lights nor a deceleration display), b) traditional brake lights, and c) the IVPL's deceleration display.

Participants drove the following vehicle in the simulation, and the experiment measured their response times for lifting their foot from the accelerator and applying the brake, their braking magnitude, and the speed and deceleration profile of the following vehicle. I expect that the deceleration display should provide equal or better initial detection of lead vehicle deceleration as evidenced by response times. In addition, if the deceleration display supports better scaling and regulation of braking responses than traditional braking displays, then deceleration profiles of the following vehicle should more closely match those of the lead vehicle as measured by higher cross-correlations. In addition, the more regulated response afforded by the deceleration display should increase the minimum of speed of following vehicles over traditional brake lights.

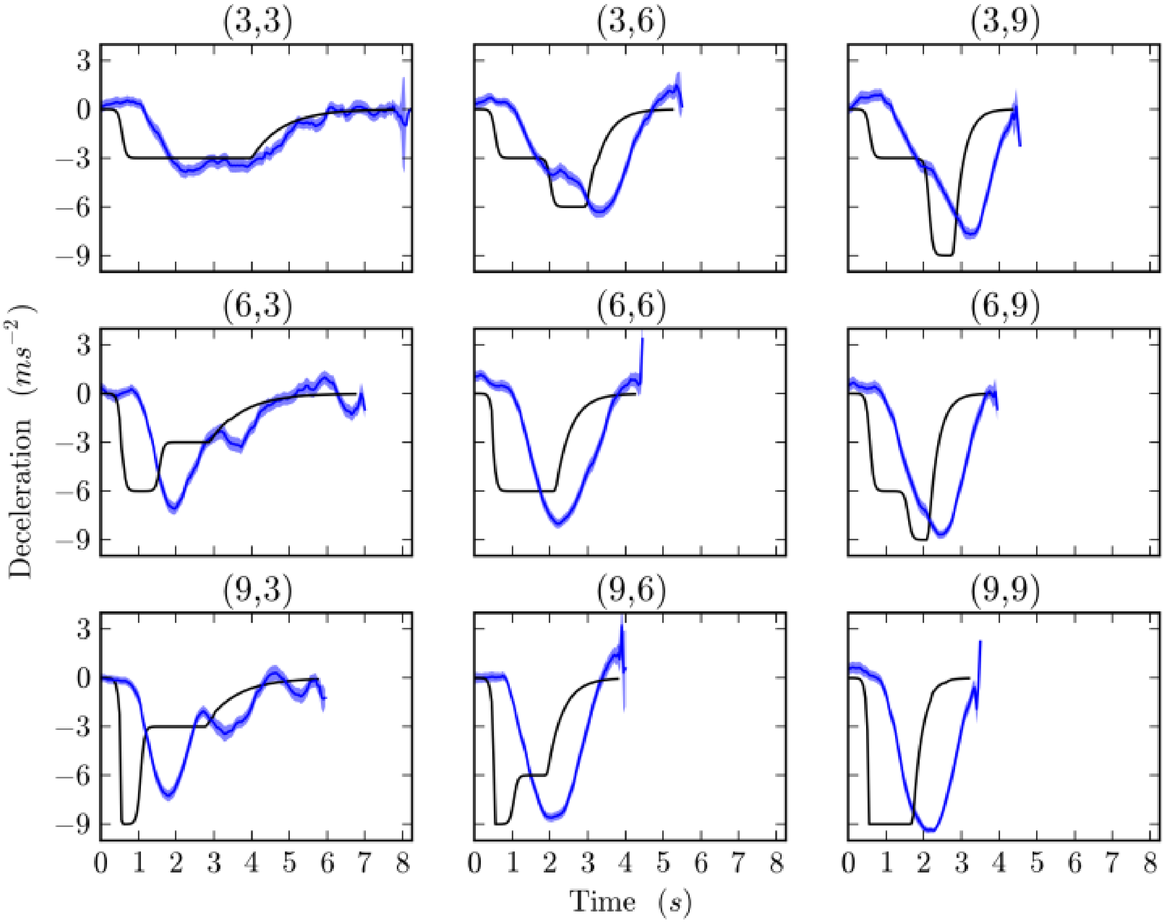

Figure 1. Averaged deceleration responses to the nine unique lead vehicle breaking events by phases. Numbers in parentheses represent Phase 1 and Phase 2 deceleration magnitudes in ms-2. The dark blue lines represent the mean deceleration of the following (controlled) vehicle averaged across all trials and participants, the black lines represent the deceleration of the lead vehicle. The light blue shaded area represents +/- 1 standard error of the mean.

Figure 2. Rear view of sedan with array of unlit deceleration display lights.

Figure 3. Rear view of truck with array of unlit deceleration display lights.

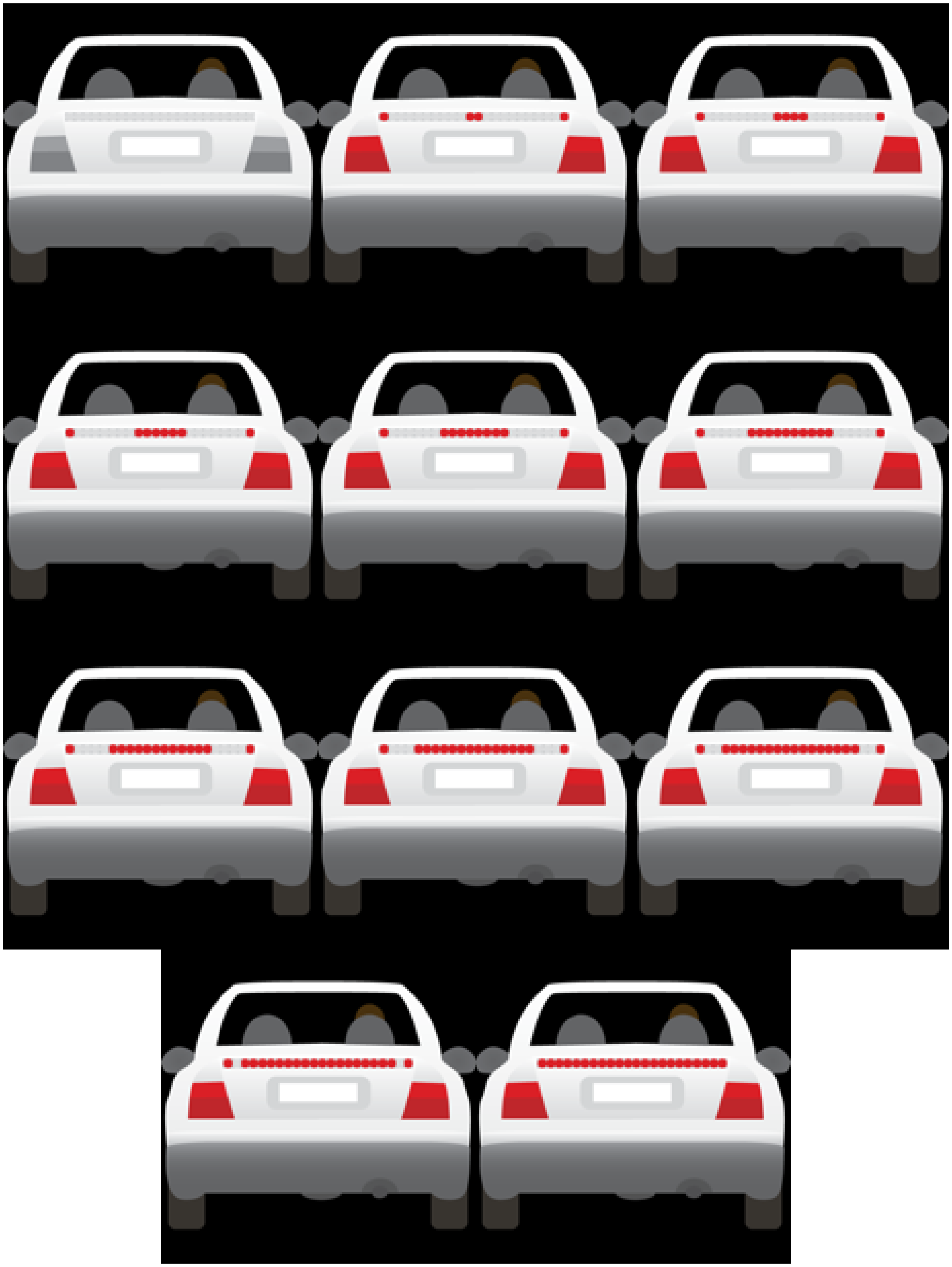

Figure 4. Depiction of the eleven possible states of the deceleration display on the sedan

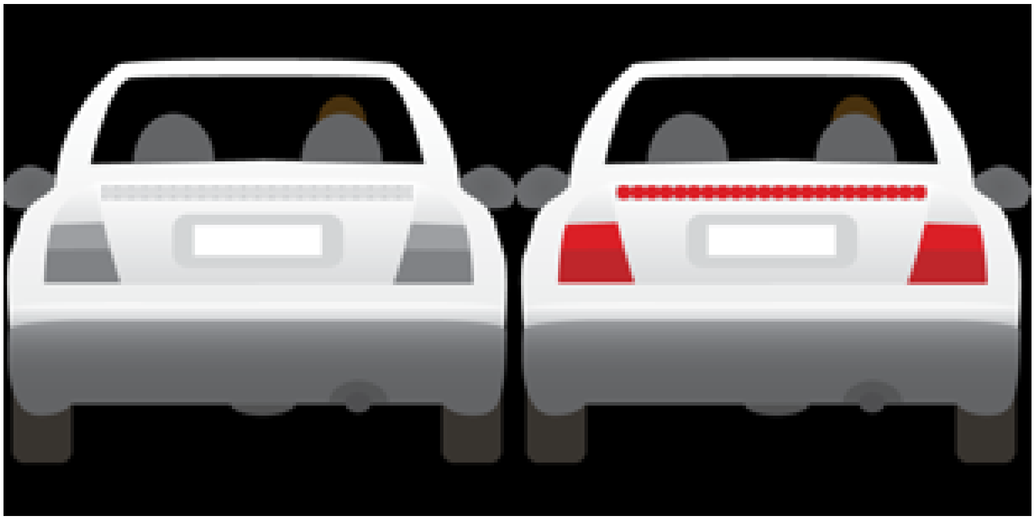

Figure 5. Depiction of the two possible brake display states on the sedan.

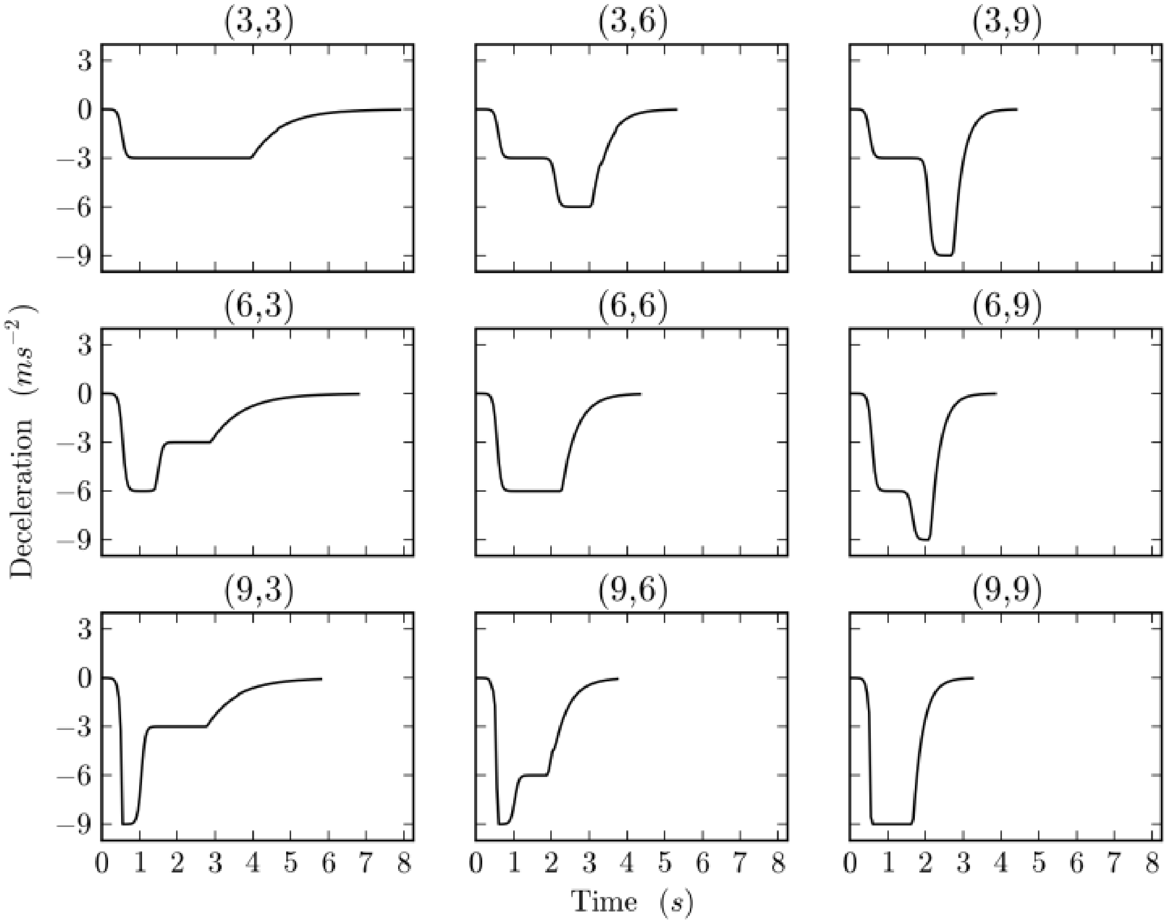

Figure 6. Profiles of the nine unique lead vehicle breaking events by phases. Numbers in parentheses represent Phase 1 and Phase 2 deceleration magnitudes in ms^{-2}.

CHAPTER 2: Method

Participants

We recruited 24 participants from the University of Idaho's psychology participant pool whom received class extra credit as incentive for participation in the study. All participants held a valid driver's license at the time of the experiment and were screened for 20-30 or better Snellen acuity while wearing their normal corrective glasses or contact lenses. The University of Idaho's Institutional Review Board approved the experimental protocol, which treated all participants in accordance with the ethical principles outlined by the American Psychological Association (APA). Participants ranged in age from 18 to 37 years old.

Stimulus and Apparatus

Participants viewed stimuli simulating forward self-motion over a straight and level textured roadway that included a broken amber center line and white side lane markers. The 7.5 m wide roadway was surrounded by a ground plane covered with a grassy texture. One meter tall reflector posts were placed every 300m along both sides of the roadway. The front hood of the participants' vehicle was simulated at the bottom of the display. The simulations placed a lead vehicle in front of participants that varied in size (Sedan or Truck; 64" and 81" simulated real world widths respectively) across trials. Variation in lead vehicle size was used to help reduce the effectiveness of optical motion cues for detecting the lead vehicle's dynamics.

Each trial started with both the lead vehicle and the participant's vehicle moving forward at 30 ms^{-1} with the participant's vehicle following at a distance of either 60 m (2s interval) or 30 m (1s interval). The initial 10 seconds of each trial served as a preview period during which both the lead and following vehicles moved at constant velocity (control inputs were turned off). After the initial 10 second preview period the lead vehicle completed a total of nine braking events randomly distributed over the remaining 330s of the trial. For these braking events the lead vehicle decelerated from 30 to 5 ms^{-1} before then accelerating back to 30 ms^{-1}. The nine braking events each contained a unique deceleration profile, defined by two phases in which the deceleration magnitudes were be 3, 6, or 9 ms^{-2} in each phase. Transitions between different deceleration levels were ramped according to the following logistic function, where MDLV represents the maximum (steady-state) deceleration of the lead vehicle for each phase:

$$l(t) = \frac{MDLV}{1 + \exp(-10(t - .5))}$$

Participants viewed the stimuli bi-ocularly while seated in a dark room 1.5 m from a 60 Hz CRT rear-projection screen. The screen subtended a visual angle of 45 by 34° (H x V). A dedicated graphics workstation rendered the simulations at a spatial resolution of 1280 x 1024 pixels (H x V) and frame rate of 30 Hz using the ViEWER 2.23 software package (Dyre, Grimes & Lew, 2007). The simulated eye-height of the viewpoint was 1.5 m.

To control the simulated vehicle, the participants used a Microsoft PC gaming steering wheel and foot operated accelerator and decelerator. The steering wheel controlled yaw with first-order control dynamics, $20°s^{-1}$ of gain at full deflection and an exponential lag with 0.1s time constant. The foot pedals controlling braking and acceleration with second order control dynamics, full-deflection gains of 10 ms^{-2} and zero lag. The speed of the participant's vehicle was constrained to a minimum of 0 and a maximum of 35 ms^{-1}. To simulate wind and rolling resistance, the vehicle exhibited a constant drag of $-2ms^{-2}$ which required the driver to depress the accelerator slightly to maintain constant forward velocity.

Rationale and Research Design

The experiment examined how the external characteristics (size, displays) and acceleration dynamics of a lead vehicle affect the behavior of following drivers in a simulated car-following task. We employed a 2 x 2 x 3 x 3 x 3 x 3 mixed factorial design. Within-subjects factors included: a) lead vehicle size (sedan or truck), b) initial following distance (one or two seconds), c) the magnitude of lead vehicle initial (Phase 1) deceleration (3, 6, 9 ms^{-2}), d) the magnitude of lead vehicle secondary (Phase 2) deceleration (3, 6, 9 ms^{-2}), and e) replicate (1, 2, 3). The lone between-subjects factor was the type of lead vehicle display (traditional brake lights, deceleration display, or no display). Over two sessions of testing, each participant experienced a total of twelve trials, six during session one, and six during session two. Within each trial, participants experienced nine lead vehicle deceleration episodes with unique profiles created by factorially combining the three levels of Phase 1 and Phase 2 decelerations (see figure 5). To control for order and carry-over effects the order of presentation for these nine deceleration profiles was determined randomly for each participant. To reduce confusion, we blocked the manipulation of initial following distance across the two experimental sessions, with the order of initial following distances counter-balanced. Within each session participants experienced 3 replicates of each of the two lead vehicle sizes, ordered using blocked randomization. The two sessions of the study were separated by a two day window.

Our measures aimed to assess the effects of these manipulations on following drivers' abilities to rapidly detect the onset of a deceleration episode and appropriately scale the magnitude of their braking response to the dynamics of the lead vehicle to maintain a safe gap without braking unnecessarily severely. Two of our measures reflected the ability of participants to detect deceleration onset: response time for lifting the foot from the accelerator, and initial braking response time, both measured from the start of the lead vehicle's deceleration. Three measures reflected participants' ability to maintain a safe gap during the deceleration episode: number of collisions, minimum following distance and average following distance. Four measures reflected participants' abilities to appropriately scale the magnitude of braking during a deceleration episode: a) cross correlations between the lead and following vehicle deceleration profiles (scaled between -1.0 and 1.0, these correlations indicate how well the participant matched the deceleration profile of the simulated lead vehicle with a constant time lag), b) initial brake gain—the first peak gain approached monotonically, c) maximum brake gain, and d) minimum speed. We used one additional measure, following distance at deceleration onset, to check that participants maintained the appropriate following distance as instructed.

Procedure

Eight of the 24 drivers were randomly assigned to each of the three display conditions. Prior to testing, drivers read and signed the consent forms and were screened for 20-30 Snellen acuity. We then instructed drivers verbally to focus on the first ten seconds of each trial, which demonstrated either a two- or one-second following distance (dependent on a counter–balanced order and day of participation), and to maintain that following distance throughout the trial. To familiarize drivers with the vehicle dynamics the drivers first completed a practice trial, selected at random from the set of experimental trials. Questions about the experimental procedure were addressed during this practice trial. Participants were given a 2-4 minute break every 3 trials or 16.5 minutes. Following the experimental trials, drivers filled out a debriefing form. Testing generally was completed in less than fifty minutes per session.

CHAPTER 3: Results and Discussion

For each dependent variable a 2 x 2 x 3 x 3 x 3 x 3 (Car Type x Following Distance x Replicate x Phase 1 deceleration magnitude x Phase 2 deceleration magnitude x Technology) mixed ANOVA was performed. The Greenhouse-Geisser correction was applied to all estimates of type I error probability to correct for violations of sphericity. For each of the dependent variables, all statistically reliable main effect and interactions with a corrected probability less or equal to $\alpha = .05$ are reported below.

Detecting Deceleration Onset

Drivers took significantly longer to initially depress the brake, *F* (2, 23) = 4.80, *p* < .05, η_G^2 = .076, observed power = .34 when following a vehicle that had no display (*M* = 2.42s, *SE* = .05) versus a vehicle with a display. When following a vehicle with brake lights or the deceleration display, reaction time was reliably reduced (*M* = 1.91s, *SE* = .05 and deceleration display *M* = 1.84, *SE* = .03, respectively), though the difference between displays was not significant, *p* > .05. The deceleration display also showed a higher lift response time, (*M* = .85s, *SE* = .05) than did the brake display (*M* = .58s, *SE* = .04), with the highest seen in no display (*M* = .92s, *SE* = .03), *F* (2,23) = 476.97, *p* < .05, η_G^2 = .269, observed power = .32. The longer lift response time suggest a less extreme response when following vehicles with the deceleration display.

Maintenance of a Safe Following Distance

Maintenance of a safe following distance is reflected by three measures: collision frequency, average following distance, and minimum following distance. Collisions occurred nearly five times as often when displays were absent and following drivers relied only on optical variables for controlling deceleration, as compared to following vehicles with traditional brake lights or the deceleration display (see Tables 1 and 2). Following distance also affected collision rate, with more collisions occurring at 1s following distances than 2s (see Tables 1 and 2). Chi-square goodness of fit tests found both of these differences in collision rates to be reliable (See Table 1), though the result for following distance must be interpreted with caution because this variable was manipulated within-subjects and therefore violates the independence assumption of the chi-square goodness of fit test. It is also important to note that 22 of the 28 collisions for the 1s following distance occurred when the phase 1 deceleration of the lead vehicle was at its highest level, 9 ms^{-2} and 18 of those 22 collisions occurred for the no display group. This collection of collisions at the highest phase 1 deceleration magnitude suggests that the 2s rule of thumb following distance may help reduce collision incidence, particularly when brake displays are disabled (See Table 2).

The drivers following the deceleration display had an overall lower minimum following distance, F (1, 21) = 55.91, $p < .05$, η_G^2 = .031, observed power = .08 (M = 18.53m, SE = .31) compared to the brake display (M = 20.73m, SE = .37; See Table 3). When average following distance was analyzed across replicates, I found that the following drivers proceeded to get closer as their trials went on (M = 28.16m to M = 27.43m to M = 26.72m) (see Table 4). As seen in Figure 8, replicate had little effect on average following distance when drivers followed at 30 m (a 1s gap, left panels); however, when following at 60 m (a 2s gap; right panels), average following distance decreased with each replicate, and was overall lowest for the deceleration display. This decrease in average following distance likely reflects drivers learning to use the deceleration display to avoid slowing down more than necessary.

Minimum following was reliably affected by Car Type, Display, and the magnitude of the Phase 2 lead vehicle deceleration (See Table 3). On average, closer minimum distances were found for following the sedan as compared to the pick-up truck, which suggests the size of a vehicle is used as a cue for regulating braking. The deceleration display also showed closer minimum following distances than the brake display, though these distances were still safe and did not significantly increase the frequency of collisions. Finally, greater phase 2 deceleration rates resulted in closer minimum following distances, which one would expect given that the lead vehicle is slowing more quickly.

Appropriate Scaling of the Magnitude of Braking

To assess whether the deceleration display aided drivers in appropriately scaling the magnitude of their braking response I will first discuss the results for the measure of maximum brake gain before turning to the measures of initial brake gain, cross-correlations in lead and following vehicle trajectories, and minimum speed.

As seen in Tables 5 and 6 and Figure 7, when following a vehicle with either brake lights or a deceleration display, drivers showed significantly lower maximum brake gain, $F(2,23) = 6.36$, $p < .05$, $\eta_G^2 = .142$, observed power = .43, (brake display $M = -8.78$ ms^{-2}, $SE = .06$; deceleration display $M = -8.74$ ms^{-2}, $SE = .05$) than when no display was present ($M = -9.73$ ms^{-2}, $SE = .03$). This effect was particularly pronounced at lower levels of lead vehicle deceleration that call for a more moderate braking reaction. These lower maximum brake gains suggest that the deceleration display and brake lights were equally effective in alerting drivers to a slowing lead vehicle and allowed them to avoid the slam-on-the-brakes response found with no display (see also, Hope et al., 2012). Further, no reliable difference in brake gain was found between the brake display and deceleration display, just the scaling improvement from display to non-display. In contrast, drivers following vehicles without a display had a near ceiling max brake gain ($M = -9.73$ ms^{-2}, $SE = .03$) when using only optically controlled braking response, even when accounting for phase of braking. A higher brake gain is characteristic of a non-regulated response due to the compensation of deceleration needed for a safe following. This result, combined with significantly higher collisions rates underscores the importance of displays in alerting drivers to a decelerating lead vehicle.

Following distance also significantly affected maximum brake gain, *F*(1,21) = 32.19, $p < .05$, η_G^2 = .040, observed power = 1.00, with greater maximum gains observed for the one-second following distance (M = -8.22 ms^{-2}, *SE* = .07) as compared to the two-second following distance (M = -7.99 ms^{-2}, *SE* = .06). This effect suggests that drivers were sensitive to the increased risk of following closely and braked accordingly.

The presence of either a deceleration display or brake lights also reliably reduced initial brake gain, *F* (2,21) = 4.80, p < .05, η_G^2 = .076, observed power = .34. Drivers following vehicles with no display exhibited higher initial brake gains (*M* = -8.85 ms^{-2}, *SE* = .07) than when following vehicles with brake lights (*M* = -7.55 ms^{-2}, *SE* = .09) or a deceleration display (*M* = -7.91 ms^{-2}, *SE* = .07; see Table 7). Post-hoc tests revealed no significant differences between the two display conditions. Furthermore, display and phase 1 deceleration magnitude had a significant interactive effect on initial brake gain (see Table 7 and Figure 9). This interaction shows that displays such as brake lights and the deceleration display lead to a reduction in over-braking when the lead vehicle decelerations are low. Following a car with no display results in higher initial magnitudes of braking, which when taken together with increased response times, suggests that drivers had difficulty in detecting lead vehicle decelerations in these cases and responded late with greater force.

Following vehicles with either brake lights or a deceleration display also produced significantly higher cross correlations in vehicle trajectories than following vehicles with no display. The cross correlations represent how well following drivers were able to mimic the trajectory of the lead vehicle. For the cross correlation measure, display significantly interacted with the magnitude of both phase 1 and phase 2 deceleration magnitudes (see Table 8 and Figure 10). Overall, higher correlations were found when the deceleration of the lead vehicle increased from phase 1 to phase 2, a result consistent with a tendency to monotonically increase braking force throughout the deceleration. This result replicates a similar result found by Hope et al. (2012). Another interesting pattern in the cross correlation coefficients is that the deceleration display appears to have its greatest benefit above brake lights for the 6 ms^{-2} phase 1 decelerations. This increase may be the result of the deceleration display providing information to reduce uncertainty about whether the lead vehicle was increasing or decreasing its deceleration during phase 2. For the 3 and 9 ms^{-2} phase 1 decelerations, the lead vehicle either maintained constant deceleration or always increased or decreased deceleration (respectively). Hence, for these conditions there was less uncertainty about how the lead vehicle might change its trajectory.

Following distance also had an significant effect on cross correlations, $F(1,21) = 9.07$, $p < .05$, $\eta_G^2 = .018$, observed power = 1.00. Drivers mimicked lead vehicle decelerations more accurately when following at the closer one-second following distance (*M* = .70, *SE* = .00) rather than the two-second following distance (*M* = .67, *SE* = .00; See Table 8). Vehicle type also significantly affected cross correlations, with the following driver more accurately mimicking the trajectory of the larger pick-up truck (*M* = .69, *SE* = .00) than the smaller sized sedan (*M* = .68, *SE* = .00; See Table 8). Following drivers appear to have slightly less difficulty scaling the deceleration of the larger vehicle.

Consistent with the cross correlations and the results for initial and maximum brake gains, I found a main effect of display type on minimum speed, *F*(2,23) = 3.22, p < .05, η_c^2 = .05, observed power = .24 (see Table 9 for main effects). Minimum speeds while following vehicles with deceleration displays were significantly higher (*M* = 2.95m/s, *SE* = .06) than minimum speeds while following vehicles with brake lights (*M* = 2.66m/s, *SE* = .06), which were significantly higher than following vehicles with no display (*M* = 2.06 m/s, *SE* = .07), exhibiting a characteristic of a moderated braking strategy (see Figure 11). This was seen more evident in the 1s following. The deceleration display minimum speeds rose (*M* = 2.99 m/s, *SE* = .09) and the brake display were seen lower (*M* = 2.45 m/s, *SE* = .08) at this closer distance, though the comparison was not statistically significant (p>.05). Also, higher minimum speeds were seen (p >.05) with the deceleration display at the more moderate and extreme magnitudes of phase 2 decelerations, 6 ms^{-2} (*M* = 3.06 m/s, *SE* = .10), and 9ms^{-2} (*M* = 2.11 m/s, *SE* = .10) than when participants following the brake display, 6 ms^{-2} (*M* = 2.64 m/s, *SE* = .09), and 9ms^{-2} (*M* = 1.81 m/s, *SE* = .10). A higher minimum speed, particularly at these later high magnitudes is characteristic of a moderated response, especially when compared to optically controlled responses 6 ms^{-2} (*M* = 2.22 m/s, *SE* = .12), and 9ms^{-2} (*M* = 1.22 m/s, *SE* = .10).

Table 1. Chi-Squared Analysis of Following Distance, Car Type, and Display on Collision Frequency

Variable	Observed Frequencies	Expected Frequencies (= grand mean)	*df*	X^2 Statistic	*p*
Following Distance			1	3.93	< .05
1s	28	21.5			
2s	15	21.5			
Vehicle Type			1	.58	> .05
Sedan	24	21.5			
Truck	19	21.5			
Display			2	25.72	< .05
None	30	14.33			
Brake	6	14.33			
Deceleration	7	14.33			

Table 2. Multidimensional Table of Collision occurrences by Display Type and Following Distance

		Display Type		
Following Distance	Control	Brake Display	Deceleration Display	*n*
1s	20	2	6	28
2s	10	4	1	15
n	30	6	7	43

Table 3. Reliable Effects of Following Distance, Car Type, Replicate, Phase 1, Phase 2, and Display on Minimum Following Distance

Variable	Mean(s)	SE(s)*	*df*	*F* Statistic	*p*	η_G^2	Power
Vehicle Type		.32	(1, 21)	14.28	< .05	.012	1.00
Sedan	17.78m						
Pick-up Truck	19.65m						
Display Type		.21	(1, 21)	55.90	< .05	.031	.08
Brake Display	20.73m						
Deceleration Display	18.53m						
Phase 2		.36	(2,42)	18.44	< .05	.02	1.00
$3ms^{-2}$	20.00m						
$6ms^{-2}$	19.10m						
$9ms^{-2}$	17.04m						

All other main effects and interactions were not significant (p > .05)
**this SE was computed using the within-Ss Loftus-Masson approach*

Table 4. Reliable Effects of Following Distance, Car Type, Replicate, Phase 1, Phase 2, and Display on Average Following Distance

Variable	Mean(s)	SE(s)*	*df*	*F* Statistic	*p*	η^2_G	Power
Vehicle Type		.46	(1, 21)	10.91	< .05	.007	1.00
Sedan	26.67m						
Pick-up Truck	28.21m						
Replicate		.39	(2, 42)	4.11	< .05	.004	1.00
1	28.16m						
2	27.43m						
3	26.72m						
Following Distance x Phase 2 x Block x Display	See Figure 8	.99	(8, 168)	2.90	< .05	.005	1.00

All other main effects and interactions were not significant (p > .05)
**this SE was computed using the within-Ss Loftus-Masson approach*

Table 5. Reliable Effects of Following Distance, Car Type, Replicate, Phase 1, Phase 2, and Display on Max Brake Gain

Variable	Mean(s)	SE(s)*	*df*	*F* Statistic	*p*	η_G^2	Power
Following Distance		.06	(1, 21	32.19	< .05	.040	1.00
1S	-9.31						
2S	-8.86						
Display		2.59	(2,21)	6.36	< .05	.142	.43
None	-9.73						
Brake	-8.78						
Deceleration	-8.74						
Phase 1 x Phase 2 x Display	See Figure 7	.14	(8, 84)	2.96	< .05	.011	.769

All other main effects and interactions were not significant (p > .05)

**this SE was computed using the within-Ss Loftus-Masson approach*

Table 6. Mean Maximum Brake Gains for the Phase 1 x Phase 2 x Display Interaction

Phase 1	Phase 2	Display	Mean
3	3	None	-9.381
		Brake	-6.935
		Deceleration	-6.956
	6	None	-9.546
		Brake	-8.235
		Deceleration	-8.162
	9	None	-9.757
		Brake	-9.057
		Deceleration	-8.753
6	3	None	-9.720
		Brake	-8.399
		Deceleration	-8.407
	6	None	-9.752
		Brake	-8.773
		Deceleration	-8.827
	9	None	-9.937
		Brake	-9.376
		Deceleration	-9.172
9	3	None	-9.660
		Brake	-9.151
		Deceleration	-9.002
	6	None	-9.877
		Brake	-9.449
		Deceleration	-9.605
	9	None	-9.890
		Brake	-9.681
		Deceleration	-9.833

Table 7. Reliable Effects of Following Distance, Car Type, Replicate, Phase 1, Phase 2, and Display on Initial Magnitude of Deceleration

Variable	Mean(s)	SE(s)*	*df*	*F* Statistic	*p*	η_G^2	Power
Display		3.38	(2,21)	4.80	< .05	.076	.34
None	-8.85						
Brake	-7.55						
Deceleration	-7.91						
Display x Phase 1	See Figure 10	.18	(4,42)	7.71	< .05	.027	1.00

All other main effects and interactions were not significant (p > .05)
**this SE was computed using the within-Ss Loftus-Masson approach*

Table 8. Reliable Effects of Following Distance, Car Type, Replicate, Phase 1, Phase 2, and Display on Cross Correlation Coefficients

Variable	Mean(s)	SE(s)*	*df*	*F* Statistic	*p*	η_G^2	Power
Following Distance		.01	(1, 21	9.07	< .05	.018	1.00
1S	.70						
2S	.67						
Vehicle Type		.003	(1, 21)	7.32	< .05	.002	1.00
Sedan	.68						
Pick-up Truck	.69						
Phase 2 X Display		.01	(4, 42)	3.96	< .05	.020	1.00
3ms^{-2}							
None	.57						
Brake	.65						
Deceleration	.67						
6ms^{-2}							
None	.68						
Brake	.70						
Deceleration	.73						
9ms^{-2}							
None	.73						
Brake	.73						
Deceleration	.74						
Phase 1 x Phase 2 x Display	See Figure 1	.02	(8, 84)	2.96	< .05	.011	.769

Table 9. Reliable Effects of Following Distance, Car Type, Replicate, Phase 1, Phase 2, and Display on Minimum Speed

Variable	Mean(s)	SE(s)*	*df*	*F* Statistic	*p*	η_G^2	Power
Display		.12	(2,23)	3.22	< .05	.05	.24
None	2.06m/s						
Brake	2.66m/s						
Deceleration	2.95m/s						
Following Distance		.08	(1, 21)	5.38	< .05	.006	1.00
1s	2.44m/s						
2s	2.68m/s						
Following Distance x Phase 2		.08	(2, 42)	10.89	< .05	.009	1.00
1s							
$3ms^{-2}$	3.39m/s						
$6ms^{-2}$	2.51m/s						
$9ms^{-2}$	1.40m/s						
2s							
$3ms^{-2}$	3.25m/s						
$6ms^{-2}$	2.76m/s						
$9ms^{-2}$	2.02m/s						

All other main effects and interactions were not significant (p > .05)
**this SE was computed using the within-Ss Loftus-Masson approach*

Table 10. Reliable Effects of Following Distance, Car Type, Replicate, Phase 1, Phase 2, and Display on Onset Following Distance

Variable	Mean(s)	SE(s)*	*df*	*F* Statistic	*p*	η_G^2	Power
Vehicle Type		.50	(1, 21)	8.31	< .05	.004	1.00
Sedan	35.97m						
Pick-up Truck	37.55m						
Following Distance		.50	(1, 21)	113.70	< .05	.365	1.00
1s	27.80m						
2s	45.72m						
Following Distance x Replicate		.70	(2, 42)	3.94	< .05	.006	1.00
1s							
Replicate 1	27.11m						
Replicate 2	28.18m						
Replicate 3	28.10m						
2s							
Replicate 1	47.47m						
Replicate 2	45.58m						
Replicate 3	44.11m						

All other main effects and interactions were not significant (p > .05)
**this SE was computed using the within-Ss Loftus-Masson approach*

Table 11. Reliable Effects of Following Distance, Car Type, Replicate, Phase 1, Phase 2, and Display on Brake Initiation

Variable	Mean(s)	SE(s)*	*df*	*F* Statistic	*p*	η_G^2	Power
Following Distance x Replicate		.71	(2, 42)	3.54	< .05	.005	1.00
1s							
Replicate 1	26.87m						
Replicate 2	27.95m						
Replicate 3	27.81m						
2s							
Replicate 1	46.79m						
Replicate 2	44.99m						
Replicate 3	43.73m						

All other main effects and interactions were not significant (p > .05)

**this SE was computed using the within-Ss Loftus-Masson approach*

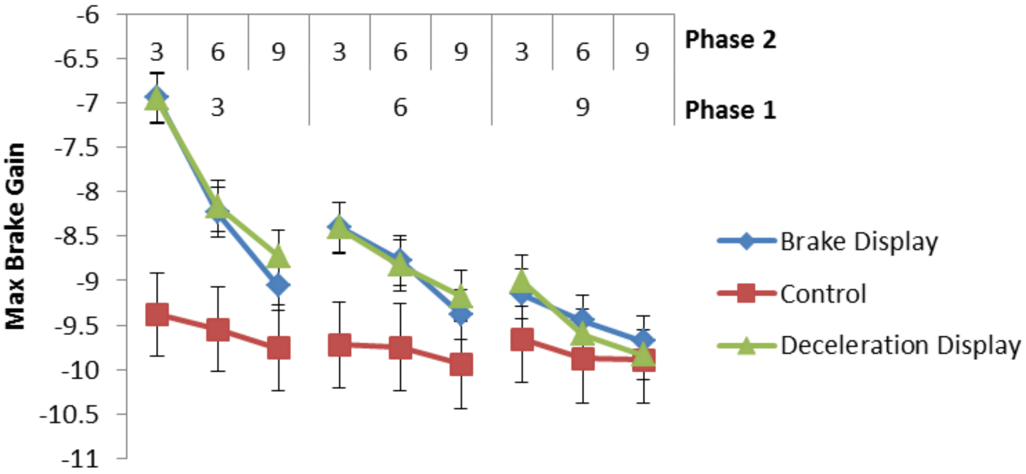

Figure 7. Graphical depiction of the 3-way interaction effect between Technology, Phase 1 and Phase 2 on Max Brake Gain.

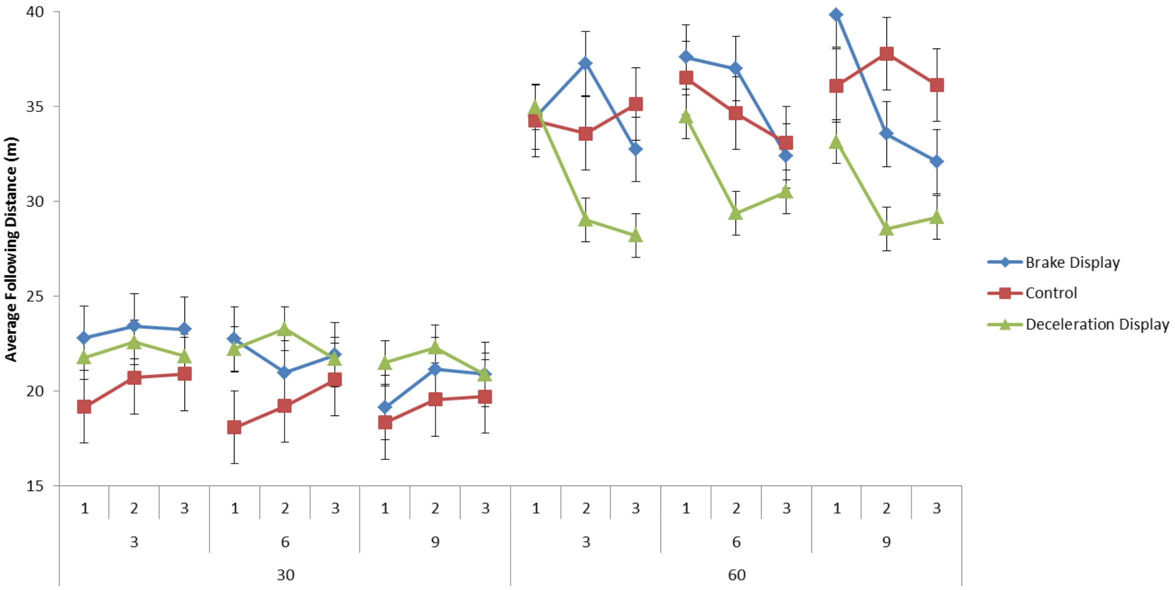

Figure 8. Graphical depiction of the 4-way interaction of Technology x Following Distance x Phase 2 x Replicate on Average Following Distance.

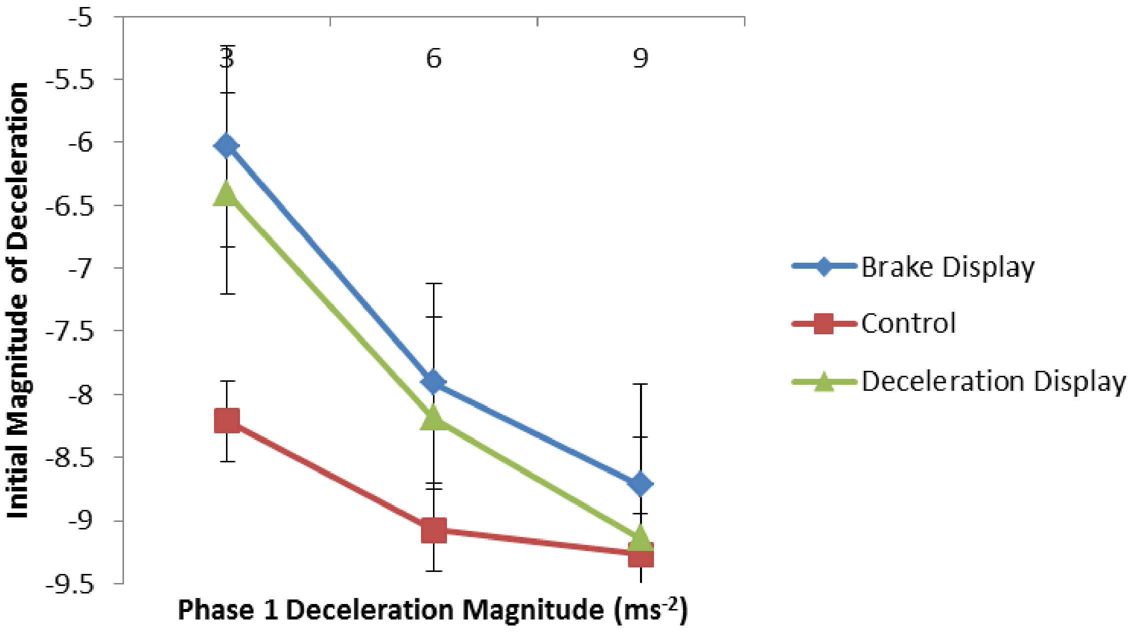

Figure 9. Graphical depiction of the interaction effect between Technology and Phase 1 on Initial Magnitude of Deceleration.(No Display 3ms^{-2} *M* = -8.213, No Display 6ms^{-2} *M* = -9.076, No Display 9ms^{-2} *M* = -9.268; Brake Display 3ms^{-2} *M* = -6.032, Brake Display 6ms^{-2} *M* = -7.910, Brake Display 9ms^{-2} *M* = -8.719; deceleration display 3ms^{-2} *M* = -6.409, deceleration display 6ms^{-2} *M* = -8.188, deceleration display 9ms^{-2} *M* = -9.142)

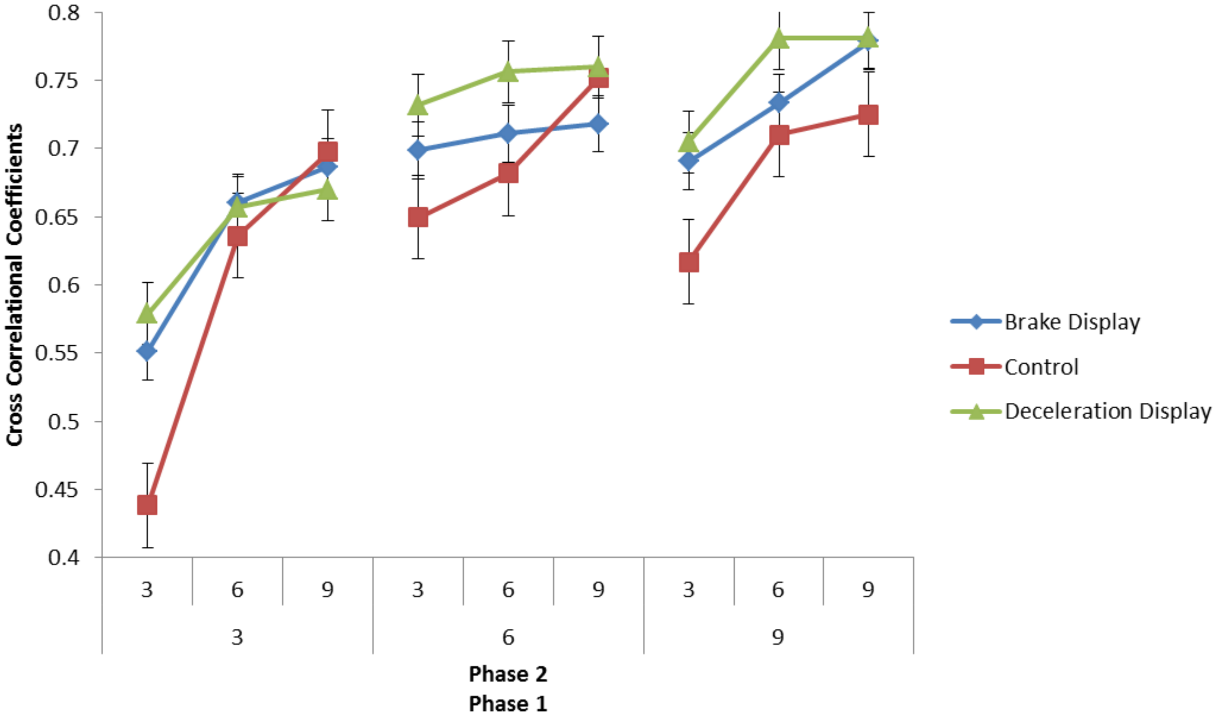

Figure 10. Graphical depiction of the 3-way interaction effect between Technology, Phase 1 and Phase2 on Cross Correlation Coefficients.

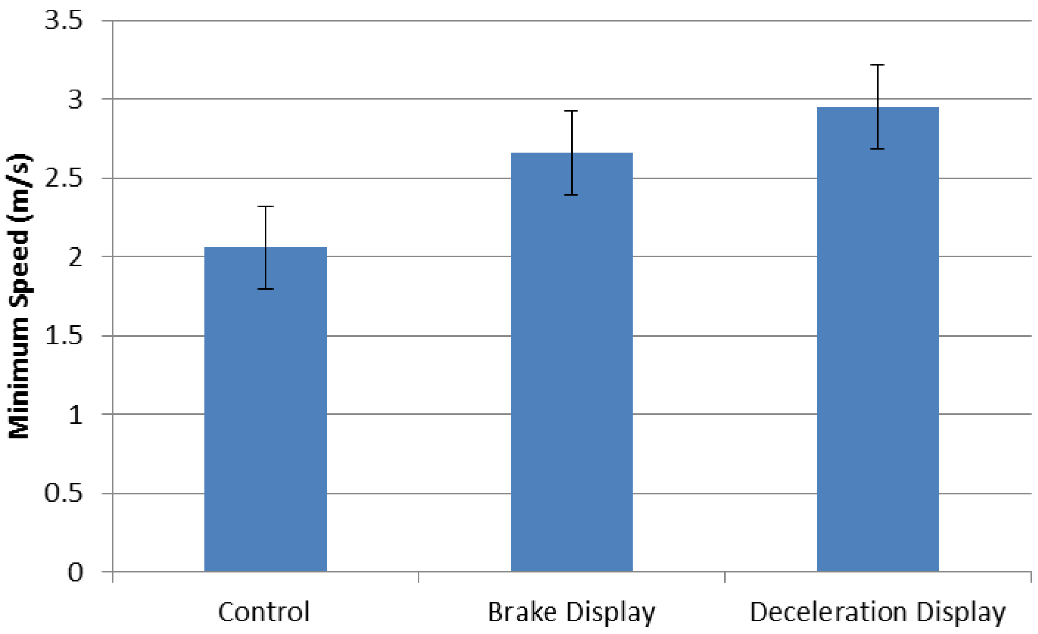

Figure 11.Graphical depiction of the minimum speed as a function of display type.

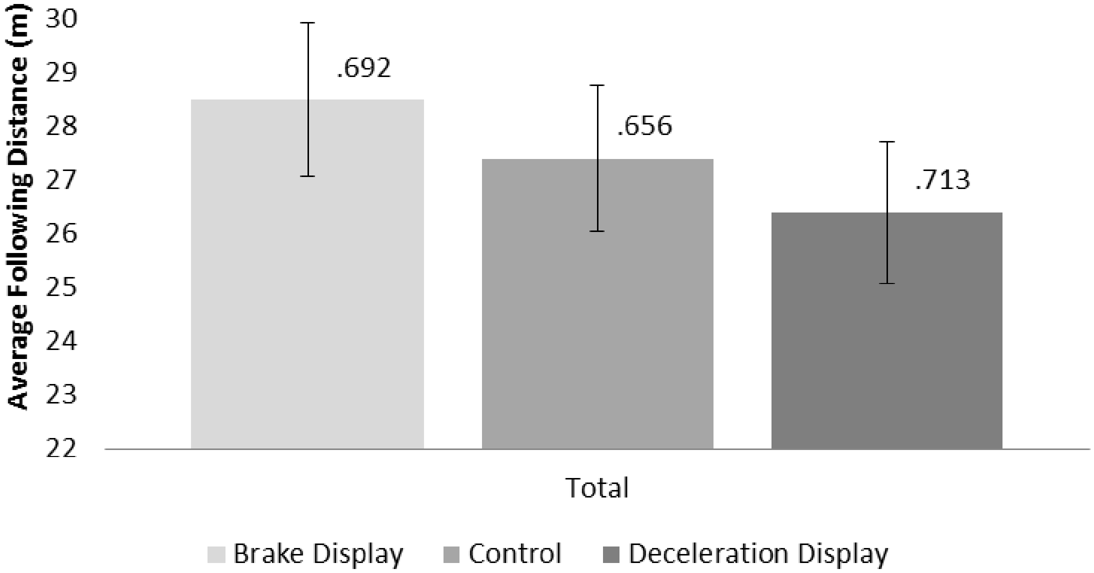

Figure 12. Graphical depiction of average following distance as a function of display type. Cross Correlation values for each type of display are listed on top of the vertical bars.

CHAPTER 4: Conclusions

The objective of this research was to determine the effects of brake and deceleration displays on speed and gap control during a car following task. Figure 9 shows the mimicking accuracy of following drivers, showing the effectiveness of a display (most specifically the deceleration display) in creating a more accurate scaling across variable decelerations. In Figure 9 the non-display group shows an improved following behavior (higher cross correlation coefficients) in the increasing magnitude braking trials, whereas the display followers produce an overall regulated response on **all** levels and combinations of deceleration. The 6-3, 9-3 and 9-6 conditions of deceleration exemplify the point that a display provides supplemental detection information and, with the deceleration display, scaling information on all levels of braking, specifically at moderate levels of deceleration followed by a decreased braking. Figure 9 also shows that lower levels of deceleration require more than the optical information, but also a display and/or scaling information to supplement the braking calculations.

The fact that following drivers can more efficiently match the deceleration of a lead vehicle with the deceleration display and do so at higher minimum speeds, gives ample support to its effectiveness in scaling deceleration. As seen in Figure 9, the lower levels of deceleration highlight the necessity of a display in accurately scaling variable decelerations. More specifically the deceleration display provides further scaling information on these less than moderate braking situations where the brake display could seem insufficient in terms of braking urgency, as evident by the higher minimum speeds. The brake display is a sufficient display of “alarm” but in terms of communication of *magnitude* of deceleration, the deceleration display improves these scaling calculations. Combining Figure 7 and Figure 10 data we see that though the deceleration display has the higher initial magnitude of deceleration, drivers following this display also had a lower overall max brake gain. These two findings together show a better scaled (regulated) response by the drivers rather than a delayed slam-on-the-brakes reaction that is less consistent across the braking trial. Showing that the supplementation of a display improves driver's braking strategy is a tremendous pull-away, but further statement about the beneficial characteristics of a dynamic display in deceleration scaling only strengthens the need for further research.

A prediction of this research was that the deceleration display would have the tradeoff of a slower response time with its higher mimicking accuracy, due to increased information load (Hick, 1952; Hyman, 1953) and unlearned method of display (possible increased cognitive load). This prediction was found false in this study. The deceleration display not only produced the highest overall accuracy in following but did so with the fastest response time, contradicting prediction of the Hick-Hyman law to the experiment. Not only did the deceleration display have a significantly lower mean response time (*M*=1.836) than the brake display (*M*=1.909) or even the no display condition (*M*=2.422), but participants following vehicles with this dynamic display also followed closer on average than in the other two following options; a combination showing support to accurate deceleration scaling (See Figure 12). Combining the unpredicted lower RT with the more accurate following driver mimicking of deceleration, higher minimum speed and the reduced following distance shows that the deceleration display lessened the chances of colliding with the lead vehicle without the cost of reduced traffic flow. The lower RT combined with Figure 10's initial magnitude of deceleration effects, not only supports the use of display (specifically the deceleration display) but also shows how these displays produce the more moderated braking that is needed for efficient traffic environments.

Figure 8 is an interesting graphical depiction to further discuss the impact of the deceleration display. As seen, the 1s following distance showed similar overall average following distances, but the difference in the 2s following forms an interesting finding. Drivers over time seemed to follow closer with the deceleration display than when they were following the brake display. This closer distance, coupled with previous suggestions about the deceleration display, prompt researchers to believe that the deceleration display is easily learned and promotes an efficient following. Specifically of importance are the moderate and lowest levels of phase 2 decelerations showing a closer distance with the deceleration display over time. Drivers regressing to a central distance with the deceleration display, while still maintaining safety and efficiency, promotes sustainability in the display that could see a reduction in rear-end collisions. Also the lower distances, specifically in the Phase 2 analysis, yet again signify this regulated response that is predicted to be the most efficient in a car following task.

When discussing the braking strategies used by following driver’s we look back to not only Yilmaz and Warren (1995) but Hope et al (2012). However, the implementation of both display and a moving object deceleration makes this research more unique. The reduction in max brake gain seen when a display is present indicates the usefulness of a display in scaling deceleration. Less brake gain is characteristic of more moderated braking, regulated throughout a braking scenario (See Figure 7). Also, in comparison to the phase 2 average following distance numbers of Hope et al. (2012), we see that a display washes out the inversed relation of Phase 1 to Phase 2 following. Display following showed a more regulated response as seen by these considerably similar Phase distances versus the slam-on-the-brakes seen with optically controlled responses in Hope et al. (2012) and non-display followers here. The higher minimum speed furthers the evidence of a moderated reaction produced by the deceleration display. Maintaining a higher minimum speed even at a 1 second following distance and throughout the late phrases of braking supports braking in moderation while a higher brake gain and lower speed is characteristic of a slamming response.

Prior to the experiment, the manipulation of vehicle size and shape was thought to have little effect on following behavior.. Contrary to prediction, car type had an effect on driving behaviors. Drivers tended to follow the truck more accurately than they did the Sedan and seemed to follow closer to the sedan in both following distance parameters. Based upon previous relative and optical size research by DeLucia and Harb, Radwan, Yan, & Abdel-Aty, researchers would predict drivers to follow farther back with the Truck due to its increased relative size and adjusted optical calculations of safety gap. However, one wouldn’t also expect that to transfer to a more accurate following when distance has been adjusted. A possible rationale for this improved mimicking is that the relative size promotes a closer perception of following, and data shows that participants follow more accurately at a closer distance. With this finding however comes the question of driver focus; does the driver focus more on the optical size adjustment and their self-calculated TTC, or does the display take precedence? The results from this study and various previous studies point strongly in the direction of the display as seen by large improvement in following behaviors when display are implemented. Further research into relative size and headway focus would help shed light on this question of focus.

As discussed earlier in the paper, drivers were seen to follow more accurately at the 1s following distance than in the 2s following distance. This seemingly small finding has great implication on this genre of research. If drivers respond more efficiently at a shorter distance, do we design for that? Are we not already? Also, the distance at brake initiation and onset following distance findings exemplify even more the accuracy of the closer following distance. The implication with that closer following distance is the need for deceleration information at a quick rate, made even more evident with a higher minimum speed. A closer following distance limits the available time for a driver to react to the deceleration of a lead vehicle. As seen by the results, a display provides essential information to the following driver about this deceleration. But the closer following distance sought by drivers coupled with the current technology could be a possible reasoning for the high occurrence of rear-end collisions. It is possible, and seen here in this study, that a more dynamic display could lower these collision numbers over time. With its increased scaling information a deceleration display could produce a more efficient traffic flow while maintaining a safe roadway.

Possible limitations for this study could include the simplistic nature of the task. Though results on braking strategies and speed/gap maintenance were pulled away, including more driving tasks (ie- passing, changing lanes) could add real world context to the deceleration display's sustainability. Also the use of more updated simulator could provide a more accurate "cab" experience versus the open environment used here in this study with just a PC gaming wheel and malleable pedal set. Also being able to sample a large demographic would further the results. A younger aged, rural college population could quite possibly show different results then an older metropolitan population of drivers. Future questions that this research would surround following distance parameters and dynamic displays. Results showing a more accurate following at a closer distance are contrary to some social norms. Future driver education could integrate such following distance research into their training to better equate the traffic delay issue now being seen on the roadways. Future work on dynamic displays could provide additional insight on the scaling improvement to following drivers. If a more dynamic display, though predicted to have higher cognitive load, produces a more moderated response on several variables (lower brake gain and higher minimum speed especially), then integrated such a display could not only maintain safety but continually improve the traffic flow. Real-world application of this horizontal array would either support or deny the improvement in responses and increase in safety.

Though this experiment found that both brake lights and the deceleration display improve the detection of deceleration as compared to using only optically controlled responses, the deceleration display showed improved scaling of deceleration magnitude. This improved scaling can lead to a more efficient response while maintaining safety. Higher correlations between lead and following vehicle trajectories, less extreme braking behavior as evident by brake gain and collisions, and higher minimum speeds when following the deceleration display are characteristic of a moderate response. This improvement in following response should increase the efficiency of traffic flow by reducing braking overreactions, while still maintaining a safe gap between vehicles.

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Appendix 1

Consent Form

CONSENT FORM
Hope Thesis
Idaho Visual Performance Laboratory
Department of Psychology and Communication Studies
College of Liberal Arts and Social Sciences
University of Idaho

During this experiment you will be presented with a display simulating movement through a virtual environment. Various parameters of the display will be manipulated to examine the visual processes underlying visual control of locomotion. In this experiment you will be asked to control your movement through the virtual world using an input device such as a steering wheel and gas/brake pedals. Your task is to maintain a **specified** following distance from the lead vehicle, as shown by the initial seconds of each trial. *Do NOT* pass the vehicle in-front of you.

During your trials, you will be presented with different vehicles in front of you, all of which have displays to show deceleration.

Your participation will help increase knowledge of visual processes underlying locomotion and aid in the design of visual displays used in transportation. Subsequent to your participation the purpose and methods of the study will be described to you and any questions you have about the study will be answered. It is our sincere hope that you will learn something interesting about your visual system from this debriefing.

We believe the risks in this study are minimal, however displays simulating movement through virtual environments may on rare occasion cause motion sickness or eye fatigue. If at any time during the experiment you feel any discomfort, eye fatigue, dizziness, headache or nausea, please let the experimenter know immediately so that you can prevent these symptoms from becoming more intense. We also schedule periodic breaks to further reduce the occurrence of these risks. As a result, these risks are generally avoided, but it is important for you to inform us immediately if they do occur. At such time we will immediately terminate the experiment and provide you with a comfortable place to rest. If your discomfort is mild and passes quickly you will be given the opportunity to continue the experiment if you so desire.

Your participation will require *2* sessions of approximately *50* minutes each. You may withdraw from this study at anytime without penalty and will receive full compensation for your time spent up to that point. However, please be aware that your data will have the greatest scientific value if you complete the experiment in its entirety.

The data you provide will be kept anonymous. There will be absolutely no link between your identity and your particular set of data.

This research project has been approved by the University of Idaho Human Assurance

Committee. As such, new information developed during the course of the research which may relate to your willingness to continue participation will be provided to you.

Thank you for your participation.

Printed Name________________________________

Signature____ Date ____________

If you have further questions or encounter problems please contact:
Dr. Brian P. Dyre
Department of Psychology and Communications Studies
University of Idaho
(208) 885-6927
bdyre@uidaho.edu

SONA ID #:

Study Dates & Times:

Appendix 2

Debriefing Form

Deceleration Display Debriefing Form

Hope Thesis

Did these trials give you an accurate representation of a common driving and braking scenario you would see in your everyday life?

What was your general strategy for maintaining constant following distance? Did this strategy change during the experiment?

Do you believe that there were factors that affected your braking behavior? If so, what factors?

Did the adjustment in following distance affect your driving strategy or how performed in the task? If so, How?

Did you notice anything changing in the displays from trial to trial?

If yes: What changed?

If no: Did you notice that the vehicles changed from trial to trial?

If yes: What features of the vehicles changed?

If size changes noticed:

Was the size change subtle or quite obvious?

Did the changing size of the vehicle have any effect on your following and braking behavior, or change the strategy you used to perform the task in any way?

Deceleration Display Debriefing Form

Hope Thesis

Size and Shape Manipulation:

This experiment is part of a series of experiments being conducted in the Idaho Visual Performance Laboratory that are examining how people respond to decelerations of vehicles in front of them. Our goal is to develop new technologies that will increase safety and efficiency of our highways. This specific study sought to uncover how participants follow a vehicle with specific displays of deceleration and to examine whether variations in these displays, adjustment in following distances and the size of vehicles affect this following behavior.

The two vehicles that you followed varied in shape and shape. They were properly measured to be accurate to a real world driving situation. Though subtle, previous research suggests that variations in size may have effects on driving behavior such as reaction time to decelerations, rates of deceleration, and following distance. Also a manipulation of following distance was used to further investigate the natural reactions of drivers under different following circumstances. Please feel free to ask any questions to your researcher or feel free to see the contact information below.

If you have further questions or encounter problems please contact:
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REMINDER OF PART TWO OF THE STUDY

Please don't forget to complete day two of this study. Thank you very much for your participation today and we will see you again for Part 2 on...

________________________________ **@ :**