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Driver Response Time to Midblock Crossing Pedestrians

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Abstract

Vehicle-pedestrian collisions account for 15% of fatal crashes in the USA, and there has been a twelve percent increase in fatal crashes in the USA from 2006 to 2015. Although research exists on the response time of drivers responding to pedestrian path intrusions, data on the response time of through drivers to jaywalking pedestrians crossing from the far side of the road has not been determined. Therefore, the purpose of this study was to quantify Driver Response Time (DRT) to a pedestrian that intrudes perpendicularly into the path of a vehicle from the far curb (adjacent to oncoming traffic). 50 ($N_{Female} = 25$; $N_{Male} = 25$) 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 approximately 10 minute experiment drive during which the pedestrian hazard was presented. Only eight percent of drivers collided with the pedestrian with a mean time-to-impact of 4.35 seconds. There were no gender differences in terms of DRT or crash rate.

Introduction

Vehicle crashes with pedestrians are on the rise, with 4795 pedestrians killed in the USA in 2006, and 5376 in 2015, reflecting an increase of twelve percent [1]. Pedestrian movements are not always predictable. Thus, while drivers expect to see other vehicles, they may not expect to see a person crossing the road especially if they are crossing mid-block [2].

Accident reconstructionists and collision investigators are often asked to reconstruct a vehicle-pedestrian collision with respect to the vehicle and pedestrian speeds and dynamics. Most often, the reconstructionist and investigator are also asked to determine if the collision with the pedestrian was avoidable by the driver. One of the challenges in this collision avoidance analysis is determining a reasonable perception-response time (i.e., the time required for the through driver to detect, perceive, and begin an evasive maneuver in response to the pedestrian) given the circumstances involved in the incident case.

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. The DRT data from this study, however, are further separated into later defined categories depending on the specific participant response choice.

To determine what DRT value or range of values are reasonable, the investigator normally relies on the most applicable research available while comparing the circumstances in which the data were collected coupled with the circumstances that would have been encountered by the incident driver. Once a DRT value or range of values are established, the collision investigator compares the time that would have been available to the driver (i.e., the moment when the pedestrian would have stepped onto the roadway until impact) with the time required to bring the vehicle to a stop before impact, or to slow the vehicle down enough to allow the pedestrian to clear the path of the vehicle. The time required to avoid the collision depends heavily on the DRT that had been established by the investigator or reconstructionist. Therefore, determining an appropriate DRT value or range of values is critical in the collision investigation process, and more specifically the driver avoidance assessment.

While studies involving pedestrian path intrusions have been conducted to determine DRT to a pedestrian who steps onto the road [2], [3], through DRT to a pedestrian running midblock across the road from the far curb (i.e., adjacent to oncoming traffic) has not been studied. Therefore, the purpose of this study was to examine the DRT of through drivers when the pedestrian runs across the street from the far curb. Depending on the situation, this research could provide DRT values that are applicable to accident reconstructionists and collision investigators when determining the avoidance potential for a pedestrian collision. This research can also be considered by roadway designers to ensure that there is sufficient visibility for drivers to perceive potential hazards such as crossing pedestrians.

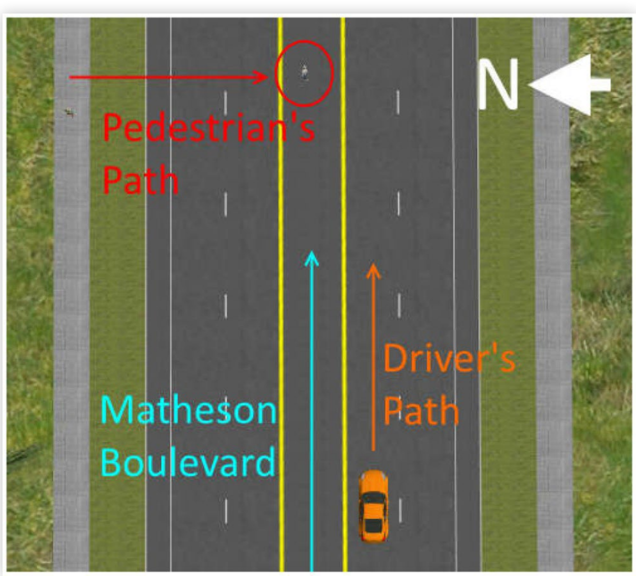
Methods

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 measured by looking at the birds-eye view recordings that the simulator creates.

Simulator

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

FIGURE 2 Top-down view of Matheson Boulevard with a pedestrian running across the road in front of the participant driver (orange).



Virtual Environment

The environment the drivers navigated was based on roadways found in Mississauga, Ontario, Canada. The road that was modeled was Matheson Boulevard West as seen in Figure 2. The road had two lanes in each direction, with a fifth lane in the middle that was not used for driving. Additionally, there were bicycle lanes on both sides of the road. The speed limit for this study was 60 km/h.

The traffic lanes were 3.5 meters wide, and bicycle lanes were 1.5 meters wide. The sidewalks were 2.3 meters wide, and 3.6 meters from the road. 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 Scenario Prior to starting any crossing movement, the pedestrian was standing on the north sidewalk with another pedestrian to simulate two people having a discussion. As the eastbound driver test participant approached the location of the pedestrians, a pedestrian turned and ran perpendicularly to the road in a southbound direction toward the south sidewalk on the opposite side. The pedestrian ran at a constant speed of 12 km/h (Figure 3) [4], [5].

This work was part of a larger study in which four different hazard types were presented over the course of the approximately 10 minute drive. The hazards were counterbalanced such that the pedestrian hazard could have appeared in any one of the four positions. A univariate analysis found that the DRT was not significantly different between the first and second hazards (p = 0.14) indicating that no learning had occurred. Therefore, the first two occurrences of the pedestrian hazard were included in the analysis.

Participants

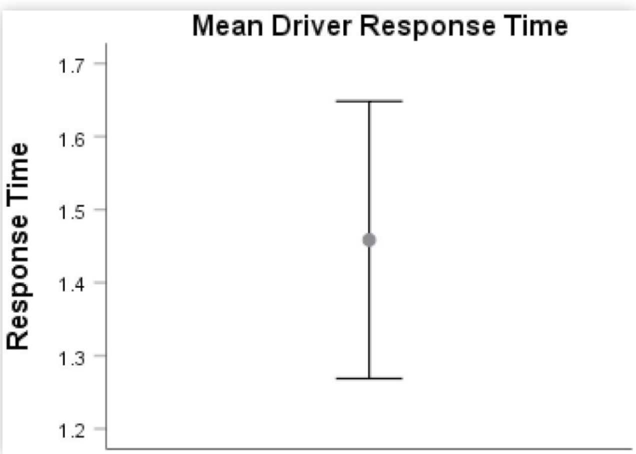
50 participants (25 male [*Mean Age* 23.4 years, SD = 2.30], 25 female [*Mean age* = 23.0 years, *SD* = 3.47]) completed the study. All participants held at least a G2 Ontario drivers' license (learner's permit that allows the driver to drive without an experienced passenger).

The time to impact for all participants was 4.35 seconds. The timing began when the pedestrian first stepped onto the

FIGURE 3 Easterly view of the pedestrian running across Matheson Boulevard.

FIGURE 4 Example of a driver test participant who crashed into the pedestrian hazard. Note that the vehicle's taillights were illuminated, indicating that this participant had applied the brakes before impact.

FIGURE 5 Response time of participants reacting to the pedestrian hazard (Error bars indicate 95% confidence interval).



road from the north curb. In other words, if the driver did not conduct any avoidance response maneuvers, the vehicle would have collided with the pedestrian 4.35 seconds after the pedestrian first stepped onto the roadway.

The participants were all travelling in the passing eastbound lane at or near the posted speed limit of 60 km/h, with some travelling close to 70 km/h. The eccentricity (i.e., the angle between the through driver's direction of view and the pedestrian when the pedestrian first stepped onto the roadway) was measured to be approximately 10 degrees.

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 three different categories, as follows:

Brake-response time (BRT): defined as the time period from when the pedestrian's foot stepped onto the roadway, until the driver reacts by touching the brake pedal.

Swerve-response time (SRT): defined as the time period from when the pedestrian's foot stepped onto the roadway, until the driver turned the steering wheel 2 degrees.

The pedestrian's first step onto the road was chosen as the onset of the DRT value because this would have been the first reasonable indication that the pedestrian was committing to crossing the road.

Collisions between the participants' vehicle and the pedestrian were detected visually through recorded video data (Figure 4).

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, along with 15th, 50th, and 85th percentile scores.

The DRT values (dependent variable) and collision rate (dependent variable) were compared between males and females (fixed factor) using analysis of variance procedures ($p \leq 0.05$).

Results

The combined DRT results for drivers responding to the pedestrian hazard (M = 1.46 s, SD = 0.66, 15th percentile = 0.82 s, 50th percentile = 1.26 s, 85th percentile = 2.01 s, S.E. Mean = 0.09 s) are shown in Figure 5. The mean collision rate was 0.08, meaning that only eight percent of the participants collided with the pedestrian.

Only 8% of drivers who braked, and none of the drivers who swerved got into a collision.

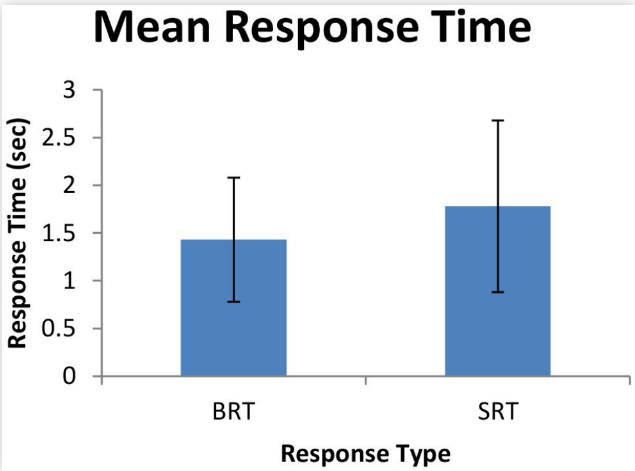
The response choices the drivers had to the hazards were fairly uniform. 90% of drivers only braked, 8% only swerved, and 2% swerved and braked. The one participant that chose a combined brake and swerve response began their braking maneuver before the swerve maneuver; however, these driver inputs were almost simultaneous. The DRT for this participant was 1.91 sec. Table 1 and Figure 6 below outline the DRT by response type.

There were no significant gender differences in terms of DRT (p = 0.49) or collision rate (p = 0.31).

TABLE 1 Driver Response Time (DRT) by response type. Brake Response Time (BRT); Swerve Response Time (SRT).

DRT	*Mean (s)*	*SD*
BRT	1.43	0.65
SRT	1.78	0.90

FIGURE 6 Response time of participants by response type. Error bars indicate SD. Brake Response Time (BRT); Swerve Response Time (SRT). Error bars indicate standard deviation.



Discussion

The majority of participants responded to the pedestrian between 0.82 and 2.01 seconds after the pedestrian set foot on the roadway; the mean response time was 1.46 seconds. Few participants in this study collided with the pedestrian with a time-to-impact of 4.35 seconds.

Based on our literature review, there is a gap in research when looking at DRT values of drivers responding to pedestrian crossing midblock at a running pace from the far side of the road. As such, a comparison of the results from this study with other literature is not possible. However, there were a few studies that quantified DRT values of drivers responding to pedestrians emerging from the near side of the road (i.e., the passenger side of the driver). Pedestrians emerging from the near side would have resulted in a shorter time-to-impact. As an example, D'Addario reported a mean BRT value of 1.0 seconds [8]. The mean BRT from the current study is 1.43 seconds which is less than half a second longer than the results found by D'Addario. However, as noted above, the pedestrian emerged from the near side of the road at a walking speed of 1.6 m/s in the D'Addario study, which would have lead to a smaller eccentricity (4 degrees), as opposed to the 10 degrees in the current study. Similarly, the time-to-impact in the D'Addario study was 2.5 seconds compared to the 4.35 seconds in the current study. Given that the D'Addario study involved a shorter time-to-impact, and a smaller eccentricity, it is not surprising that it reported shorter BRT values than the current study. A higher eccentricity results in a longer perception response time (i.e., the further the object is relative to the driver's straight ahead view, the longer it takes drivers to detect it) [6], [7].

A simulator based study conducted by Smiley also studied DRT to crossing pedestrians [9]. The study reported a mean Perception-Response Time (PRT) of 1.5 seconds (although referred to as PRT in the study, this value did not include the brake lag phase). This is similar to the findings from the current study where a mean DRT of 1.46 seconds was observed. However, there were two primary differences between the studies. In the Smiley study, the pedestrian emerged from the near side of the curb (i.e., closer to the passenger side of the vehicle) as opposed to the far curb (i.e., adjacent to the opposing lanes and closer to the driver side of the vehicle) in the current study. This would have resulted in a smaller eccentricity in the Smiley study when compared to the current study. Therefore, it would be expected that the Smiley study would result in shorter DRT values. However, the second major difference between the two research studies is that the pedestrian was walking at a speed of 6 km/h in the Smiley study, as opposed to running at a speed of 12 km/h in the current study. In contrast to the effect of having a smaller eccentricity, a slower speed for the pedestrian would likely result in a longer DRT value. Therefore, it is possible that the methodological differences between the Smiley study and the current study resulted in equal but opposite effects, which lead to mean DRT values that were quite similar.

A comparison between the results of this study and the output from the Interactive Driver Response Research (I.D.R.R.) software was also conducted. The IDRR is a tool based on mathematical equations that estimate DRT based upon a meta-analysis of previous research [10], [11]. Based on an eccentricity of 10 degrees, daytime conditions, and with the hazard being presented on a straight road (i.e., not at an intersection), the I.D.R.R. tool outputted an average DRT value (including foot movement time, but excluding any brake lag phase) of 1.7 seconds (with a 15th to 85th time of 1.1 to 2.4 seconds). This was approximately 0.24 seconds longer than the mean value of 1.46 seconds from the current research (15th percentile = 0.82 s; 85th percentile = 2.01 s).

As discussed, the brake lag phase of the vehicle was not included in the DRT. This is because the driving simulator used in this study was not equipped with hydraulic brakes (and hence did not have mechanical lag) and hence the end of the DRT values were taken at the moment the participant's foot contacted the brake pedal (i.e., before any significant force was applied). In order for the BRT values to be converted to PRT values, the investigator would need to add an appropriate brake lag time.

Please note the current research should be relied upon with extreme caution when applying the DRT results to pedestrian collisions which occur at night. This is because the lighting conditions, in addition to other factors such as glare and contrast, have a significant influence [7]. Even when assessing pedestrian collisions that occur during daytime conditions, the investigator should consider many factors (i.e., pedestrian conspicuity, traffic patterns, environment conditions, etc.) before applying the results from this study.

With respect to response choice, there were relatively few participants who responded to the pedestrian hazard by swerving, or swerving and braking. These results were consistent with previous findings that drivers are more likely to respond by braking than any other evasive maneuver [12].

The hazard presented by the midblock running pedestrian was relatively easy to avoid, as only 8% of the participants collided with the pedestrian. Even in the few cases where crashes did occur, the participants were able to substantially reduce their speed before impact. This was expected given the relatively long time-to-impact of 4.35 seconds.

It is noteworthy that there were no gender differences in terms of DRTs or collision rates.

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Appendix

Raw Data

Legend	
Gender	Male = 1; Female = 2
Reaction Type	Brake = 1; Swerve = 2; Brake and Swerve = 3
Driver Response Time (DRT)	Time (s)
Collision	No Collision = 0; Collision = 1

Participant #	Gender	Reaction Type	DRT	Collision
1	1	3	1.91	0
2	2	1	1.10	0
3	1	2	2.80	0
4	1	1	1.48	0
5	1	1	1.11	0
6	1	1	0.75	0
7	1	2	2.02	0
8	1	1	0.70	0
9	2	1	1.57	0
10	1	1	1.23	0
11	2	1	0.80	0
12	1	1	0.25	0
13	1	1	1.98	0
14	1	1	1.10	0
15	1	2	1.67	0
16	1	1	1.60	0
17	2	1	1.05	0
18	2	1	3.01	1
19	1	1	1.08	0
20	1	1	0.86	0
21	2	1	1.75	0
22	1	1	0.98	0
23	1	1	1.24	0
24	2	1	1.25	0
25	1	1	1.73	0
26	2	1	2.28	0
27	1	1	3.05	1
28	2	1	1.32	0
29	1	1	0.83	0
30	2	1	1.71	0
31	2	1	2.07	0
32	1	1	1.79	0
33	2	1	1.55	0
34	2	1	1.17	0
35	1	1	0.78	0
36	1	1	1.75	0
37	1	1	1.01	0
38	2	1	1.02	0
39	2	1	0.90	0
40	2	1	1.97	0
41	2	2	0.63	0
42	2	1	2.00	0
43	2	1	1.08	1
44	2	1	0.62	0
45	2	1	1.19	0
46	2	1	3.52	1
47	1	1	1.10	0
48	2	1	1.26	0
49	2	1	1.52	0
50	2	1	1.78	0

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