Pedestrian Crosswalk Study: Complete Report

Part I: Driving simulation data and Questionnaires

Part II: Eye tracking data

Lana Trick, PhD
Ryan Toxopeus, MSc

Table of Contents

Executive summary........................................................................................................11

Introduction................................................................................................................18

Methods....................................................................................................................19
  Design.....................................................................................................................19
  Apparatus and Materials.........................................................................................20
  Participants..............................................................................................................24
  Procedure................................................................................................................26

Part I Results: Driving data and questionnaires.......................................................29

Simulation data.........................................................................................................29
  Velocity profiles ....................................................................................................29
  Percentages of drivers stopping or not stopping as a function of signage.............32
  Drivers taking the incorrect exit at roundabouts as a function of signage.............33

Questionnaire data....................................................................................................34
  Percentage of drivers that recalled crosswalk signs (an index of noticing)...........34
  Percentage of drivers that recognized signs (a less stringent index of noticing)....34
  Sign interpretation data .........................................................................................36
  Driver opinions about the signage that would be more effective .........................37

Part II Results: Eye tracking data............................................................................39
  Data pre-processing...............................................................................................41

Which signage system is most effective at causing drivers to notice (look at) the signs?......42
  Percentages of drivers focusing on at least one type of sign ..................................43
  Numbers of different type of crosswalk sign fixated by the drivers.......................43
Average number of glances towards signs and glance duration ……………………….44

Percentages of drivers who looked at advance warning, groundmounted, and overhead…..45

**Which signage system is most likely to cause the drivers to behave appropriately, moving their eyes toward the pedestrian and allowing pedestrian to cross?**

Eye movements towards the pedestrians …..............................................45

Sequences of behaviour associated with yielding or not yielding to the pedestrian: A taxonomy of different types of crosswalk response …............................................. 46

**General Discussion**.............................................................50

Which of the signage systems is most likely to be noticed/understood by drivers?......49

Which of the signage systems is most effective in causing drivers to behave appropriately: looking at the pedestrian, braking, and yielding to the presence of pedestrians………………………………………………………………………………51

Limitations…………………………………………………………………….52

**General Conclusion**.............................................................56

**References**..................................................................................60

**Tables**...................................................................................62-79

**Table 1.** Summary showing the signage conditions with more yielding to pedestrians as indicated by more full and rolling stops and better compliance (fewer drivers failing to slow their speeds below 8 kph). Note: This summarizes the data in Figures 9-11………………62
Table 2. Percentages of drivers who missed their exit in the roundabout….

Table 3. Summary of driver opinions about what the appropriate behaviour would be in different situations shown in static screenshots of crosswalks with pedestrians. (Note: This summarizes the data in Figures 12-14)….

Table 4. Driver opinions about the appropriate place to stop in situations shown in static screen shots….

Table 5. Driver opinions about which sign would be more effective at causing drivers to come to a stop for a pedestrian at a crosswalk and their comments and justifications for their choices….

Table 6. Taxonomy of driving behaviours at crosswalks: 8 patterns of behaviour….

Table 7. A comparison of Courteous/Cautious and Opportunist drivers in terms of fixation durations to signs and pedestrians at midblock and intersection crosswalks …..
Table 8. Which condition causes better compliance to signage? Bringing together braking, eye glance, sign interpretation and driver opinion questionnaire data........................76

Figures........................................................................................................80-115

Figure 1. University of Guelph driving simulator........................................80

Figure 2. This example involves a midblock crosswalk in the Overhead condition, where there was an overhead and groundmounted sign at the crosswalk. (For half of simulations the pedestrian was on the right and for half the pedestrian was on the left)...........81

Figure 3. This example involves a crosswalk at an intersection in the Groundmount condition, where there was only a groundmounted sign at the crosswalk. (For half of simulations the pedestrian was on the right side of the road and for half the pedestrian was on the left)..............................................................................................82

Figure 4. This example involves the single lane roundabout. This is in the Overhead condition, in which there were both overhead and groundmounted signs. (For half of the simulations the pedestrian was on the right side of the road and for half the pedestrian was on the left.)..............................................................................................83
Figure 5. This example is at the entrance to the multilane roundabout. This is in the Groundmount condition, in which there was only a groundmounted sign at the crosswalk. (For half of the simulations the pedestrian was on the right side of the road and for half the pedestrian was on the left).

Figure 6. Average speeds as a function of the distance from the crosswalk and the signage (Figures 6a – 6f). Standard error bars included.

Figure 7. 25th percentile velocity (the velocity below which only 25% of the drivers travel) as a function of distance from the crosswalk (Figures 7a-7f).

Figure 8. 75th percentile velocity (velocity below which 75% of the drivers travel) as a function of distance from the crosswalk (Figures 8a-8f).

Figure 9. Percentage of drivers coming to a full stop.

Figure 10. Percentage of drivers coming to rolling stop (driving speeds over 0 kph but less than 8 kph).
**Figure 11.** Percentage of drivers that came to either a full or rolling stop (compliant drivers who yielded to the pedestrian at the crosswalk)……………………………………96

**Figure 12.** Sign interpretation: Percentage of drivers who thought that stopping was the appropriate response in the situation shown in the static screen shot of the crosswalk….97

**Figure 13.** Sign interpretation: Percentage of drivers who thought that slowing was the appropriate response in the situation shown in the static screen shot of the crosswalk….98

**Figure 14.** Sign interpretation: Percentage of drivers who thought that it was appropriate to continue on without slowing in the situation shown in the static screen shot of the crosswalk……………………………………………………………………99

**Figure 15.** Percentage of drivers who glance at at least one of the pedestrian signs in each of the conditions…………………………………………………………………………100

**Figure 16.** How many different types of sign did the drivers look at? Notice that for the Warning only condition, the maximum number of signs was one except at the exits to roundabouts in which there were no signs. For the Groundmount condition, the maximum number of signs was two in the roundabouts (warning sign plus one right side
groundmounted sign) and three midblock and at the intersection, where there were both right and left groundmounted signs. The Overhead condition had overhead signs in addition to all the signs for the Groundmount conditions. That means that the maximum number of signs in that condition was 3 in the roundabouts and 4 midblock and at intersections.

**Figure 17.** The total number of glances that drivers made to pedestrian crosswalk signs.

**Figure 18.** Total glance duration towards crosswalk signs: a). durations expressed in seconds; b). durations expressed in the percentage of crosswalk approach time.

**Figure 19.** Percentage of drivers who glanced at the advanced warning signs.

**Figure 20.** Percentage of drivers who glanced at the groundmounted signs. (Note: This represents the sum of the glances to left and right side groundmounted signs in the Midblock and Intersection environments. For the roundabouts the groundmounted signs all appear on the right side.

**Figure 21.** Percentage of drivers who glanced at the overhead signs.
Figure 22. Percentage of drivers who glanced at the pedestrians at the crosswalk…...107

Figure 23. Total glance duration towards pedestrians: a). durations expressed in seconds;
b). durations expressed in the percentage of crosswalk approach time…………………108

Figure 24. Percentages of Oblivious drivers (drivers who failed to look at any of the
crosswalk signs or pedestrian, and who did not allow the pedestrian to cross…………..109

Figure 25. Percentages of Non-compliant drivers (drivers who looked at the crosswalk
signs but did not behave appropriately given the sign). These drivers failed to look at the
pedestrian or allow the pedestrian to cross……………………………………………….110

Figure 26. Percentages of Opportunist drivers (drivers who looked at the crosswalk sign
and also looked for extended periods at the pedestrians, though they did not slow to allow
the pedestrian to cross)………………………………………………………………..111

Figure 27. Percentages of Courteous/Cautious drivers (drivers who looked at the crosswalk
signs, looked at the pedestrian, and slowed to allow the pedestrian to cross). Drivers who
were in the Warning only condition did not have any signs in the exits to roundabouts.
Consequently, these drivers were classified as Courteous/Cautious if they looked at the pedestrian and also slowed to allow the pedestrian to cross.

Figure 28. Percentages of Slow/Oblivious drivers (drivers who did not look at the crosswalk signs or the pedestrian, but were driving so slowly that the pedestrian had enough time to cross in front of them anyway.)

Figure 29. A misleading graph that shows the percentage of drivers that were driving in such a way that the simulated pedestrian would get an opportunity to cross the street.

Figure 30. Example of a perspective in which the sign at a crosswalk may make it more difficult to see the pedestrian.

Appendix A: Participant characteristics.

Appendix B: Driver characteristics for of the sample for whom we have eye tracking data.

Appendix C: Percentages of drivers in each group that fell into each of the 8 categories in each condition for each of the crosswalks.
Executive Summary

- **Research Question**: What type of signage is more likely to cause drivers to yield to pedestrians at non-signalized pedestrian crosswalks: a system that involves both overhead and groundmounted signs (the Overhead condition) or one that only has groundmounted signs (the Groundmount condition)? Two issues are implicit.

  1. Which of the signage systems is most likely to be noticed/understood by drivers?

  2. Which of the signage systems is most effective in causing drivers to behave appropriately: reducing speed, yielding to the presence of pedestrians, moving their eyes as necessary to scan for the presence of pedestrians, etc?

- **Approach**: The best way to answer these questions is to investigate what drivers actually do when faced with the different types of non-signalized crosswalk. A cost-effective way to test driver behaviour as a function of different types of signage is to use a driving simulator. The Ontario Traffic Council contacted the University of Guelph driving simulation facility (the DRIVE lab: [http://www.uoguelph.ca/drive](http://www.uoguelph.ca/drive)) to carry out the study. The lab houses a high fidelity fixed-base driving simulator: a full car body surrounded by 6 viewing screens that afford a 300 degree wrap-around virtual driving environment. The simulator provides the sights, sounds, and sensations of driving and it permits comparison of different signage systems without the necessity of having to install the signage on actual test tracks. Simulators enable drivers to be tested under carefully controlled conditions with little or no risk to drivers (or pedestrians).

- **Method**: Drivers were tested in the simulator with six different types of non-signalized pedestrian crosswalk (midblock, intersection, entrance and exit to a single lane roundabout, entrance and exit to a multilane roundabout). Data were gathered from 74 drivers in three signage conditions. The conditions were the Overhead condition (overhead + groundmounted signs at the crosswalk + an advance warning sign), the Groundmount condition (groundmounted signs at the crosswalk + an advance warning sign) and a condition in which there were no signs at the crosswalk but only an advance warning sign (the Warning condition). Drivers saw only one type of signage but each went through all six types of crosswalk. There were approximately equal numbers of young (18-24 years), medium aged (25-54 years), and older drivers (55+ years). Drivers were tested in the driving simulator to measure their velocity, braking, and yielding performance. Eye movements were measured using an eye track monitor, and questionnaires measured sign interpretation and opinions about which signage system that the drivers thought would be most effective.
**Results:** Overall results varied depending on the nature of the measure and location of the crosswalk (See Table 8 for a summary). The answers to the questions are as follows.

1. *Which of the signage systems is most likely to be noticed/understood by drivers?*

   - The most precise way to assess what drivers notice is to measure where they look. Although it was expected that larger percentages of drivers would look at signs in the Overhead condition because there were more signs in that condition, eye track analysis suggests that there were higher percentages of drivers looking at the signs in the Groundmount condition. The only time the expected benefit of the Overhead condition emerged was at crosswalks at the entrances to roundabouts, and in that case, the difference was not statistically significant. As expected, few drivers looked at signs in the Warning condition.

   ![Percentage of drivers who looked at at least one type of the signs (overhead, groundmount, or warning) available](chart.png)

   **Abbreviations:** Mid – Midblock crosswalk; Int – Intersection crosswalk; Nsr – Entrance single lane roundabout; Xsr – Exit single lane roundabout; Nmr – Entrance multilane roundabout; Xmr – Exit multilane roundabout.

   - Sign interpretation was measured by showing drivers screen shots from the simulations with pedestrians standing at the crosswalk beside different types of crosswalk sign. Overhead and Groundmount condition drivers saw the signs that they had been shown in the simulations. Generally, a higher percentage of drivers said that the appropriate behaviour was to stop when they saw the groundmounted sign alone (Groundmount condition) rather than the overhead and groundmounted sign together (Overhead condition). The only exception was for crosswalks at the entrances to multilane roundabouts.
Abbreviations: Mid – Midblock crosswalk; Int – Intersection crosswalk; Nsr – Entrance single lane roundabout; Xsr – Exit single lane roundabout; Nmr – Entrance multilane roundabout; Xmr – Exit multilane roundabout; Groundmount (first viewing) – Drivers who were in the Warning condition had never seen crosswalk signs right at the crosswalk during the simulations. To make use of their time during the sign interpretation phase, we had them evaluate static screen shots of signs in the Groundmount condition. This could be used as a partial check on the reliability in that condition. (Unfortunately, it was impossible to do this for the Overhead condition because it would have required testing another 24 drivers. It did not make sense to have one group of participants interpret both the Groundmount and Overhead signage, because there would be a high probability that once they had decided on the response to one type of sign they would give the same answer for the other.)

2. Which of the signage systems is most effective in causing drivers to behave appropriately: looking at pedestrians at the crosswalk, reducing speed, yielding to the presence of pedestrians?

- If crosswalk signage is effective, it should encourage drivers to look at the pedestrian waiting at the crosswalk. The majority of drivers looked at the pedestrians at every location except the exits to roundabouts. Of the three conditions, the Warning condition had the highest percentages of drivers looking at the pedestrian. The only places where the Overhead condition produced a highest percentage were at crosswalks at the exits to multilane roundabouts. However, in this case, only ~20% of the drivers looked at pedestrians.

- There were no marked differences in driving speed on the approach to the crosswalks as a function of signage. Part of the problem was that drivers...
came to full or rolling stops at different locations on the approach, and thus velocity profiles, which are based on speeds averaged across 10 meter areas, could not capture the effects of the signage. As well, there were marked individual differences in driving speed. Some of these were associated with age. Drivers in the 55+ years age group traveled 8 kph slower than drivers who were in the 18-24 year age group.

- Compliance to the signs was measured in terms of both braking and yielding behaviours. Braking analyses revealed that few drivers came to a full stop at the crosswalks. Rolling stops were more common (< 8 kph but > 0 kph), but the majority of the drivers did not reduce their speed below 8 kph. The number of these “non-compliant” drivers varied as a function of signage. Generally, there were higher percentages of drivers making full and rolling stops (compliant drivers) in the Overhead condition at the entrance to the multilane roundabout than in the Groundmount condition, but this finding is complicated by the fact that there was even more compliance in the Warning condition, in which there were no signs at all at the crosswalk. In contrast, the Overhead condition produced the worst compliance at the entrance to single lane roundabouts.

![Percentage of compliant drivers](image)

**Abbreviations:** Mid – Midblock crosswalk; Int – Intersection crosswalk; Nsr – Entrance single lane roundabout; Xsr – Exit single lane roundabout; Nmr – Entrance multilane roundabout; Xmr – Exit multilane roundabout

- Because braking data may underestimate the number of compliant drivers, another measure was calculated. In the simulation, the simulated pedestrian was programmed to cross the road if the drivers reduced their speed to less than 36 kph and left the pedestrian enough time to cross. The
percentages of drivers who allowed the pedestrian to cross for each of the six crosswalks were assessed. Higher percentages of drivers allowed pedestrians to cross at roundabout crosswalks, and particularly those at roundabout exits. The results of this analysis were not necessarily consistent with the braking data and moreover, braking and yielding data can be misleading in absence of eye tracking data. For example, although most drivers slowed or stopped on the exits to roundabouts, a large percentage looked at neither the signage nor the pedestrian and they stopped so early that the pedestrian had time to cross the road several times. This suggests that they were not slowing because of the pedestrian, but instead they were reducing their speed for other reasons (e.g. difficulties negotiating the roundabout).

- Analyses that combined yielding and eye tracking data suggest that there were 8 patterns of driving performance at crosswalks, though some were more common than others. At midblock and intersection crosswalks, the majority of drivers exhibited the Courteous/Cautious pattern of behaviour (drivers looked at both the signs and pedestrian, and allowed the pedestrian to cross) or the Opportunist pattern (drivers looked at both signs and pedestrians, but did not allow the pedestrian to cross). At these locations, the issue seemed to be crosswalk compliance rather than whether the driver noticed the crosswalk. However, at roundabouts, and especially roundabout exits, there were higher numbers of drivers who missed the signs or the pedestrian (or both), and in fact, the most common category of behaviour at the exits to roundabouts was Slow/Oblivious, (drivers did not look at the signs or pedestrian, but they were driving so slowly that the pedestrian had more than enough time to cross).

- Driver Opinion Questionnaire. At the end of the study, the 74 drivers were shown screen shots of both the Overhead and Groundmount condition signage and they were asked to indicate which one they thought would be most effective at causing drivers to stop for the pedestrians at each of the six crosswalks. Interestingly, their answers were not always consistent with their compliance to the different signs as measured in the driving simulator or even with their sign interpretation data for static screenshots from the crosswalks. For each crosswalk, the majority of the drivers indicated that they thought more yielding would occur if there were both overhead and groundmounted signs as compared to when there were only groundmounted signs. This suggests that drivers believe that increasing the number of signs would increase the chances that the drivers would see and comply to the signs. Nonetheless, the preference for the Overhead over Groundmount signage was weakest at the entrance and exit to the single lane roundabout and the exit to the multilane roundabout, with substantial numbers commenting that the overhead signage produced too much visual clutter or made it difficult to see other things in the driving scene.
• **Limitations.**

  o This is a small-scale study that was carried out in a short period of time. It would have been better to show each driver only one crosswalk with one type of sign to avoid sensitizing drivers to crosswalks but this would have required approximately two years of testing and six times more participants.

  o In driving simulators, there are no real costs to reckless or discourteous behaviour. Drivers may be more likely to yield to real rather than simulated human beings. Conversely, drivers may be more aware that their driving is being evaluated in a simulator, and they may be on their best behaviour. However, it is important to note that there is no reason to believe that either of these considerations would affect one signage condition more than another. Overall, there was no evidence that the drivers as a group were all reckless and discourteous. There was also no evidence that they were unrealistically conscientious. Instead, some drivers slowed or stopped and some did not, and a given driver sometimes stopped for one crosswalk and not another. The location of the crosswalk seemed to have an effect on how they performed at the crosswalk.

  o This study only tested driver compliance to crosswalk signs under ideal viewing conditions where both the pedestrian and the sign could be clearly seen. The advantages of overhead signage may only become apparent when there are stopped or parked vehicles or other obstacles that obstruct the drivers’ street-level views of pedestrians. However, at this point it is unclear whether drivers would slow down or stop at crosswalks in absence of clear views of a pedestrian even if overhead signs were present. The results of this study suggest that few drivers will look at a sign and then slow to yield without also looking the pedestrian.

• **General Conclusions and Recommendations**

  o The only unequivocal support for the use of overhead signs in addition to groundmounted signs comes from driver opinion questionnaires. At every crosswalk, the majority of drivers indicated that they thought the Overhead condition signage would be most effective in causing drivers to come to a stop for a pedestrian, though the size of this majority varied. Drivers justified their decision by saying that the extra signage made the crosswalk more visible.

  o In contrast, the eye tracking, sign interpretation, and driving simulation results do not support the idea that the Overhead condition is most effective. For example, even though there were more signs in the
Overhead condition, a higher percentage of drivers looked at the signs in the Groundmount condition for most crosswalks. The exception was at the entrances to roundabouts, where higher percentages of drivers looked at signs in the Overhead condition. The sign interpretation test indicated that higher percentages of drivers thought that drivers should stop for the pedestrian in the Groundmount condition at every crosswalk those at the entrance to multilane roundabouts.

- Compliance to signage can be measured in several ways. One is by assessing the percentage of drivers who looked at the pedestrian. For every crosswalk except those at the exits to a multilane roundabout, higher percentages of drivers in the Warning condition looked at the pedestrian at the crosswalk. The only exception was at the exit to multilane roundabouts, but very few drivers looked at the pedestrian in that location.

- Braking/yielding behaviour was inconsistent across locations, with no condition exhibiting a clear advantage. The results suggest that there is no “one size fits all” solution to the problem of signage at different types of non-signalized pedestrian crosswalks insofar that the effects of signage systems varied depending on the location of the crosswalk.

- Overall, the results do not support the idea that the extra expenditures associated with having both overhead and groundmounted signs at crosswalks are fully justified at every location given that this condition did not necessarily result in higher percentages of drivers noticing (looking at) or responding appropriately to the signs. Moreover, at midblock and intersection crosswalks the problem does not seem to be that drivers do not notice the crosswalk, but rather drivers differ in their ideas about what they should do at the crosswalk, with some exhibiting Courteous/Cautious behaviour (looking at the signs and pedestrians and then allowing the pedestrian to cross), and others exhibiting Opportunist behaviour (looking at the signs and the pedestrians, and still taking precedence over the pedestrian at the crosswalk). It is only at the exits to roundabouts where substantial numbers of drivers seem to be unaware of the crosswalk, but these drivers tend not to look at the signs regardless of the number of signs and there were larger minorities of drivers who reported that the extra signage produced visual clutter.
**Pedestrian Crosswalk Study**

The goal of this project was to determine how to best ensure that drivers respond appropriately to the presence of pedestrians at non-signalized pedestrian crosswalks. There are two conflicting points of view. According to one, the more signage, the better. That is, a system that employs three different modes of warning (overhead and groundmounted signs at the crosswalk in addition to an advance warning sign) would be superior to a system that employs two modes (groundmounted sign at the crosswalk and an advance warning sign) or just one (an advance warning sign). According to another point of view, although the groundmounted system at the crosswalk is important to ensuring drivers stop for pedestrians, the addition of extra overhead signage may actually distract drivers away from important information on the road in complex driving environments, potentially putting individuals at risk (drivers, pedestrians, other road users). Furthermore, from this perspective, it could be argued that it would be difficult to justify the cost of additional overhead signage, if the ground-mount + overhead sign failed to reduce risks as compared to the groundmounted signage alone at crosswalks.

Arguments can be made on both sides, but in the end, it is an empirical question. The best way to resolve the issue is to measure how drivers perform in response to the signage systems. There are two issues implicit:

1) Which of the signage systems is most likely to be noticed/understood by drivers?

2) Which of the signage systems is most effective in causing drivers to behave appropriately: reducing speed, yielding, looking at the pedestrian, etc.?
This is the complete laboratory report that incorporates driving simulation, eye track, and questionnaire data. Because there are a large number of tables and figures, the tables and figures are collected together at the end of the laboratory report (standard APA format). This prevents readers from having to hunt through the document to compare the results from different tables and figures. (It is best to print out the tables and figures separately and read the prose sections with the tables and figures beside you.)

**Methods**

*Design*

The experimental design involved comparing three different signage systems for a non-signalized pedestrian crosswalk. These systems varied in terms of how many pedestrian signs were involved. At one extreme, there was a system that involved both overhead and groundmounted signs at the crosswalk as well as an advance warning sign. This condition will be referred to as the *Overhead* condition. The condition with the second most signage will be referred to as the *Groundmount* condition. That condition only had groundmounted signs at the crosswalk and an advance warning sign. Finally, the *Warning* condition had the least signage. In that condition there were no signs at the crosswalk and only the advance warning sign.

Participants were randomly assigned to experience one of the signage conditions, and they saw the signage system in use in four environments: midblock, at an intersection, and in single and multilane roundabouts. Drivers experienced the four environments in different orders, though there was a balance across signage conditions in terms of the number who started with each environment. Because drivers sometimes react badly when there are too many turns early in the
drive (i.e., they develop simulator sickness), the two roundabouts were saved for the end of the drive.

A driving simulator was used to measure the extent to which drivers reduced their speed and yielded to the pedestrians positioned at the curb beside the crosswalk. The numbers and durations of eye glances towards the signage and pedestrians at the crosswalk were assessed during the drive using an eye track monitor to assess whether drivers noticed the signs and pedestrians as they drove. After the simulations, drivers’ memories for signage was measured as a rough index of whether they made note of the signs, and their interpretation and judgments about the effectiveness of the signage were also assessed with questionnaires.

**Apparatus and Materials**

The study was carried out in the University of Guelph Driving lab using a DriveSafety DS600c fixed-base driving simulator (Figure 1). The simulator is made up of a full car body surrounded by six 7-foot high viewing screens designed to project a 300-degree wrap-around virtual driving environment. Sound and vibration transducers on the simulator provide some of the sights and feelings of driving (engine sounds, the vibration of the steering wheel as the vehicle moves). The simulator can be used to project a variety of different driving scenes with different types of traffic, pedestrians, cyclists, and even construction and emergency vehicles. Driver performance data is gathered at a rate of 60 Hz by the simulator. (More details about the University of Guelph driving simulator can be found at http://www.uoguelph.ca/drive/.)

Driving simulations were created for four different environments with non-signalized pedestrian crosswalks. The first two were of straight sections on standard two lane urban streets (one lane in each direction). One of the simulations featured the midblock crosswalk (Figure 2)
whereas the other had the crosswalk at an intersection (Figure 3). Both had three other non-
signalized intersections where there was traffic but no pedestrians at the intersection. A single
lane roundabout was custom designed by Drive Safety Inc (http://www.drivesafety.com). It was
a typical urban/residential roundabout with a diameter of 60 meters measured to the inside of the
lane, as shown in Figure 4. The lanes at the approach to the roundabout were 3.6 meters
(standard width) with a 0.5 meter shoulder. Inside the roundabout the lane width was increased
to 5 meters to provide room for merging. There was also a 1 meter shoulder, a 0.2m gutter, a
raised curb, a slightly angled traversable apron, and a second raised curb and a vegetated center
island with a low (1m) vertical wall. The driver was instructed to take the second exit in the
roundabout to a city called Longmont, which was half way around the roundabout. The
multilane roundabout was initially designed for another study (Smiley, Smahel, Trick &
Toxopeus, 2010), and it was similar to the single lane roundabout in terms of the lane widths,
shoulders, and gutters, and central isle with vegetation. However, the multilane roundabout had
2-3 lanes with individual widths of 5 meters (Figure 5). This roundabout was not perfectly round
but instead had a diameter of 58 meters in one direction and 63 meters in another as measured
from the edge of the outside lane. For this, drivers were instructed to take the Highway 406 exit,
which was the second exit and three-quarters of the way round the roundabout.

All of the simulations were designed in such a way that they had a range of different
buildings, light standards, trees, and garbage cans and a variety of different types of roadside
signs, including commercial signs, directional signs and speed limits. Within the simulation, the
road and visibility conditions were good. The posted speed limit of 60 kph appeared at the
beginning of the drive and there were speed signs posted after each intersection. There was
moderate vehicle traffic in each of the simulations and there were also a number of pedestrians walking down the sidewalks at different rates.

Crosswalks were indicated by the standard crosshatch markings on the road (e.g., Figures 2-5). There was one test crosswalk each for the midblock and intersection but two crosswalks for each of the two roundabouts, one at the entrance and one at the exit. Roadside crosswalk warning signs were posted 85 m in advance of the midblock, intersection, and roundabout entry crosswalks, though the roadside warning at the entrance of the roundabout also served as the warning for the exits. That means that there were no warning signs specific to the roundabout exits. For the midblock and intersection crosswalks only there were also road markings (X’s) 30 meters in advance of the crosswalk, as shown in Figures 2-3. In the Warning condition those were the only signs for the crosswalks. In the Groundmount condition (Figures 3 and 5) there was a groundmounted warning sign right at the crosswalk in addition to the markings and signs in the Warning condition. These groundmounted signed appeared at both the left and right side of the road for the midblock and intersection crosswalks, and they appeared on the right side of the road for the entrances and exits for the two roundabouts. The Overhead condition had all of the markings and signs of the Groundmount condition and an overhead crosswalk sign as well (Figures 2 and 4). Each driver experienced four simulated drives (midblock, intersection, single lane roundabout, and multilane roundabout) and a total of six crosswalks but each driver only experienced one type of signage, either the Overhead, Groundmount, or Warning conditions.

A pedestrian was stationed at the curb of each of the designated crosswalks. The pedestrian was in a stance that would be classified as moderately aggressive, with feet close to the curb, a position that studies suggest indicates to drivers that the pedestrian intends to cross (Gerushat & Hasan, 2005). It was important to avoid having the pedestrian standing on the road because of
the danger that the results would be less likely to reflect a response to the signage than to the immediate threat of a pedestrian stepping into the path of the vehicle. The drives were counterbalanced in such a way that every driver experienced pedestrians on the left and right side of the crosswalk, and for every crosswalk approximately half of the drivers experienced the pedestrian on the left side of the road and half of the drivers experienced the pedestrian on the right. In the roundabouts, where there were crosswalks at both the entrance and exit, one of the pedestrians was on the left side of the road and one was on the right. Half the drivers had the pedestrian on the left side at the entrance and the right side at the exit, and the other drivers saw the reverse. The traffic in the simulation was carefully controlled in such a way that there was no traffic at the critical crosswalks where driver behaviour was measured. This ensured that leading or oncoming cars did not obscure the driver’s view of the pedestrian or the signs, and it also ensured that drivers could not be cued by how the simulated traffic responded to the presence of the pedestrian. The simulation was designed in such a way that the pedestrian only crossed the road if the driver slowed to less than 36 kph on the approach to the crosswalk and there was adequate time for the pedestrian to cross.

Questionnaires were designed to assess driver health and driving history and the Ferris et al. (1982) *Early Treatment of Diabetic Retinopathy acuity test (ETDRS)* and the *Pelli-Robson* contrast sensitivity test (Pelli, Robson, & Wilkins, 1988) were used to assess vision. There were also tests designed to identify and screen out individuals with a high probability of experiencing simulator adaptation syndrome (simulator sickness), a malady that afflicts some people when they are tested in driving simulators. Individuals with this syndrome exhibit one or more of the following symptoms: disorientation, dizziness, headache, eyestrain, stomach discomfort, and in severe cases, nausea. Screening tests can be used to identify individuals with the highest
probability of developing simulator sickness (see Kennedy et al. 1993), but these measures are not perfect, which is to say that some people who pass the screening test become ill when tested in the simulator. If a participant becomes ill then simulator testing must be terminated. Nonetheless, the use of screening tests maximizes the likelihood that most of the participants will be able to complete the study.

An Applied Science Laboratories 501 head-mounted eyetrack monitor was used to assess eye movements during the simulation (see http://www.asleyetracking.com/Site for an example of how the apparatus was fit).

Participants

A community sample was recruited through advertisements in local papers, on Kijiji (an online forum for classified ads), and by posters put up in various locations throughout the city, including at seniors recreational centres (the Evergreen Centre in Guelph), car dealerships, and coffee shops. Potential recruits were invited to phone the University of Guelph DRIVE lab. During the initial telephone interview the participants were screened to ensure that all were licensed drivers 18 years of age or older, in good health, and at low risk for simulator sickness.

The drivers who passed the screening test were invited to the DRIVE lab to be tested in the driving simulator. These individuals were all paid a $50 honorarium for their participation, even if they could not complete the study. As it turns out, there were some who did not complete the study, and whose data could not be used. Twelve of the 88 individuals initially invited for testing had to be dropped because they developed simulator sickness (12/88 represents a lower than average sickness rate, given the range of ages tested). Two other drivers had to be dropped because of irregularities during testing. Specifically, one had to be dropped when it became
apparent that she was not familiar with the rules of the road in Ontario. (She admitted that she had just moved to Ontario from Vermont; she interpreted the speed signs in miles per hour.) A second failed to follow instructions and her data had to be dropped because she asked the research staff for advice on whether or not she should stop for pedestrians. Although we initially planned to have only 72 drivers, we tested an additional 2 young adults because there were technical problems that resulted in the loss of data in two of the four drives for 2 young drivers. Two additional young adults had to be tested to make up for the data loss. Given that it did not make sense to use the data from these individuals for only 2 drives we included these 2 extra participants in the full sample. Thus, the final sample size was 74.

The characteristics of the final sample were as follows. The average age of the drivers was 40.1 years and all had been living in Ontario for at least 4 years. 43% of the drivers were female. (Equal numbers of males and females were recruited but females are more susceptible to simulator sickness.) Based on the ETDRS acuity and Pelli Robson contrast sensitivity tests, all of the drivers had normal or corrected to normal vision, though several older drivers reported having cataracts. All drivers had at least a G2 license and 87% had a full G license or better. More information on participant characteristics can be found in Appendix A.

Drivers were randomly assigned to one of three signage conditions (Overhead, Groundmount, Warning). We ensured that there were equal numbers of drives in each age group for each signage condition. Specifically, for each signage condition, there were at least 8 from each age group (18-24, 25-54, and 55+ years) though there were 9 younger adults instead of 8 for two types of sign for two of the crosswalks. Thus, overall, the percentages of drivers in each age group were 34, 32, and 32% of the sample for the young, middle, and older age groups respectively.
Procedure

During the study, care was taken to avoid sensitizing the participants to crosswalks before they began the simulations. All advertisements and consent materials described the study as an investigation of normal driving behaviours in rural and urban environments and there was no explicit mention of crosswalks until after the simulations were over. On arrival at the DRIVE Lab, drivers were ushered into a waiting room, where they filled out questionnaires about their health and driving history. The ETDRS acuity and Pelli-Robson contrast sensitivity tests were also administered at this time.

Participants were then shown into the room with the driving simulator. Drivers were fitted with the eye track monitor and the monitor was calibrated by having the driver fixate their eyes on a series of points in a standard image to ensure the system was measuring their eye movements accurately. They were then given general instructions about the simulator and were given a 5-minute practice drive through a residential area to allow them to get used to the feeling of the simulator. In simulations, there is sometimes a danger that drivers may consider the simulated pedestrians as “mere scenery” rather than active independent entities. To combat this tendency, the participants were given several opportunities to see simulated pedestrians in action. The practice began with drivers waiting at a stop sign in a residential area as several pedestrians crossed the intersection in front of them (some from the left and some from the right) while the drivers were receiving their instructions. Drivers were also given a chance to observe three instances of pedestrians jaywalking, and in one of these situations the jaywalking occurred within a half a block of the driver. In this way we were hoping to make the drive seem more realistic and impress upon the drivers that pedestrians were independent entities that might do unexpected things such as demand right of way on the road.
Once the practice drive was complete the main part of the study began. Drivers were told that the goal of the study was to examine natural driving behaviours and they were instructed to drive as they normally would. They were tested individually with no other person in the vehicle and they did 4 drives in the simulator. These simulations were 4-7 minutes in length. Two drives were through standard straight urban roads, in which there was one lane in each direction. One involved a midblock crosswalk and the other involved a crosswalk at an intersection. The other two drives involved roundabouts, one single lane and one multilane.

Each drive began with a description of the intended destination and directions how to get there. These directions were presented orally through the simulator speakers and visually on the simulator’s front viewing screen. For the midblock and intersection drives, the drivers were simply told to go straight until they came to the roadblock at the end of the road. For the two roundabouts drivers were instructed to take a specific exit, the exit to Longmont for the single lane roundabout and the exit to Highway 406 for the multilane (the second exit for each roundabout). Drivers were given the option of taking a 2-3 minute break at the end of each simulated drive.

On completion of the 4 simulated drives, the participants were asked questions about their experiences on the drives. The first goal was to determine whether the drivers noticed the crosswalk signs. Because people tend to remember things that they notice, memory for the crosswalks was assessed. We used two techniques. The first was a free recall test, which is a stringent type of memory test. For the free recall test, drivers had to describe what they remembered about the drive. The second test measured recognition memory, which is a weaker form of memory that measures feelings of familiarity. Drivers were given a deck of 21 laminated cards that each had a single sign on it, and they were asked to pick out the signs that they had
seen on the drive (signs were randomly ordered). Of the 21 signs, 12 had been present during the drive and 9 had not. Of the 12 signs that were on the drive, 3 were the pedestrian crosswalk signs (the warning and the left and right facing pedestrian signs that appeared at the crosswalk). There were also 4 other safety related signs (e.g. speed limits, 2-way traffic, stop, yield) and 5 commercial signs (billboards). Of the 9 signs that were not presented during the drive, 4 were safety-related and 5 were commercial billboards.

Sign interpretation tests were given next. Drivers were shown screen shots taken from the simulations for each of the six crosswalks. Each had a pedestrian standing at the curb beside a crosswalk sign. Drivers in the Overhead condition saw both overhead and groundmounted signs at the crosswalk whereas those in the Groundmount condition saw only the groundmounted signs. These drivers were making decisions about crosswalk situations that they had actually experienced in the driving simulation. However, the Warning condition drivers had never experienced signs right at the crosswalk. To make the best use of their time, we had them do a sign interpretation test as well, looking at screen shots taken from the Groundmount condition. These “first viewing” drivers were used as a partial check on performance in the Groundmount condition, to see if drivers who had previously viewed the scene in the simulation would be more or less likely to say that stopping was the appropriate response to the sign. (Unfortunately there were not enough participants to provide a “first viewing” group for the Overhead condition. There was only one warning group and it did not make sense to show participants both signage conditions.)

During the interpretation test, drivers were first asked what to do (stop, slow down, or continue at the same speed), justifying their decision. They were then asked to indicate the location where they would stop if they were to stop for the pedestrian. Finally, all of the drivers
were shown both types of crosswalk signage (overhead + ground-mount as compared to the ground-mount alone) and they were asked to indicate which type of signage they thought would be more effective in causing drivers to come to a stop at a pedestrian crosswalk. At the end of the study, the drivers were told the purpose of the investigation and then paid their honorarium.

**Part I Results: Driving simulation and Questionnaire Data**

*Simulation data*

*Velocity profiles.* One way to assess the effectiveness of different types of crosswalk signs is to look at velocity profiles. More effective crosswalk signs should produce greater speed reductions as the driver approaches the crosswalk. Velocity profiles for the lead up to the crosswalk were assessed by deriving the average speed across 10 meter intervals before the crosswalk (50, 40, 30, 20, and 10 meters in advance), and the velocity right at the crosswalk (0 meters). However, before these analyses began, preliminary calculations were carried out to determine if the position of the pedestrian (left or right side of the road) had an effect on velocity. Trials were counterbalanced in such a way that for each type of signage and each crosswalk location, and for each driver, the pedestrian was on the left about half of the time. As it turns out, the position of the pedestrian had negligible effects on driving speed. Overall, on average, driving speeds were 1.2 kph faster for left side pedestrians than right, a result that was far from being statistically significant (*F* < 1). This comparison was also made for individual crosswalks. Though driving speeds were slightly faster for left side pedestrians, the differences in speed were only 3.2, 0.6, .08, 1.0, 1.59 and 1.0 kph for the midblock, intersection, single lane roundabout entrance and exit, and multilane roundabout entrance and exit crosswalks respectively. There was no evidence that the velocity profile was different for left and right side
pedestrians; nor was there evidence that signage had different effects based on the position of the pedestrian. Because there seemed to be little difference in driving speeds for left and right side pedestrians, the results were combined.

Mixed factorial Analyses of Variance were carried out with distance from the crosswalk (50, 40, 30, 20, 10, 0 m) as the within subjects factor and signage (Overhead, Groundmount, Warning) as the between subjects factor. Results are shown in Figures 6a-f. There were significant changes in driving speed as a function of the distance from the crosswalk in all conditions ($p < .01$ for 0-50 meters and also $p < .01$ if only the 10-50 meter zone were considered). In some situations there was a marked drop in speed up to the 10 meter mark, as occurred in single and multilane roundabouts, where the maximal change in velocity as the crosswalk approached was up to 31 and 28 kph respectively. Such pronounced decreases in speed on the approach to crosswalks were only evident at the entrances to roundabouts. It seems probable that these changes in speed were more indicative of the drivers’ reaction to the roundabout than the pedestrian crosswalk. In some cases, there were even slight increases in speed as the crosswalk approached, as occurred at the exit to multilane roundabouts. However, in every case, speeds were no higher than the 60 kph limit posted at the outset of the drive, and in some situations the speeds on the approach were 15-20 kph lower.

Contrary to prediction, signage had no significant effect on velocity, regardless of the location of the crosswalk ($p > .1$ for 0-50 meter range and also $p > .1$ if only the 10-50 meter range was analyzed). The maximal difference in average driving speeds among the Overhead, Groundmount, and Warning conditions ranged from a low of 0.7 kph in the exit of the multilane roundabout to a high of 4.6 kph in the intersection (maximal differences = 2.7, 4.6, 2.6, 1.3, 1.2, 0.7 kph for the midblock, intersection, entrance and exit to the single lane roundabout, entrance
and exit to the multilane roundabout crosswalks respectively). Moreover, there was no consistency across crosswalk locations in terms of the signage conditions that produced the fastest and slowest speeds. Overall, the maximal difference in speed between the Overhead, Groundmount, and Warning conditions was only 1.2 kph, with speeds in the Warning condition slowest and the Overhead condition fastest. There was also no significant interaction between signage condition and distance from the crosswalk ($p > .1$), so it seems the profile of speed change on the approach to the crosswalk did not vary as a function of whether the drivers were in the Overhead, Groundmount or Warning sign conditions.

There were notable individual differences in driving speed though. Figures 7 and 8 show the 25th and 75th percentile driving speeds for each signage condition and crosswalk location. The 25th percentile represents the speeds below which 25% of the drivers travel (the bottom quarter of the sample in terms of driving speed) whereas the 75th percentile represents the speeds below which 75% of the drivers travel (the top quarter of the sample in terms of driving speed). The patterns of results were different for 25th and 75th percentile speeds. These differences may be partly accounted for by age differences within the sample. Each signage condition had roughly the same number of young, medium aged, and older adults. As is often the case, age had a marked effect on driving speed ($p < .001$). On average the oldest drivers (55+ years) traveled 8.2 kph slower than the youngest drivers (18-24 years), and 3.1 kph slower than the 25-54 year old drivers. Consequently, it seems probable that older drivers are disproportionately represented in the group whose driving speeds put them in the bottom 25% of the sample. Unfortunately there were not enough participants to determine whether the signage had different effects on different age groups (there would have to be more in each group per sign). Thus, overall, there were no significant differences in the velocity profiles among drivers in the Overhead, Groundmount and
Warning conditions. This may be partly due to marked individual differences in driving speed but it is also possible that the effects of signage were lost because of the need to calculate average speeds across 10 meter zones. There were pronounced differences in where drivers came to a stop. In this study, Velocity analyses were not sensitive enough to capture the differences between different types of signage.

*Percentages of drivers stopping or not stopping as a function of signage.* A more direct way to assess the differential effectiveness of the crosswalk signs is to measure the percentage of drivers who yielded to the pedestrian at the crosswalk. Studies conducted on residential streets suggest that only 5-20% of the drivers come to full stops at stop signs (e.g. Homburger et al. 1989) and consequently, both full and rolling stops were assessed. Full stops were defined as cases where drivers reduced their speed to zero somewhere within 50 meters of the crosswalk. Rolling stops were defined as cases where driving speeds were greater than zero but less than 8 kph in that area, a definition that has been used in other studies (e.g. Sarker et al. 1999).

Overall, across all conditions and crosswalk locations, 0-26% of the drivers came to a full stop (Figure 9) and 0-68% came to rolling stops (Figure 10). We also measured non-compliance, the percentage of drivers who failed to come to either a full or rolling stop; 12-92% of the drivers fell into that category, though the results varied markedly depending on the location of the crosswalk and type of signage. It is sometimes easier to talk about compliance than non-compliance. To put this in a different way, between 8% and 88% were compliant (100% - the non-compliant drivers), and Figure 11 plots the percentage of compliant drivers (those that came to either a full or rolling stop). In the document that follows I will sometimes refer to driver compliance rather than non-compliance.
Chi square analyses were performed to determine if the proportion of drivers who stopped varied significantly as a function of signage. Table 1 presents a summary of the analyses, indicating the condition that had better yielding to pedestrians, as judged by higher percentages of drivers coming to a full or rolling stop, and lower percentages that were non-compliant. Overall, few drivers came to a full stop (see Figure 9), and there were no significant differences in the proportion who came to a full stop among the Overhead, Groundmount, and Warning conditions ($p > .1$). There were significant differences in the percentages of non-compliant drivers though (drivers who failed to reduce their speed to < 8 kph anywhere in the approach to the crosswalk), but the effects were not consistent. For some crosswalk locations, the Overhead condition produced better compliance, whereas in others the Groundmount or Warning condition produced better compliance. For example, the Overhead signage condition produced significantly better compliance at the exit to multilane roundabouts ($p < .005$ difference with the Warning condition) and a non-significant advantage over the other two conditions midblock. However, the Overhead condition also produced significantly worse compliance than the other two conditions at the entrance to single lane roundabouts ($p < .05$). Sometimes it was better to have no signage at all at the crosswalk. The Warning condition produced better yielding at the entrance to multilane roundabouts ($p < .005$ than the Groundmount condition) and a slight (but non-significant) advantage at intersections. Thus, the effectiveness of Overhead, Groundmount, and Warning condition signage varied as a function of the location of the crosswalk. Based on this result, it seems that there is no “one size fits all” solution for all crosswalks.

Drivers taking the incorrect exit at roundabouts as a function of pedestrian signage. One way to measure whether the different types of signage have distracting effects is to observe
driver performance on another task. For both the single and multilane roundabouts drivers had to take a specific exit in the roundabout to arrive at their assigned destination, and this required that the drivers maintain information about the required destination in memory and apply it at the appropriate point in the roundabout. We measured the percentage of drivers who missed their exit as a function of signage and the type of roundabout. As can be seen from Table 2, significantly more drivers missed their exit in the Warning than overhead condition for single lane roundabouts, \( p < .05 \). The trend was the reverse in the multilane roundabout, with the best performance in the Warning condition and worst in the Overhead condition, though Chi square analysis revealed this was only a marginally significant effect \( (p < .1) \). Given this pattern of results, it is possible that drivers were making tradeoffs, either putting more attention towards the looking for pedestrians or finding the correct exit on the roundabout.

**Questionnaire data**

*Percentage of drivers that recalled the crosswalk signs (an index of noticing).* Chi square analysis revealed that significantly more drivers recalled the pedestrian crosswalk in the Overhead and Groundmount conditions (75% and 68% respectively) than in the Warning condition (48% of the drivers). This result is to be expected given that there were more signs to remember when there were signposts right at the crosswalk \( (p < .05) \). There was no significant difference between the Overhead and Ground-mount conditions though (a 7% difference is not statistically significant).

*Percentage of drivers that recognized signs (a less stringent index of noticing).* Drivers were given a set of laminated cards with pictures of commercial and safety-related signs and asked to
pick out the ones that they had seen during their drives in the simulator. In particular, we were interested in determining whether the group that had seen the overhead sign recognized more crosswalk signs than the group that just had groundmounted signs. For each group, there were 3 pedestrian signs to be recognized: the warning sign and the left and right side pedestrian signs. (The overhead sign had the same appearance as one of the groundmounted signs. Consequently, the number of recognizable pedestrian signs was equal for the Overhead and Groundmount groups.) There was no difference in the average number of pedestrian crosswalk signs remembered between the Overhead and Groundmount conditions ($M = 2.08$ signs in both conditions), and in fact, there was no significant difference between the two groups in their recognition of the other safety-related signs either ($M = 2.28$ and 2.31 out of 4 in the Overhead and Groundmounted conditions, $F < 1$) though the Overhead group did recognize significantly fewer commercial signs ($M = 1.44$ and 2.88 signs respectively out of a maximum of 5, $p < .005$). There were also no differences between the groups in terms of the number of times they falsely recognized signs that they had not experienced during the drives ($M = 1.63$ and 1.73 in the Overhead and Groundmount conditions out of a possible 9 signs that were not presented during the drive, $p > .1$). Thus, the recognition data suggest that there was no difference between the Overhead and Groundmounted groups. Given that people generally have to attend things to recognize them, this suggests that there was no real difference in the extent to which the signs were noticed. However, the eye movement data (presented in a later section of this report) can provide a more precise index of whether the drivers made note of the signs during each drive. The memory data only assesses if drivers remember each type of sign, not if they noticed them at each crosswalk.
Sign interpretation data. After the two memory tests, drivers were shown static screen shots of pedestrians at crosswalks that were taken right from the simulations. The drivers in the Overhead and Groundmount conditions were shown the signage they had experienced in the simulation. The Warning condition drivers were also shown screenshots from the Groundmount condition and they will be referred to as the first viewing condition for this analysis. This condition served as a partial check on the reliability of the data in the Groundmount condition. (In fact, the results from the Groundmount and first viewing Groundmount conditions were very similar.)

It is important to note that when drivers are shown pictures dominated by crosswalks with pedestrians standing beside crosswalk signs, there is a certain amount of implicit pressure for drivers to say the appropriate behaviour would be to stop. As can be seen by comparing Figures 12 and 9, many more drivers said that the appropriate behaviour was to stop in the sign interpretation test than actually stopped when driving through those same crosswalks in the simulations. Nonetheless, there were differences in opinion based on location of the crosswalk and the crosswalk sign, with 20-72% of the drivers indicating that the appropriate behaviour would be to stop.

Chi square analysis was carried out to find if there were differences in the percentages of drivers who thought stopping was the appropriate behaviour in the screen shots, and the results are summarized in Table 3. These analyses revealed that significantly higher percentages of drivers thought that stopping was the appropriate response with Groundmounted signs when the signs were midblock, at the entrance to a single lane roundabout, or the exit to a multilane roundabout ($p < .05$), whereas significantly more drivers in the Overhead condition thought the appropriate response was stopping at the entrance to the multilane roundabout ($p < .05$). There
was a trend to higher percentages of drivers endorsing stopping as the appropriate response at intersections and the exit to single lane roundabouts with groundmounted signs, but this effect was not statistically significant. There was a general trend towards more drivers in the Overhead condition indicating that slowing down was enough. Interestingly, a small percentage of drivers persisted in saying that it was acceptable to continue without slowing or stopping, despite the experimental demand created by viewing scenes that focused on pedestrians standing beside crosswalk signs. This minority ranged in size from 0-28% of the sample. Generally, there was no significant difference between signage conditions in the prevalence of these drivers. The exception to this general rule occurred in the entrance to the multilane roundabout, where a significantly higher percentage of drivers thought it was appropriate to continue without slowing or stopping in the Groundmount condition than the Overhead condition.

Finally, after being asked what to do at the crosswalk, drivers were then asked where to stop. Results are presented in Table 4. When forced to indicate where the stop should occur, most indicated a location, though there were considerable differences in opinion about what that location should be, and there were still 4-8% of the drivers who persisted in stating that it was inappropriate to stop for the pedestrian. At this point, it is unclear if this represents defensive behaviour (a few drivers unwilling to admit that their response to the pedestrian in the simulated drive may have been incorrect), or if it represents a firm belief among a few that pedestrians should not be given right of way at pedestrian crosswalks.

Driver opinions about the signage that would be most effective. All drivers were shown static screenshots of both the Overhead and Groundmount signage conditions for each of the six crosswalks. In each, a pedestrian was standing beside a crosswalk sign waiting to cross. Drivers
were asked to indicate which of the two signage systems that they thought would be most effective in causing drivers to come to a stop for the pedestrian. They were then asked to justify their response. The majority of the drivers thought that the Overhead signage condition would be more effective for all crosswalks, though the size of this majority varied depending on the location of the crosswalk, ranging from a low of 64% to a high of 91%. The lowest endorsements for the overhead sign came for the crosswalks at the exits to roundabouts, whereas the highest endorsement was for the midblock and intersection crosswalks and the entrance to the multilane roundabout.

When asked to justify their decision, the most common response was that the signage condition (typically the overhead signage condition) improved crosswalk visibility. However, there were also drivers who said there was no difference between the signage conditions and that the groundmounted system was good enough. Others commented that the overhead system covered up things the drivers needed to see, and that there was “overkill”, redundancy, and visual clutter with too many signs. Several older drivers commented that they were more used to the groundmounted signs. Results from this part of the study are presented in Table 5.

Thus, to summarize, the majority of drivers indicated that they thought that the Overhead signage (the system that included both overhead and groundmounted signs) would be more effective than the Groundmount condition, and they generally justified their response by asserting that increasing the number of signs would increase the visibility of the crosswalk, making it more likely that the driver would stop for the pedestrian. However, the drivers’ expectations about the effectiveness of the signs did not always conform to the actual effectiveness, as shown in their performance in response to these different types of signage when tested in the simulator, or even in terms of their responses to the sign interpretation test, where
there was a general tend to assume that it was more acceptable to just slow down (and not stop) in the Overhead condition than the Groundmount condition at every crosswalk except the one that occurred at the entrance to a multilane roundabout.

Part II Results: Eye tracking data

In order to assess the relative effectiveness of the Overhead, Groundmount, and Warning conditions, eye movement analysis was performed to find out whether the drivers looked at the signs and the pedestrians. Eye movement analysis is the most precise way to find out where drivers attend as they drive. In most cases people move their eyes so that objects that they are attending are projecting onto the fovea, the part of the retina in the eye that has the best acuity. When observers look straight at an object, to thread a needle or read for example, they use their fovea to extract the information. The fovea is necessary for object recognition because object recognition requires fine-detail information. To extract information from a particular part of an image the eye has to fixate (stay fixed on a location) so that the image falls on the fovea and the retinal neurons have enough time to extract the information. When exploring a visual environment people make a series of quick glances called saccades, where they move their eyes to “foveate” different parts of the image. Saccades can be initiated (started) in as little as 100 ms in response to sudden flashes of light in the periphery but typically initiating a saccade requires around 250 ms. Time to completion for the saccade varies based on the distance the eyes have to move. For saccades, information is not collected during the actual eye movement. (This was shown through experiments where observers made eye movements and researchers changed the visual image in dramatic ways during the eye movement. The observers had no awareness of these changes.) Instead, information is only gathered once the eyes stop moving, when the eyes fixate. Consequently, it is possible to get an index of what drivers notice by determining the
objects that they fixate. In determining whether drivers were moving their eyes appropriately at the crosswalk, we focused on a number of critical regions: signs (the advance warning, groundmounted, and overhead signs) and the pedestrian standing at the crosswalk. We also measured the number of glances towards those areas and total fixation durations.

The ASL eye track monitor involves a headband, scene and eye cameras, a monocle and a small mirror that reflects an image of the observer’s eye into the eye camera so that the pupil of the eye is visible. In this way it is possible to project the position of the pupil of the eye onto the driving scene to see where the driver is looking. For each driver, the headband, mirror, and monocle had to be carefully positioned so that the reflection of the eye (the corneal reflection) would project properly into the camera so that the pupil could be seen. At the beginning of the experimental drives, calibration was checked to ensure the monitor was measuring eye position.

However, there is always data loss when eye movements are measured. Data loss occurs because the headband shifts in such a way that the corneal reflection is lost. This can occur when participants touch their head or face, or if they sneeze or change their body position, bumping the seat, door, or the roof. Drivers were specifically instructed to avoid such movements, but in a series of 4-7 minute drives it is impossible to prevent some data loss. As well, it is especially challenging to monitor eye movements in individuals with glasses, particularly those with bifocals or coated lenses as these can interfere with the corneal reflection. Despite these complications, we were able to get eye-tracking data from 57 drivers for most crosswalks, 19 in each of the three conditions. This represents 79% of the sample of 72 for which we had all four simulator drives. The overall average age of this sample was 38.9 years. See Appendix B for more information on the characteristics of the sample from which we were able to collect eye-tracking data.
Data pre-processing

Eye movement data were sampled at a rate of 30 Hz (30 frames of motion per second). Thus for example, for each subject, for a 5 minute drive, there would be 30 X 60 seconds per minute X 5 minutes = 9000 frames of motion data. In this study, there were four drives that varied in length between 4-7 minutes. Analyses had to be done for all participants, even though we could only use the data from 57 because data has to be extracted and analyzed to determine whether there was data loss for a particular participant.

The first step in eye movement analysis involved locating the crosswalk in the data stream. Eye movement measurements were concentrated on the 145 meters in advance of the crosswalk for the midblock, intersection, and entrances to the single and multi-lane roundabouts. For these crosswalks, the advance warning signs appeared 85 meters before the crosswalks, and eye movement measurements preceded the warning signs by 60 meters, when the sign became visible. For the roundabout exits, measurements began as soon as the crosswalk came into view on the scene camera. All measurements were focused on the “decision zone”, the zone in which there was uncertainty about the driver’s response. The decision zone would end once the driver entered the crosswalk or the pedestrian began to move to cross the street. (Pedestrians would move into the crosswalk if the driver reduced their speed to below 36 kph in enough time for them to cross at their characteristic rate.)

Glances and glance duration were measured in the decision zone on the approach to the crosswalk. A glance was defined as a situation in which drivers fixated on an object for 4 or more frames of motion (133 ms or more). Differences in age and experience dictate how rapidly information can be extracted from a glance. (Age slows data extraction; experience makes it faster.) In this study, drivers either did not fixate at all or they fixated for 4 frames or more
(typically more). Some drivers made repeated glances to the same location. Glances in excess of 1 second apart were defined as separate glances (there were no cases in which the drivers returned to the same spot in under 1 second). Glance duration was defined as the total time that the driver fixated on the object across glances. The eye tracking data made it possible to answer the following questions.

**Which signage system is most effective in causing drivers to notice (look at) the signs?**

To clarify the discussion, a brief review of the setup for the six types of crosswalk and three conditions is in order. There were road markings indicating the presence of an upcoming crosswalk 30 meters in advance of the crosswalk for the midblock and intersection crosswalks (X’s on the road). There were also warning signs located 85 meters in advance of the crosswalks for the midblock, intersection crosswalks, and crosswalks at the entrances to single and multi-lane roundabout entrances. There were no advanced warning signs for the exits to roundabouts because there was no room for them after the roundabout entrance. That means that drivers in the Warning condition that only experienced advanced warning signs did not experience advance warning at the exits to roundabouts. In both the Groundmount and Overhead conditions, drivers had all of the signs and markings that the Warning condition drivers had, but they also had groundmounted crosswalk signs. These signs appeared at the crosswalk on the left and right side of the road for the midblock and intersection crosswalks. Groundmounted signs only appeared on the right side of the road for the entrances and exits to the roundabouts. For the Overheard condition, the drivers had all the signage and road markings from the Groundmount condition in addition to overhead signs.
Percentages of drivers focusing on at least one type of sign. A first comparison involved determining the percentage of drivers in each condition who fixated on at least one sign, regardless of the type of sign. Based on the number of signs available, it was predicted that a higher percentage of drivers in the Overhead condition would fixate at least one sign given that there were more signs for them to examine (they had warning, groundmounted and overhead signs available). This prediction is based on the idea that the probability of “hitting on” a sign while scanning the driving scene is higher if there are more signs to hit (the justification used by drivers when explaining why they thought the Overhead condition would be more effective). Using this reasoning, the Overhead condition should have the highest and the Warning condition the lowest percentage of drivers who fixated at least one sign.

Figure 15 shows that this prediction was not borne out. In general, the percentage of drivers who focused on at least one type of sign was higher in the Groundmounted condition rather than the Overhead condition. The only exception occurred at entrances to multilane roundabouts. However, as predicted, in every condition, the Warning condition had the lowest percentages of drivers fixating one or more signs. Chi square analysis revealed that condition had a significant effect on the percentage of drivers who saw at least one sign at every crosswalk except the ones at the exits to roundabouts (p < .05).

Numbers of different type of crosswalk sign fixated by the drivers. Figure 16 shows the average number of different types of pedestrian signs fixated by drivers. The maximum possible for Warning conditions drivers was one, and in fact there were no signs available for these drivers at the exits to roundabouts. Drivers in the Groundmount condition saw two more types of sign (left and right side groundmounted signs) in addition to the warning condition signs, and Overhead condition drivers saw one more type of sign than that. Consequently, based on the
number of types of available signs, it was predicted the average number of signs would be lowest in the Warning condition and highest in the Overhead condition. Analysis of variance revealed that signage had a significant effect on the number of different types of sign viewed (p < .05). The average number of different types of viewed sign was lowest in the Warning condition, as predicated, but it was sometimes non-significantly higher in the Groundmount than Overhead condition, as occurred at midblock and intersections crosswalks. However, the predicted advantage of the Overhead condition emerged at the entrances to roundabouts, though this difference was not statistically significant. At most crosswalks, on average, in conditions where there was more than one type of sign, drivers looked at between one and two pedestrian signs, though for the roundabout exits this number was much lower.

*Average number of glances towards signs and glance duration.* In some cases drivers fixated multiple signs and in others they glanced several times at the same sign. Figure 17 shows the average number of separate glances toward the pedestrian sign regardless of the type of sign. Analyses of variance revealed that the signage condition had significant effects (p < .01) on the average number of glances at every crosswalk except the ones that occurred at the exits to roundabouts, and generally, the average number of glances was lowest in the Warning condition. The Groundmount condition had significantly more separate glances to signs midblock and at intersections (significantly so for intersections), whereas the Overhead condition had significantly more glances to signs at the entrances to roundabouts. This finding is partially replicated in the glance duration data (Figures 18a and 18b). Analysis of variance indicated that condition had statistically significant effects on glance duration at intersections and the entrances to single lane roundabouts (p < .05) and marginal effects midblock and at entrances to multilane roundabouts (p > .05 but < .13). LSD tests of means revealed that at midblock and intersections
crosswalks, average glance durations were significantly longer for the Groundmount condition than the Overhead condition (p < .05). The Overhead condition had longer eye glance durations to signs at the entrances to roundabouts though tests of means revealed that this difference was not statistically significant. Figure 18b measures this duration in terms of a percentage of time that the driver spent on the approach to the crosswalk. (Drivers varied in terms of how quickly they cleared the crosswalk and for the roundabout exits the decision zone was short. The percentage of fixation time was calculated by dividing fixation duration to the signs by the total duration of the decision zone on the approach to the crosswalk for each driver.)

Percentages of drivers who looked at advance warning, groundmounted, and overhead signs.

Figures 19, 20, and 21 compare the three conditions in terms of the percentage of drivers who glanced at least once to an advanced warning, groundmounted, or overhead sign. Generally, in the Overhead condition there was a tendency for some of the drivers to focus on the overhead signs and others to focus on the groundmounted signs. Consequently, the percentage of drivers who looked at the groundmounted signs was lower in the Overhead than Groundmount condition. The percentage of drivers in the Overhead condition who looked at overhead signs varied between 6% and 52%.

Which of the signage systems is most likely to cause the drivers to behave appropriately, moving their eyes toward the pedestrian and allowing the pedestrian to cross?

Eye movements towards the pedestrian. If drivers comply with the message on the signs as they approach the crosswalk then they should look for pedestrians waiting to cross. The percentage of drivers who glanced at the pedestrian at the crosswalk is presented in Figure 22. For the midblock and intersection crosswalks, most drivers looked at the pedestrian, though these percentages were lower at the entrances and exits to roundabouts. Chi square analyses revealed
that there were significant differences ($p < .05$) between the three conditions at every crosswalk except the ones at intersections. However, at every location except the exits to multilane roundabouts, it was the Warning condition with the highest percentage of drivers looking at pedestrians. Total glance durations towards pedestrians are shown in Figures 23a and 23b. Analyses of variance revealed no significant difference in total glance duration between conditions except at midblock crosswalks ($p < .05$). The pattern of results was not completely consistent with that in Figure 22, perhaps because some drivers just glanced briefly at pedestrians whereas drivers in the other conditions fixated for longer periods of time.

*Sequences of behaviour associated with yielding or not yielding to the pedestrian: A taxonomy of different types of crosswalk response.* Certain sequences of events should occur at non-signalized crosswalks: Drivers should look for signs, they should look at the pedestrian, and they should adapt their behaviour to make it possible for the pedestrian to cross. Although the braking results are reported in an earlier section (e.g. see Table 1), if the driver slowed at the right time, it was possible for the pedestrian to cross safely without the need for “hard” braking. In this study, as in the real world, pedestrians played an active role in choosing whether or not to make a crossing based on how drivers behaved. The simulated pedestrians were programmed to step off the curb and cross the road if and only if drivers reduced their speed to below 36 kph in an adequate amount of time to permit the pedestrians to cross safely (without having to run for their lives). The decision zone (the point of ambiguity in the crosswalk) ended once the pedestrian began to move because after that point there was no longer any ambiguity about what had to be done to avoid hitting the pedestrian. (None of the drivers ran over the simulated pedestrian.)
By looking at the glance data for signs and pedestrians and combining it with the information about whether the driver behaved in such a way as to allow the pedestrian to cross, it is possible to derive 8 different patterns of driver behaviour at crosswalks. There were four for drivers who did not allow the pedestrian to cross and four for drivers that did (see Table 6). Some of these patterns are of particular concern for traffic safety professionals, and consequently these will be discussed in detail. (See Appendix C for the remainder. For the Warning condition roundabout exit data are reported separately because there was no advance warning sign at the exits to roundabouts.) It is important to note that the sample size is very small for this type of analysis given the number of drivers for whom eye tracking data was unavailable. In future, it would be beneficial to replicate these findings with a larger sample. Nonetheless, this type of classification may provide useful information for future investigations of crosswalk behaviour.

Of the drivers that did not slow enough for the pedestrian to cross, there was one group that sailed straight through the crosswalk without looking at the signs or the pedestrian. These types of drivers behave as if they were unaware of the crosswalk, and this pattern of behaviour shall be called **Oblivious**. As can be seen from Figure 24, this pattern was rare. Generally, oblivious behaviour was most often seen at roundabouts (particularly the single lane roundabout). The three conditions had approximately equal (and low) percentages of this type of driver.

Another category of behaviour occurs when drivers fixate at least one of the signs and yet they nonetheless do not comply with the signs, which should compel drivers to look for pedestrians and modify their speed in such a way that the pedestrian could cross. This pattern of behaviour is called **Non-compliant**; the drivers are presumably aware of the sign (they look at it) and yet they choose not to comply with its message. This type of behaviour is also quite rare, as shown in Figure 25, and it seems to mostly be associated with the midblock crosswalk.
Interestingly, it was only observed in the Overhead and Groundmount conditions even though the Warning condition had fewer signs.

There were drivers who looked at the pedestrian and not the sign but more commonly, when drivers failed to yield, they looked at both the pedestrian and sign (Figure 26). This pattern shall be called **Opportunist** insofar as drivers are taking the opportunity to take precedence over the pedestrians. They force pedestrians to either wait for them to pass through the crosswalk, or risk a collision by stepping into the path of the vehicle when there is inadequate time for the pedestrian to cross in safety. If the pedestrian does step out, drivers may be able to brake in time to avoid a collision if they are monitoring the pedestrian closely. It is also possible that the pedestrian might have to resort to increasing their speed, running across the road to avoid being hit.

There are also interesting patterns of behaviour for drivers who permit the pedestrian to cross. Of the drivers that stopped, one common pattern is the **Courteous/Cautious** driver (Figure 27). This type of driver looked at the crosswalk signs, looked at the pedestrian, and reduced their speed enough to allow the pedestrian to cross safely. In general, the Courteous/Cautious drivers are similar to the Opportunistic drivers insofar as they spend periods of time looking at pedestrians and signs (see Table 7). There are no significant differences in glance durations between the two groups midblock or at intersections for either signs or pedestrians. However, this finding is complicated by two opposing factors: 1) Opportunistic drivers are traveling faster so their decision zone is shorter in terms of the number of frames of motion (the amount of time) it takes them to clear the crosswalk. 2) Opportunistic drivers do not let the pedestrian cross, and consequently their decision zone would tend to be longer, because for them the decision zone ends right at the crosswalk whereas for the Courteous/Cautious drivers it ends before the
crosswalk. Courteous/Cautious drivers slow down to let the pedestrian to cross, and thus the pedestrian would begin moving before the driver gets to the crosswalk. Consequently, a second analysis was carried out, looking at the proportion of the decision zone in which drivers were looking at the signs and pedestrians for midblock and intersection crosswalks. For both types of crosswalk, the Opportunists were looking at the signs and pedestrians for a significantly larger percentage of their decision zone time than the Courteous/Cautious drivers (p < .005 for both).

The final pattern of interest is Slow/Oblivious drivers (Figure 28). These drivers were driving slowly enough to permit the pedestrian to cross but they showed no sign of noticing either the signs or the pedestrian while driving. This pattern of response was prevalent at the exits to roundabouts, where a large percentage of drivers stopped so early that the pedestrian had ridiculous amounts of time to cross the road (see Appendix C). Although the pedestrian crossed safely, there is still cause for concern because it seems possible that the drivers were having such difficulty determining what to do at the roundabout that they were not really aware that they were approaching a pedestrian crossing and their response was not geared to the presence of the pedestrian but the difficulty of the roundabout.

Combining eye movement and yielding data in this way is useful in that it provides insights that the study of each alone could not. For example, Figure 29 shows the percentage of drivers who yield to the pedestrian (slowing down enough for the pedestrian to cross). Based on these data, it might be tempting to conclude that the signage was especially effective at roundabouts given the percentage of drivers who allowed the pedestrian to cross. However, the eye movement analysis makes it clear that the opposite is true. Signs were least effective at the exits to roundabouts. Few drivers looked at the signs or the pedestrians and this suggests neither was
attended. The pedestrians were able to cross because the drivers were driving slowly perhaps because they were having difficulty negotiating the roundabout.

**General Discussion**

The results of the study are complex (see Table 8), and vary with the location of the crosswalk. Nonetheless, the study began with two questions, and in the following section the answers to these questions will be discussed, and afterwards the limitations of the study.

*Which of the signage systems is most likely to be noticed/understood by drivers?*

The eye movement data is the most direct way to assess which signage system was most likely to be noticed insofar as drivers are more likely to notice things that they look at. Contrary to prediction, although the Overhead condition had more signs, higher percentages of drivers looked at signs in the Groundmount than Overhead conditions. This was true at every location except at the entry to multilane roundabouts. The signage condition had statistically significant effects for all of the crosswalks except for those at the exits to roundabouts, but in many cases it was the difference between the best and the worst condition (typically the Warning condition) that was the source of the effect.

Sign interpretation was measured by showing drivers screenshots of pedestrians standing at the crosswalk, waiting to cross, with the signage from the Overhead or Groundmount conditions. Drivers were shown the type of crosswalk they had seen in the simulation and they were asked to indicate what the appropriate behaviour would be. In every location except at the entrance to multilane roundabouts, higher percentages of drivers in the Groundmount condition said that the appropriate behaviour was to stop. The effects of the signage condition were statistically significant for every crosswalk except those at the intersection and exit to the single lane roundabout. Thus, in general, at most locations, higher percentages of drivers thought that the
appropriate behaviour was to stop for the pedestrian when they saw Groundmounted signage. This suggests that overall, the groundmounted signs were better understood. Interestingly, although there was extra signage in the Overhead condition, higher percentages of the drivers decided that it would be permissible to slow rather than stop.

*Which of the signage systems is most effective in causing drivers to behave appropriately: looking at the pedestrian, braking, and yielding to the presence of pedestrians?*

Generally, the majority of drivers looked at the pedestrian at every location except the exits to roundabouts. Chi square analyses revealed that condition had a statistically significant effect on the percentage of drivers looking at the pedestrian at every location except the intersection crosswalk. In this case, it was generally the Warning condition that produced superior performance. The exception was in exits to multilane roundabouts, where there were higher percentages in the Overhead condition. At most locations there was little difference between the Overhead and Groundmount conditions.

Overall the velocity analysis was inconclusive, but two measures of yielding were calculated. One measured braking (full or rolling stops) and the second measured the percentages of drivers who slowed adequately to permit the simulated pedestrian to cross. The results for these two analyses were not exactly the same because braking may not be necessary when drivers slow in an adequate amount of time for the pedestrians to cross. The signage condition had no significant effect on the percentage of compliant drivers (those that came to either a full or rolling stop) except at the entrance to single lane roundabouts and both the entrance and exit to multilane roundabouts. The percentages of drivers who slowed enough to allow the driver to stop only varied significantly at the entrance to multilane roundabouts. However, drivers may
slow or stop for other reasons than the presence of signs or pedestrians and it is misleading to
make conclusions without considering the eye movement data as well. For example, although
the majority of the drivers slowed to allow the pedestrian to cross at the exits to roundabouts, the
eye movement data indicated that the majority looked at neither the signs nor the pedestrians.
Furthermore, the drivers slowed so far in advance of the pedestrian had more than enough time
to cross (see Appendix C). This suggests that the drives were not slowing for the pedestrian but
they were slowing because they were having difficulty deciding what to do at the exit to the
roundabout.

By using the eye movement data together with the yielding data, it is possible to delineate 8
different categories of driving behaviour. This type of analysis is speculative because the
numbers of drivers per category were often quite small. Nonetheless, overall, for midblock and
intersection crosswalks, the majority of the drivers in the Overhead and Groundmount conditions
looked at both the signs and the pedestrian, but drivers varied in terms of whether or not they
allowed the pedestrian to cross (Courteous/Cautious drivers versus Opportunist drivers
respectively). When these results were analyzed, the results were inconsistent. Although the
Warning condition typically had the lowest percentage yielding, the Overhead and Groundmount
conditions alternated in terms of which produced the most Courteous/Cautious and the least
Opportunist driving (see Appendix C). There was little evidence that Overhead signage produced
a consistent advantage because effects varied as a function of crosswalk. The pattern of results
was very different at roundabouts than on the crosswalks that occurred in straight sections of
road.

Limitations. It is impossible to measure everything in a single study. This study focused on
crosswalk signs and did not take into account the critical information that may have been gleaned
from road markings on the approach to a crosswalk. (There were advance road markings for the midblock and intersection crosswalks.) As well, it is important to remember that eye tracking data is an imperfect index of what drivers attend. For example, there are cases where drivers may fixate their eyes on an object and nonetheless exhibit no awareness of it (the basis of the looked but didn’t see collision: see White & Caird, 2010) and also situations where the attentional focus moves faster than eye fixation, so that drivers may be attending to an object that they have not yet fixated (the basis of covert orienting: Posner, 1980). However, in most situations people look at things that they are attending. The study had a number of other limitations or shortcomings. The problems fall into three broad categories. In the sections below these factors will be discussed and their impact on the study will be assessed.

1. Sample size

The advantage to having a large number of participants in a study is that it increases the probability that the sample will be representative (typical) of the general population. However, in this study compromises were necessary to ensure that it could be completed in a reasonable amount of time and at a reasonable cost. In driving simulation studies that involve eye movement analysis, testing and data analysis are very time consuming and laborious. The sample size for this study was designed to be comparable to similar studies involving driving simulation (e.g. Fisher & Garay-Vega, 2012; Gomez et al. 2011). Drivers were randomly assigned to experience the Overhead, Groundmount, or Warning conditions to avoid sensitizing them to crosswalks (it was bad enough that they saw crosswalks at six locations). Random assignment is a way of trying to ensure that drivers in the different conditions are not too different from one another. However, random assignment is more likely to succeed in equating groups when the sample size is large. Although we matched drivers in age and sex across conditions, if drivers in one
condition were more aggressive than the others, this could affect the driving simulations and sign interpretation tests, where each group only evaluated the signage for the condition to which they were assigned. That being said, there is little evidence that this is the case in the present study because there was variation between conditions in terms of which drivers showed the most aggressive/least courteous behaviour at different locations. Thus, although it would have been nice to have a larger sample, it seems the study did not suffer too much as a result of limited sample size. At least it was adequate to produce a number of statistically significant effects (i.e., the design had sufficient statistical power).

2. Idealized conditions at the crosswalk and the positioning of the pedestrians in the simulation

In this study, care was taken to ensure that conditions were optimal for viewing both the signs and the pedestrian. Pedestrians are at higher risk when they are “screened” by vehicles or other obstacles (e.g., Fisher & Garay-Vega, 2012; Gomez et al. 2011). This study may underestimate the usefulness of Overhead signage because their advantages may be more apparent when the drivers’ views of the pedestrians are obstructed. Nonetheless, the results of this study do not provide much support to the idea that drivers will slow based on viewing of a sign when they do not look at the pedestrian. For example, at midblock and intersection crosswalks, in all three conditions 0% of the drivers slowed enough to allow a pedestrian to cross when drivers looked at the sign but not the pedestrian (see Appendix C).

It is also possible that the results of the study would have been different if the pedestrians were positioned differently, at a different location on the curb or even right on the road. It is likely that more stopping would have been observed if the pedestrians stood on roadside instead of on the sidewalk. However, if this had been done, the observed driver behaviour might have
been more indicative of reactions to potential obstacles on the road rather than compliance to signage. It is even possible that under those conditions the most effective signs would yield the worst hazard response to pedestrians on the road, because drivers might be looking at signs rather than the road. Keeping the pedestrians on the sidewalk focused the investigation on adherence to the message on the sign. Consequently, this study may be better understood as an investigation of whether signage can improve driver courtesy towards pedestrians. Given the limited scale of this study it was also impossible to consider the impact of the pedestrian’s precise position no the curb. For example, if the pedestrians had been teetering on the very edge of the curb there may have been more yielding. It was impossible to study everything in a single investigation, but these factors may be important to study in future investigations.

3. Performance in a driving simulator may not reflect real-world driving

In simulator studies there is always the danger that drivers may not drive as they would in real life. There are no costs for reckless or inconsiderate behaviour in driving simulators though there are in real life and drivers may be more inclined to yield for a real human being than a simulated one. Conversely, drivers may be acutely aware that their driving is being assessed in a driving simulator, and they might go out of their way to drive safely and courteously. Although there is always a danger that drivers may not behave normally when tested in a simulator, there are important advantages to the use of simulation to answer questions about the reactions to traffic safety infrastructure. In many cases, it is more cost-effective to run the study in a simulator than build the infrastructure on a closed course -- and there are fewer risks. There is no danger of drivers or pedestrians getting injured in simulated collisions for example. Second, simulators permit the close control of conditions on the road. In day to day driving there may be
dozens of factors that have an impact on driver behaviour, factors such as weather, lighting, road conditions, vehicle dynamics, and the surrounding traffic. In driving simulators these factors can be controlled so that every driver experiences the same drive and consequently the effects of the factor under investigation, in this case, different types of signage, can be isolated. At any rate, if all of the drivers were on their best behaviour, or alternatively, if they were all driving recklessly because there was no real cost to inconsiderate behaviour, at least that factor was constant across the three signage conditions in this study. It seems unlikely that it would have affected one type of signage more than the others. Based on the evidence from this study, there is little indication that the drivers as a group ignored all the pedestrians or paid extra attention to all the pedestrians. Instead, some yielded to the simulated pedestrian and some did not, and the proportions of drivers in each category varied based on the location of the crosswalk and the type of signage.

**General Conclusion**

The results of the study are complex and vary based on the location of the crosswalk (see Table 8). Thus, driver behaviour at roundabouts crosswalks is very different than that at straight sections of the road (midblock or intersection crosswalks). However, this study is clear in showing that drivers generally believe that increasing the number of types of sign at the crosswalk makes it more likely that the driver would see the signs and stop for the pedestrian. When asked to decide between the Overhead condition (overhead + groundmount + warning signs) and the Groundmount condition (groundmount + warning signs), the majority of drivers thought that the Overhead condition would be more effective it causing the drivers to stop for the pedestrian at every crosswalk.
Although drivers believe this to be true, there is little support for this idea from their eye movement, sign interpretation, or driving performance data. The eye movement data show that at every location except the entrance to multilane roundabouts, higher percentages of drivers looked at signs in the Groundmount condition than in the Overhead condition. However, it seems that having some sort of signage at the crosswalk is beneficial, because smallest percentages of drivers looked at signs in the Warning condition.

Similarly, in sign interpretation tests, a greater percentage of drivers indicated that the appropriate response would be to stop in the Groundmount than Overhead conditions at every location except the entrance to multilane roundabouts. Conversely, higher percentages of drivers who saw the Overhead condition thought it would be adequate to slow down rather than stop. The information on braking and yielding is more complex. Few drivers come to a full stop, and rolling stops were relatively uncommon. There was no consistent advantage in compliance (full or rolling stops) of the Overhead condition over the other conditions with less signage. Similar inconsistencies emerged when measurements were taken of the percentage of drivers who slowed sufficiently and in an adequate time to allow the simulated pedestrian to cross. Braking/yielding data are somewhat misleading though unless they are interpreted in context of the eye movement data, because in some situations the drivers were slowing/stoping for reasons other than pedestrians. For example, driving speeds were low in roundabouts and this permitted more pedestrians to cross. (Many Guelph drivers are unfamiliar with roundabouts.) However, a large percentage of the roundabout drivers looked at neither the sign nor the pedestrian at exits, and when they slowed/stopped, they did so long before it was necessary for safe crossing of the pedestrian (see Appendix C). This suggests that the drivers were not responding to the needs of pedestrian but rather the complexities of the roundabouts.
When policy makers decide on how taxpayer money is to be used on traffic safety infrastructure, they may be under pressure to bow to public opinion, and in the general public there seems to be a belief that increasing the number of signs will increase safety, at least as indicated by the drivers in this study. However, signs contribute to visual clutter. The mere presence of a sign does not guarantee that it will be seen or obeyed and signs may distract drivers from other important safety-related information and may even obstruct their view (see Figure 30). This is a small-scale study but the results suggest that the expense of extra signage (the addition of an overhead sign in addition to the ground-mount signs) may not be justified in terms of improvements in driver performance at crosswalks, as measured by eye movements and stopping/yielding behaviour. Furthermore, strangely, when drivers saw overhead signs in addition to groundmounted signs, a lower percentage indicated that the appropriate behaviour was to stop. Perhaps the drivers assumed that the overhead signage indicated that the road was a high priority thoroughfare. Overall, the results show that there was no clear advantage to Overhead signage condition and in some cases, performance was worse.

Moreover, the eye movement data makes it clear that outside roundabouts, the problem does not seem to be so much that the drivers are unaware of crosswalks (a difficulty that might be remedied with signs), but rather that the drivers vary in their opinion about what to do at the crosswalk (if and when to stop). At midblock and intersection crosswalks, the majority of the drivers looked at both the signs and the waiting pedestrian. The problem was that some drivers accommodated the pedestrian by slowing in time to allow the pedestrian to cross (Courteous/Cautious driver) whereas others did not give the pedestrian a chance to cross (the Opportunistic driver). It is possible that there were more Opportunistic drivers in this study than in real life because it involved simulated pedestrians, but the results suggest that it may be more
effective to devote energy to driver/pedestrian education about what to do at crosswalks rather than in the installation of extra (overhead) signage.
References


Table 1

Summary showing the signage conditions with more yielding to pedestrians as indicated by more full and rolling stops and better compliance (fewer drivers failing to slow their speeds below 8 kph). Note: This summarizes the data in Figures 9-11.

The conditions with the highest percentage of drivers making each response are listed below.

*Bold italics indicate that there are statistically significant differences between signage conditions in terms of the proportions as indicated by Chi square analysis. (Two conditions are listed if the proportions were exactly equal in those conditions.)*

<table>
<thead>
<tr>
<th>Crosswalk position</th>
<th>Higher % full stops</th>
<th>Higher % rolling stops</th>
<th>Higher % compliant (&lt; 8 kph) (i.e. Lower % non-compliant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midblock</td>
<td>Overhead</td>
<td>Warning</td>
<td>Overhead</td>
</tr>
<tr>
<td>Intersection</td>
<td>Warning</td>
<td>Groundmount</td>
<td>Warning</td>
</tr>
<tr>
<td>Entrance single lane roundabout</td>
<td>Warning = Groundmount</td>
<td>Warning = Groundmount</td>
<td><strong>Warning = Groundmount better than Overhead</strong></td>
</tr>
<tr>
<td>Exit single lane roundabout</td>
<td>Groundmount = Overhead</td>
<td>Groundmount</td>
<td>Groundmount biggest difference with Warning</td>
</tr>
<tr>
<td>Entrance multilane Roundabout</td>
<td>Warning</td>
<td><strong>Warning</strong></td>
<td><strong>Warning</strong> biggest difference with Groundmount</td>
</tr>
<tr>
<td>Exit multilane roundabout</td>
<td>Warning</td>
<td><strong>Overhead</strong></td>
<td><strong>Overhead</strong> biggest difference with Warning</td>
</tr>
</tbody>
</table>

**Abbreviations.**

**Overhead:** Both overhead and groundmounted signs at crosswalk with advance warning.
**Groundmount:** Groundmounted sign at the crosswalk with advance warning.
**Warning:** No signs posted at crosswalk but advance warning signs.
Table 2

Percentages of drivers who missed their exit in the roundabout rounded to the nearest percent point

<table>
<thead>
<tr>
<th>Type of roundabout</th>
<th>Single lane</th>
<th>Multilane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>8%</td>
<td>46%</td>
</tr>
<tr>
<td>Groundmount</td>
<td>17%</td>
<td>40%</td>
</tr>
<tr>
<td>Warning alone</td>
<td>22%</td>
<td>36%</td>
</tr>
</tbody>
</table>

Abbreviations.

**Overhead:** Both overhead and groundmounted signs at crosswalk with an advance warning sign.

**Groundmount:** Groundmounted sign at the crosswalk with an advance warning sign.

**Warning:** No signs posted at crosswalk but an advance warning sign.

*Note that there was no data loss due to missed exits. The other roundabout exits also had crosswalks with waiting pedestrians and measurements were taken from the crosswalk that the driver used.*
Table 3

Summary of driver opinions about what the appropriate behaviour would be in different situations shown in static screenshots of crosswalks with pedestrians. (Note: This summarizes the data in Figures 12-14).

The conditions with the highest percentage of drivers making each response are listed below.

*Bold italics indicate that there are statistically significant differences between signage conditions in terms of the proportions in different categories as indicated by Chi square analysis.*

<table>
<thead>
<tr>
<th>Crosswalk position</th>
<th>% Think should stop</th>
<th>% Think should slow</th>
<th>% Think should continue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midblock</td>
<td>Groundmount</td>
<td>Overhead</td>
<td>Groundmount</td>
</tr>
<tr>
<td>Intersection</td>
<td>Groundmount</td>
<td>Overhead</td>
<td>Groundmount</td>
</tr>
<tr>
<td>Entrance single roundabout</td>
<td>Groundmount</td>
<td>Overhead</td>
<td>Groundmount</td>
</tr>
<tr>
<td>Exit single roundabout</td>
<td>Groundmount</td>
<td>Overhead</td>
<td>Groundmount</td>
</tr>
<tr>
<td>Entrance multilane roundabout</td>
<td>Overhead</td>
<td>Groundmount</td>
<td>Groundmount</td>
</tr>
<tr>
<td>Exit multilane roundabout</td>
<td>Groundmount</td>
<td>Overhead</td>
<td>Groundmount</td>
</tr>
</tbody>
</table>

**Abbreviations.**

*Overhead:* Both overhead and groundmounted signs at crosswalk with an advance warning sign.

*Groundmount:* Groundmounted sign at the crosswalk with an advance warning sign.

*Warning:* No signs posted at crosswalk but an advance warning sign.
Table 4

Driver opinions about the appropriate place to stop in situations shown in static screen shots.

Midblock Overhead

<table>
<thead>
<tr>
<th>What to do?</th>
<th>Stop</th>
<th>Slow</th>
<th>Continue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>20%</td>
<td>76%</td>
<td>4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Where stop?</th>
<th>At Line</th>
<th>Before Line</th>
<th>Before X</th>
<th>At X</th>
<th>After X</th>
<th>No Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>12%</td>
<td>32%</td>
<td>8%</td>
<td>36%</td>
<td>8%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Midblock Groundmount

<table>
<thead>
<tr>
<th>What to do?</th>
<th>Stop</th>
<th>Slow</th>
<th>Continue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundmount</td>
<td>44%</td>
<td>44%</td>
<td>12%</td>
</tr>
<tr>
<td>First viewing</td>
<td>36%</td>
<td>56%</td>
<td>8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Where stop?</th>
<th>At Line</th>
<th>Before Line</th>
<th>Before X</th>
<th>At X</th>
<th>After X</th>
<th>No Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundmount</td>
<td>12%</td>
<td>20%</td>
<td>28%</td>
<td>24%</td>
<td>12%</td>
<td>4%</td>
</tr>
<tr>
<td>First viewing</td>
<td>12%</td>
<td>24%</td>
<td>12%</td>
<td>32%</td>
<td>20%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Abbreviations.

Overhead: Drivers who had seen the Overhead signage condition (overhead + groundmounted signs at the crosswalk) in the simulation interpret what to do in the situation shown in the static screenshot.

Groundmount: Drivers who had seen the Groundmount signage condition (groundmounted signs only at the crosswalk) in the simulation interpret what to do in the situation shown in the static screenshot.

First viewing: Drivers in who had seen neither overhead nor groundmounted signage at the crosswalk in the simulation (i.e. those in the Warning condition) make their first interpretation of what they should do in the situation shown in the static screenshot of Groundmount signage.
Intersection Overhead

<table>
<thead>
<tr>
<th>What to do?</th>
<th>Stop</th>
<th>Slow</th>
<th>Continue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>36%</td>
<td>60%</td>
<td>4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Where stop?</th>
<th>At Line</th>
<th>Before Line</th>
<th>Before X</th>
<th>At X</th>
<th>After X</th>
<th>No Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>8%</td>
<td>28%</td>
<td>8%</td>
<td>40%</td>
<td>12%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Intersection Groundmount

<table>
<thead>
<tr>
<th>What to do?</th>
<th>Stop</th>
<th>Slow</th>
<th>Continue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundmount</td>
<td>48%</td>
<td>36%</td>
<td>16%</td>
</tr>
<tr>
<td>First viewing</td>
<td>48%</td>
<td>48%</td>
<td>4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Where stop?</th>
<th>At Line</th>
<th>Before Line</th>
<th>Before X</th>
<th>At X</th>
<th>After X</th>
<th>No Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundmount</td>
<td>16%</td>
<td>12%</td>
<td>32%</td>
<td>32%</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>First viewing</td>
<td>8%</td>
<td>40%</td>
<td>16%</td>
<td>32%</td>
<td>4%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Abbreviations.

**Overhead**: Drivers who had seen the Overhead signage condition (overhead + groundmounted signs at the crosswalk) in the simulation interpret what to do in the situation shown in the static screenshot.

**Groundmount**: Drivers who had seen the Groundmount signage condition (groundmounted signs only at the crosswalk) in the simulation interpret what to do in the situation shown in the static screenshot.

**First viewing**: Drivers in who had seen neither overhead nor groundmounted signage at the crosswalk in the simulation (i.e. those in the Warning condition) make their first interpretation of what they should do in the situation shown in the static screenshot of Groundmount signage.

Table 4 continues
### Single Lane Roundabout Entrance Overhead

<table>
<thead>
<tr>
<th>What to do?</th>
<th>Stop</th>
<th>Slow</th>
<th>Continue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>44%</td>
<td>56%</td>
<td>0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Where stop?</th>
<th>At Line</th>
<th>Before Line</th>
<th>Before X</th>
<th>At X</th>
<th>After X</th>
<th>No Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>16%</td>
<td>72%</td>
<td>12%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

### Single Lane Roundabout Entrance Groundmount

<table>
<thead>
<tr>
<th>What to do?</th>
<th>Stop</th>
<th>Slow</th>
<th>Continue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundmount</td>
<td>64%</td>
<td>28%</td>
<td>8%</td>
</tr>
<tr>
<td>First viewing</td>
<td>56%</td>
<td>40%</td>
<td>4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Where stop?</th>
<th>At Line</th>
<th>Before Line</th>
<th>Before X</th>
<th>At X</th>
<th>After X</th>
<th>No Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundmount</td>
<td>16%</td>
<td>68%</td>
<td>12%</td>
<td>0%</td>
<td>0%</td>
<td>4%</td>
</tr>
<tr>
<td>First viewing</td>
<td>16%</td>
<td>68%</td>
<td>16%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

### Abbreviations.

**Overhead**: Drivers who had seen the Overhead signage condition (overhead + groundmounted signs at the crosswalk) in the simulation interpret what to do in the situation shown in the static screenshot.

**Groundmount**: Drivers who had seen the Groundmount signage condition (groundmounted signs only at the crosswalk) in the simulation interpret what to do in the situation shown in the static screenshot.

**First viewing**: Drivers in who had seen neither overhead nor groundmounted signage at the crosswalk in the simulation (i.e. those in the Warning condition) make their first interpretation of what they should do in the situation shown in the static screenshot of Groundmount signage.

Table 4 continues
Abbreviations.

**Overhead:** Drivers who had seen the Overhead signage condition (overhead + groundmounted signs at the crosswalk) in the simulation interpret what to do in the situation shown in the static screenshot.

**Groundmount:** Drivers who had seen the Groundmount signage condition (groundmounted signs only at the crosswalk) in the simulation interpret what to do when in the situation shown in the static screenshot.

**First viewing:** Drivers in who had seen neither overhead nor groundmounted signage at the crosswalk in the simulation (i.e. those in the Warning condition) make their first interpretation of what they should do in the situation shown in the static screenshot of Groundmount signage.

Table 4 continues
Abbreviations.

**Overhead**: Drivers who had seen the Overhead signage condition (overhead + groundmounted signs at the crosswalk) in the simulation interpret what to do in the situation shown in the static screenshot.

**Groundmount**: Drivers who had seen the Groundmount signage condition (groundmounted signs only at the crosswalk) in the simulation interpret what to do when in the situation shown in the static screenshot.

**First viewing**: Drivers in who had seen neither overhead nor groundmounted signage at the crosswalk in the simulation (i.e. those in the Warning condition) make their first interpretation of what they should do in the situation shown in the static screenshot of Groundmount signage.

Table 4 continues
Multilane Roundabout Exit
Overhead

<table>
<thead>
<tr>
<th>What to do?</th>
<th>Stop</th>
<th>Slow</th>
<th>Continue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>44%</td>
<td>48%</td>
<td>8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Where stop?</th>
<th>At Line</th>
<th>Before Line</th>
<th>Before X</th>
<th>At X</th>
<th>After X</th>
<th>No Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>12%</td>
<td>60%</td>
<td>12%</td>
<td>0%</td>
<td>4%</td>
<td>12%</td>
</tr>
</tbody>
</table>

Multilane Roundabout Exit
Groundmount

<table>
<thead>
<tr>
<th>What to do?</th>
<th>Stop</th>
<th>Slow</th>
<th>Continue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundmount</td>
<td>72%</td>
<td>16%</td>
<td>12%</td>
</tr>
<tr>
<td>First viewing</td>
<td>64%</td>
<td>28%</td>
<td>8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Where stop?</th>
<th>At Line</th>
<th>Before Line</th>
<th>Before X</th>
<th>At X</th>
<th>After X</th>
<th>No Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundmount</td>
<td>8%</td>
<td>76%</td>
<td>12%</td>
<td>0%</td>
<td>0%</td>
<td>4%</td>
</tr>
<tr>
<td>First viewing</td>
<td>20%</td>
<td>64%</td>
<td>12%</td>
<td>0%</td>
<td>0%</td>
<td>4%</td>
</tr>
</tbody>
</table>

**Abbreviations.**

**Overhead:** Drivers who had seen the Overhead signage condition (overhead + groundmounted signs at the crosswalk) in the simulation interpret what to do when in the situation shown in the static screenshot.

**Groundmount:** Drivers who had seen the Groundmount signage condition (groundmounted signs only at the crosswalk) in the simulation in the simulation interpret what to do when in the situation shown in the static screenshot.

**First viewing:** Drivers in who had seen neither overhead nor groundmounted signage at the crosswalk in the simulation (i.e. those in the Warning condition) make their first interpretation of what they should do in the situation shown in the static screenshot, though they have never seen any signage at the crosswalk.

End of Table 4
Table 5

Driver opinions about which sign would be more effective at causing drivers to come to a stop for a pedestrian at a crosswalk and their comments and justifications for their choices. (Percentages of drivers making each decision are listed, rounded to the nearest percentage point. Some drivers made more than one comment.)

**Midblock crosswalk**

Percentage of the sample who preferred Overhead signage: 91%

Justification

- Improves visibility
  - 87%
- No difference really/ It is good enough
  - 3%
- The sign is sometimes covering up where I want to look
  - 0%
- Too many signs/ clutter/ overkill/ redundant
  - 5%
- The sign implies the need to stop
  - 1%
- I am used to lower signs rather than overhead signs
  - 3%
- The sign looks strange the way it sits over driving scene
  - 0%

**Intersection crosswalk**

Percentage of the sample who preferred Overhead signage: 89%

Justification

- Improves visibility
  - 87%
- No difference really/ It is good enough
  - 1%
- The sign is sometimes covering up where I want to look
  - 0%
- Too many signs/ clutter/ overkill/ redundant
  - 8%
- The sign implies the need to stop
  - 1%
- I am used to lower signs rather than overhead signs
  - 1%
- The sign looks strange the way it sits over driving scene
  - 0%
Crosswalk at the entrance to a single lane roundabout

Percentage of the sample who preferred Overhead signage: **74%**

Justifications and comments

- Improves visibility* 75%
- No difference really/ It is good enough 4%
- The sign is sometimes covering up where I want to look 4%
- Too many signs/ clutter/ overkill/ redundant 16%
- The sign implies the need to stop 0%
- I am used to lower signs rather than overhead signs 0%
- The sign looks strange the way it sits over driving scene 0%

Crosswalk at the exit to a single lane roundabout

Percentage of the sample who preferred Overhead signage: **68%**

Justifications and comments

- Improves visibility 68%
- No difference really/ It is good enough 12%
- The sign is sometimes covering up where I want to look 5%
- Too many signs/ clutter/ overkill/ redundant 13%
- The sign implies the need to stop 0%
- I am used to lower signs rather than overhead signs 0%
- The sign looks strange the way it sits over driving scene 0%

*Sometimes drivers used the “improves visibility” comment when referring to the Groundmount condition signs.*
Crosswalk at the entrance to a multi-lane roundabout

Percentage of the sample who preferred Overhead signage: 91%

Justifications and comments

Improves visibility 88%
No difference really/ It is good enough 3%
The sign is sometimes covering up where I want to look 1%
Too many signs/ clutter/ overkill/ redundant 7%
The sign implies the need to stop 0%
I am used to lower signs rather than overhead signs 0%
The sign looks strange the way it sits over driving scene 0%

Crosswalk at the exit to a multi-lane roundabout

Percentage of the sample who preferred Overhead signage: 64%

Justifications and comments

Improves visibility* 65%
No difference really/ It is good enough 8%
The sign is sometimes covering up where I want to look 8%
Too many signs/ clutter/ overkill/ redundant 13%
The sign implies the need to stop 0%
I am used to lower signs rather than overhead signs 0%
The sign looks strange the way it sits over driving scene 5%

*Sometimes drivers used the “improves visibility” comment when referring to the Groundmount condition signs.
Table 6

Taxonomy of driving behaviours at crosswalks: 8 patterns of behaviour

**Drivers who do NOT allow the pedestrian to cross**

<table>
<thead>
<tr>
<th>Allows pedestrian to cross?</th>
<th>Looks at signs?</th>
<th>Looks at pedestrian?</th>
<th>Categorization</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Oblivious</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Non-compliant but sees sign</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Sees pedestrian but does not stop</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Opportunistic</td>
</tr>
</tbody>
</table>

**Drivers who DO allow the pedestrian to cross**

<table>
<thead>
<tr>
<th>Allows pedestrian to cross?</th>
<th>Looks at signs?</th>
<th>Looks at pedestrian?</th>
<th>Categorization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Courteous/Cautious</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Sees pedestrian but not sign and stops</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Sees sign but not pedestrian and stops</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Slow but Oblivious to both signs and pedestrian</td>
</tr>
</tbody>
</table>
Table 7.

A comparison of Courteous/Cautious and Opportunist drivers in terms of fixation durations to signs and pedestrians at midblock and intersection crosswalks. (Measurements are presented in seconds and percentages of decision zone approach time.)

**Measurement in Seconds**

<table>
<thead>
<tr>
<th></th>
<th>Courteous/Cautious</th>
<th>Opportunistic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Miblock crosswalks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signs</td>
<td>1.06s</td>
<td>1.22s</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>0.92s</td>
<td>1.04s</td>
</tr>
<tr>
<td><strong>Intersection crosswalks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signs</td>
<td>1.50s</td>
<td>1.14s</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>0.97s</td>
<td>1.52s</td>
</tr>
</tbody>
</table>

**Measurement expressed in percentages of decision zone approach time**

<table>
<thead>
<tr>
<th></th>
<th>Courteous/Cautious</th>
<th>Opportunistic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Miblock crosswalks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signs</td>
<td>6.7%</td>
<td>13.1%</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>5.6%</td>
<td>11.3%</td>
</tr>
<tr>
<td><strong>Intersection crosswalks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signs</td>
<td>11.0%</td>
<td>15.2%</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>7.0%</td>
<td>20.2%</td>
</tr>
</tbody>
</table>
Table 8

Which condition causes better compliance to signage? Bringing together braking, eye glance, sign interpretation and driver opinion questionnaire data.

**Note:** Abbreviations: O = Overhead condition (overhead, groundmount + warning signs), G = Groundmount condition (groundmount + warning signs), W = Warning signs only condition. Better compliance is associated with larger percentages of drivers braking (coming to a full or rolling stop), slowing in enough time for pedestrians to cross, and fixating their eyes on signs or pedestrians (for longer durations). Compliance is also indicated when drivers are shown static screenshots of a pedestrian at a crosswalk with signage, and larger percentages of drivers indicate that the driver should stop in that situation. Drivers were also asked their opinion about which signage system they thought would be most effective in causing drivers to stop for pedestrians. Statistically significant effects are denoted by an asterisk * (p < .05) and **boldface**. If two conditions are not significantly different from one another but they differ from the third, the two conditions that are equal are listed together and then the third is listed. For example, *OG > W means that the Overhead and Groundmounted conditions did not differ from one another (though the Overhead condition had a higher score) but both were better than the Warning only condition. OGW indicates that the Overhead condition was best followed by the Groundmount and Warning conditions though the differences were not statistically significant. *OGW means that there were only differences between first and third listed conditions. For example, this would mean O differs significantly from W but O does not differ from G and G does not differ from W.

**Midblock crosswalk**

**Braking** (Potentially misleading in isolation: See section on taxonomy of yielding behaviour).

| % of drivers coming to a full or rolling stop | OWG |
| % Drivers slowing enough to allow the pedestrian to cross. ((Note: If drivers slow down early enough they may not have to brake.)) | O G=W |

**Eye glance data**

| % drivers who fixate at least one sign | *G>OW |
| Average sign fixation duration | GOW |

| % of drivers who fixate on the pedestrian | *WOG |
| Average pedestrian fixation duration | *W > OG |

**Questionnaire data**

| % of drivers who thought the driver should stop crosswalks when shown static screenshots of pedestrians at crosswalks standing beside these types of signs (Overhead vs. Groundmount only) | *GO |

Driver opinions about the signage they thought would be most effective in causing drivers to stop for the pedestrian (Overhead vs. Groundmount only)

- *OG (91% preference)
**Intersection crosswalk**

Braking (Potentially misleading in isolation: See section on taxonomy of yielding behaviour)

- % of drivers coming to a full or rolling stop  
  WGO
- % Drivers slowing enough to allow the pedestrian to cross. (Note: If drivers slow down early enough they may not have to brake.)  
  GWO

Eye glance data

- % drivers who fixate at least one sign  
  *G>OW
- Average sign fixation duration  
  *G>OW
- % of drivers who fixate on the pedestrian  
  WOG
- Average pedestrian fixation duration  
  OGW

Questionnaire data

- % of drivers who thought the driver should stop crosswalks when shown static screenshots of pedestrians at crosswalks standing beside these types of signs (Overhead vs. Groundmount only)  
  GO

Driver opinions about the signage they thought would be most effective in causing drivers to stop for the pedestrian (Overhead vs. Groundmount only)

*OG (89% preference)

**Single lane roundabout entrance crosswalk**

Braking (Potentially misleading in isolation. See taxonomy of yielding behaviour)

- % of drivers coming to a full or rolling stop  
  *GW>O
- % Drivers slowing enough to allow the pedestrian to cross. Note: If drivers slow early enough they will not have to brake. For roundabouts many were slowed down substantially before the crosswalk, probably due to the roundabout per se  
  OWG

Eye glance data

- % drivers who fixate at least one sign  
  *GO>W
- Average sign fixation duration  
  *OGW
- % of drivers who fixate on the pedestrian  
  *WGO
- Average pedestrian fixation duration  
  OGW=W

Questionnaire data

- % of drivers who thought the driver should stop crosswalks when shown static screenshots of pedestrians at crosswalks standing beside these types of signs (Overhead vs. Groundmount only)  
  *GO

Driver opinions about the signage they thought would be most effective in causing drivers to stop for the pedestrian (Overhead vs. Groundmount only)

*OG (74% preference)
Single lane roundabout exit crosswalk (Note there are no signs for the Warning condition)

Braking (Potentially misleading in isolation. See taxonomy of yielding behaviour).

- % of drivers coming to a full or rolling stop: GOW
- % Drivers slowing enough to allow the pedestrian to cross. Note: If drivers slow early enough they may not have to brake: WGO

Eye glance data

- % drivers who fixate at least one sign: G=O (few fixate)
- Average sign fixation duration: GO
- % of drivers who fixate on the pedestrian: *WOG
- Average pedestrian fixation duration: WOG

Questionnaire data

- % of drivers who thought the driver should stop crosswalks when shown static screenshots of pedestrians at crosswalks standing beside these types of signs (Overhead vs. Groundmount only): GO

Driver opinions about the signage they thought would be most effective in causing drivers to stop for the pedestrian (Overhead vs. Groundmount only)

*OG (68% preference)

Multi-lane roundabout entrance crosswalk

Braking (Potentially misleading in isolation. See taxonomy of yielding behaviour)

- % of drivers coming to a full or rolling stop: *WOG
- % Drivers slowing enough to allow the pedestrian to cross. Note: If drivers slow early enough they will not have to brake: *WOG

Eye glance data

- % drivers who fixate at least one sign: *OG>W
- Average sign fixation duration: OGW
- % of drivers who fixate on the pedestrian: *WOG
- Average pedestrian fixation duration (short duration fixations): WOG

Questionnaire data

- % of drivers who thought the driver should stop crosswalks when shown static screenshots of pedestrians at crosswalks standing beside these types of signs (Overhead vs. Groundmount only): *OG

Driver opinions about the signage they thought would be most effective in causing drivers to stop for the pedestrian (Overhead vs. Groundmount only)

*OG (91% preference)
Multi-lane roundabout exit crosswalk (Note there are no signs for the warning condition)

Braking (Potentially misleading in isolation. See taxonomy of yielding behaviour).

% of drivers coming to a full or rolling stop \( ^*OGW \)

% Drivers slowing enough to allow the pedestrian to cross. Note. If drivers slow early enough they may not have to brake. (Many slow substantially for roundabouts but they slow long before the crosswalk.) \( G=W \ (100\%) \ O \)

Eye glance data

% drivers who fixate at least one sign \( GO \) (few fixate)
Average sign fixation duration \( G=O \)

% of drivers who fixate on the pedestrian \( ^*OWG \) (few fixate)
Average pedestrian fixation duration \( OWG \)

Questionnaire data

% of drivers who thought the driver should stop crosswalks when shown static screenshots of pedestrians at crosswalks standing beside these types of signs (Overhead vs. Groundmount only) \( ^*GO \)

Driver opinions about the signage they thought would be most effective in causing drivers to stop for the pedestrian (Overhead vs. Groundmount only)

\( ^*OG \) (64% preference)
Figure 1. University of Guelph driving simulator.
Figure 2. This example involves a midblock crosswalk in the Overhead condition, where there was an overhead and groundmounted sign at the crosswalk. (For half of simulations the pedestrian was on the right side of the road and for half the pedestrian was on the left).
Figure 3. This example involves a crosswalk at an intersection in the Groundmount condition, where there was only a groundmounted sign at the crosswalk. (For half of simulations the pedestrian was on the right side of the road and for half the pedestrian was on the left).
Figure 4. This example involves the single lane roundabout. This is in the Overhead condition, in which there were both overhead and groundmounted signs. (For half of the simulations the pedestrian was on the right side of the road and for half the pedestrian was on the left.)
Figure 5. This example is at the entrance to the multilane roundabout. This is in the Groundmount condition, in which there was only a groundmounted sign at the crosswalk. (For half of the simulations the pedestrian was on the right side and the other half the left.)
Figure 6. Average speeds as a function of the distance from the crosswalk and the signage for the midblock (Figure 6a) and intersection crosswalk (Figure 6b). Standard error bars included.
Figure 6. Average speeds as a function of the distance from the crosswalk and the signage for the entrance and exit to single lane roundabout (Figures 6c and 6d). Standard error bars included.
Figure 6. Average speeds as a function of the distance from the crosswalk and the signage for entrance and exit to the multilane roundabout (Figures 6e and 6f). Standard error bars included.
25th percentile velocity as a function of distance from the crosswalk and the signage at the midblock crosswalk

- Overhead + Groundmount
- Groundmount
- Warning

Distance from crosswalk (m)

25th percentile velocity as a function of distance from the crosswalk and the signage at intersection crosswalk

- Overhead + groundmount
- Groundmount
- Warning

Distance from crosswalk (m)

Figure 7. 25th percentile velocity (velocity below which only 25% of the drivers travel) for midblock and intersection crosswalk (Figures 7a and 7b).
Figure 7. 25th percentile velocity (velocity below which only 25% of the drivers travel) for the entrance and exit to the single lane roundabout (Figures 7c and 7d respectively).
Figure 7. 25th percentile velocity (velocity below which only 25% of the drivers travel) for the entrance and exit to the multilane roundabout (Figures 7e and 7f respectively).
Figure 8. 75\textsuperscript{th} percentile velocity (velocity below which 75\% of the drivers travel) the midblock and intersection crosswalks (Figure 8a and 8b).
Figure 8. 75th percentile velocity (velocity below which 75% of the drivers travel) for the entrance and exit to the single lane roundabout (Figures 8c and 8d respectively).
75th percentile velocity as a function of distance from the crosswalk at the entrance to the multi-lane roundabout

![Graph showing 75th percentile velocity as a function of distance from the crosswalk at the entrance to the multi-lane roundabout]

75th percentile velocity as a function of distance from the crosswalk at the exit to the multi-lane roundabout

![Graph showing 75th percentile velocity as a function of distance from the crosswalk at the exit to the multi-lane roundabout]

**Figure 8.** 75th percentile velocity (velocity below which 75% of the drivers travel) for the entrance and exit to the multilane roundabout (Figures 8e and 8f respectively).
**Abbreviations**

Mid – Midblock crosswalk  
Int – Intersection crosswalk  
Nsr – Entrance single lane roundabout  
Xsr – Exit single lane roundabout  
Nmr – Entrance multilane roundabout  
Xmr – Exit multilane roundabout  

Figure 9. Percentage of drivers coming to a full stop.
Percentage of drivers coming to rolling stop ( < 8 kph) at various crosswalks as a function of signage

Figure 10. Percentage of drivers coming to rolling stop (driving speeds over 0 kph but less than 8 kph).

Abbreviations

Mid – Midblock crosswalk

Int – Intersection crosswalk

Nsr – Entrance single lane roundabout

Xsr – Exit single lane roundabout

Nmr – Entrance multilane roundabout

Xmr – Exit multilane roundabout
Figure 11. Percentage of drivers that came to either a full or rolling stop (compliant drivers who yielded to the pedestrian at the crosswalk).

Abbreviations

Mid – Midblock crosswalk
Int – Intersection crosswalk
Nsr – Entrance single lane roundabout
Xsr – Exit single lane roundabout
Nmr – Entrance multilane roundabout
Xmr – Exit multilane roundabout
Figure 12. Sign interpretation: Percentage of drivers who thought that stopping was the appropriate response in the situation shown in the static screen shot of the crosswalk.

Abbreviations

Mid – Midblock crosswalk

Int – Intersection crosswalk

Nsr – Entrance single lane roundabout

Xsr – Exit single lane roundabout

Nmr – Entrance multilane roundabout

Xmr – Exit multilane roundabout

Groundmount (first viewing) – Drivers who were in the Warning condition had never seen crosswalk signs right at the crosswalk during the simulations. To make use of their time during the sign interpretation phase, we had them evaluate static screen shots of signs in the Groundmount condition. This could be used as a partial check on the reliability in that condition. (Unfortunately, it was impossible to do this for both conditions because it would have required testing another 24 drivers.)
Figure 13. Sign interpretation: Percentage of drivers who thought that slowing was the appropriate response in the situation shown in the static screenshot of the crosswalk.

Abbreviations

Mid – Midblock crosswalk

Int – Intersection crosswalk

Nsr – Entrance single lane roundabout

Xsr – Exit single lane roundabout

Nmr – Entrance multilane roundabout

Xmr – Exit multilane roundabout

Groundmount (first viewing) – Drivers who were in the Warning condition had never seen crosswalk signs right at the crosswalk during the simulations. To make use of their time during the sign interpretation phase, we had them evaluate static screen shots of signs in the Groundmount condition. This could be used as a partial check on the reliability in that condition. (Unfortunately, it was impossible to do this for both conditions because it would have required testing another 24 drivers.)
Percentage of drivers who thought it was appropriate to continue on without slowing in situation shown in the static screen shot

![Diagram showing percentage of drivers' responses in different driving environments]

**Figure 14.** Sign interpretation: Percentage of drivers who thought that it was appropriate to continue on without slowing in the situation shown in the static screen shot of the crosswalk.

**Abbreviations**

- **Mid** – Midblock crosswalk
- **Int** – Intersection crosswalk
- **Nsr** – Entrance single lane roundabout
- **Xsr** – Exit single lane roundabout
- **Nmr** – Entrance multilane roundabout
- **Xmr** – Exit multilane roundabout

**Groundmount (first viewing)** – Drivers who were in the Warning condition had never seen crosswalk signs right at the crosswalk during the simulations. To make use of their time during the sign interpretation phase, we had them evaluate static screen shots of signs in the Groundmount condition. This could be used as a partial check on the reliability in that condition. (Unfortunately, it was impossible to do this for both conditions because it would have required testing another 24 drivers.)
Figure 15. Percentage of drivers who glanced at at least one of the pedestrian signs in each of the conditions.

Abbreviations

Mid – Mid-block crosswalk
Int – Intersection crosswalk
Nsr – Entrance single lane roundabout
Xsr – Exit single lane roundabout
Nmr – Entrance multilane roundabout
Xmr – Exit multilane roundabout
Figure 16. How many different types of sign did the drivers look at? Notice that for the Warning only condition, the maximum number of signs was one except at the exits to roundabouts in which there were no signs. For the Groundmount condition, the maximum number of signs was two in the roundabouts (warning sign plus one right side ground-mounted sign) and three midblock and at the intersection, where there were both right and left ground-mounted signs. The Overhead condition had overhead signs in addition to all the signs for the Groundmount conditions. That means that the maximum number of signs in that condition was 3 in the roundabouts and 4 midblock and at intersections.

Abbreviations
Mid – Mid-block crosswalk; Int – Intersection crosswalk; Nsr – Entrance single lane roundabout Xsr – Exit single lane roundabout; Nmr – Entrance multilane roundabout
Figure 17. The total number of glances that drivers made to pedestrian crosswalk signs.

Abbreviations

Mid – Mid-block crosswalk
Int – Intersection crosswalk
Nsr – Entrance single lane roundabout
Xsr – Exit single lane roundabout
Nmr – Entrance multilane roundabout
Xmr – Exit multilane roundabout
Figure 18. Total glance duration towards crosswalk signs: a). durations expressed in seconds; b). durations expressed in the percentage of crosswalk approach time.


Figure 19. Percentage of drivers who glanced at the advanced warning signs.

Abbreviations

Mid – Mid-block crosswalk

Int – Intersection crosswalk

Nsr – Entrance single lane roundabout

Xsr – Exit single lane roundabout

Nmr – Entrance multilane roundabout

Xmr – Exit multilane roundabout
Figure 20. Percentage of drivers who glanced at the ground-mounted signs. (Note: This represents the sum of the glances to left and right side ground-mounted signs in the Midblock and Intersection environments. For the roundabouts the ground-mounted signs all appear on the right side).

**Abbreviations**

Mid – Mid-block crosswalk  
Int – Intersection crosswalk  
Nsr – Entrance single lane roundabout  
Xsr – Exit single lane roundabout  
Nmr – Entrance multilane roundabout  
Xmr – Exit multilane roundabout
Figure 21. Percentage of drivers who glanced at the overhead signs.

Abbreviations

Mid – Mid-block crosswalk
Int – Intersection crosswalk
Ns – Entrance single lane roundabout
Xsr – Exit single lane roundabout
Nmr – Entrance multilane roundabout
Xmr – Exit multilane roundabout
Figure 22. Percentage of drivers who glanced at the pedestrians at the crosswalk.

Abbreviations

Mid – Mid-block crosswalk
Int – Intersection crosswalk
Nsr – Entrance single lane roundabout
Xsr – Exit single lane roundabout
Nmr – Entrance multilane roundabout
Xmr – Exit multilane roundabout
Figure 23. Total glance duration towards pedestrians: a). durations expressed in seconds; b). durations expressed in the percentage of crosswalk approach time.
Figure 24. Percentages of Oblivious drivers (drivers who failed to look at any of the crosswalk signs or pedestrian, and who did not allow the pedestrian to cross).

Abbreviations

Mid – Mid-block crosswalk
Int – Intersection crosswalk
Nsr – Entrance single lane roundabout
Xsr – Exit single lane roundabout
Nmr – Entrance multilane roundabout
Xmr – Exit multilane roundabout
Figure 25. Percentages of Non-compliant drivers (drivers who looked at the crosswalk signs but did not behave appropriately given the sign). These drivers failed to look at the pedestrian or allow the pedestrian to cross.

**Abbreviations**

Mid – Mid-block crosswalk

Int – Intersection crosswalk

Nsr – Entrance single lane roundabout

Xsr – Exit single lane roundabout

Nmr – Entrance multilane roundabout

Xmr – Exit multilane roundabout
Figure 26. Percentages of Opportunist drivers (drivers who looked at the crosswalk sign and also looked for extended periods at the pedestrians, though they did not slow to allow the pedestrian to cross).

**Abbreviations**

Mid – Mid-block crosswalk  
Int – Intersection crosswalk  
Nsr – Entrance single lane roundabout  
Xsr – Exit single lane roundabout  
Nmr – Entrance multilane roundabout  
Xmr – Exit multilane roundabout
Figure 27. Percentages of Courteous/Cautious drivers (drivers who looked at the crosswalk signs, looked at the pedestrian, and slowed to allow the pedestrian to cross). Drivers who were in the Warning only condition did not have any signs in the exits to roundabouts. Consequently, these drivers were classified as Courteous/Cautious if they looked at the pedestrian and also slowed to allow the pedestrian to cross.

Abbreviations
Mid – Mid-block crosswalk
Int – Intersection crosswalk
Nsr – Entrance single lane roundabout
Xsr – Exit single lane roundabout
Nmr – Entrance multilane roundabout
Xmr – Exit multilane roundabout
Figure 28. Percentages of Slow/Oblivious drivers (drivers who did not look at the crosswalk signs or the pedestrian, but were driving so slowly that the pedestrian had enough time to cross in front of them anyway.)

Abbreviations

Mid – Mid-block crosswalk

Int – Intersection crosswalk

Nsr – Entrance single lane roundabout

Xsr – Exit single lane roundabout

Nmr – Entrance multilane roundabout

Xmr – Exit multilane roundabout
Figure 29. A misleading graph that shows the percentage of drivers that were driving in such a way that the simulated pedestrian would get an opportunity to cross the street. Notice that this figure suggests that the crosswalk signs were especially effective at roundabouts. In fact, eye movement analysis suggests the opposite. It shows that there are a large number of drivers who do not look at the sign or pedestrian at all in the roundabouts, particularly in the exits to roundabouts. Eye movement analyses suggest that the slow driving speeds that permit the pedestrian to cross occur in reaction to the complexities of the roundabout rather than the pedestrian crosswalk.
Figure 30. Example of a perspective in which the sign at a crosswalk may make it more difficult to see the pedestrian.
Appendix A

Driver Characteristics (n = 74: 32 females and 42 males).

*Note: Standard deviation is abbreviated SD. All percentages rounded to the nearest percentage point, which means that sometimes there will be rounding error (percentages will not always add to exactly 100%).*

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Range</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>40.7</td>
<td>18-79</td>
<td>18.8</td>
</tr>
<tr>
<td>Youngest group (18-24) n = 26*</td>
<td>20.4</td>
<td>18-24</td>
<td>2.0</td>
</tr>
<tr>
<td>Middle (25-54) n = 24</td>
<td>40.3</td>
<td>26-54</td>
<td>9.0</td>
</tr>
<tr>
<td>Oldest group (55+) n = 24</td>
<td>63.1</td>
<td>55-79</td>
<td>7.0</td>
</tr>
</tbody>
</table>

*Two extra young drivers were tested because of a technical problem that resulted in the loss of data for 2 young drivers in one of the four driving simulations.*

Driving History

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Range</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of time living in Ontario (years)</td>
<td>33.8</td>
<td>4-67</td>
<td>17.4</td>
</tr>
<tr>
<td>Length of time driving in Ontario (years)</td>
<td>20.5</td>
<td>1-53</td>
<td>16.4</td>
</tr>
<tr>
<td>Age that you started driving (years)</td>
<td>17.8</td>
<td>10-42</td>
<td>5.5</td>
</tr>
<tr>
<td>Age when license obtained (years)</td>
<td>18.0</td>
<td>15-42</td>
<td>5.4</td>
</tr>
<tr>
<td>Number of days/ month driving</td>
<td>25.2</td>
<td>2-30</td>
<td>8.3</td>
</tr>
<tr>
<td>Distance driven/day (km)</td>
<td>44.4</td>
<td>3-350</td>
<td>51.9</td>
</tr>
<tr>
<td>Time duration per day (minutes)</td>
<td>57.61</td>
<td>10-540</td>
<td>69.1</td>
</tr>
</tbody>
</table>
## Percentages of drivers endorsing each response

### Type of License

<table>
<thead>
<tr>
<th>License</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>G2</td>
<td>13%</td>
</tr>
<tr>
<td>G or better</td>
<td>87%</td>
</tr>
</tbody>
</table>

### Do you own a car?

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>79%</td>
</tr>
<tr>
<td>No</td>
<td>20%</td>
</tr>
<tr>
<td>No response</td>
<td>1%</td>
</tr>
</tbody>
</table>

### How many times have you been in a crash as a passenger?

<table>
<thead>
<tr>
<th>Times</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>60%</td>
</tr>
<tr>
<td>1</td>
<td>32%</td>
</tr>
<tr>
<td>2</td>
<td>7%</td>
</tr>
<tr>
<td>No response</td>
<td>1%</td>
</tr>
</tbody>
</table>

### How many times have you been in a crash as a driver?

<table>
<thead>
<tr>
<th>Times</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>43%</td>
</tr>
<tr>
<td>1</td>
<td>32%</td>
</tr>
<tr>
<td>2</td>
<td>10%</td>
</tr>
<tr>
<td>3</td>
<td>5%</td>
</tr>
<tr>
<td>4</td>
<td>7%</td>
</tr>
<tr>
<td>5</td>
<td>1%</td>
</tr>
<tr>
<td>No response</td>
<td>1%</td>
</tr>
</tbody>
</table>
How many speeding tickets do you have?

<table>
<thead>
<tr>
<th>Number of Tickets</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>38%</td>
</tr>
<tr>
<td>1</td>
<td>31%</td>
</tr>
<tr>
<td>2</td>
<td>12%</td>
</tr>
<tr>
<td>3</td>
<td>8%</td>
</tr>
<tr>
<td>4</td>
<td>1%</td>
</tr>
<tr>
<td>5</td>
<td>1%</td>
</tr>
<tr>
<td>6</td>
<td>4%</td>
</tr>
<tr>
<td>7</td>
<td>1%</td>
</tr>
<tr>
<td>No response</td>
<td>3%</td>
</tr>
</tbody>
</table>

How many times have you been charged with reckless driving?

<table>
<thead>
<tr>
<th>Number of Charges</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>97%</td>
</tr>
<tr>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>No response</td>
<td>1%</td>
</tr>
</tbody>
</table>

Other information volunteered by the participants.

- Commercial driver: 7%
- Commuter: 3%
- Driving instructor: 1%

- The collisions that I had as driver were not my fault: 5%
Health related items

Visual acuity and contrast sensitivity

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Range</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETDRS acuity</td>
<td>-.022</td>
<td>-0.28 - +0.28</td>
<td>.12</td>
</tr>
</tbody>
</table>

logMAR score

The ETDRS (Early Treatment of Diabetic Retinopathy Scale) test measures visual acuity in high contrast conditions (large differences in brightness between the letters on the letter chart and the background). It is referenced against the familiar Snellen chart insofar as 0 on the logMar scales indicates 20/20 vision on the Snellen chart. The logMar score is indicated in log units, with positive numbers indicating worse vision. For example, if a person had 20/200 vision, their logMAR score would be +1.0 (200 is 10 times 20). If their vision is 20/40, the logMar score would be +0.3. In contrast, if the logMAR score is less than 0, that means the person has better than normal vision. For example, if a person had 20/10 vision their logMar score would be twice as good as normal, and the logMar score would be -0.3. All of the drivers had at least 20/40 vision in this study, and the average was slightly better than normal acuity.

Pelli Robson

Contrast Sensitivity

The Pelli Robson test measures another aspect of acuity: the ability to see in low contrast conditions. The contrast (the difference in brightness between the lines in the letters and the background) is manipulated. A score of less than 1.35 indicates significant contrast impairment, meaning that there has to be the contrast in brightness between lines and the background has to be significantly larger for a person to see lines. A number of visual disorders produce reductions in contrast sensitivity, as does normal aging. The normal range on the Pelli Robson test is 1.8 - 1.95. No one was impaired in the sample and in fact, the average contrast sensitivity was on the high end of the normal range.
Percentages of drivers with the following perceptual problems

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cataracts</td>
<td>3%</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>0%</td>
</tr>
<tr>
<td>Macular Degeneration</td>
<td>0%</td>
</tr>
<tr>
<td>Focusing disorders (nearsighted, farsighted, astigmatic)</td>
<td>62%</td>
</tr>
</tbody>
</table>

*Note: All of these focusing disorders were corrected to normal either by glasses, contacts, or laser surgery

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hearing problems</td>
<td>9%</td>
</tr>
<tr>
<td>Attention Deficit Disorder</td>
<td>0%</td>
</tr>
</tbody>
</table>
Appendix B

Driver characteristics for the sample for whom we have eye tracking data (n = 57: 23 females and 34 males).

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Average</th>
<th>Range</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full sample (n = 57)</td>
<td>38.9</td>
<td>18-72</td>
<td>17.4</td>
</tr>
<tr>
<td>Overhead (n = 19)</td>
<td>38.3</td>
<td>18-66</td>
<td>17.2</td>
</tr>
<tr>
<td>Groundmount (n = 19)</td>
<td>42.2</td>
<td>18-72</td>
<td>19.3</td>
</tr>
<tr>
<td>Warning alone (n = 19)</td>
<td>36.32</td>
<td>18-63</td>
<td>16.04</td>
</tr>
</tbody>
</table>

Percentage of the sample in each age group

<table>
<thead>
<tr>
<th></th>
<th>18-24 years</th>
<th>25-54 years</th>
<th>55+years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead</td>
<td>36.8%</td>
<td>36.8%</td>
<td>26.3%</td>
</tr>
<tr>
<td>Groundmount</td>
<td>31.6%</td>
<td>31.6%</td>
<td>36.8%</td>
</tr>
<tr>
<td>Warning alone</td>
<td>42.1%</td>
<td>36.8%</td>
<td>21.1%</td>
</tr>
</tbody>
</table>
Appendix C

Percentages of drivers in each group that fell into each of the 8 categories in each condition for each of the crosswalks.

**Midblock crosswalks (percentages of drivers)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Overhead</th>
<th>Groundmount</th>
<th>Warning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oblivious</td>
<td>5.6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Non-compliant</td>
<td>5.6</td>
<td>15.8</td>
<td>0</td>
</tr>
<tr>
<td>No stop/ looks at pedestrian but not sign</td>
<td>5.6</td>
<td>0</td>
<td>63.2</td>
</tr>
<tr>
<td>Opportunistic</td>
<td>33.3</td>
<td>47.8</td>
<td>0</td>
</tr>
<tr>
<td>Courteous/cautious</td>
<td>38.9</td>
<td>36.8</td>
<td>15.8</td>
</tr>
<tr>
<td>Allows to cross/ looks at sign but not pedestrian</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Allows to cross/ looks at pedestrian but not sign</td>
<td>11.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Slow/Oblivious</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
## Intersection crosswalks (percentages of drivers)

<table>
<thead>
<tr>
<th></th>
<th>Overhead</th>
<th>Groundmount</th>
<th>Warning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oblivious</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Non-compliant</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No stop/ looks at</td>
<td>18.8</td>
<td>6.7</td>
<td>31.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pedestrian but not sign</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opportunistic</td>
<td>43.8</td>
<td>46.7</td>
<td>37.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Courteous/cautious</td>
<td>18.8</td>
<td>33.3</td>
<td>18.8</td>
</tr>
<tr>
<td>Allows to cross/</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>looks at sign but not pedestrian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allows to cross/</td>
<td>18.8</td>
<td>13.3</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>looks at pedestrian but not sign</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slow/Oblivous</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
### Single lane roundabout ENTRANCE crosswalks (percentages of drivers)

<table>
<thead>
<tr>
<th></th>
<th>Overhead</th>
<th>Groundmount</th>
<th>Warning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oblivious</td>
<td>0</td>
<td>5.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Non-compliant</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No stop/ looks at</td>
<td>6.3</td>
<td>0</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pedestrian but not sign</td>
<td>6.3</td>
<td>15.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Opportunistic</td>
<td>6.3</td>
<td>15.3</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Courteous/cautious</td>
<td>43.8</td>
<td>57.9</td>
<td>28.6</td>
</tr>
<tr>
<td>Allows to cross/</td>
<td>25</td>
<td>10.5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>looks at sign but not pedestrian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allows to cross/</td>
<td>6.3</td>
<td>5.3</td>
<td>42.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>looks at pedestrian but not sign</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slow/Oblivous</td>
<td>12.5</td>
<td>5.3</td>
<td>7.1</td>
</tr>
</tbody>
</table>
**Single lane roundabout EXIT crosswalks (percentages of drivers).** Note that Warning condition data are presented in a separate table because there were no warning signs at the exit to roundabouts and consequently there were only 4 categories of possible behaviour for that group.

<table>
<thead>
<tr>
<th></th>
<th>Overhead</th>
<th>Groundmount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oblivious</td>
<td>6.3</td>
<td>0</td>
</tr>
<tr>
<td>Non-compliant</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No stop/ looks at</td>
<td>6.3</td>
<td>6.3</td>
</tr>
<tr>
<td>pedestrian but not sign</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opportunist</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Courteous/cautious</td>
<td>6.3</td>
<td>0</td>
</tr>
<tr>
<td>Allows to cross/</td>
<td>12.5</td>
<td>18.8</td>
</tr>
<tr>
<td>looks at sign but not pedestrian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allows to cross/</td>
<td>6.3</td>
<td>0</td>
</tr>
<tr>
<td>looks at pedestrian but not sign</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slow/Oblivious</td>
<td>62.5</td>
<td>75</td>
</tr>
</tbody>
</table>

*Drivers who slowed/stopped far too early, giving the pedestrian more than enough time to cross (Eye movements are not factored in here)*

<table>
<thead>
<tr>
<th></th>
<th>Warning</th>
</tr>
</thead>
<tbody>
<tr>
<td>No stop and did not look at pedestrian</td>
<td>0</td>
</tr>
<tr>
<td>No stop but did look at pedestrian</td>
<td>0</td>
</tr>
<tr>
<td>Allows pedestrian to cross and looked at pedestrian</td>
<td>35.7</td>
</tr>
<tr>
<td>Allows pedestrian to cross but did not look at pedestrian</td>
<td>64.3</td>
</tr>
</tbody>
</table>

*Drivers who slowed/stopped far too early, giving the pedestrian more than enough time to cross (Eye movements are not factored in here)*

<table>
<thead>
<tr>
<th></th>
<th>Warning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>78.6</td>
</tr>
</tbody>
</table>
### Multi-lane roundabout ENTRANCE crosswalks (percentages of drivers)

<table>
<thead>
<tr>
<th></th>
<th>Overhead</th>
<th>Groundmount</th>
<th>Warning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oblivious</td>
<td>0</td>
<td>14.3</td>
<td>0</td>
</tr>
<tr>
<td>Non-compliant</td>
<td>5.9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No stop/ looks at pedestrian</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Opportunist</td>
<td>0</td>
<td>7.1</td>
<td>0</td>
</tr>
<tr>
<td>Courteous/cautious</td>
<td>41.2</td>
<td>28.6</td>
<td>13.3</td>
</tr>
<tr>
<td>Allows to cross/ looks at sign</td>
<td>35.3</td>
<td>35.7</td>
<td>20.0</td>
</tr>
<tr>
<td>Allows to cross/ looks at pedestrian but not sign</td>
<td>17.6</td>
<td>14.3</td>
<td>53.3</td>
</tr>
<tr>
<td>Slow/Oblivious</td>
<td>0</td>
<td>0</td>
<td>13.3</td>
</tr>
</tbody>
</table>
Multi-lane roundabout EXIT crosswalks (percentages of drivers). Note that Warning condition data are presented in a separate table because there were no warning signs at the exit to roundabouts and there were consequently only 4 patterns of possible behaviour for that group.

<table>
<thead>
<tr>
<th></th>
<th>Overhead</th>
<th>Groundmount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oblivious</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Non-compliant</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No stop/ looks at</td>
<td>5.9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opportunistic</td>
<td>5.9</td>
<td>0</td>
</tr>
<tr>
<td>Courteous/cautious</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Allows to cross/</td>
<td>11.8</td>
<td>21.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slow/Oblivous</td>
<td>58.8</td>
<td>71.4</td>
</tr>
<tr>
<td>*Drivers who slowed/ stopped far too early, giving the pedestrian more than enough time to cross (Eye movements are not factored in here)</td>
<td>47.1</td>
<td>64.3</td>
</tr>
</tbody>
</table>

Multi-lane roundabout EXITS for the Warning condition

<table>
<thead>
<tr>
<th></th>
<th>Warning</th>
</tr>
</thead>
<tbody>
<tr>
<td>No stop and did not look at pedestrian</td>
<td>0</td>
</tr>
<tr>
<td>No stop but did look at pedestrian</td>
<td>0</td>
</tr>
<tr>
<td>Allows pedestrian to cross and looked at pedestrian</td>
<td>6.7</td>
</tr>
<tr>
<td>Allows pedestrian to cross but did not look at pedestrian</td>
<td>93.3</td>
</tr>
<tr>
<td>*Drivers who slowed/stopped far too early, giving the pedestrian more than enough time to cross. (Eye movements are not factored in here)</td>
<td>73.3</td>
</tr>
</tbody>
</table>