2018-01-0521 Published 03 Apr 2018

Driver Response Time to Left-Turning Vehicles at Traffic Signal Controlled Intersections

Shady Attalla Kodsi Engineering

Ryan Toxopeus University of Guelph

Sam Kodsi Kodsi Engineering

Michele Oliver University of Guelph

Citation: Attalla, S., Toxopeus, R., Kodsi, S., and Oliver, M., "Driver Response Time to Left-Turning Vehicles at Traffic Signal Controlled Intersections," SAE Technical Paper 2018-01-0521, 2018, doi:10.4271/2018-01-0521.

Abstract

Left-turn crashes account for almost one quarter of all collisions. Although research has quantified the response time of drivers to left-turning vehicles with high acceleration profiles, research is lacking for driver responses to realistic left-turning vehicle acceleration. The purpose of this research was to determine the Driver Response Time (DRT) to a left-turning vehicle from the first lateral movement of the left-turning vehicle. The DRT was measured from first lateral movement of the left turning vehicle, until the through driver reacts, whether by touching the brake pedal, swerving, releasing/applying the accelerator, or a combination of these inputs.

Ninety-eight ($N_{Female} = 48$; $N_{Male} = 50$) licensed volunteer drivers took part in a study at the University of Guelph Driving Research in Virtual Environments (DRiVE) lab using an Oktal complete vehicle driving simulator. After a brief practice drive to acclimatize to the virtual environment, participants completed the eight kilometer drive experiment where two types of left hand turn hazards were presented to drivers in random order. In one scenario, the left-turning vehicle was stopped at the intersection before accelerating (LHTS), and in the other scenario the vehicle approached the intersection and turned at a constant speed (LHTNS). There were significant differences in DRT values between the LHTS and LHTNS scenarios with drivers taking longer to respond to the LHTS vehicle. This difference in DRT values corresponded with a higher collision rate in the LHTS scenario when compared to the LHTNS. However, collisions were common in both situations, with a mean time-to-impact of 3.66 seconds. Female DRT trended toward being slightly longer than males, but there were no differences in collision rates.

Introduction

There are several reasons for left turn collisions. One reason is when the left turning driver fails to observe or detect the through vehicle, either due to poor visibility, view obstruction, or inattention. A second reason is when the left turning driver underestimates or misjudges the through vehicle's distance from the intersection (i.e., the gap), and incorrectly assumes that it is safe to perform their turn. This often occurs when the through vehicle is travelling at a high rate of speed (i.e., much faster than the posted speed limit). A third reason is when the left turning driver makes the wrong assumption about the action of the through vehicle. An example of this is when the driver incorrectly assumes that the through vehicle is going to stop for the traffic light [1].

In addition to reconstructing a collision with respect to speeds and vehicle dynamics, accident reconstructionists and collision investigators are often asked to determine if a collision involving a left turning vehicle is avoidable by a typical through driver. For this collision avoidance analysis, the investigator is required to apply a reasonable driver response time (i.e., the time required for the through driver to detect, perceive and begin an evasive maneuver in response to the left turning vehicle) while considering the circumstances involved in the particular scenario.

Please note that there are many terms (i.e., perception-response time, brake-response time, perception-reaction time, etc.) used in the literature that interchangeably refer to the different phases of DRT, thus requiring the reconstructionist and collision investigator to interpret and apply literature values carefully. In the current study, the term "Driver-Response Time" (DRT) is used to refer to all the different response choices including braking, swerving, accelerator release or combinations of these responses. DRT data are further separated into later defined categories which depend on participant responses.

To determine a reasonable DRT or range of DRTs, the investigator relies on the most applicable literature. They must interpret how the research methodology influences the circumstances encountered by the incident through driver. In the case of drivers reacting to left turning vehicles, however,

there is limited research which quantifies DRT. While there is research that has quantified DRT values of drivers reacting to vehicles turning left at relatively high accelerations [2], DRT values of drivers responding to more normal, slower acceleration profiles associated with left turns have not been studied. Therefore, the purpose of this study was to examine the DRT of through drivers when the left-turning vehicle accelerates normally from a stopped position, or continues through the intersection into their turn at a constant speed. Depending on the situation, this research can provide DRT values that are applicable to accident reconstructionists and collision investigators when determining the avoidance potential for a left turn collision. The research can also be considered by roadway designers to ensure that there is sufficient visibility for drivers to perceive potential hazards such as left turning vehicles.

Methods

Simulator

The study was conducted at the University of Guelph using a complete car Pontiac G6 convertible driving simulator (Oktal, Paris, France). The vehicle, as seen in Figure 1, is surrounded by 300 degrees of wrap-around screens using HD projectors to give the driver an immersive experience. The steering wheel has force feedback, and vibrations are created in the car body through subwoofer speakers and two ButtKicker mini LFE units mounted to the vehicle frame. The simulator collected data on all the variables of interest: brake pedal pressure, accelerator pedal pressure, and steering wheel angle. Collisions were analyzed through looking at birds-eye view recordings that the simulator creates.

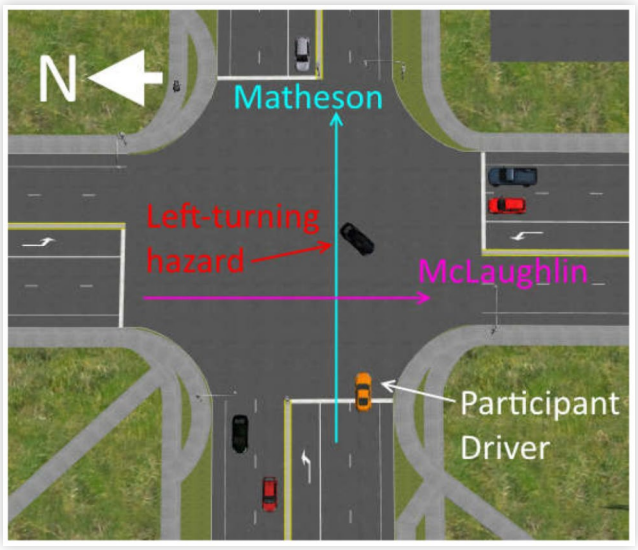
Virtual Environment

The environment the drivers navigated was based on roadways found in Mississauga, Ontario, Canada. The straight sections had two lanes in each direction, with a fifth merge lane in the middle. This fifth middle lane converted into turning lanes at intersections.

Additionally, there were bicycle lanes on both sides of the road. The specific intersection modeled was at Matheson Boulevard West and McLaughlin Road (MM), as seen in Figure 2. The speed limit used was 60 km/h.

FIGURE 1 University of Guelph Driving Research in Virtual Environments (DRiVE) Lab full car Oktal driving simulator.

FIGURE 2 Intersection with hazard vehicle (black) turning in front of participant driver (orange).



The traffic lanes were 3.5 meters wide, and the bicycle lanes were 1.5 meters wide. The medians between east- and westbound traffic were 0.5 meters wide. The radius of the turn for the left-turning vehicle was 21 m. This radius was also consistent with the average radius seen in Happer et al. [3] where the left turn path appeared to be close to an arc.

Ambient traffic and pedestrians were added to the scenario to give drivers a rich visual experience. The lighting and visibility were consistent with daytime clear weather conditions.

Hazardous Scenarios

Two hazardous situations were created, one where the left-turning vehicle was stopped at the intersection before accelerating (LHTS), and the other where the left-turning vehicle approached the intersection at a steady speed and continued through the intersection at that speed without stopping (LHTNS).

In all of the left turn scenarios, there was a clear line of sight between the through driver and the left turning vehicle at the beginning of its left turn. The left turning vehicles also had their left turn signals activated before their left turn maneuver was initiated.

The participants were all travelling in the curb lane at or near the posted speed limit of 60 km/h, with some travelling close to 70 km/h. The traffic light was programmed to always be green as the participants approached the intersection; this was done to allow the participants to travel at a constant speed before the hazard was presented.

Left Hand Turn, Stopped (LHTS) As discussed, one of the hazards involved a vehicle that was stopped in the oncoming left hand turn lane before the vehicle proceeded into its left turn (Figure 3). The reason this vehicle position was chosen was due to the simulated environment. It was important that the vehicle be stationary before it started its

FIGURE 3 Left-turning hazard vehicle at its starting position in the Matheson Boulevard West and McLaughlin Road intersection.

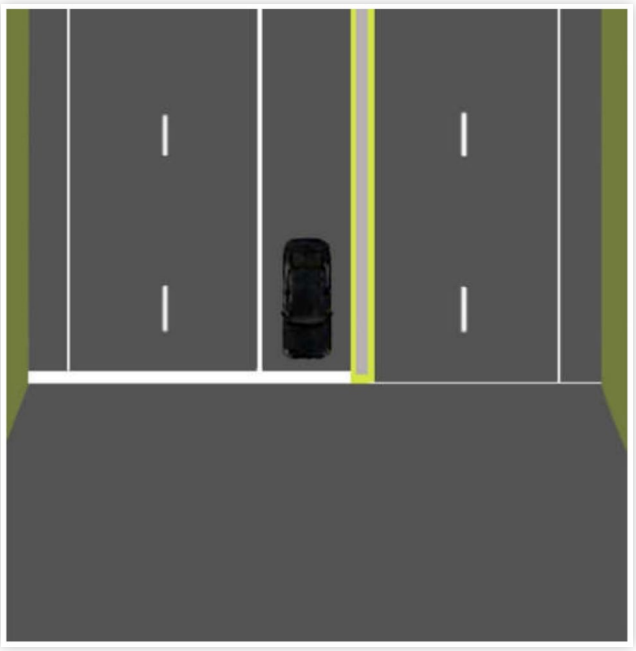


FIGURE 4 Left-turning hazard vehicle at the Matheson Boulevard West and McLaughlin Road intersection.

maneuver. If the vehicle had been stationary *within* the intersection, it would have gotten in the way of northbound traffic as the traffic lights changed. It was therefore deemed easiest to start the car behind the stop bar, and have the light change colour as the participant driver approached the intersection. As the participant approached, the hazard proceeded into the intersection at an average acceleration of 0.98 m/s^2 (0.1 g) [3].

The time to impact for all participants in this scenario was 4.00 seconds. In other words, the left-turning vehicle was programmed to begin its left turn and start its lateral movement across the intersection 4.00 seconds before the vehicles would have collided if the through driver did nothing to respond. The time-to-impact is the total time available for the test driver to perceive, respond, and attempt to avoid the collision. The eccentricity in this scenario (or the angle between the through driver and the left turning vehicle) was measured to be approximately 4 to 6 degrees. Figure 4 shows what the hazard vehicle looked like from the perspective of the participant driver as they entered the intersection.

Left Hand Turn, Not Stopped (LHTNS) The second hazard involved a vehicle moving into the left turn lane and turning through the intersection at a constant speed of 22 km/h [3]. The time to impact for all participants in this scenario was 3.31 seconds. In other words, the left-turning vehicle was programmed to begin its lateral movement into its left turn exactly 3.31 seconds before the vehicles would have collided if the through driver did nothing to respond. The eccentricity in this scenario was measured to be approximately 4 to 5 degrees.

This work was part of a larger study where four different hazard types were presented. The hazards were counterbalanced such that every test participant experienced either the LHTS or LHTNS hazard early in the study. The results of an ANOVA analysis found that the DRT values were not significantly different between the first and second hazard presentations ($p = 0.083$). The same analysis showed a significant difference between the first and third ($p < 0.001$), and first and fourth hazard presentations ($p < 0.001$). This indicated that participants were more cued to the hazards after the second hazard presentation. It is possible that the participants believed the first hazard was not intentional (or not part of the experiment), and hence they were not any more alerted to a second hazard being presented, than they would normally be. It is also possible that they expected a second hazard to be identical to the first. However, after the second hazard emerged, it is likely that the participants gained more of an understanding of what was to come, and began to predict that more and different hazards were going to present themselves. Since there was no learning before then, the first and second hazards were included in the analysis.

Participants

98 participants (50 male [*Mean Age* 23.8 years, SD = 2.63], 48 female [*Mean age* = 22.4 years, *SD* = 3.10]) completed the study. All participants held at least a G2 Ontario drivers' license (learner's permit that allows the driver to drive without an experienced passenger).

Measures

For the purpose of this study, the term "Driver Response Time" (DRT) is used in the general sense to refer to all different response choices. The data, however, are presented in four different categories, as follows:

Brake-response time (BRT): defined as the time period from first lateral movement of the left turning vehicle, until the driver reacts by touching the brake pedal.

Swerve-response time (SRT): defined as the time period from first lateral movement of the left turning vehicle, until the driver turned the steering wheel 2 degrees.

Accelerator release-response time (ART): defined as the time period from first lateral movement of the left turning

vehicle, until the driver took their foot off the accelerator if they neither pressed the brake pedal nor swerved.

Brake & Swerve-response time (BSRT): defined as the time period from first lateral movement of the left turning vehicle, until the driver reacts by touching the brake pedal or turning the steering wheel by 2 degrees, in the situation that they reacted by braking and swerving.

The first lateral movement of the left turning vehicle was chosen as the onset of the DRT (i.e., BRT, SRT, ART or BSRT) because this would have been the first reasonable indication that the vehicle was going to begin a left turn maneuver, and not yield the right of way to the through vehicle.

Collisions were detected visually through recorded video data, since the simulator crash detection variable was unreliable.

Statistical Analyses

Analyses were conducted using SPSS (IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY). First, frequencies were calculated to find the means and standard deviations of DRT for both scenarios, along with 15th, 50th, and 85th percentile scores.

DRT values (dependent variable) were compared between LHTS and LHTNS (fixed factor) using analysis of variance procedures ($p \leq 0.05$).

Finally, collision rates between the LHTS and LHTNS scenarios were compared using a Chi-square analysis ($p \leq 0.05$).

Results

The test driver response choice to the hazards presented by the left-turning vehicles varied. In the LHTS scenario, 60% of drivers only braked, 20% swerved and braked, 14% only swerved, and 6% only lifted their foot off the accelerator. In the LHTNS scenario, 51% of drivers braked, 23% braked and swerved, 23% only swerved, and 2% accelerated and swerved.

Table 1 outlines the DRT of the participants who reacted by braking only, swerving only, and a combined braking and swerving response for the two hazard scenarios.

Data for participants that chose a combined braking and swerving response was further assessed with respect to which maneuver was initiated first. There were 10 participants that chose a combined braking and swerving response in the LHTS scenario, and 11 participants in the LHTNS scenario. All 10 participants that chose this combined response for the LHTS scenario began their swerve maneuver first. However, out of the 11 participants who.

Chose this combined response for the LHTNS scenario, 3 braked first, and 8 swerved first. When data for the participants who swerved first, and braked first (in the combined response) were combined with the data for the participants that only braked, and only swerved, the DRT values become as outlined in Table 2. Note that there were no significant statistical differences between the combined responses and the single responses.

In addition to the data presented above, there were 3 participants that reacted by removing their foot off the accelerator in the LHTS scenario (ART value with $M = 3.37$ s, and $SD = 0.13$), and 1 participant who reacted by accelerating and swerving in the LHTNS scenario (DRT of 1.67 s).

Figure 5 shows that the LHTS scenario resulted in a significantly longer DRT ($M = 2.67$ s, $SD = 0.55$, 15th percentile = 2.10s, 50th percentile = 2.64 s, 85th percentile = 3.23 s, S.E. Mean = 0.078 s) than the LHTNS scenario ($M = 2.0$ s, $SD = 0.48$, 15th percentile = 1.58 s, 50th percentile = 1.92 s, 85th percentile = 2.67 s, S.E. Mean = 0.070 s), $F(1,96) = 38.54$, $p < .01$. This resulted in a significantly higher collision rate in the LHTS scenario ($M = 0.63$) compared to the LHTNS scenario ($M = 0.43$), $\chi(1) = 4.67$, $p = 0.031$.

Figure 6 shows the percentage of participants that responded by braking as well as those that responded by swerving for each of the two scenarios (LHTS, and LHTNS).

Figure 7 looks deeper into the response choices and collisions in the two scenarios. In the LHTS scenario, 45% of drivers who chose to brake, and 88% of those who swerved got into a collision. In the LHTNS scenario, 21% of drivers who braked, and 71% of those who swerved got into a collision.

Figure 8 shows the mean BRT and SRT values when both scenarios are combined, while Figure 9 shows the BRT and SRT values when both scenarios are separate.

Figure 10 shows the DRT data for females ($M = 2.51$ s, $SD = 0.71$) and males ($M = 2.23$ s, $SD = 0.62$), which uncovered

TABLE 1 Driver Response Time (DRT) of participants who reacted by braking (BRT), swerving (SRT), and braking and swerving (BSRT), for the two scenarios; left-hand turn no stop (LHTNS); left-hand turn stopped (LHTS).

	LHTS		LHTNS		LHTS&LHTNS Combined	
DRT	*Mean (s)*	*SD*	*Mean (s)*	*SD*	*Mean (s)*	*SD*
BRT	2.70	0.59	2.02	0.49	2.40	0.64
SRT	2.60	0.47	2.07	0.48	2.28	0.53
BSRT	2.62	0.49	2.27	0.45	2.44	0.49

TABLE 2 Driver Response Time (DRT) of participants who reacted by braking, swerving and combined braking and swerving for the two scenarios. Left-hand turn no stop (LHTNS); left-hand turn stop (LHTS). Brake Response Time (BRT); Swerve Response Time (SRT); Braked First Then Swerved (BFTS); Swerved First Then Braked (SFTB).

	LHTS		LHTNS		LHTS&LHTNS Combined	
DRT	*M (s)*	*SD*	*M (s)*	*SD*	*M (s)*	*SD*
Combined BRT&BFTS	2.70	0.59	2.04	0.50	2.23	0.64
Combined SRT&SFTB	2.62	0.47	2.15	0.46	2.33	0.48
Combined BRT, BFTS, SRT&SFTB	2.66	0.55	2.04	0.54	2.35	0.62

FIGURE 5 Drivers took longer to respond to the left turning vehicle when it was initially stopped, compared to when the left turning vehicle turned at a constant speed without initially stopping. Error bars indicate standard deviation. Driver Response Time (DRT); left-hand turn no stop (LHTNS); left-hand turn stopped (LHTS).

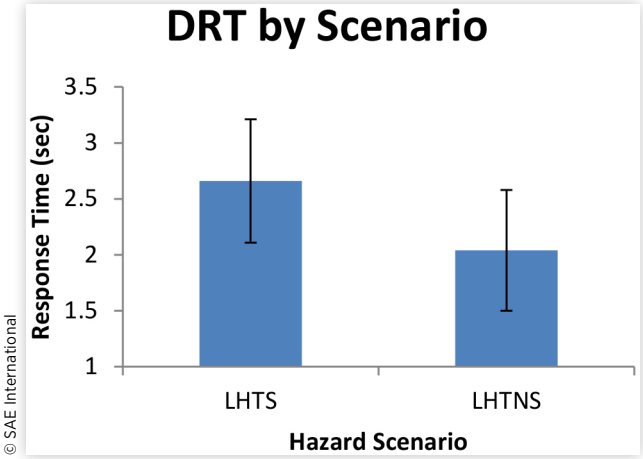
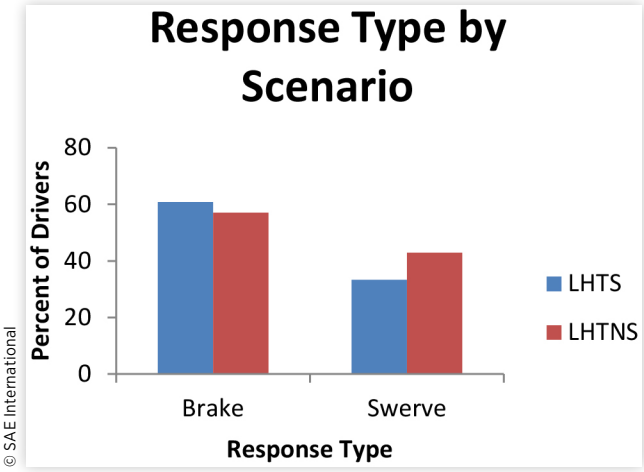


FIGURE 6 Response types by hazardous scenario type. Left-hand turn no stop (LHTNS); left-hand turn stop (LHTS).



a statistically significant relationship with females responding slightly slower than males ($F(1,97) = 4.18$, $p = 0.044$), but this difference did not translate into a difference in collision rates ($p = 0.617$).

Discussion

One of the only comparable studies that would be expected to yield similar results is the D'Addario study which utilized a simulator [2]. D'Addario quantified BRT and SRT values for through drivers reacting to left turning vehicles that were initially stopped

FIGURE 7 Percentage of drivers who crashed, depending on their response choice to the hazard. Left-hand turn no stop (LHTNS); left-hand turn stop (LHTS).

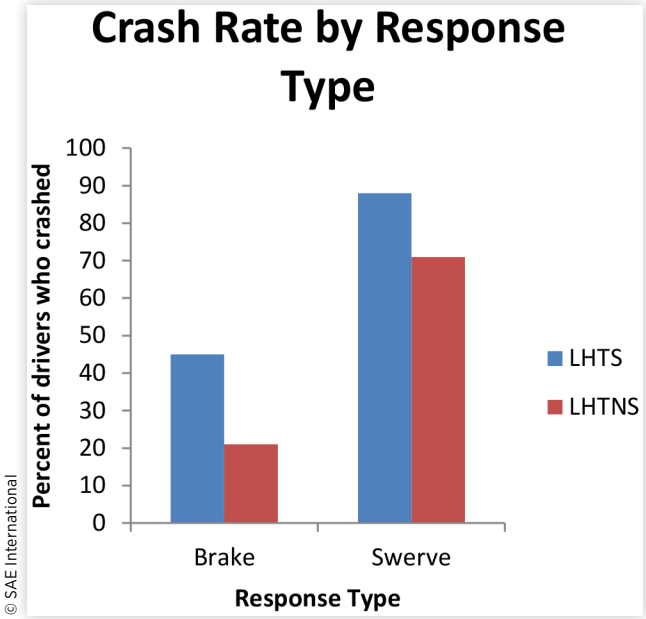
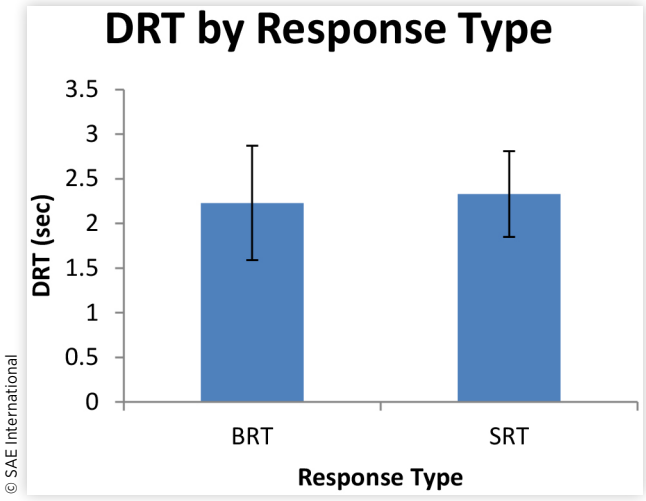


FIGURE 8 Driver Response (DRT) did not vary much by response type. Error bars indicate standard deviation. Brake Response Time (BRT); Swerve Response Time (SRT).



(i.e., the LHTS scenario in this study). The major difference was that D'Addario used an acceleration rate of 2.0 m/s^2 (0.2 g) for the left turning vehicles, while the current study used a more normal acceleration rate of 0.98 m/s^2 (0.1 g). The second major difference was that the through drivers in D'Addario were travelling in the passing lane of the road while in the current study participants were travelling in the curb lane. This would have resulted in a higher eccentricity in the current study.

D'Addario reported a mean BRT of 2.02 seconds with a standard deviation of 0.24, and a mean SRT of 1.77 seconds

FIGURE 9 Driver Response Time (DRT) did not vary much by hazard type and response type. Error bars indicate standard deviation. Brake Response Time (BRT); Swerve Response Time (SRT); Left-hand turn no stop (LHTNS); left-hand turn stop (LHTS).

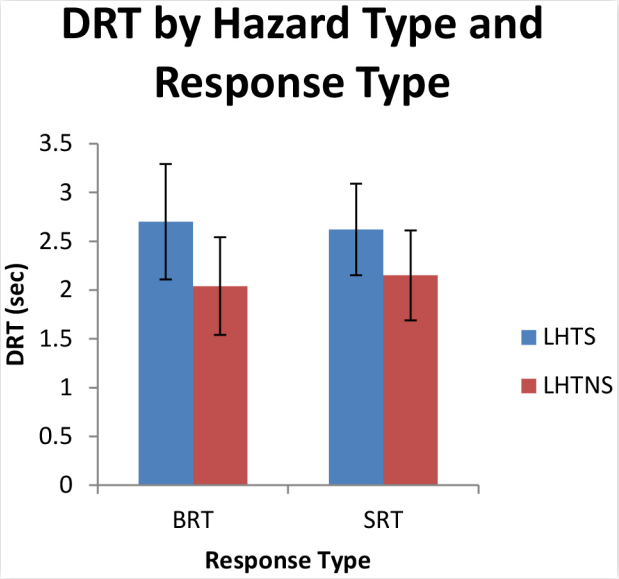
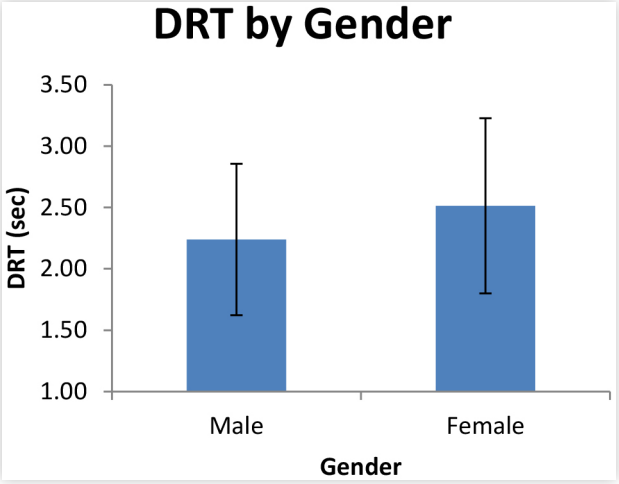


FIGURE 10 Females were slightly slower to respond to the hazards than males. Error bars indicate standard deviation. Driver Response Time (DRT).



with a standard deviation of 0.42. This was shorter than the results from this study as summarized in Table 3, below.

It is likely that the BRT and SRT values reported in D'Addario were shorter than the values from the LHTS scenario in the current study due to the higher acceleration rate utilized in D'Addario. This is because a hazard that is accelerating at a higher rate is expected to be more detectable by the through driver, hence requiring a shorter DRT. During the first second, the left turning vehicle would have moved only 0.49 m based on an acceleration of 0.98 m/s^2. This is approximately half the distance that would have been travelled by the left turning vehicle in the first second when accelerating at 2.0 m/s^2. It is therefore not surprising that a through driver would be able to detect the higher accelerating left turning vehicle earlier than the slower accelerating vehicle.

TABLE 3 A comparison between D'Addario [2] and the current study. Driver Response Time (DRT); Brake Response Time (BRT); Swerve Response Time (SRT).

	D'Addario [2]		LHTS Scenario From the Current Study	
DRT	*Mean (s)*	*SD*	*Mean (s)*	*SD*
BRT	2.02	0.24	2.70	0.59
SRT	1.77	0.42	2.62	0.47

It is also possible that the D'Addario DRT values were shorter due to lower eccentricity than the current study. It is again expected that a hazard intruding into the path of the through driver at a smaller angle would be detected earlier hence requiring a shorter DRT.

The fact that the LHTS DRT values were longer than the LHTNS DRT values suggests that the test participants detected the moving vehicle earlier than they did the stopped vehicle, with some drivers taking considerably longer to respond to the LHTS hazard. This longer DRT in the LHTS scenario is expected [5, 6] given that a stopped vehicle accelerates a very short distance in the beginning making it difficult for the through driver to recognize that it has actually begun its left turn. As discussed above, during the first second, the left turning vehicle would have moved only 0.49 m, and reached a speed of 3.5 km/h, based on an acceleration rate of 0.98 m/s^2. This is less than a tenth of the distance that would have been travelled by the left turning vehicle that was travelling at a constant speed of 22 km/h.

It is also possible that when the stopped vehicle was observed by the through driver (i.e., before the vehicle began its turn), the through driver assumed that the left turning driver was going to yield to them, therefore, almost cognitively eliminating them as a potential hazard. Further analysis of this phenomenon is currently underway, using eye-tracking and motion capture technology to determine if test drivers actually observe the moving hazard in a LHTNS scenario earlier than in a LHTS scenario.

Overall, however, the crashes were difficult to avoid, with over sixty percent of drivers colliding with the left turning vehicle in the LHTS scenario, and over forty percent of drivers colliding with the left turning vehicle in the LHTNS scenario. Most drivers in the LHTS scenario had a DRT between 2.13 seconds and 3.30 seconds after the hazard vehicle began its lateral movement into its left turn. In contrast, most drivers in the LHTNS scenario had a DRT between 1.58 seconds and 2.67 seconds after the hazard vehicle began its lateral movement. With the longer DRT values in the LHTS than the LHTNS scenario, it is not surprising that there was a corresponding twenty percent higher crash rate in the LHTS over the LHTNS scenario.

One thing that is prevalent across both scenarios is that drivers who swerved in response to the hazard were more likely to get into collisions. While a greater percentage of drivers reacted by swerving in the LHTNS scenario than in the LHTS scenario, 100% of those who served in the LHTS

scenario got into a crash. In contrast, fewer crashed (80%) when they swerved in the LHTNS scenario. This may not be the case in the real world, however. When drivers decide to respond by swerving, they typically swerve away from the direction of approach of the hazard (in this case to the right) in an attempt to increase their opportunity to avoid the collision by increasing the time to impact [4]. In the real world, this increased time might be all that is needed for the left turning driver to brake to a stop, or slow down enough to allow the through vehicle to clear their path without an impact. However, in our study, the left turning vehicles were programmed to proceed with their turn without any braking, and hence the vehicles collided (in the cases where a collision occurred).

As outlined in the Results section of the study, there were 3 participants who reacted by removing their foot off the accelerator in the LHTS scenario. The mean ART value was 3.37 s, with a standard deviation of 0.13. This was approximately three quarters of a second longer than the mean DRT of the participants who chose to brake or swerve in the LHTS scenario. In other words, in the 3 occurrences where the participants released the accelerator pedal, the participants were reacting much later, or required a longer time to begin their response. It is possible that in these 3 occurrences, the participants simply did not have enough time to get on the brake pedal, or simply realized that the collision was unavoidable and did not attempt to brake. This premise is supported by the fact that in all 3 acceleration release occurrences, the participants collided with the left turning vehicle.

It is important to note that the brake lag phase of a vehicle is not included in the DRT reported in this study. This is because the driving simulator used for this study was not equipped with hydraulic brakes (and hence did not have mechanical lag). The other reason it is not included is because the end of the DRT value was taken to be the moment the participant's foot contacted the brake pedal (before any significant force was applied). In order for the BRT values reported in this study to be converted to a PRT value (which normally includes the brake lag phase), the investigator would need to add an appropriate brake lag time period.

With respect to response choice, our results were consistent with previous findings that drivers are more likely to respond by braking, than by any other evasive maneuver [4]. Note that in real world, and based on referenced research, drivers may also choose to react by using their horn in addition to other avoidance response choices (i.e. swerving or braking). However, since the participants from this study were aware that using the horn would have no effect on the hazard, none of them applied their horn.

References

1. National Highway Traffic Safety Administration (NHTSA), "Crash Factors in Interaction-Related Crashes: An On-Scene Perspective," https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811366, accessed Oct 2017.
2. D'Addario, P.M., "Perception-Response Time to Emergency Roadway Hazards and the Effect of Cognitive Distraction," Masters thesis, Mechanical and Industrial Engineering Department, University of Toronto, Toronto, 2014.
3. Happer, A.J. et al., "Analysis of Left-Turning Vehicles at a 4-Way Medium-Sized Signalized Intersection," *SAE Int. J. Passeng. Cars - Mech. Syst.* 2(1):359-370, 2009, doi:10.4271/2009-01-0107.
4. Muttart, J.W., "Factors that Influence Drivers' Response Choice Decisions in Video Recorded Crashes," SAE Technical Paper 2005-01-0426, 2005, doi:10.4271/2005-01-0426.
5. Interactive Driver Response Research, Computer Software, Crash Safety Solutions, LLC, Eastern Hampton, CT, 2017.
6. Muttart, J.W., "Development and Evaluation of Driver Perception-Response Equations Based upon Meta-Analysis," *Transactions Journal of Passenger Cars-Mechanical Systems*, 2003.

Contact Information

Michele Oliver
moliver@uoguelph.ca

Acknowledgments

The authors gratefully acknowledge the financial support provided by the Natural Sciences and Engineering Research Council of Canada and the Ontario Centres of Excellence. The authors also thank Mr. Diego Gonzalez and Mr. David Johnson for helping with participant recruitment and data collection.

The authors would like to thank Mr. Diego Gonzalez and Mr. David Johnson for their assistance during data collection.

Definitions/Abbreviations

LHTS - Left-Hand Turn, Stopped

LHTNS - Left-Hand Turn, Not Stopped

BRT - Brake-response time

BSRT - Brake and swerve-response choice

SRT - Swerve-response time

ART - Accelerator release-response time

PRT - Perception-response time

Appendix

Raw Data

Legend	
Gender	Male = 1; Female = 2
Hazard Order	First Hazard = 1; Second Hazard = 2
Hazard Type	Left Hand Turn Stopped = 1; Left Hand Turn Not Stopped = 2
Reaction Type	Brake =1; Swerve = 2; Accelerate = 3; Foot off accelerator = 4; Brake and Swerve = 5; Acceleration and Swerve = 6
First Reaction Type	Brake = 1; Swerve = 2
Driver Response Time (DRT)	Time (s)
Collision	No Collision = 0; Collision = 1

Participant #	Gender	Hazard Order	Hazard Type	Reaction Type	First Reaction Type	DRT (s)	Collision
1	2	1	1	1		3.12	1
2	2	1	1	1		3.15	1
3	2	1	1	1		3.07	0
4	2	1	1	1		3.67	1
5	2	1	1	5	2	2.15	1
6	2	1	1	1		2.58	0
7	2	1	1	1		3.20	1
8	2	1	1	1		3.40	1
9	2	1	1	5	2	2.93	1
10	2	1	1	1		2.18	0
11	2	1	1	2		2.62	1
12	2	1	1	1		3.42	1
13	2	1	2	1		1.68	0
14	2	1	2	5	1	2.12	0
15	2	1	2	5	2	2.67	1
16	2	1	2	5	2	2.25	0
17	2	1	2	1		1.90	0
18	2	1	2	2		2.20	1
19	2	1	2	1		2.77	1
20	2	1	2	1		2.65	1
21	2	1	2	5	2	2.90	1
22	2	1	2	1		1.70	0
23	1	1	1	1		1.98	0
24	1	1	1	1		2.07	0
25	1	1	1	1		2.72	1
26	1	1	1	1		2.55	0
27	1	1	1	1		1.77	0
28	1	1	1	1		3.18	1
29	1	1	1	2		2.28	1
30	1	1	1	1		2.88	0
31	1	1	1	1		3.63	1
32	1	1	1	1		3.63	1
33	1	1	1	5	2	3.52	1
34	1	1	1	1		2.53	0

(Continued)

Participant #	Gender	Hazard Order	Hazard Type	Reaction Type	First Reaction Type	DRT (s)	Collision
35	1	1	1	4		3.25	1
36	1	1	2	2		1.20	1
37	1	1	2	1		1.90	0
38	1	1	2	1		2.83	0
39	1	1	2	2		1.83	1
40	1	1	2	2		2.45	1
41	1	1	2	5	2	1.83	0
42	1	1	2	2		2.23	0
43	1	1	2	1		1.75	0
44	1	1	2	5	2	2.42	1
45	1	1	2	1		2.58	1
46	1	1	2	1		2.07	0
47	1	1	2	1		1.58	0
48	1	1	2	5	2	1.87	0
49	2	2	1	1		3.08	1
50	2	2	1	1		1.59	0
51	2	2	1	4		3.28	1
52	2	2	1	5	2	2.32	1
53	2	2	1	1		2.25	0
54	2	2	1	1		2.44	1
55	2	2	1	1		1.70	0
56	2	2	1	1		2.37	0
57	2	2	1	1		2.19	0
58	2	2	1	2		3.10	1
59	2	2	1	1		3.25	1
60	2	2	1	2		3.01	1
61	2	2	1	5	2	2.57	1
62	2	2	2	1		1.20	0
63	2	2	2	2		2.53	0
64	2	2	2	5	1	2.83	1
65	2	2	2	1		2.27	0
66	2	2	2	1		2.87	1
67	2	2	2	6	2	1.67	0
68	2	2	2	1		1.38	0
69	2	2	2	2		2.68	1
70	2	2	2	1		2.43	1
71	2	2	2	5	2	2.65	1
72	2	2	2	1		1.80	0
73	2	2	2	1		2.48	0
74	2	2	2	1		2.40	0
75	1	2	1	1		2.56	1
76	1	2	1	5	2	1.84	0
77	1	2	1	1		2.39	0
78	1	2	1	2		2.49	1
79	1	2	1	5	2	2.67	1
80	1	2	1	5	2	2.89	1
81	1	2	1	5	2	2.31	0
82	1	2	1	5	2	3.04	1
83	1	2	1	2		1.77	1
84	1	2	1	4		3.48	1

(Continued)

Participant #	Gender	Hazard Order	Hazard Type	Reaction Type	First Reaction Type	DRT (s)	Collision
85	1	2	1	1		2.76	0
86	1	2	1	1		2.26	0
87	1	2	1	2		2.96	1
88	1	2	2	2		1.65	1
89	1	2	2	2		1.88	1
90	1	2	2	1		1.73	0
91	1	2	2	1		1.92	0
92	1	2	2	1		1.63	0
93	1	2	2	5	2	1.92	1
94	1	2	2	1		1.48	0
95	1	2	2	5	1	1.57	0
96	1	2	2	2		2.62	1
97	1	2	2	2		1.60	1
98	1	2	2	1		1.57	0

ISSN 0148-7191