Examining Distracted Drivers' Underestimation of Time and Overestimation of Speed

SAFETY RESEARCH USING SIMULATION

UNIVERSITY TRANSPORTATION CENTER

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A Report on Research Sponsored by

SAFER-SIM

September 2017

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Abstract

Thirty-four drivers participated in a driving simulator experiment that investigated time and speed perception as it related to cognitive workload resulting from secondary tasks. Each participant drove the virtual drive twice, once with either an audio or a map task and again with no distractions as a control. Participants knew from a practice drive that they would be asked to estimate their speed and time duration of driving, so this study used the prospective paradigm. Based on previous literature, it was expected that there would be an underestimation of time and an overestimation of speed. The reverse occurred: participants overestimated time and underestimated their speed. This suggests that drivers may have found the drive unstimulating, despite the secondary tasks, and that the rural environmental may have impacted speed perception. Additionally, a large group of participants, nine out of 34, crashed the virtual vehicle at a horizontal curve that not was problematic in previous simulator studies. When investigating these crashes further, it was found that drivers who crashed in the second drive had significantly worse time perception in the first drive than drivers who did not crash in the second drive. This finding suggests that current time perception may be a predictor of future speed selection.

1 Introduction

Distracted driving is defined as driving while performing any activity that diverts attention from the primary driving task, including calling or texting, eating or drinking, talking to passengers in your vehicle, playing with the radio, or adjusting an entertainment or navigation system [1]. Distracted driving is a major problem in roadway safety when the usage of mobile phones and other electronic devices becomes the primary task instead of paying attention to the road. It has been estimated that 660,000 drivers use electronic devices while driving every day [1]. In 2015, 3,477 people lost their lives due to distracted driving, and more than 391,000 were injured in the United States alone [1]. Young drivers, 16-24 years old, were the largest age group reported as distracted in fatal crashes [1]. In research conducted by the National Highway Traffic Safety Administration (NHTSA) [1], it was estimated that distracted driving is a contributing cause in 25 percent of police-reported crashes.

It has been theorized that, as many aspects of the primary driving task become automated, drivers will become capable of multitasking between the primary task of driving and secondary tasks, such as operating a cell phone, without any serious consequences to driving performance or safety. However, drivers might also become distracted to the point that they are unable to meet the demands of the driving environment or to compensate for the loss in attention to the primary driving task when manual driving becomes necessary. For example, distracted drivers have less time to reduce speed or perform maneuvers due to slower reaction times [2, 3]. In this current study, drivers' perception of time and speed will be investigated from a distracted driving perspective.

Cognitive load is defined in psychology as the total amount of mental effort being used in the working memory, which directly affects short-term decision making [2]. Previous studies have shown that when cognitive load increases, the performance of driving tasks that require cognitive control degrades [5]. In this study, we will observe how drivers react under varying levels of cognitive loads and how cognitive loads may or may not alter their perceptions of time and speed.

Most of the previous studies that focused on the perception of time used two approaches: the retrospective and the prospective paradigms. The retrospective paradigm approach is when study participants are unaware that they are going to be asked to estimate the size of an interval. In the prospective paradigm, participants are aware that they will be asked to estimate the length of an interval during the study [6]. In the prospective paradigm, which is what will be used in this specific study, subjects tend to underestimate time if the cognitive load is high. Cognitive load has been identified as a main factor influencing interval duration estimates for both the retrospective and prospective paradigms, regardless of the paradigm chosen [7]. By contrast, when a task has a low cognitive load, or is boring, previous research has shown that time durations are overestimated [8].

While there is significant research on time perception as cognitive load varies, there is limited research on how speed perception varies with cognitive load. There is a need to determine how drivers perceive time and speed when distracted, versus when they are solely focused on the driving task. More specifically, there is a need to quantify how different types of distractions, such as texting or navigating, affect drivers' perception of time and speed. This is critical because with the implementation of automation, drivers will often need to quickly re-engage in the driving task, and speed and time perception could influence subsequent speed selection.

The objectives of this current study were to determine how drivers perceive time and speed with and without the influence of visual or audio distractions, and to determine how each different distraction task affects drivers' perception of time and speed.

2 Methods

The driving simulator in the Arbella Insurance Human Performance Laboratory at UMass Amherst was used to conduct a simulation experiment that used a previously developed environment that was altered to decrease the visual cognitive workload outside of the car so that drivers could concentrate on in-vehicle secondary tasks (distractions). A user-friendly environment was developed to accurately examine how participants perceived time and speed under varying cognitive workloads. This section details the methods that were used to address the objectives of this study.

2.1 Participants

Thirty-four licensed drivers 19 years and older (19 males and 15 females) from the greater Amherst, MA, area were recruited to participate in this study. During the recruitment stage, it was advertised that participants would be paid $20 for their time. Participants were selected based on the need for a wide variety of age groups to participate in the study. As younger drivers more frequently text while driving than older drivers, the majority of participants were in the 18-24 age group. Moreover, a larger number of male participants were not able to complete some of the drives, so extra male participants were recruited in an effort to have a similar number of completed experiments for both males and females.

The experiment consisted of four different groups (Table 2.1), all of which drove the same virtual scenario twice, once with no distraction and once with either an audio or navigating distraction. Most of the participants completed all of the drives without any issues. One participant did not complete the last drive due to technical difficulties with the simulator that resulted in a partial dataset. Nine participants did not complete one of the drives due to high speeds along turns which led to a "crash" of the virtual vehicle. These crashes also resulted in partial datasets. The reason for these crashes along with their implications is discussed in Section 3.3. A comparison of participant demographics by group is shown in Table 2.1**.**

Table 2.1 Participant demographics.

Group (Drive 1/Drive 2)	Male Total (Complete)	Female Total (Complete)	Driver Age (yr) Mean ± Std. Dev.	Driving Experience (yr) Mean ± Std. Dev.
Control/Map	4 (3)	3 (3)	25.3 ± 4.3	9.0 ± 4.4

Map/Control	5 (3)	4 (3)	21.2 ± 3.2	3.1 ± 1.9
Control/Audio	4 (4)	3 (2)	26.9 ± 5.5	8.7 ± 7.3
Audio/Control	6 (3)	5 (3)	27.2 ± 10.7	9.2 ± 7.9

Before the virtual practice drive, participants completed a questionnaire that evaluated their aggressive driving tendencies. Participants were asked to rate each question either "Never," "Rarely," "Sometimes," or "Often." The questionnaire included 13 actions such as "Tailgate others to force move" and "Deliberately prevent other from passing." By assigning a value of 1-4 for Never to Often, a mean aggressiveness score could be computed for each participant and thus each group. The mean scores of the different groups were statistically similar for the four groups; this fact, coupled with the balancing of age and sex, indicates that the driving tendencies of the four groups were likely similar.

2.2 Apparatus

The Realtime Technologies Inc. (RTI) driving simulator, depicted in Figure 2.1, used in the current study is a full-cab, fixed-base setup that includes a fully equipped 1996 Saturn sedan with three screens subtending 135 degrees horizontally. At a resolution of 1024 x 768 pixels and at a frequency of 60Hz, the virtual environment is projected on each screen through a network of four advanced RTI simulator servers equipped with high-end multimedia chips. The participant sits in the driver's seat and operates the controls, just as he or she would in a normal car. A Dolby surround system consisting of side speakers and two subwoofers located under the hood of the car provides realistic wind, road and other vehicle noises with appropriate direction, intensity and Doppler Effect Shift. Previous studies involving this simulator found that participants, with no distractions, perceived their travel speed approximately 5 mph higher in the driving simulator but that actual speeds observed in the field closely matched speeds observed in a simulated environment that replicated the field drive [9, 10].

Figure 2.1 Driving simulator at UMass Amherst.

2.3 Scenarios and Experimental Design

The entire drive consisted of a rural two-lane roadway with no posted speed limit and contained two signalized intersections, as shown in Figure 2.2. At these intersections, drivers had to make an unprotected left turn with vehicles traversing the intersection in the opposite direction.

There were three left horizontal curves and three right horizontal curves. Each curve had a length of 157 m and a radius of 100 m. Lanes were 3.66 m wide (12 ft) with a 0.30 m shoulder (1 ft). There were no significant roadside objects or hazards. Individual vehicles were scripted in the oncoming direction to travel at 35 mph. This individual scripting allowed the oncoming traffic to be consistent for every participant.

"Pass with Care" signs were placed along tangent segments throughout the drive and served as a cue to the experiment to play the audio, which asked participants, "How fast are you currently going? How long have you been driving?" Participants left all watches and phones outside of the vehicle, and the car clock and speedometer were obscured so that participants had no way to definitively measure their time or speed. Each experimental drive lasted 9-12 minutes. A full layout of the virtual drive is depicted in Figure 2.2.

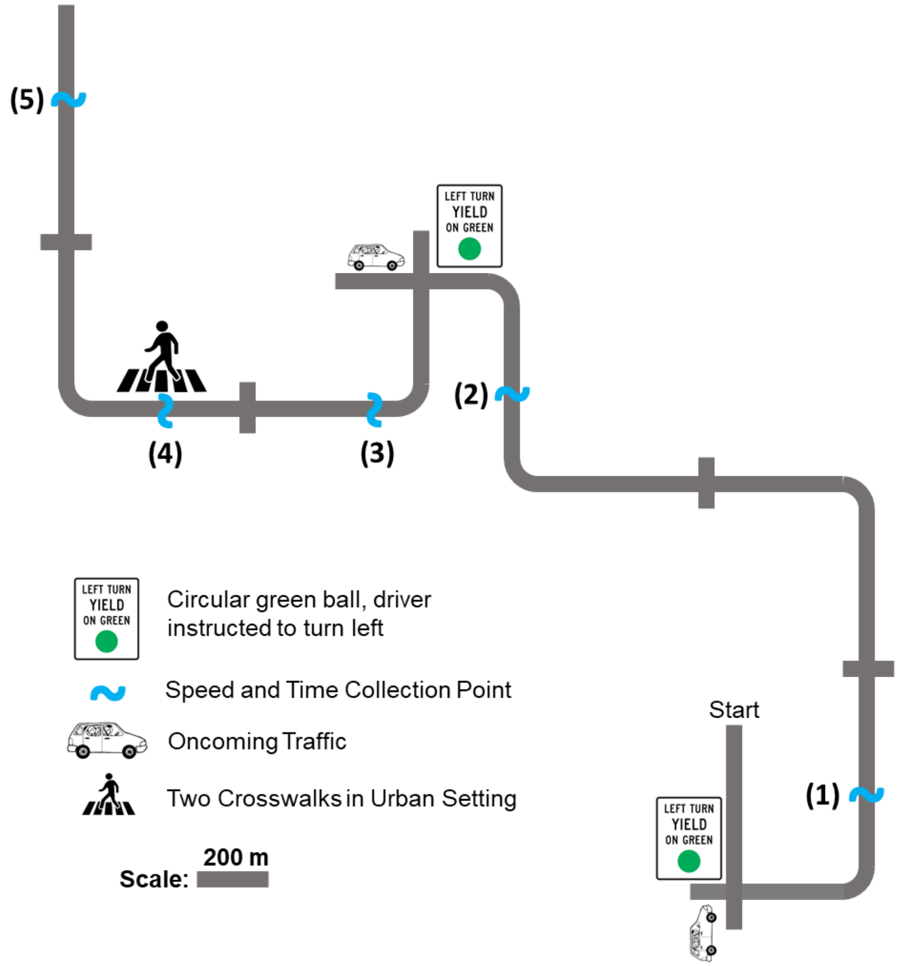

Figure 2.2 Schematic of virtual drive depicting various elements participants encountered.

2.4 Procedures

The objectives of this study were addressed by subjecting participants to two types of distractions, an audio distraction task or a visual distraction task. By using both distraction types, the amount and type of cognitive load used on each task could be examined. First, each participant provided informed consent, filled out a demographic and driving aggressiveness questionnaire, and then completed a short practice drive in order to get used to the features and controls of the driving simulator. In the practice drive, the distraction tasks and questions were presented and explained so that participants were comfortable with the tasks and questions during the experimental drive. Next, participants were randomly assigned a distraction task to complete throughout a drive, either an audio or a visual distraction task. The participants also had to complete the same drive without the distraction task. The experimental drives, which were the second and third drives, occurred in a random order so that the ordering of the drives did not produce a confounding effect.

The three different drive types were as follows:

1. Audio Distraction Task (Audio Task): Participants were asked to verbally respond to a sentence, played through the speakers, by stating the subject and object of the sentence, as well as whether or not the sentence made sense.
   Example: The kid threw the ball. Subject: the kid, object: the ball, sentence makes sense.
2. Visual Distraction Task (Map Task): Participants were asked through the speakers to locate a street on a map while driving. They had to verbally respond with the coordinates of where the street name appeared on the map.
3. Control: In this task, participants were only asked to perceive the time intervals since the start of the drive and the speed at each checkpoint. The control drive did not include distractions.

3 Results and Discussion

The current driving simulator study examines how drivers' perception of time and speed is impacted by secondary tasks and varying workload levels. A hybrid between/within-subjects experimental design was utilized in which each participant did a control drive with no secondary task and a second drive with either an audio or map task. The order of the drives was counter-balanced, so half the participants did the control drive first and half did the distraction task drive first. The controlled laboratory settings allowed for the consistent manipulation of critical variables as well as the direct measurement of dependent variables. All statistical tests conducted were unpaired two-sample Student's t-tests using the software package Minitab. All error bars represent 95% confidence intervals; a statistically significant difference at 90% ($p < 0.10$) is denoted by (*), and a statistically significant difference at 95% ($p < 0.05$) is denoted by (**).

3.1 Actual Speeds and Speed Perception

As depicted previously in Figure 2.2, actual speeds and times along with perceived times and speeds were collected at fived fixed points spaced roughly evenly throughout the drive. Figure 3.1 displays the mean speeds at these five fixed points for the three drive types. When comparing checkpoints within the groups, Checkpoints 3 and 4 had statistically lower mean speeds than Checkpoints 1, 2, and 5 for both the control drive and audio task but not for the map task. Looking back at Figure 2.2, lower speeds at Checkpoint 3 were likely due to its proximity to the right horizontal curve, and lower speeds at Checkpoint 4 were likely due to the urban stretch of roadway with crosswalks. By comparison, the other three checkpoints occurred in straightaway rural environments. A comparison of the groups shows that there were no statistically significant differences in actual speeds between the audio task and control drives. However, speeds at the following checkpoints for the map task were significantly lower than for the control drive: Checkpoint 1, control (M = 45.0, SD = 7.8), map task (M = 37.3, SD = 8.4), $t(27) = 3.10$, $p = 0.004$; Checkpoint 2, control (M = 46.2, SD = 7.0), map task (M = 40.2, SD = 9.5), $t(24) = 2.21$, $p = 0.037$; Checkpoint 3, control (M = 40.4, SD = 4.4), map task (M = 37.2, SD = 6.0), $t(24) = 1.92$, $p = 0.066$; Checkpoint 5, control (M = 48.7, SD = 8.2), map task (M = 38.8, SD = 8.2), $t(24) = 1.92$, $p = 0.002$. The varying degrees of freedom in the unpaired two-sample t-test are due to the varying sample sizes at the five checkpoints as a result of the "crashes" that happened at various points throughout the drive. The cause of these "crashes" and the insights they provide on experimental design are discussed later in this section.

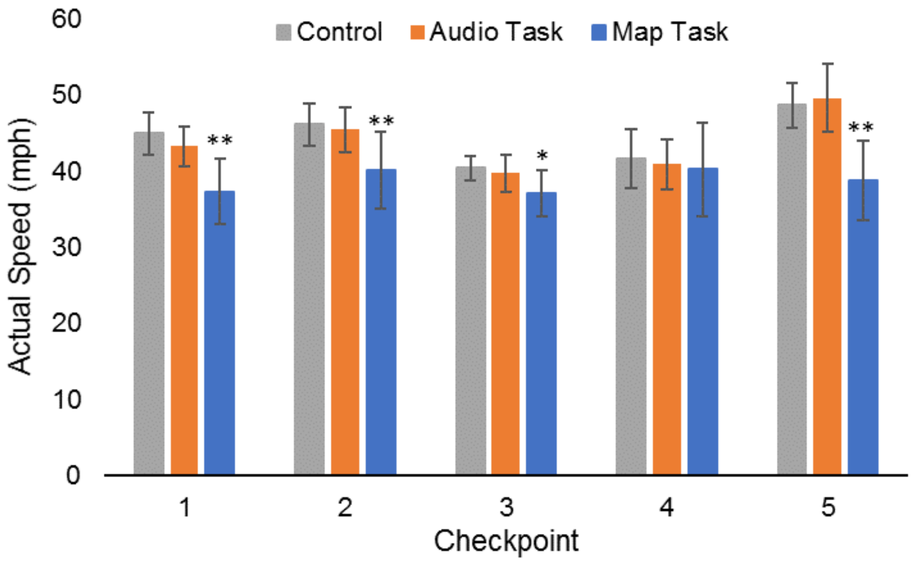

Figure 3.1 Mean actual speeds of participants for three drive types at five checkpoints.

Table 3.1 displays the sample sizes at each checkpoint along with the mean speeds. The sample size for the control group was much higher than for the audio or map tasks because all subjects drove the control drive, whereas subjects drove either the map or audio task. The mean actual speeds are an early indicator that the map task was a bigger distraction than the audio task and resulted in a larger cognitive workload because subjects did not have to reduce speeds to safely complete the audio task but they did to safely complete the map task.

Table 3.1 Mean actual speeds and sample sizes at each checkpoint for the three groups.

Checkpoint	Mean Speed (mph) and Sample Size		
	Control	Audio Task	Map Task
1	45.01 (34)	43.29 (18)	49.64 (16)
2	46.16 (29)	45.48 (18)	37.32 (16)
3	40.43 (28)	39.75 (17)	37.15 (16)
4	41.69 (27)	40.91 (17)	40.25 (16)
5	48.68 (26)	49.64 (17)	38.84 (13)

At the five fixed points where speed was captured, participants were asked how fast they thought they were going. Without a speedometer, the vibrations of pavement conditions from a real vehicle, or the familiarity of their own vehicle, this question was very difficult for participants. Figure 3.2 shows the difference between actual speeds and perceived speeds at the five checkpoints across the three groups. When combining all groups and all checkpoints, subjects perceived their speed 5.6 mph lower than their actual speeds. This finding is counter to that of an earlier study [9], which found a speed perception of ~5 mph higher than actual simulator speeds. However, in this study, the simulated environment was very rural and open, whereas in the previous study the environment was more suburban and there was more visual flow. This open environment was likely the cause of the lower perceived speeds as previous research on roadside vegetation and clear zone size showed that as the density of roadside vegetation, and thus the level of visual flow, increases, perceived speeds exceed actual speeds [11].

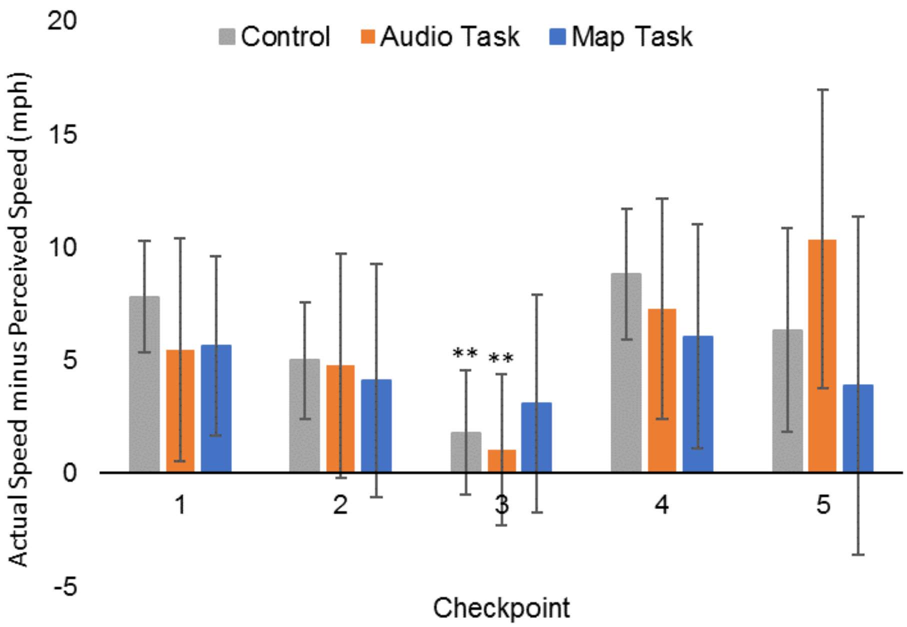

Figure 3.2 Mean differences between actual and perceived speeds for the three drive types.

When comparing speed perception by drive type at each checkpoint, there were no statistically significant differences. The largest difference occurred at the last checkpoint between the audio task and the map task; however, due to the smaller sample size of the distraction drives by the fifth checkpoint (n=17 for audio task and n=14 for map task), this difference was not statistically significant. Statistically significant differences were present within the groups between the different checkpoints. For all three groups, subjects had more accurate speed perception at Checkpoint 3 than at any other checkpoint, with significant differences occurring with the control and audio task groups.

Table 3.2 shows the mean differences in speed perception at each checkpoint along with statistical comparisons of Checkpoint 3 and the other four checkpoints.

Table 3.2 Differences in speed perception and statistical comparisons with Checkpoint 3.

Checkpoint	Mean Difference Between Actual and Perceived Speed (mph)			P-value of difference with Checkpoint #3 (df in parantheses)		
	Control	Audio Task	Map Task	Control	Audio Task	Map Task
1	7.8	5.5	5.6	**0.003 (56)***	0.130 (31)	0.386 (29)
2	5.0	4.8	4.1	0.126 (54)	0.198 (31)	0.775 (28)
3	1.8	1.0	3.1	--	--	--
4	8.8	7.3	6.1	**0.002 (52)***	**0.032 (30)***	0.383 (29)
5	6.3	10.3	3.9	0.143 (38)	**0.012 (25)***	0.834 (23)

The reason for improved speed perception at Checkpoint 3 was likely due to the lower actual speeds at Checkpoint 3. As discussed previously, these significantly lower speeds only existed in the control and audio task groups, and those were the same groups that had significantly better speed perception. This finding confirms the intuitive knowledge that speed perception is easier at lower speeds due to the smaller margin of error. While Checkpoint 4 also had significantly lower actual speeds, there was not the same improvement in speed perception as seen at Checkpoint 3. This is likely due to the roadway environment; Checkpoint 3 was in the same rural environment as the other checkpoints, but Checkpoint 4 was in an urban stretch of the drive with crosswalks and parked vehicles. While participants did slow down at Checkpoint 4, as discussed previously, the checkpoint occurred towards the end of the urban section, so their actual speed was not as low as they had perceived over the past approximately one minute of urban driving.

Figure 3.3 and Figure 3.4 show mean speeds and mean speed perception, respectively, based on drive order. There were no differences in actual speeds based on drive order. While there appears to be a slight improvement in speed perception between the first and second drives, specifically in Checkpoints 4 and 5, these differences were not statistically significant ($p = 0.162$ and 0.679, respectively).

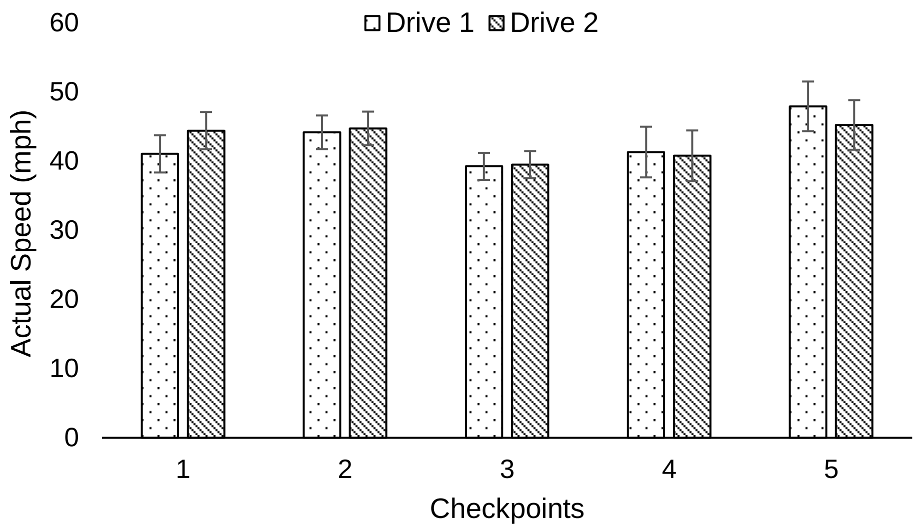

Figure 3.3 Mean actual speeds of the first drive versus the second drive.

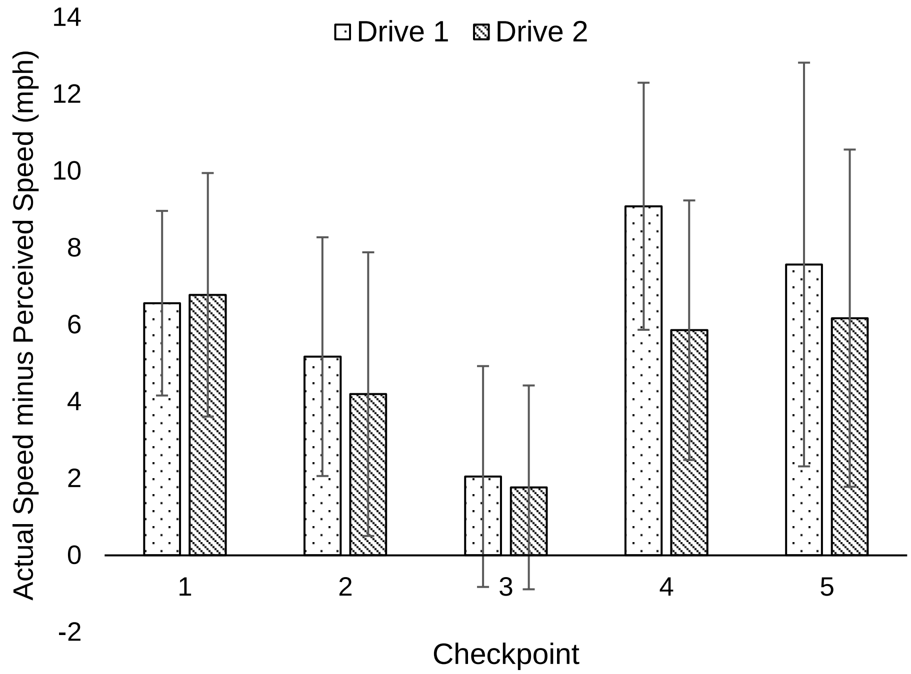

Figure 3.4 Mean differences between actual and perceived speeds for Drives 1 and 2.

3.2 Time Perception

The second focus of this study was time perception. Participants were asked at the same five checkpoints how long they thought they had been driving. The clock in the vehicle was obscured, and any watches and cell phones were left outside of the vehicle. Figure 3.5 displays the mean actual times of the three groups at each checkpoint. These times obviously correlate with the vehicle speeds; there are no significant differences between the control and audio task, but subjects with the map task took 68 seconds longer to reach the fifth checkpoint than subjects in the control drive, a statistically significant result (p = 0.013).

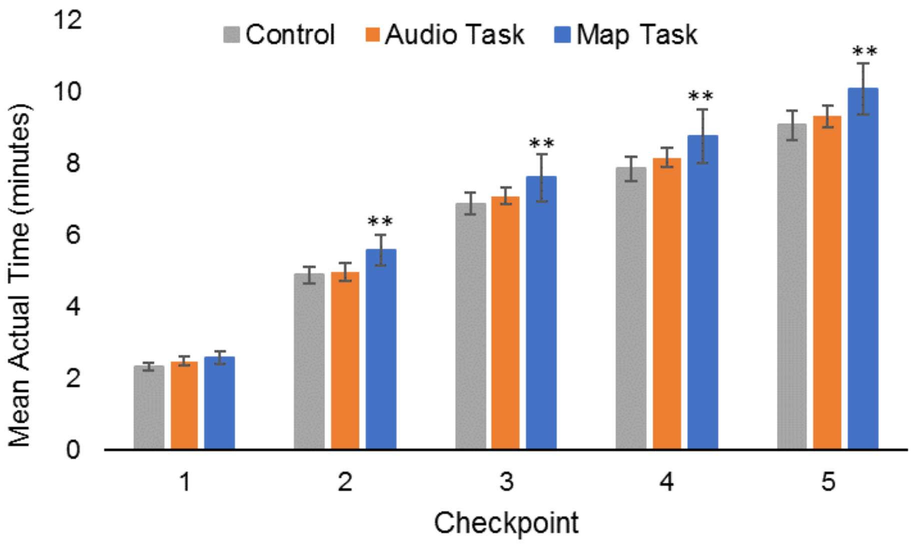

Figure 3.5 Mean actual times at each checkpoint for the three groups.

In the introduction, previous research by Block and Zakay [7] was cited; they found that subjects in the prospective paradigm tended to underestimate time. In addition, Sucala et al. [8] found that when the cognitive load was low, the task was "boring" and subjects overestimated time. Figure 3.6 shows the difference in speed perception at the five checkpoints between the three groups. Despite using the prospective paradigm, where subjects knew they would be asked about time duration, all three groups overestimated the time interval, possibly indicating that the driving simulator task was found to be boring or that the cognitive workload was low despite the secondary tasks. While there is a trend that shows that time perception with the audio task was worse than with the map task or the control, these differences were not statistically significant. This difference could have been the result of an individual subject with poor time perception who did the audio task but not the map task. While the difference at Checkpoint 5 between the audio task and the control was approaching significance (p = 0.124), a larger sample size would be needed to draw definitive conclusions.

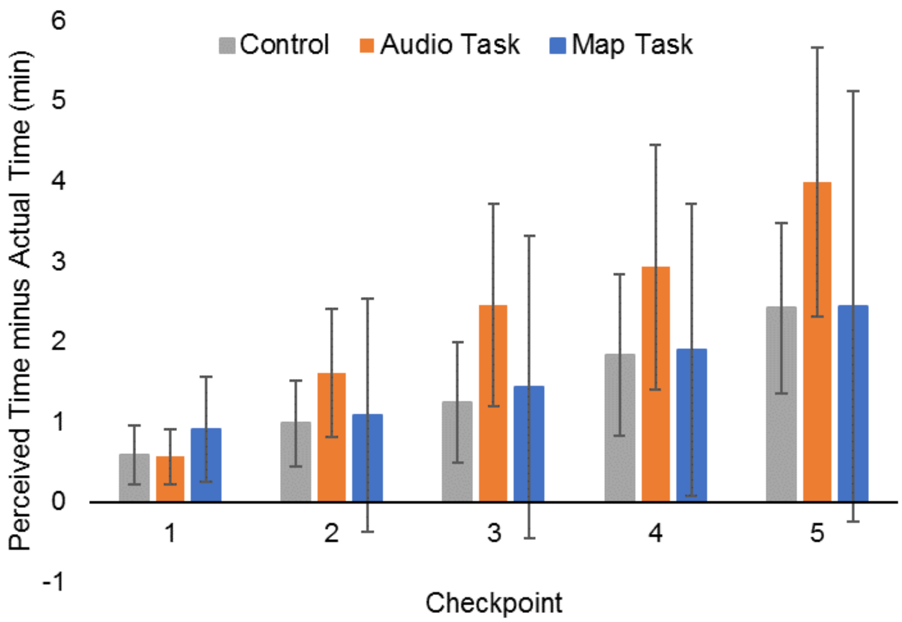

Figure 3.6 Mean differences in perceived time and actual time for the three drive types.

Figure 3.7 examines the difference in time perception between the first drive and the second drive. There were no significant changes in time perception between the drives, and this was the expected result as participants did not receive any feedback on the accuracy of their time perception between Drive 1 and Drive 2.

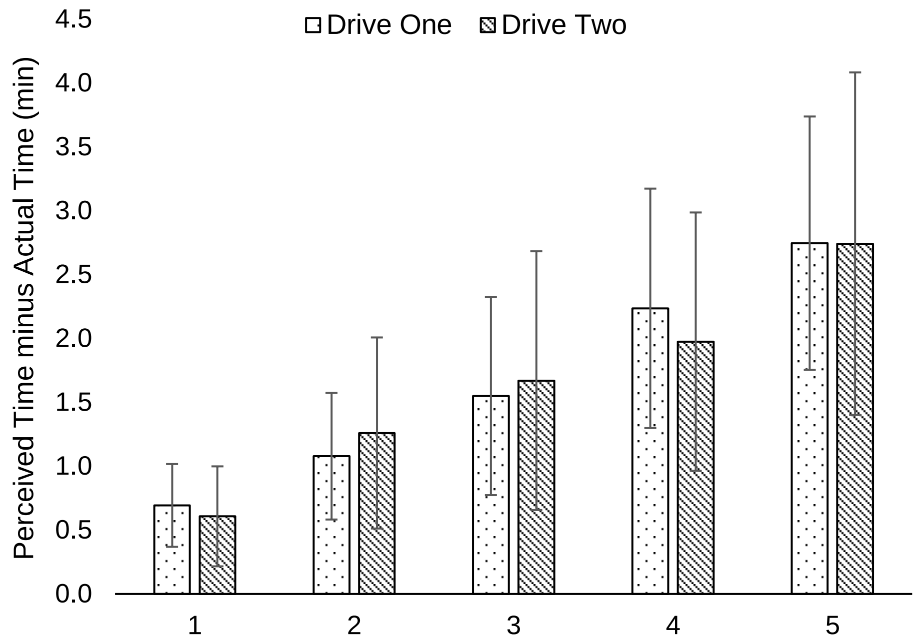

Figure 3.7 Mean differences in perceived time and actual time for Drive 1 versus Drive 2.

3.3 Crashes

As mentioned previously, nine out of the 34 drivers crashed the virtual vehicle, ending the drive and resulting in a partial dataset. Six subjects crashed in the second drive, two crashed during the first drive, and one crashed in both the first and second drives. All of these crashes occurred on a right horizontal curve; the same roadway geometry was used in an earlier study [12] examining roadside vegetation and clear zone size, and no crashes occurred. However, during that study, the curve warning signs had an advisory speed, and participants could see the speedometer. While there were curve warning signs in the current study, there were no advisory speed limits (in order to not influence speed perception) and participants could not see the speedometer. When looking at the last recorded speed of drivers who crashed compared to the speeds of the non-crashing drivers, it is clear that these crashes occurred due to excessive speeds: last speed recorded of crashing drivers, ($M = 54.8$, $SD = 11.3$), all speeds of non-crashing drivers ($M = 41.6$, $SD = 7.6$); $t(9) = -3.67$, $p = 0.005$.

Figure 3.8 further investigates the issue of crashing drivers by comparing the perceived time differences during the first drive of drivers who crashed in the second drive versus drivers who did not crash in the second drive. Despite the extremely small sample of drivers who crashed in the second drive and not in the first ($n = 6$), the difference in time perception with drivers who did not crash at all was statistically significant at 90% for Checkpoints 3, 4, and 5. This shows that drivers who perceived a longer time interval during the first drive, or were more bored by the drive, were more likely to crash during the second drive. This is an interesting finding, as it suggests that current time perception may be used as predictor for future speed selection.

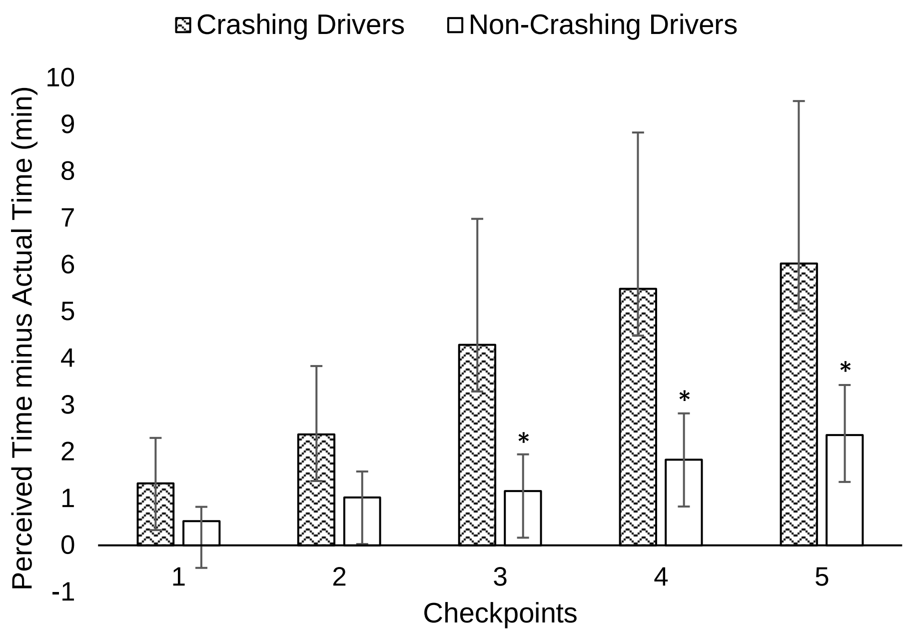

Figure 3.8 Mean differences in perceived and actual times during the first drive for drivers who crashed in the second drive versus drivers who did not crash.

3.4 Limitations and Future Work

The limited sample size was a significant limitation to this study. The high number of crashes due to excessive speeds around corners was unanticipated and severely limited the power of the statistical analyses. A future study should alter the roadway geometry so that the horizontal curves are more safely navigated at higher speeds. The overestimation of time in the prospective paradigm was unexpected based on previous literature; a future study could use a more stimulating roadway environment to see if the roadway environment significantly affects the cognitive stimulation and thus influences time perception. A more stimulating environment may also lead to more accurate speed perception, making the distinction worth exploring. Finally, splitting participants into one secondary task or the other may obfuscate the results due to individual behavior variances. A future study should focus on a single secondary task so that definitive conclusions can be made about how a specific type of distraction influences time and speed perception.

4 Conclusions

Thirty-four drivers participated in a driving simulator experiment that investigated time and speed perception as it related to cognitive workload resulting from secondary tasks. Each participant drove the virtual drive twice, once with either an audio or a map task and again with no distractions as a control. Participants knew from a practice drive that they would be asked to estimate their speed and time duration of driving, so this study used the prospective paradigm. Based on previous literature, it was expected that there would be an underestimation of time and an overestimation of speed. The reverse occurred: participants overestimated time and underestimated speed. This suggests that drivers may have found the drive unstimulating, despite the secondary tasks, and that the rural environmental may have impacted speed perception. Additionally, a large group of participants, nine out of 34, crashed the virtual vehicle at a horizontal curve that was not problematic in previous simulator studies. When investigating these crashes further, it was found that drivers who crashed in the second drive had significantly worse time perception in the first drive as compared to drivers who did not crash in the second drive. This finding suggests that current time perception may be a predictor of future speed selection.

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