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Driver reaction times to familiar but unexpected events

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TRL Limited

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Executive summary

The *Driver Reaction Times to Familiar but Unexpected Events* study was undertaken as part of the TRL re-investment program to promote internal research. The study was designed to take advantage of existing data collected during previous trials in the CARSIM, together with bespoke studies designed to be integrated into new trials.

The aim of the study was to provide additional evidence in the field of driver reaction times to aid in defining a reference model of a driver to common and less common driving events where the driver is expected to react to an unfolding emergency. Current studies relate more to the emergence of pedestrians and vehicle into the path of a subject, and while this study utilises similar data to act as a validation of the CARSIM, the study goes further to explore stationary vehicles, collapsing motorway gantry and fatigue.

In collision investigation, it is the perception and response of a driver to a familiar, but unexpected event (such as the sudden movement of a pedestrian crossing from behind a parked vehicle) that is of considerable importance when reconstructing an incident for criminal or civil proceedings. Factors that influence the reaction can be the number of stimuli within the environment and the variety of avoidance manoeuvres available to the driver. The definition of a reference model for a typical driver's perception-response time allows a better understanding of the variability of, and between, drivers in different situations, which is an important factor in the investigation of many road traffic collisions.

Using a driving simulator to measure reaction times can offer a cheap, repeatable and safe environment in which a driver's response to a potential hazard can be determined. The results will help address one of the areas of considerable uncertainty in accident investigation and also assess the suitability of using advanced simulator technology as an alternative method to assess driver responses.

Literature regarding driver reaction times for accident investigation purposes is vast. Olson analysed a number of these studies and was able to summarise them into a range of likely reaction times. He stated *"Given a reasonably clear stimulus and a fairly straightforward situation, there are good data indicating that most drivers (i.e. about 85 to 95%) will respond by about 1.5 seconds after the first appearance of the object or condition or concern. The evidence also indicates that the minimum perception-response times for reasonably straightforward situation is about 0.75 second."*

Four separate studies were conducted in the CARSIM at TRL, these being:

Trial 1: Brake Assist Trial – drivers were expected to brake to a series of familiar events (pedestrians and vehicle emerging into their path). The trial setup meant that initially drivers would not expect the hazard; however, with subsequent runs they would become familiar with the trials aims.

Trial 2: Gantry Collapse – drivers were free to choose the appropriate reaction to an unfamiliar event. This being steering, braking or neither.

Trial 3: Unexpected Stationary Vehicle – drivers were again free to choose the reaction to a stationary vehicle, and while this should be a familiar event, the distance ahead would mean that the stationary vehicle would not necessarily be seen as a hazard when it first comes into view.

Trial 4: Driver Fatigue – in this trial, drivers were told how to react to the appearance of a red bar on the screen in front of them. This was a simple response of flashing headlights to an expected event.

This report brings together the findings of four trials in the TRL car simulator, each being designed to assess a driver in a different way. Comparison of results must be considered carefully even though all of the projects' outcomes have been to measure the participants' reaction. These differences include one project measuring the brake application to an emergency situation, another to a situation which may not be deemed as an emergency, as well as the final project measuring the flash of the headlights as the reaction response.

	Average	15th Percentile	50th Percentile	85th Percentile
Brake Assist				
Run 1 (Cars / Pedestrians Emerging)	0.85	0.67	0.81	1.02
Run 1 (Braking Vehicle Ahead)	1.30	0.80	0.99	2.01
Gantry Collapse				
Time to Apply Brake	1.53	1.18	1.35	1.84
Time to Apply Steering	1.54	1.08	1.45	2.15
Unexpected Stationary Vehicle				
Time to Apply Brake	3.52	2.17	3.35	4.79
Time to Apply Steering	5.08	4.23	5.00	6.34
Driver Fatigue				
Run 1, All Reaction Tasks	1.12	0.86	1.05	1.38

Table – Driver Reaction Time Summary Table

The fastest reaction times measured across the four studies were for the brake assist trial, where an average time of 0.85 second was observed.

The next shortest reaction times measured were in the driver fatigue trial, where the average reaction time was 1.12 seconds. One of the reasons why these times may have been low in a study assessing fatigue could be associated with the participants being told what to expect and how to react. This would in effect reduce the decision and identification phases of the perception reaction time.

Both the Gantry Collapse and Unexpected Stationary Vehicle trials measured braking and steering responses of the participant, whereas the Brake Assist trial was predominantly designed to assess a driver's braking reaction as the emergency events simulated lent themselves to a driver braking as opposed to steering to avoid. The gantry collapse trial could be described as being an unfamiliar event, where an experienced driver is less likely to have a 'pre-programmed' response. It was found that the reaction times were longer that for the path intrusion trials, although similar average reaction times were measured for braking and steering. It was found that the steering response had a greater reaction time range than for braking.

The reaction times measured in the trials in this TRL study, appear to be consistent with the work of Olson, partially because of the nature of the definition of Olson's reaction time range. Instead of taking the range as fixed, the collision investigator needs to understand how the range was calculated and whether a particular event needs the range to be modified, such as when the detection and identification phases may have been undertaken before a particular hazard enters the road.

Some collision reconstructionists have employed the equations developed by Muttart (Muttart developed three equation to be used in different situations), which use a range of situational variables. This method does not give the investigator the option of using his/her knowledge and experience to control the range. It was shown that Muttart's equations can overestimate the actual reaction times for pedestrian and vehicles emerging into a driver's path. Additionally, for the unexpected stationary vehicle, the range of reaction times depend on the equation used and it is not clear which should be the most relevant. One equation results in covering only the lower end of the reaction time range, while the other equation gives a range so large (5 seconds) that it is possible it would be of little benefit to a collision investigator.

Perhaps one of the significant shortcomings of the Muttart equations is the collision investigator's choice of the appropriate factors, some of which have a great bearing on the calculated reaction times.

1 Introduction

1.1 Background

In collision investigation, it is the perception and response of a driver to a familiar, but unexpected event (such as the sudden movement of a pedestrian crossing from behind a parked vehicle) that is of considerable importance when reconstructing an incident for criminal or civil proceedings. Factors that influence the reaction can be the number of stimuli within the environment and the variety of avoidance manoeuvres available to the driver. The definition of a reference model for a typical driver's perception-response time allows a better understanding of the variability of, and between, drivers in different situations, which is an important factor in the investigation of many road traffic collisions.

The TRL driving simulator has been used in numerous trials where the effects of various environments and new technology can be assessed on a wide range of the driving population. In some of these studies, drivers are briefed of the aims and objectives of the project and are even advised of the appropriate response to take, while in other studies the reaction event is completely unexpected and the driver is allowed to react in any way they see fit.

1.2 Research Method

Three of the four trials making up this research study involved the re-analysis of previous car simulator studies conducted at TRL. Although these previous studies assessed driver reaction times to some extent, this was generally only a small part of the trial's aims and therefore the previous analysis conducted was limited. This study allowed a much greater understanding of the reaction events.

Only in one study, that assessing a driver's reaction to a stationary vehicle, was an event added to a new simulator trial.

Using a simulator to measure reaction times can offer a cheap, repeatable and safe environment in which a driver's response to a potential hazard can be determined. The results will help address one of the areas of considerable uncertainty in accident investigation and also assess the suitability of using advanced simulator technology as an alternative method to assess driver responses.

2 Literature Review

2.1 Introduction

The reaction times of drivers have been extensively researched over many years and in various ways, often with different results.

Throughout this review, the reaction time of a driver will also be referred to as perception-response time. It is first important to understand what is actually meant by the term perception-response time and Olson (2003) describes this time as having four major steps which a driver goes through when reacting to an event. The first of these is detection something comes into the field of view of the driver and ceases once the driver has become conscious of it being there. The second stage is known as identification where the driver needs to take in as much information as possible to allow a decision on what to do to be made. The third is the decision, where the driver makes the decision of how he is going to react to the situation, such as do nothing, steer or brake. Lastly is the response, where the action is carried out. These four steps will be adhered to for an unexpected situation; however, for experimental purposes especially, they can all be altered or some removed from the sequence to shorten the reaction time. An example of this is enabling the driver to react to a situation by a single response, such as to apply the brakes then the decision time has been removed from the stages.

Variations in the number of decisions that the driver has to make will widely change the reaction time expected from a reasonably competent driver. The more choices there are to make, for example in a 'real' situation there could be options such as to slowly decrease speed, apply the brake, apply steering or a combination of many. These three possible choices alone can increase the decision and response time and therefore the total reaction time from the time expected for someone who has been informed to complete one specific task. Likewise, in a situation where there are a number of potential hazards that a driver must detect, identify and monitor, reaction times can increase. The effect that the number of choices has on the reaction time can be observed using Hicks Law (Hicks 1952). This enables the time for a person, where there is a 'human-computer interaction', to make a decision depending on the number of choices that are available to them to be calculated. The formula used to calculate the reaction time is:

$$T = b\log_2(n+1)$$

where 'n' is the number of choices available and 'b' is a constant that is obtained from measured data.

Hole and Langham (1997) conducted a review of previous studies that assessed factors affecting reaction times stating that "*performance is impaired when reaction-time is the secondary task and the subject is concentrating on maintaining performance on a primary task.*"

There have been many different ways in which researches have tried to determine reaction times to both unexpected and expected events. The three main areas of research related to this study are: simple tasks (pushing a button after a light has shown), track/road situations and those in a simulator.

2.2 Simple Tasks

The simplest of all reaction time events would be to reduce the detection, identification and decision sections as much as possible. The reaction time is therefore only the time to complete the action requested by the tester.

One of the earliest investigators to measure specific reaction times was Donders (1868), as reported in the book of Schmidt and Lee in 2005. He split his trial into three sections, the first was known as a simple reaction task, where the participant had to respond to a single stimulus using a single response, for example a coloured light and a key to press. The second known as go/no-go was where the driver had to distinguish between two light stimuli and only respond if a selected stimulus was shown. The final section was the choice reaction task where the two stimuli were still shown, but this time the participant was required to respond using a set action depending on which stimuli is shown. The logic of Donders' subtractive method was that the three tasks could be ordered accordingly to the number of stages involved, and the differences in reaction times would relate to certain stages of the reaction event. The choice reaction (denoted as b-reaction by Donders) involves the processes of discrimination of the stimulus as well as the selection of response. The c-reaction (go/no go), however, requires only discrimination of the stimulus, and no selection. Thus, the difference between a c-reaction and a b-reaction reflects the time to perform response selection. Donders provided a table showing reaction times that were 0.2 second for the simple task, 0.23 seconds for the go/no go and 0.285 seconds for the choice reaction task. In reality, it would appear that these reaction times are very low when compared to a driver reaction time but are reasonable results for simple reaction tasks, and it is unclear whether the basis for these hypothetical times was any physical testing. These results show that as the amount of stimuli and the choice of reaction tasks increase, the reaction time also increases. These reaction times will be expected to greatly increase for a driving situation, where there are many more stimuli present and the choice of reaction tasks available multiplies.

2.3 Assessing Driver Reaction times on Road/Track Environments

Olson (2003) describes, in chapter 15 of his book *Forensic Aspects of Driver Perception and Response*, studies relating to testing driver reaction time on actual road environments. He comments on a study by Lerner (1993), where drivers were unaware of the reaction event, who measured the time to apply the brakes or steer out of the way of a large barrel that was rolled in front of the drivers. This study calculated that the mean reaction time to apply the brakes was 1.5 seconds, with an 85^{th} percentile response of 1.9 seconds.

Another study that Olson describes, was that undertaken by Summula (1981), where a door on a parked vehicle was opened in front of the test subject driver, hence causing the drivers to serve out of the way. Again, the participants in the study were unaware of the reaction time event. His results showed that this lateral displacement started, on average, 1.5 seconds after the door had been opened.

The 'trapping' method can be used to get a driver to apply the brakes at a specific time on the open road without being forewarned. The study relies on two cars, the first of which would pull in front of a member of the public driving, while the other pulled behind. The lead vehicle applied the brake lights without slowing down and the rear vehicle timed the response time for the driver to apply his own brakes. However, it was found that because there was no speed change, and hence headway change, this did not require a rapid response from the driver due to 'no immediate threat'. This type of investigation is no longer used due to the dangers involved and the test subjects not giving their prior consent, therefore more recent investigations use simulators only to determine reaction times.

Rumar (in Jansson (1994)) conducted an investigation into the different reaction times with regards to expected and unexpected events. He compiled an experiment of where a driver was to apply the brakes after a klaxon horn was sounded, the drivers therefore knew what they needed to react to and what to do, the only thing the drivers were unsure of was when the horn was going to sound. To obtain reaction times for an unexpected event, a buzzer, which had been placed within the vehicle, sounded at random long intervals. He stated that there was a direct correlation between the time to react for the expected and unexpected events, and discussed a correction factor of 1.35 seconds between the two. This factor can be used to obtain the brake reaction times for an unexpected event, when a measure of an anticipated event is made. Summula who also carried out his investigations on an open road environment obtained an average reaction time of 1.5 seconds.

2.4 Comparison of Physical Testing and Simulator Studies

A number of studies have been conducted with the aim of determining driver reaction times in lifelike environments. The results of such studies have provided useful data for other investigators to create and validate realistic driving simulators. These studies were designed to establish whether the vehicle driving simulators can be used to determine realistic driver reaction times, in a safer environment.

A literature review for the validation of driving simulators was completed by Blana (1996) where it was found that many researchers have discovered that people can behave very differently when driving in the simulator, especially when their steering behaviour is examined. Blana stated that in a report completed by Reed and Green (1995) the authors found that some participants, in a static system without motion or feedback, corrected "*a lane-edge exceedance in the simulator with large, rapid steering motion that would have produced tyre squeal, high lateral acceleration and body roll, and possibly a loss of control*".

The level of accuracy of a study involving the use of a simulator is paramount in relation to a 'real' situation is very important when using these times for an investigation. Therefore, the simulators used must present an as near to a real situation as possible. Blana also adds that '*Rolfe et al* (1970) stated "*The value of a simulator depends on its ability to elicit from the operator the same sort of response that he would make in the real situation.*"'

McGehee et al (2000) investigated the difference in reaction times for an intersection on a test track and for the same situation within the simulator. The drivers were not informed of the purpose of the study and therefore the reaction event was unexpected. The drivers were instructed to follow a lead vehicle at a set headway, completing three laps of the route without any reaction event. On the fourth lap, a foam representation of a General Motors Saturn car was propelled into their path. The trial required the participants to drive 3.5 times around the track, and it was clear that the drivers were becoming aware of the intersection each time they drove through, especially as other vehicles were using the intersection. The reaction tasks measured in this investigation were the time to initial accelerator pedal release, the time to achieve maximum braking and time to initial steering. The results of this trial showed that there was a close correlation in reaction times between the test track and simulator with regards to applying the brake application (2.2 seconds for the simulator and 2.3 seconds on the track) and to the initial steering response (1.64 seconds for the simulator and 1.67 seconds on the track). However, the authors found there to be a difference of 0.32 second in the mean time for accelerator pedal release between the two methods. The authors explain these differences in reaction times as being due to the different methods used between the track and simulator. One such factor was that there were repeated track trials, whereas there was no repetition in the simulator trial. Also, on the test track, drivers had to follow a lead vehicle unlike in the simulator. It is therefore unclear whether the reaction times measured between the two methods can be directly compared.

More specifically, the TRL car simulator has been validated previously, in a study by Duncan (1995), where similar tasks were performed on the test track trials and in the car simulator. These tasks consisted of many different variables including speed estimation, lateral position when completing secondary tasks and headway. The speed estimation section was used to determine how participants judge the vehicles speed in the simulator compared to that on the track. Each driver was required to drive around the circuit at 45mph with the instrument panel covered up, a second time with the panel showing and a final third time with it covered up. Duncan stated that, "*Initial speed estimates did not differ significantly between the simulator and the track. After the speedometer circuits, mean speed did increase significantly in both environments, most markedly in the simulator, +2.08mph. The post-speedometer mean estimate in the simulator, 46.54mph, was also significantly greater than its counterpart on the track, 44.77mph.*"

For the secondary tasks the participants were required to drive around the circuit at a 'safe' speed, not greater than 60mph, while in one instance staying as close to the centre line as possible and secondly while completing an in-vehicle task, where a series of 12 number arrays were displayed on the dashboard and the participant was to use the indicator control if they contained the number '2'. During the first part the lateral deviation decreased by 10% in the simulator and by 18% on the track, and for the second section the lateral deviation rose by 22% and 6% in the simulator and track respectively. It was found that the participants always ensured there was a greater headway in the simulator than on the test track. In conclusion, it was found that the TRL simulator's relative validity as a test tool was demonstrated, as the direction, if not the absolute value, was always consistent.

The TRL CARSIM was validated with regards to impairment due to alcohol intake by Sexton (1997), by conducting track and simulator trials to assess driver reaction times. These reaction time events in the simulator consisted of a vehicle either pulling out, directly in front of the participant, or a vehicle changing lanes, pulling in front of the participant. Both of these events were unexpected by the driver. Within the simulator element of the study the average brake reaction time was measured giving the results for the drivers with no alcohol intake of 0.67 seconds for the vehicle pulling out in front of the driver (from a side road), and an average time of 2.25 seconds when a vehicle pulled in in front of the participant (lane change). However, it appears that the reaction events on the track and in the simulator were not directly comparable due to the tasks not being the same. The non simulator tasks included a computer based tracking task, reaction time to hazards shown on a video and lateral deviation while driving around a small loop on the TRL test track. The results for the computer based tracking test gave an average mean tracking speed of 15.16 m/s, average reaction time of 1.29 seconds for the hazard perception and lateral deviation of 117.0m and 103.1m, right handed and left handed curve respectively. Sexton concluded from all of the comparison tasks, including normal, non emergency, driving tasks that "*the relationship between the 'real' driving task on the TRL test track correlates positively with the results from the similar simulated task thus demonstrating that the simulator is indicative of what happens in 'real' driving.*"

2.5 Simulator Reaction Tasks

There have been numerous studies to determine driver reaction times that solely use a driving simulator, since in many instances attempting such tests on the road would prove dangerous. Warshawsky-Livne and Shinar (2002) investigated reaction times based on the time taken to apply the brake pedal on the appearance of brake lights on a lead vehicle. They concluded in their report a perception reaction time of 0.35 to 0.43 second. The found that the reaction time increased with age, but that there was no significant difference in the data between gender. In this investigation the participants were told what to expect and how to react and therefore the reaction times measured relates to an expected situation with the decision response already known. It can therefore be expected that the reaction times will be quicker than expected on a 'real' road.

In another study, Young and Stanton (2007) attempted to identify any differences in the reaction time with a change in driver technical aids. These technical aids, such as adaptive cruise control and active steering systems, are the next generation of safety systems for passenger cars. The participants were informed to follow a lead vehicle and, in all conditions, the participants were told that the lead vehicle would brake periodically. They were instructed to stay behind the lead vehicle, relying on an Adaptive Cruise Control (ACC) system to maintain headway as much as possible. The brake reaction time for this trial with ACC was 2.37 seconds for learner drivers, with an average age of 20 years, and 2.13 seconds for the more experienced drivers who had an average age of 23 years. The brake reaction time for learner and experienced groups with regards to active steering were 2.38 seconds and 2.48 seconds respectively. The authors related their results to those from Rudin-Brown and Parker (2004) to conclude that the use of these driver aids can slow reactions by 1-1.5 seconds.

Edwards et al (2003) investigated the reaction time performance of younger, 19 to 22 year old drivers and older, 65-83 year old, drivers at intersections. This study included four reaction time events which took place when the vehicle was within the vicinity of the intersection. The participants were unaware of the order of events and each event changed so the driver was unable to expect the same thing to happen the next time around; however they would have been aware that this was a reaction time test. The driver reaction times were calculated on the time it took for the participant to release the accelerator or apply the brake pedal. The first event observed by the participant was a pedestrian emerging in front of the vehicle when undertaking a right turn, the reaction for this was 0.97 second for the younger drivers and 1.44 seconds for the older drivers. The further event consisted of a last second yellow light, giving reaction time results of 0.76 second for the younger drivers and 1.26

seconds for the older drivers. One of the reaction events was to the unexpected movement of a pedestrian into the road, while at the same time a special grey mask was used in the simulator to induce change blindness (a phenomenon where a person viewing a visual scene apparently fails to detect large changes in the scene), and resulted in reaction times of 0.62 second and 1.40 seconds for the two age groups (increasing with age). The final reaction event was to another vehicle at the intersection continuing through a red light, and this showed results of 1.14 seconds for the younger drivers and 1.50 seconds for the older drivers. During the latter of the four 33% of the older group and 8.3% of the younger group did not release the accelerator.

2.6 Reaction Times used in Accident Investigation

The use of reaction times in accident investigation is very important in determining whether a driver may have reacted in a reasonable manner to the unfolding situation. The reaction time allows an investigator to reposition participants at the point of reaction and to calculate the alternative outcomes had the reaction occurred at a different point.

While not explicitly stated, the Highway Code (2007) used a reaction time of approximately 0.68 second. This time is based on the thinking distances used which relates to 1 foot per 1 mph. The reaction time used by the Highway Code is at the lower end of the time that could be expected of a reasonably alert driver. Extensive research by Olson has shown that a far more reasonable approach is to use a range of reaction times, this being of the order of 0.7 to 1.5 seconds to most familiar and clear stimuli. Depending on the situation the driver is in, the time of day and whether it was possible to perceive the hazard prior to the emergency, the values can range from approximately 0.5 second to 2.0 seconds. The lower end of the times relate to a driver already covering the brake pedal, and the upper end relating to an increased difficulty in identifying the hazard, such as at night.

Olson conducted a detailed literature review that included the reaction tasks that would be relevant to a collision investigation. The main references and results are tabulated below:

Study	Description	Reaction Time Range
TRL (1952)	Subjects drove a car in an urban setting with instructions to apply the brakes whenever they saw a pedestrian step into the street Although the stimulus was realistic; expectancies of the subjects were not.’	Average 0.71 s 85th Percentile 1.2 s
Gazis (1960)	Start of the yellow phase of traffic lights to the onset of the brake lights of cars whose drivers elect to stop	Average 1.14s Range 0.6 to 2.4s
Wortman and Matthias (1983)	Similar study to Gazis, but at a number of sites	85th percentile range 1.5 to 2.1s
Allen Corporation (1978)	Trapping Study. Head vehicle brakes and subject vehicle behind’s response is assessed by a third vehicle	Average 1.45s
Sivak (1979)	Same as Allen Corporation	Average 1.25s 85th percentile 1.9s
Summula (1981)	Reaction time assessment to a vehicle door being opened to assess reaction requiring lateral movement	Average 1.5s
Triggs and Harris (1982)	Created a number of real situations on a highway to produce a braking response from a driver. Some situations did not require an emergency response	85th percentile range 1.5 to 3.6s
Olson (1984)	Foam rubber object in carriageway. Driver had no expectation	85th percentile 1.3s 95th percentile 1.6s
Olson (1984)	Foam rubber object in carriageway. Driver had expectation	85th percentile 0.93s 95th percentile 1.13s

Table 1 – Olson Literature Review

Olson summarised the data and stated *"Given a reasonably clear stimulus and a fairly straightforward situation, there are good data indicating that most drivers (i.e. about 85 to 95%) will respond by about 1.5 seconds after the first appearance of the object or condition or concern. The evidence also indicates that the minimum perception-response times for reasonably straightforward situation is about 0.75 second."*

Study Type	Detection	Identification	Decision	Response
Simple Response Time	Minimal	Minimal	Minimal	Minimal
Choice Response Time With Multiple Stimuli	Minimal	Longer	Minimal	Minimal
Choice Response Time With Multiple Stimuli and Options	Minimal	Longer	Longer	Longer
Simple field Studies	Longer	Minimal	Minimal	Normal
Semi-Alerted Field Studies	Longer	Longer	Minimal	Normal
Passing Driver Studies	Longer	Longer	Longer	Normal

Table 2 – Factors Affecting the Stages of Perception-Response Time

Table 2 shows the effect that the type of study had on four sub-parts of the reaction time. Details of the factors that can affect the length of time associated with each part of the detection, identification, decision and response, as discussed by Olson, are summarised below:

- Detection – Affected by conspicuity. Larger and moving objects are easier to detect.
- Identification – Can be complicated by poor visibility, such as at night-time or in fog.
- Decision - If the driver has no choice in the decision, such as only braking is an option, and then the decision interval may be shorter.
- Driver Expectancy – Investigators are typically concerned with violations to a driver's expectancy, for example they would expect a pedestrian to stay on footpath or no object to be in the road. Likewise, seeing a young child at the side of the road unaccompanied could alter the expectancy.
- Night vs. Day – Visibility is generally degraded at night, and therefore longer reaction times may be appropriate. However, in many cases the perception response time at night will be the same as during the day. At night the detection and identification stages could be lengthened.
- Chemicals/Fatigue – Alcohol and drugs can affect reaction times. Driver fatigue can also increase a driver's reaction time.
- Age and Sex – Overall, research shows reaction times to increase with age, but on a case by case basis, and elderly person could still react quicker than a much younger person. Gender has a small effect.

A more complex analysis of driver perception reaction times was undertaken by Muttart (2003a and 2003b). This took the form of a meta-analysis study of previous driver reaction time studies, attempting to provide a more robust method for determining the reaction time of a driver in an accident investigation scenario. He developed a series of equations which would allow the accident investigator to calculate a reaction time for a particular set of collision variables. The equations included only the most influential parameters (as determined in the study), with the constants derived from the regression analysis. The level to which the derived equations accounted for the variation in the raw data varied between 54 % and 70 %. The equations were further optimised based on an additional 143 real life traffic collisions recorded at a '7-way intersection in Louisville, Kentucky'.

Muttart's research was based on grouping driver reaction time studies into three categories of reaction tasks, these being a Vehicle Changing Lanes, Path Intrusions and Vehicle Following, observing the reactions of drivers through video evidence and combining them with the analysis of reaction times by previous researchers.

The equations relating to the three reaction tasks, from the latest work by Muttart, were:

Path Intrusions (Angular Conflicts).

Driver Reaction Time (DRT) = 413T+30E+224NL+716S-496To+7

Vehicle Following (In Line Situations).

DRT = 393H+764T+509S+26E-421R-703To+306

Vehicle Changing Lanes

DRT = 303NL+340L+13E+113

Where E = Eccentricity In degrees, Ex = Experiment Location (Laboratory etc), H = Headway (seconds), L = Lanes, NL/Dn = Natural Lighting, R = Response Complexity, To = Topography, T = Transition Time and S = Number of reported stimuli.

The equations developed by Muttart rely on the user being able to correctly determine the appropriate value for the variable, and that in itself can be difficult and potentially lead to errors in the calculated reaction times. Taking the number of reported stimuli 'S' as an example, there are two options a '1' or '2', relating to single or multiple stimuli. However, the multiplying constant associated with this can lead to a difference in reaction time of 0.7 second.

Muttart also determined equations to give the 75th percentile of driver reaction times. The results obtained from the equations are then either added or subtracted from the driver reaction time previously calculated to give the 75th percentile.

Range:

Vehicle changing lanes:

Range = $3 \times 10^{-4} DRT^2 - .78DRT + 834.0$ 'Muttart (2003) explains that '*69.4% of estimates were within a plus or minus of this range from the actual response time*'.

Path Intrusions:
'*For the 43 path intrusion situations the 75th percentile accuracy of the estimates can be expressed mathematically as*;

Range = $4.84 \times 10^{-6} DRT^2 + .433DRT - 192.5$ ' 76.2%

Vehicle Following: This equation has been calculated using 11 recorded responses.

'Range = $1.49 \times 10^{-4} DRT^2 + .101DRT + 494.0$ ' 63.6%

These equations and how representative they are of the driver reaction time in this current TRL study are further explored in the discussion.

The wide range of potential reaction times can result in an accident reconstruction showing a number of possible scenarios of whether a driver reacted appropriately. The investigator needs to utilise their expertise and experience to determine whether it is possible to reduce the range of reaction times given the circumstances of the situation.

Therefore, reaction time studies are extremely useful to an accident investigator to help establish a baseline driver behavioural model, against which the performance of a driver in an accident can be compared. However, care must be taken with many of these studies to determine whether the reaction times measured are realistic in particular circumstances.

3 Summary of the Trials

3.1 Introduction

A short report was complied for each of the four trials, outlining the methodology used, the variables measured and the analysis undertaken.

The separate reports can be found in the appendices. The descriptions below provide a brief explanation of the original trial, whether they were modified in any way for the requirements of this study and the type of reaction time events that were extracted.

3.2 TRL CARSIM

The latest iteration of the TRL CARSIM, as utilised in all of the studies reported here, uses a Honda Civic family hatchback. Its engine and major mechanical systems have been replaced by a sophisticated electric motion system that drives rams attached to the axles underneath each wheel. These impart limited motion in three axes (heave, pitch, and roll) and provide the driver with an impression of the acceleration forces and vibrations that would be experienced when driving a real vehicle. All control interfaces have a realistic feel and the manual gearbox can be used in the normal manner (automatic gears can be simulated).

Surrounding the simulator vehicle are large display screens onto which are projected the graphic images that represent the external visual environment to the driver. The driving environment is projected at a resolution of 1280×1024 onto three forward screens to give the driver a 210º horizontal forward field of view. The presence of the two flat side screens adjacent to the driver gives a very strong impression of other vehicles travelling alongside of the vehicle. A rear screen provides a 60º rearward field of view, thus enabling normal use of all mirrors. A stereo sound system with speakers inside and outside the vehicle generates realistic engine, road, and traffic sounds to complete the representation of the driving environment. The software used to implement the simulation is called SCANeR II and was created by OKTAL to provide a flexible and powerful simulation with a highly advanced traffic model.

Surveillance video cameras are mounted in the car and participants can be recorded during their drive. There is also an intercom facility for communication between the vehicle and the control room. An in-car colour LCD display can also be used to give instructions or provide other task-related information.

Within the simulations there are more than fifty autonomous traffic vehicles which all have dynamic properties of their own – they appear to pitch realistically under acceleration and braking, and vehicle graphics include body tilt and roll under braking, acceleration and turning; speed dependent rotating wheels and fully working brake, indicator, fog, and head lights.

The simulator also includes a full integrated SmartEye eye –tracking system for the analysis of driver visual behaviour. This system, in addition to being able to report the driver’s gaze direction, is integrated with the 3D environment presented in the simulation, such that the eye-tracker can report in the simulator data the specific element on which the participant is fixating – a specific road sign, traffic light, the road ahead, or interior items such as the instrument panel or infotainment system.

3.3 Brake Assist Simulator Trial

The original trial had initially been set up to investigate the effectiveness of Brake Assist Systems (BAS) as part of a European Union funded project. The participants were required to react to a variety of emergency scenarios within a simulated environment, which consisted of a pedestrian emerging from the left or right, a vehicle crossing into the main road from the left or right and a vehicle conducting emergency braking in front of the participant.

The route consisted of many junctions with vehicles and pedestrians in close proximity, but only at four of these junctions did either a pedestrian or vehicle emerge into the road. This ensured that it was more difficult for a driver to pre-determine when a reaction event would occur. Each participant had to react to these five events in various orders in three separate trials.

The main reactions assessed in this trial related to the times from the event start to accelerator pedal release, brake application and the intervening time.

The trial used 36 participants, with the average age of the drivers being 41 years old, ranging from 27 to 54, showing therefore a limited range of the population, although a reasonable split between gender was used (17 female and 19 male).

3.4 Gantry Collapse Simulator Trial

As part of a larger project on passively safe motorway gantry support posts, a simulator trial was commissioned to assess the way in which drivers would react to the transom section of the gantry (horizontal section across the carriageway) partially falling after the gantry was impacted by a vehicle that left the nearside of the motorway striking the support post. The environment was a long section of motorway with other vehicles and roadside furniture. The data gathered during this trial was analysed in greater depth for the study reported on here.

The study was to determine driver reactions, using 24 participants, to the collapsing gantry which occurred when they were either 150 or 200m away. The design of the gantry was such that once the nearside section had fallen to the road, it would form an angle (with the offside still attached to its support post) that would allow all driver to pass safely beneath. Additionally, there was enough time for the participants to safety stop the vehicle prior to reaching the gantry should they wish to do so. The drivers were able to react how they felt necessary given the situation.

Two separate age groups were define, from new drivers aged 17 through to 44 years old, and older drivers older than 45 years. The actual youngest driver in the sample was 19 years, ranging to the oldest driver of 74 years. There were an equal number of males and females in the sample.

Each driver had only one run in the simulator and therefore there was no issue with familiarisation. Due to the nature of the event, drivers undertook different reactions to the collapsing gantry and therefore assessment was made for the time to release the accelerator, apply the brake or apply steering. The amount of steering and braking applied was also assessed, to highlight any differences in the participants driving style.

3.5 Unexpected Stationary Vehicle Simulator Trial

The original simulator trial was commissioned to determine whether participants could distinguish between standard fuels and performance fuels. The simulated environment was a two lane carriageway set in a rural area rural, with other vehicles travelling in both directions. The speed limit for the road was the national speed limit of 60 mph. Each of the participants had 5 separate drives of the trial and therefore had the opportunity to familiarise themselves with the route as they continue through each run.

This trial was modified for the purposes of the driver reaction time study reported on here. The original trial did not require the driver to undertake any kind of emergency reaction; it was purely a simple driving activity. To introduce such an event, towards the end on the last run, and only for those participants under the constraint of finishing the trial within a specific time, a black 1995 model Mercedes SLK, without lights, was stationary against the kerb on a gentle right bend with a radius 529m. On the section of road containing the stationary vehicle there were no oncoming vehicles, so it was safe for a driver to steer around the vehicle. There was also enough visibility for a driver to safely stop if they wished to do so, even from high speeds.

The trial consisted of 48 men, with the first 24 all members of a performance fuels club, ranging in age from 25 years old to 73 years old; however the majority (38%) were aged between 61 and 70 years old.

The reactions of interest in this trial related to the times for the drivers to release the accelerator pedal, apply the brake and/or steer around the stationary vehicle.

The time to release the accelerator was considered important in this trial as this may be the first point of reaction from the participants, especially as the stationary vehicle up ahead may not be deemed an emergency situation.

3.6 Driver Fatigue

A trial was commissioned to assess driver fatigue and the effect that two drinks containing a different amount of caffeine and glucose could decrease the levels of fatigue. A third control drink was used for the baseline responses. The trial consisted of a number of measures to determine the level of alertness of a driver, one of which was to assess a reaction time. Due to this, the level of analysis of driver reaction times was limited.

Each of the participants undertook a practice run on the day before the actual trial began where they were assessed over three separate days. Each day the drivers had to drive for approximately one hour, at a time just after lunch where fatigue is known to be high.

The drinks used by this investigation, one of which was consumed before each trial, consisted of a control drink which had been dyed the same colour as the others (drink one), a level one drink 60g glucose and 25mg caffeine (drink two) and a level 2 drink 60g glucose and 40mg caffeine (drink three).

The trial consisted of four separate sections, which were driven by the participants, one after the other, making up the hour. Each of these sections contained a reaction task. The reaction tasks within each of the sections occurred at set distances into the trial, where a red bar would appear on the screen in front the participant. They had been informed before the trial started that when this bar appeared they were to flash their headlights.

The trial started with a 60km motorway section followed by 19km travelling on a two lane curved road. The next 23km required the participants to follow a lead vehicle at a set distance, with chevrons used to initially to assist in separation distance. These chevrons ceased for part of the journey and then reappeared later to establish whether the driver could maintain the headway without a visual guide. The lead vehicle changed its speed between 50mph and 70mph to enable the distances between the two vehicles to change. Finally the participants were informed to rejoin the motorway where they continued for 25km in normal traffic. Due to the nature of the study, participants would become more familiar with the trial, and specifically the location of the reaction events, with the greater number of drives.

4 Main Results

4.1 Brake Assist Simulator Trial

Within the trials to assess the benefits of Brake Assist systems, drivers were required to react to pedestrians and vehicles entering the road ahead of them, as well as reacting to a slowing vehicle in front.

The main variables that have been considered during this study included the time from the event start to release the accelerator, to apply the brake and the time difference between the two. There were very few instances of a driver swerving whilst reacting and the raw data did not allow for a significant analysis of this to be undertaken.

Table 3 shows the average braking reaction times for the different scenarios and run number. In general, the times were seen to reduce with the increasing run number. The table also shows that in a number of scenarios, where the sample size is extremely low, making any meaningful trend analysis difficult. In the instances of small sample sizes (less than 5) it is not possible to rely on the reaction times as being representative of the population as a whole.

	Pedestrian Emerging from the Left		Pedestrian Emerging from the Right		Car Emerging from the Left		Car Emerging from the Right		Car Emergency Braking	
Run	Average Reaction Time (sec)	Sample Size	Average Reaction Time (sec)	Sample Size	Average Reaction Time (sec)	Sample Size	Average Reaction Time (sec)	Sample Size	Average Reaction Time (sec)	Sample Size
1st	0.8	19	0.9	11	0.8	22	0.9	9	1.3	18
2nd	0.7	15	0.8	9	0.7	12	1.1	4	1.2	16
3rd	0.7	10	0.6	2	0.7	15	0.5	1	1.2	17

Table 3 – Average Driver Reaction Times to Different Hazards

This study found that drivers tended to undertake a braking reaction in the same time irrespective of whether the pedestrian emerged from the left or right side of the road. The 15th and 85th percentile responses from the left were 0.59 second and 0.99 second, while from the right the reaction times were 0.61 second and 1.01 seconds, for the 15th and 85th percentiles respectively.

However, a similar analysis for the vehicle emerging found that at the 50th and 85th percentile response levels, reaction times were longer for the scenario where the vehicle emerges from the right, compared to emerging from the left. For a vehicle emerging from the right, the responses were a 15th percentile of 0.60 second, a 50th percentile of 0.94 second and an 85th percentile of 1.29 seconds. For the vehicle emerging from the left, the response were a 15th percentile of 0.65 second (similar to the time for right emerging vehicle), and 50th and 85th percentiles at 0.76 second and 0.87 second, respectively, which are significantly shorter. It would appear that a vehicle emerging immediately onto the participants' traffic lane was deemed to be more of an emergency.

Several issues arose during this investigation. These included, on occasion, very small sample sizes and also the driver becoming more and more familiar with the aims of the study, which would clearly put them on a higher state of alert for reacting. This could be one of the reasons for the reaction times being slightly lower than in other reaction time studies. The potential issue with the sample size is especially seen in Table 3. It should also be noted that there were not equal sample sizes for both the pedestrian and car emerging from the left and right. For both of these there were a greater number of reaction events encountered for them emerging from the left.

In the final of the scenarios previously discussed, a reaction event to a lead vehicle conducting emergency braking, the 15th percentile response to apply braking was 0.79 second and the 85th percentile was 1.91 seconds. These results show considerably longer reaction times than for the other four scenarios. This could be due to the difficultly a following driver would have in initially judging whether the vehicle in front is slowing down rapidly or lightly touching the brakes.

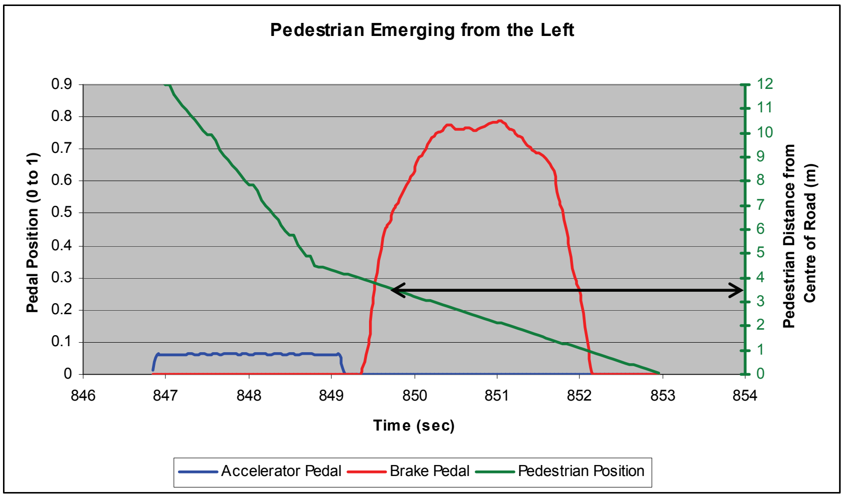

Figure 1 – Driver Behavioural Profile for Left Emerging Pedestrian

Figure 1 shows one driver's reaction to a pedestrian emerging from the left. The black arrow shows the point at which the pedestrian begins to enter the road (when 3.65 metres from the middle of the road). This diagram illustrates that the participant has already observed the pedestrian and started to react by releasing the accelerator and applying the brakes before the pedestrian entered the road. The result of this means that the analysis does not include this case as the beginning of the reaction event only began when the pedestrian entered the road.

There were many instances where this was the case, accounting for 24% of all situations included the participants already having applied the brakes before the hazard had entered the road. This could also explain why the reaction times seen for the scenario where the vehicle in front conducted emergency braking were high compared to the other four scenarios, as in this case the brakes were not applied before the brake lights shown.

4.2 Gantry Collapse Simulator Trial

The trial was designed for the gantry collapse to be an unexpected and unfamiliar event, and with only a single run in the simulator, the participants are likely to react as they would in a normal driving situation. The results measured and assessed were therefore the time to release accelerator, the time to apply the brake and the time to apply steering. The reaction times were measured from the moment the saloon vehicle collided with the gantry support. However, it should be acknowledged that it may have been possible for the participants to have reacted slightly before this when they saw the saloon car veer off the motorway in front of them.

The results showed that nearly all (21 out of 24) of the participants released the accelerator, with this being either their only reaction or being followed by brake application. The steering reaction was found to occur in isolation or in tandem with accelerator and brake pedal use.

The average time taken by participants to release the accelerator was 0.63 second, in the 15th to 85th percentile range of 0.30 to 0.95 second.

All of the participants were split into two age groups for the analysis of the results. These groups consisted of Group One which contained 17-44 year olds and Group Two of 45 years plus.

Out of all of the participants who applied the brakes, the average reaction time was 1.53 seconds, with an 85th percentile for Group 1 of 1.66 seconds compared to Group Two of 2.21 seconds. The 15th percentile reaction time for participants in Group Two was faster than for those in Group One with a result of 1.17 seconds, where as Group One had a 15th percentile of 1.29 seconds. The fastest recorded time by any participant to apply the brake was 1.15 seconds.

Another reaction that was taken into account during this study was the time taken to apply steering. The steering response had to be significant, and a limit of at least 1.0 metres of lateral movement across the road was used. The Group one average time to apply steering was 1.60 seconds with a 15th percentile of 1.01 seconds and an 85th percentile of 2.33 seconds. For Group Two the steering reaction time results had smaller range, with an average of 1.48 seconds, and a 15th and 85th percentile of 1.31 seconds and 1.91 seconds respectively.

During this study, the first reaction of the participants was also analysed, to compare the relationship between braking or steering response choices. The time taken for a driver to apply either steering or braking as a first reaction had a 50th percentile of 1.3 seconds overall. The 50th percentile for those who applied the brake as a first reaction was 1.23 seconds and those for steering 1.34 seconds.

Four participants did not apply any braking at all, where as nine applied the brakes and stopped before the collapsed gantry.

4.3 Unexpected Stationary Vehicle Simulator Trial

As with the previous trials, the participants were free react in any way they deemed necessary for the hazard. These therefore consisted of the accelerator release, the applied brake and applied steering control.

The data used in this report has data for only 26 out of the 48 participants, as the remaining participants did not have the stationary car within the last run.

The first possible point of perception of the stationary vehicle was calculated, from the simulator, to be 12597.5m after the start, with the stationary vehicle being 203.4m ahead.

The average time to release the accelerator pedal was calculated to be 3.13 seconds, with 19 out of the 26 participants reacting in this way as their first reaction. 5 of the remaining 7 were not applying the accelerator when the stationary car became visible.

The time to apply the brake, as can be seen in Figure 2, for the 23 participants who did so, took on average 3.52 seconds, where the average distance travelled before the brakes were applied being 107.9m, after the first possible point of perception. The distance travelled and the distance before the stationary vehicle depends on the travelling speed of the participants throughout the whole trial, which ranged from their own averages of 49mph to 97mph.

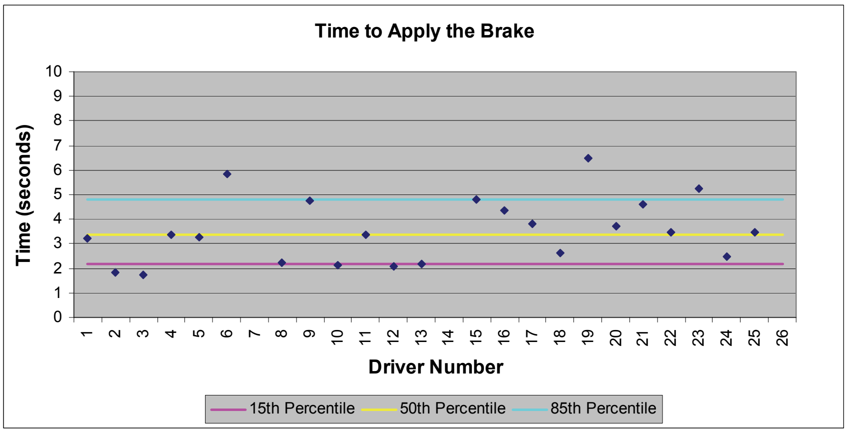

Figure 2 – Time Taken by Participants to Apply the Brake

Drivers also steered the vehicle to avoid the stationary car, this being on average after 5.08 seconds from first possible perception of the stationary vehicle, but it also ranged from as little as 0.45 second to a maximum 8.25 seconds.

In addition, this report was assessed with regards to the trend with age and driving style. A general trend between increasing age and the increasing time to apply the brakes was observed, showing slight positive correlation; however the time does vary between individuals and does not show a strong correlation.

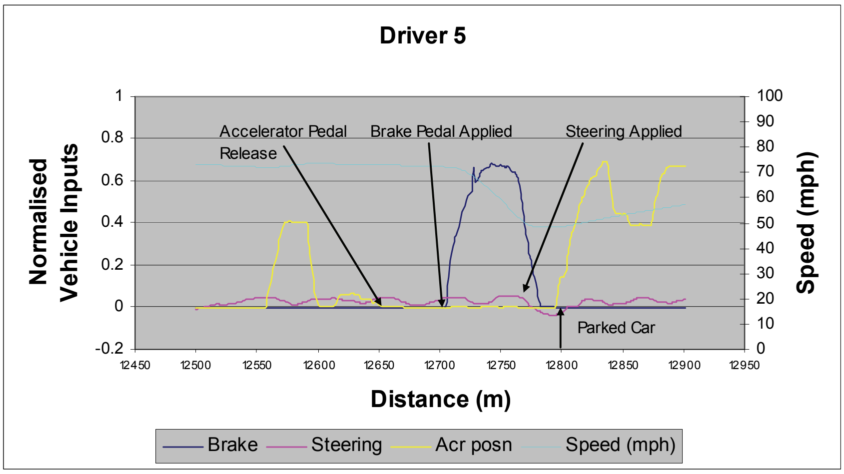

Figure 3 – Driver 5 Behavioural Profile

Figure 3 shows how a typical driver reacted to situation appearing ahead of them. It can be seen that the accelerator pedal was released slowly before the brake pedal was applied, slowing the vehicle to 48mph enabling a steering manoeuvre to be carried about past the stationary vehicle.

4.4 Driver Fatigue

During this investigation many variables were considered and analysed, these consisted of the speed of the participants vehicle, the headway between the participants vehicle and the car they were following (only in the following section), the reaction times to each reaction task, the gender of the participants and the drink they had consumed before driving in the simulator.

The participants travelled at or slightly above the speed limits for each road, these slightly higher speeds could be due to the participants having a time pressure.

A general tend was observed showing that as the participants completed more runs, their reaction times decreased, as seen in Figure 4.

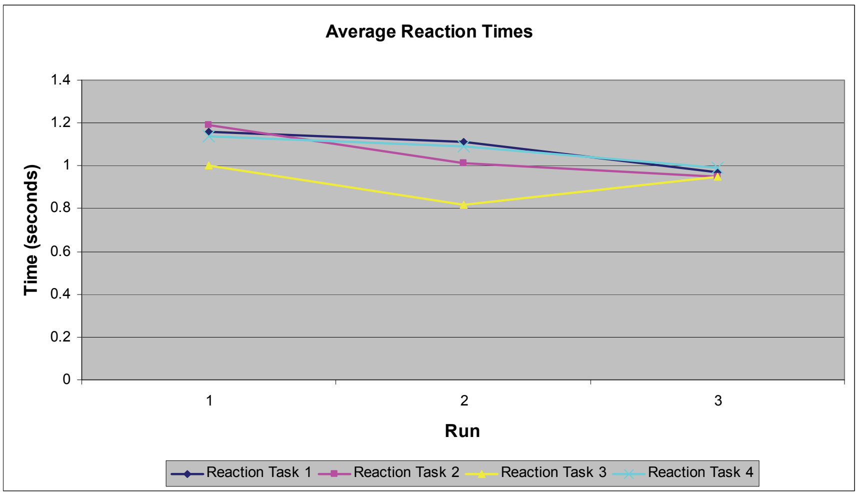

Figure 4 – Trend between Reaction Tasks and Familiarity

Figure 4 shows that for reaction task one, general motorway driving, the reaction time decreased from 1.16 seconds to 1.11 seconds and finally to 0.97 second, for runs one, two and three respectively. The only reaction task which did not follow this trend was reaction task three which started as 1.0 second for run one, to 0.82 second and then increasing for run three to 0.95 second.

Reaction task three was constantly faster than the other reaction tasks, with an average time of 0.92 second, which could be due to the participants having to concentrate on the vehicle they were following and therefore be in a more alert state of mind.

The data also showed that males were consistently faster than females for all of the reaction tasks and all of the runs with an average reaction time of 0.99 for males and 1.07 for females. Overall though, this difference is less than 0.1 second and for incident reconstruction purposes would have little effect.

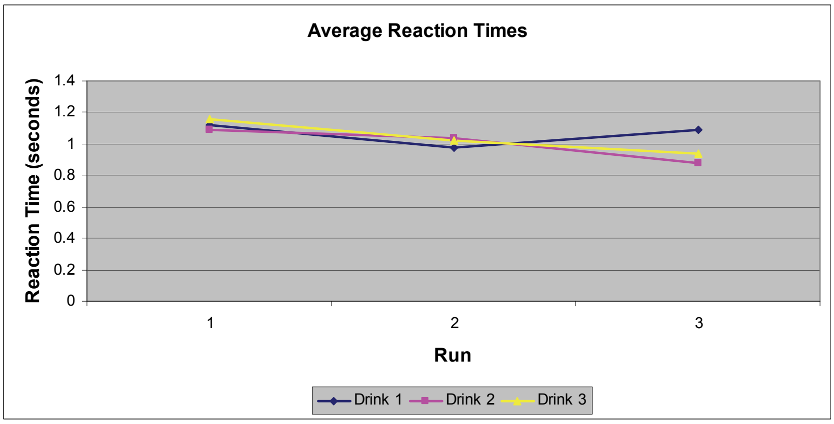

Figure 5 – Effect of Familiarity and Drink Type on Reaction Time

Figure 5 shows the effect of drink on reaction time, together with the run number to help demonstrate a familiarity with the trial. The average reaction time, irrespective of run number and reaction task, for drink one was 1.06 seconds, drink two 1.00 second and drink three 1.04 seconds. There was found to be no distinct correlation between either drink or run number which may have been due to the small amount of data available for each set when split into drink type, run number and finally reaction task.

5 Discussion

5.1 Simulator Trials

The project was initially undertaken in order to enable a better understanding of the variability in perception-response times between individuals. The project was therefore designed to piggy back on new trials that were being conducted in the TRL simulator as well as analysing existing data, enabling different scenarios and different potential hazards to be examined.

Using a simulator to measure reaction times can offer a cheap, repeatable and safe environment in which a driver's response to a potential hazard can be determined. The results will help address one of the areas of considerable uncertainty in accident investigation and also assess the suitability of using advanced simulator technology as an alternative method to assess driver responses.

As previously discussed, there are four main sections to a perception-response time, consisting of detection, identification, decision and response. These sections become very important as the studies all vary in what they are timing a driver to achieve. For example, a very simple reaction time event would be to reduce the detection, identification and decision times, as well as ensuring the response time is low, which can be achieved by informing the participant that they must react to something, telling them what it is they are expecting and telling them how to react to this.

It is known that the most reliable method to obtain the most accurate results from a group of participants would be to test them on the road and without their prior knowledge of the trial. However, due to safety concerns this kind of investigation is rarely undertaken.

Undertaking these projects enables an accident investigator to determine what a reasonable driver could be expected to do in different situations, and therefore whether a driver could have reacted in a shorter time to either avoid or reduce the severity of the collision. These investigators must also bear in mind that complex environments, night time and adverse weather conditions could affect the perception-response time of a driver. It is therefore very important not to solely rely on the value on which the Highway Code is based, as this is not suitable for all drivers in all conditions.

This report brings together the findings of four trials in the TRL car simulator, each being designed to assess a driver in a different way. This makes it very difficult to compare the projects to each other even though all of the projects' outcomes have been to measure the participants' reaction to a situation. These differences include one project measuring the brake application to an emergency situation, another to a situation which may not be deemed as an emergency, as well as the final project measuring the flash of the headlights as the reaction response.

	Average	15th Percentile	50th Percentile	85th Percentile
Brake Assist				
Run 1 (Cars / Pedestrians Emerging)	0.85	0.67	0.81	1.02
Run 1 (Braking Vehicle Ahead)	1.30	0.80	0.99	2.01
Gantry Collapse				
Time to Apply Brake	1.53	1.18	1.35	1.84
Time to Apply Steering	1.54	1.08	1.45	2.15
Unexpected Stationary Vehicle				
Time to Apply Brake	3.52	2.17	3.35	4.79
Time to Apply Steering	5.08	4.23	5.00	6.34
Driver Fatigue				
Run 1, All Reaction Tasks	1.12	0.86	1.05	1.38

Table 4 – Driver Reaction Time Summary Table

The table above (Table 4) shows the reaction times associated with only the first time a participant undertook the trial. Subsequent runs were excluded to reduce the level of familiarity. The fastest reaction times measured across the four studies were for the brake assist trial, where an average time of 0.85 second was observed.

The next shortest reaction times measured were in the driver fatigue trial, where the average reaction time was 1.12 seconds. One of the reasons why these times may have been low in a study assessing fatigue could be associated with the participants being told what to expect and how to react. This would in effect reduce the decision and identification phases of the perception reaction time.

Both the Gantry Collapse and Unexpected Stationary Vehicle trials measured braking and steering responses of the participant, whereas the Brake Assist trial was predominantly designed to assess a driver's braking reaction as the emergency events simulated lent themselves to a driver braking as opposed to steering to avoid. The gantry collapse trial could be described as being an unfamiliar event, where an experienced driver is less likely to have a 'pre-programmed' response. It was found that the reaction times were longer that for the path intrusion trials, although similar average reaction times were measured for braking and steering. It was found that the steering response had a greater reaction time range than for braking.

The longest "reaction" times of all were in the unexpected stationary vehicle trial, and an analysis of this particular trial highlights a number of potential issues. The first possible point of perception was from a distance in excess of 200 metres, and at a travelling speed of 60 mph, this would mean that the participant was more than 7 seconds away, which is unlikely to constitute an immediate threat requiring a real emergency reaction. This was still a reaction time study, but it clearly shows that if such a study became incorporated into a detailed meta analysis, it could aversely affect the creation of a generic set of driver reaction time equations. This case may be an extreme, but even with 100 metres of visibility, a driver would not be expected to perceive a stationary vehicle as an emergency event, unless of course travelling at a speed much greater than the speed limit on UK roads.

The unexpected stationary vehicle had the longest reaction times for both time to apply the brake and to apply steering. The average time to apply the brake was 3.25 seconds and to apply steering was 5.08 seconds. This longer reaction time may be due to the stationary vehicle not being deemed as such an emergency, and the participants were able to continue around the vehicle.

However in the gantry collapse showed very similar times for both time to apply the brake and steering, of 1.53 seconds and 1.54 seconds respectively. Although time to apply the steering has a larger spread of time taken, at a 15^{th} percentile of 1.08 seconds, compared with 1.18 for braking applied and an 85^{th} percentile of 2.15 seconds compared with 1.84 seconds.

A variable that was investigated in detail was the average time to apply the brake, which was calculated in the gantry collapse and the unexpected stationary vehicle investigations as 1.53 seconds and 3.25 seconds respectively. It can be seen from these two results that there is a large variation in the different tasks, this could be due to the gantry collapse deemed more as an emergency situation and would have been very unexpected to the participants. Out of the four trials in this report the gantry collapse trial is the only investigation that is based on an unfamiliar event. The other events especially the stationary car trial and the brake assist trial consist of events that would be expected driving in a normal situation.

During this trial the participants will also become more familiar with the events that are occurring. It was observed that in all but one case that the times to react to the events decreased on average by 0.075 second as the run increased. The one event where this was not case was the car emerging from the right where the average reaction time increased from 0.9 second to 1.1 seconds for runs 1 and 2, and decreased for run 3 to 0.5 second.

For two of the trials the steering manoeuvre applied by the participants was examined, these trials were the gantry collapse and the stationary vehicle. An average steering time for the gantry collapse was 1.45 seconds compared with an average of 5.08 seconds for the stationary vehicle; again this high discrepancy can be due to the trials being very dissimilar. These differences can also be seen for the times to release the accelerator which were 0.63 second and 5.08 seconds, for the gantry collapse and stationary vehicle respectively.

5.2 Comparison to Olson and Muttart Reaction Time Ranges

5.2.1 Muttart Equations

The constants in the equations developed by Muttart have, in some instances changed quite dramatically between his two publications (2003a and 2003b), which leads to the question as to how they were developed. The factors in his equations were:

E = Eccentricity In degrees, Ex = Experiment Location (Laboratory etc), H = Headway (seconds), L = Lanes, NL/Dn = Natural Lighting, R = Response Complexity, To = Topography, T = Transition Time and S = Number of reported stimuli

As an example of how the constants have changed, in the path intrusion equations, the constant relating to day or night accidents (NL/Dn) was 0.47 second, which reduced to less than half that value in a later study (0.22 second).

It is also worth noting that within each equation there is generally an over-riding factor that can have the greatest influence on the calculated reaction time. In the path intrusion equation, both ‘S’ and ‘To’ very high factor (0.7s and 0.5s respectively) and therefore the selection of the wrong value for the factor can lead to a large change in the driver reaction time up to 0.7 second.

By stating the variables used in each equation it enables the thought that no other factors will affect the reaction time, however this is not the case and will solely depend on each incident. It can also be seen that in using these equations in a real life investigation will involve a lot of estimating and therefore could result in a completely different reaction time than that of the driver.

Using the Muttart equations, the average values for the minimum and maximum times (based on 2 seconds headway) were calculated as:

Path Intrusion	Lane Change	Vehicle Following
0.40 to 4.43	0.77 to 2.44	-0.70 to 3.30

The latter of these is interesting in that a reaction time cannot be negative as this implies that the driver will start reacting before there has been a hazard for him to react to. These results show that without knowing exactly what numbers to put into the equations then an incorrect reaction time can be calculated. The response complexity ‘R’ had one of the greatest influences on the calculated reaction time as the constant multiplier was 0.42 second, not knowing how the driver would have needed to respond to the situation in order to avoid the collision can change the calculated reaction time dramatically.

As part of our analysis, the Muttart (2003b) equations for driver reaction times were used and compared to the reaction times calculated during the Brake Assist Trial. The results using Muttart showed a range of 1.28 seconds to 2.62 seconds for path intrusion whereas the analysis of the investigation showed a range between 0.67 seconds and 1.02 seconds, it can be seen that the higher range is more than double in the Muttart’s calculation, while the lower end is still greater than the 85th

percentile response from the Brake Assist project. The effect of reducing the stimuli so that only a single stimulus is used in the equation would result in the reaction time reducing by 0.7 second; however during the Brake Assist trial there were many stimuli present such as pedestrians and vehicles around the intersection.

The similar comparison was made for the vehicle following scenario where Muttart showed a range of 0.56 second to 2.61 seconds, while the actual reaction times measured in the study here was 0.80 second to 2.01 seconds.

In the case of the unexpected stationary vehicle, it is difficult to assess which of the equations would be suitable, given that the car was not illuminated in any way (neither driving lights nor brake lights) and it did not emerge into the path of the participant. Using the path intrusion equation, it was found that the mean reaction time was 1.28 seconds, in the range of 0.91 to 1.65 seconds. The vehicle following equation results in an average time of 3.33 seconds, in the range of 0.85 to 5.81s. The unexpected stationary vehicle trial, reported on here, measured a brake reaction time range of 2.17 to 4.79 seconds, which falls within the range for a vehicle following situation. However, it could also be said that when the stationary vehicle is so far ahead that this would not be a real emergency situation and the range reflects this in nearly a 5 second range.

The Brake Assist Trial (path intrusion and vehicle following situations) showed that Muttart's ranges are much greater than those observed within the investigation; however, they do cover the whole range in the vehicle following situation the actual reaction times do fall within Muttart's range. For pedestrian and vehicle path intrusion, the equation greatly overestimates the actual reaction time range.

5.2.2 Olson

Olson (2003) defines a range for reaction times of 0.75 to 1.5 seconds. When comparing this range to the Brake Assist Trial (15^{th} to 85^{th} percentile reaction time range of 0.67 seconds to 1.02 seconds), shows that the lower end of the Olson range appears to be more consistent. Given that the trial tended to clearly show a pedestrian or vehicle before they entered the road, this would affect the detection and identification phases of the reaction, and therefore it could be expected that an investigator would use the lower end of the Olson range.

For the vehicle following trials, the simulator study showed a 15^{th} to 85^{th} percentile range of 0.80 second to 2.01 seconds. While Olson's range tends to cover the lower end of the perception reaction times, it would appear that it could underestimate the reaction time by as much as 0.5 second. Again, this is where the investigator needs to apply some experience and knowledge that a driver will not always immediately attempt to brake when they see brake lights on a lead vehicle illuminate. It could be that a driver notes the illumination but that they would also assess to what level the braking ahead is. This could account for the slightly longer times

It is difficult to assess the gantry collapse trial given that it is an unfamiliar event. The reaction time ranges for braking and steering were similar, and compared with the upper end and beyond the range of Olson. This tends to indicate that the "unfamiliar" part of the perception-reaction could be around ½ second.

5.2.3 Comparison of Studies

The reaction times measured in the trials in this TRL study, appear to be more consistent with the work of Olson, partially because of the nature of the definition of Olson's reaction time range. Instead of taking the range as fixed, the investigator needs to understand how the range was calculated and whether a particular event needed it to be modified.

In contrast, the work by Muttart does not give the investigator the option of using their own knowledge and experience to control the range. The reaction time ranges above show that Muttart's equations can overestimate the actual reaction times for pedestrian and vehicles emerging into a driver's path. Additionally, for the unexpected stationary vehicle, the range of reaction times depend on the equation used and it is not clear which should be the most relevant. One equation results in covering only the lower end of the reaction time range, while the other equation gives a range so large (5 seconds) that it is possible it would be of little benefit to a collision investigator.

The work by Muttart is used in the field of accident investigation and reconstruction, and provides a useful insight into the factors that can affect a driver's reaction time. However, it must be recognised that a careful selection of the parameters is paramount to avoid generating inappropriate reaction times in certain circumstances, such as complex environments. The TRL study shows there to be a critical influence of the decision stage of the reaction event, either due to the number of possibilities (Hick's Law) or due to additional time being available as the braking response is not required straight away as the hazard is not immediate.

Acknowledgements

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Appendix A. Brake Assist Simulator Trial

A.1 Introduction

A trial was conducted on the TRL car simulator to assess the effectiveness of a number of Brake Assist Systems (BAS) on behalf of the EU. To determine their operation effectiveness, drivers were faced with a number of different emergency scenarios to which they were expected to react and brake the vehicle. While the intricacies of the BAS trials are beyond the scope of this study, details relating to the various stages of driver reaction time to these events were investigated.

Five separate emergency events were simulated, these being a pedestrian emerging from the left or right of the road, a vehicle crossing into the main road from the left or right, and a vehicle in front conducting an emergency braking manoeuvre.

A total of 36 drivers were used in these trials, each having to react to all of the above in different orders and also assessing the different BAS systems. This means that each driver would undertake five emergency manoeuvres, in each of three separate drives in the simulator.

There were a number of junctions along each driving route in the trial, each having a number of pedestrians and vehicles in close proximity. It was only at four of these junctions where either a pedestrian or car emerged into the main road. Even so, it is believed that the design of the trial would lead to some familiarity of the drivers to what is expected of them. In fact, in a number of the runs, drivers were taking their foot off the accelerator, or even braking, prior to the pedestrian or car emerging into the road.

The reaction times calculated refer to the point that the pedestrian enters the road, the car emerges over its junction give-way line, or the vehicle in front commences braking. However, although there were walls around the junctions, preventing perfect visibility, these walls were only 1.3 metres high to the left and 1.0 metre high to the right. The wall to the right was also set back approximately 2.0 metres from the carriageway edge, while that to the left was almost on top of the kerb line. Walls of this height would potentially allow a driver to see adult pedestrians approaching the road from behind them.

Generally, it is believed that this trial offers an optimistic analysis of driver reaction time. Following a driver’s first one or two events, it could be said that they would be on a heightened level of alertness, and therefore reaction times would be towards the lower end of that expected in the real-world.

The main focus of the data analysis was for runs where the driver still had their foot on the accelerator pedal when each event started. Further, but more limited analysis, was made of runs where there the accelerator pedal had already been released, or when the brake pedal was already being applied prior to the event start. Although this latter behaviour of accelerator pedal release or brake application could be based on a driver’s perception of an impending emergency, it could also be related to one of the simulator driver tasks for maintaining a speed of around 40 to 50 mph.

A.2 Results

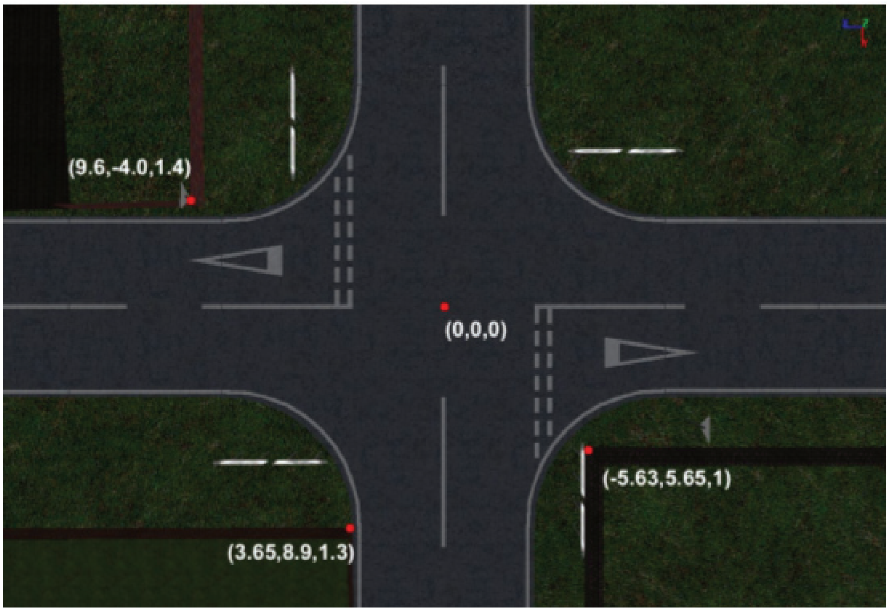

Figure A-1. Road Environment and Datum

Above is a typical junction design for this project, with the zero point being located at the centre point of the junction.

Time to accelerator pedal release and time to first application of the brake pedal were calculated, allowing a further calculation of the time taken between the two to be made. Simulator runs where the subject did not appear to react in a fast enough time were removed from the analysis so as not to bias the sample towards the longer end. There were instances where after releasing the accelerator pedal it took the driver 12 seconds to apply braking.

Percentile	Time to accelerator release (sec)	Time to brakes application (sec)	Accelerator release to brake pedal time (sec)
15th	0.31	0.58	0.17
50th	0.45	0.68	0.22
85th	0.74	0.99	0.39
Average	0.49	0.75	0.27

Table A-1. Pedestrian Emerging from the Left (44)

Percentile	Time to accelerator release (sec)	Time to brakes application (sec)	Accelerator release to brake pedal time (sec)
15th	0.29	0.61	0.17
50th	0.52	0.81	0.26
85th	0.74	1.01	0.44
Average	0.50	0.82	0.32

Table A-2. Pedestrian Emerging from the Right (22)

The response of drivers to the emergence of the pedestrian into the main road appears to be very similar, irrespective of the side of the road they enter from. Average reaction times, which are the same as the time to brake application, of 0.75 and 0.82 seconds are towards the lower end of what is generally acceptable as driver reactions to such events. The 85th percentile response is approximately 1.0 second.

Percentile	Time to accelerator release (sec)	Time to brakes application (sec)	Accelerator release to brake pedal time (sec)
15th	0.44	0.65	0.13
50th	0.55	0.72	0.19
85th	0.64	0.87	0.26
Average	0.54	0.76	0.22

Table A-3. Car Emerging from the Left (49)

Percentile	Time to accelerator release (sec)	Time to brakes application (sec)	Accelerator release to brake pedal time (sec)
15th	0.15	0.60	0.19
50th	0.51	0.81	0.35
85th	0.78	1.29	0.49
Average	0.57	0.94	0.37

Table A-4. Car Emerging from the Right (14)

Unlike for pedestrians, the reaction times appear to be considerably different, depending of whether the car emerges from the left or the right. However, the sample sizes are considerably different, which could lead to a biasing of the results. In fact, as the analysis later in this report shows, many drivers had already begun to brake before the vehicle emerged from the right into the main road, which was the defined start of the event. This could suggest must faster reaction times, although equally it could be an artefact of the trials where the drivers are pre-empting the emergency.

Percentile	Time to accelerator release (sec)	Time to brakes application (sec)	Accelerator release to brake pedal time (sec)
15th	0.61	0.79	0.12
50th	0.75	0.98	0.20
85th	1.21	1.91	0.69
Average	0.86	1.22	0.36

Table A-5. Vehicle Ahead Braking (51)

The reaction times for a vehicle braking in front of the test subject resulted in the longest times. This is quite typical, as even when brake lights show on the vehicle in front, it can take the following driver longer to determine the level at which that vehicle is braking. It is the time taken to release the accelerator pedal that shows the greatest difference between the other events, while the average time to move the foot from the accelerator to the brake pedal remains consistent, albeit that the 85th percentile is significantly higher.

The table below shows the simulator run configuration for events involving pedestrians emerging from the left, when the driver had already begun to brake prior to the pedestrian entering the road. Of particular interest are the columns names "Subject Run Number" and "Event Number".

Subject Number	Subject Run Number	BAS System	Route Number	Event Number	Event Code
5	3	2	3	3	1
9	3	3	2	5	1
12	3	1	2	5	1
14	1	1	2	5	1
14	3	2	3	3	1
19	3	3	1	1	1
24	1	3	2	5	1
24	3	1	1	1	1
25	1	1	3	3	1
25	2	2	1	1	1
25	3	3	2	5	1
28	3	1	2	5	1
32	2	3	2	5	1
33	1	2	3	3	1
33	2	1	2	5	1
35	2	1	2	5	1
36	1	3	3	3	1
36	2	2	2	5	1

Table A-6. Summary of Driver's Braking before Event Start (Pedestrian Emerging from the Left)

The highlighted rows are for drivers who it could be said are less aware of the likely events within the simulator trials, and may have reacted in a normal manner but to a stimulus before the event started. It is also worth noting that five drivers appear more than once in this data set. Apart from the highlighted rows, many of the drivers were already on their second session in the simulator or completing the last event from their first session, which therefore indicates a familiarity with the trials.

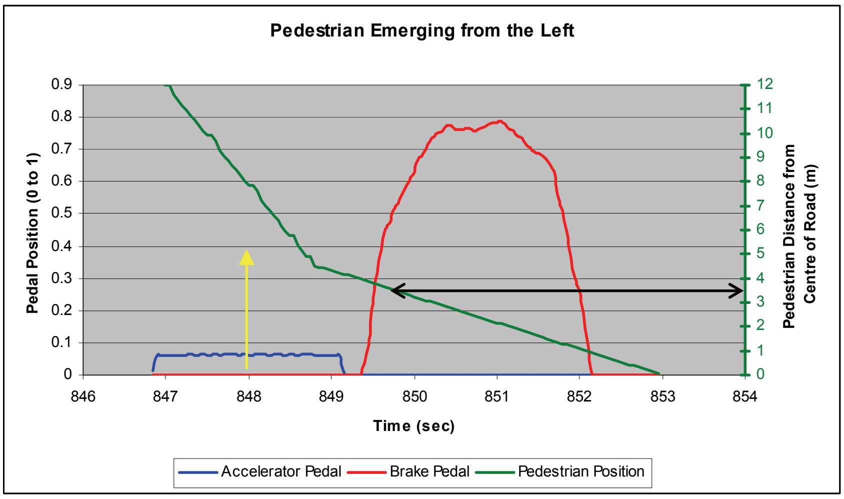

Figure A-2. Driver Reaction to Emerging Pedestrian

The figure above shows the accelerator pedal release and brake application prior to the pedestrian entering the road (when 3.65 metres from the zero position and the mid point of the main road). The black arrow shows the point at which the pedestrian first enters the road. While part of the pedestrian would have been masked by the wall to the left of the approaching driver, it may have been possible to see this movement over the top of the wall that was 1.3 metres in height. If one applies a similar (average) reaction time to pedestrian emerging from the left of 0.76 seconds that was calculated previously, then it would appear that the driver is reacting around the time shown by the yellow arrow, equating to the pedestrian being slightly over 5 metres from the centre of the road and approximately 1.5 metres before reaching the edge of the road.

The following figures show the number of times each test subject braked before the defined event start.

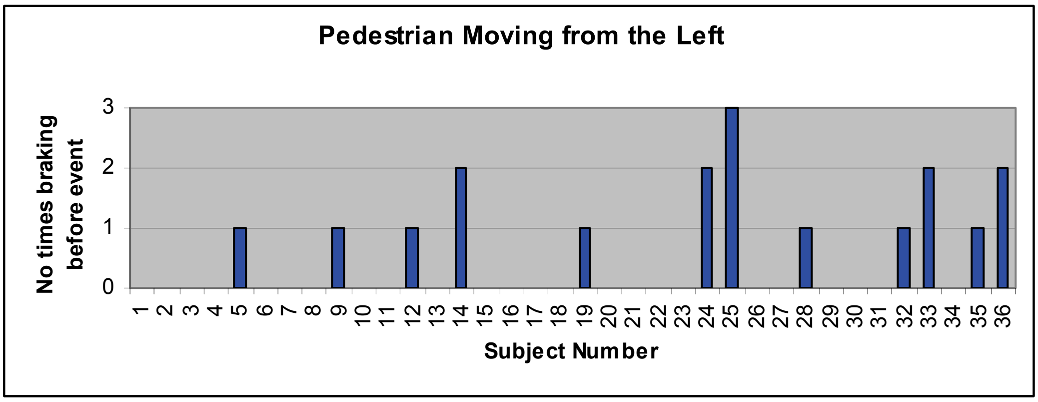

Figure A-3. Braking Prior to Event Start – Pedestrian Emerging from Left

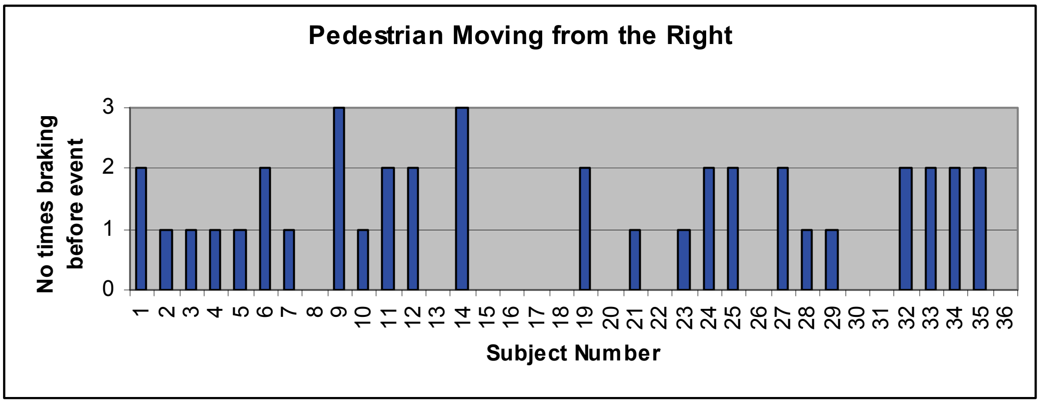

Figure A-4. Braking Prior to Event Start – Pedestrian Emerging from Right

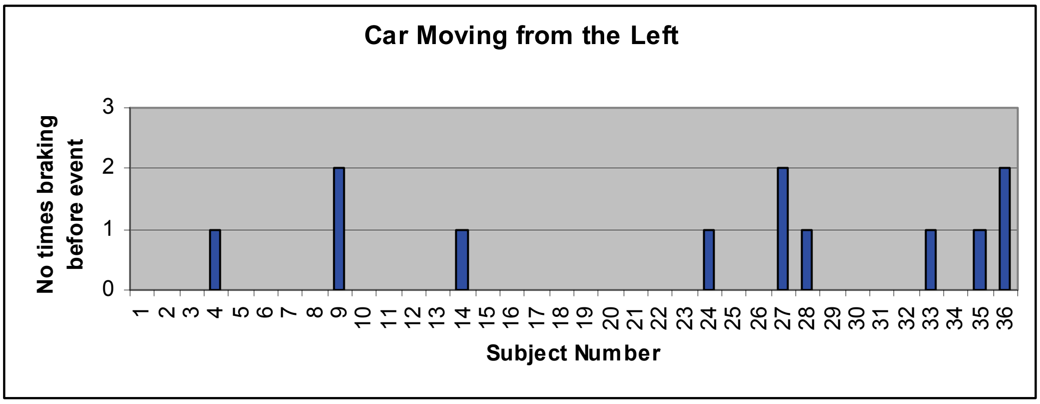

Figure A-5. Braking Prior to Event Start – Car Emerging from Left

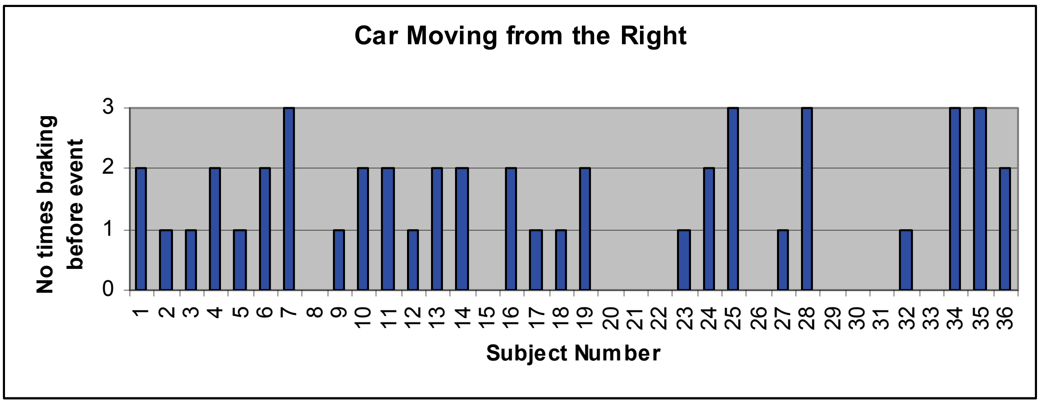

Figure A-6. Braking Prior to Event Start – Car Emerging from Right

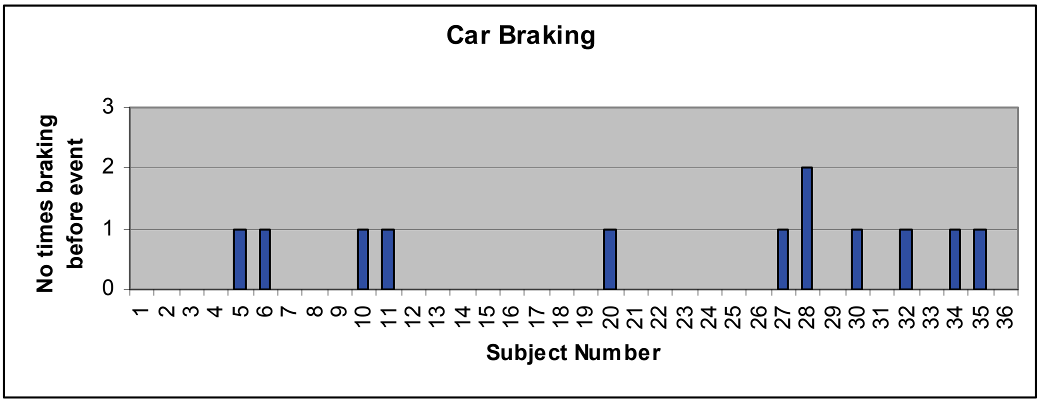

Figure A-7. Braking Prior to Event Start – Vehicle Braking Ahead

The above figures show that the number of instances of drivers reacting before the event start is less for pedestrians and cars emerging from the left, and least of all for a vehicle in front undergoing an emergency stop. This result is intuitive, since the design of the junction layout is such that vehicles and pedestrians emerging from the right are more visible on their approach to the main road.

The figure below is a summation of the individual events to show how often the different drivers braked before the event start.

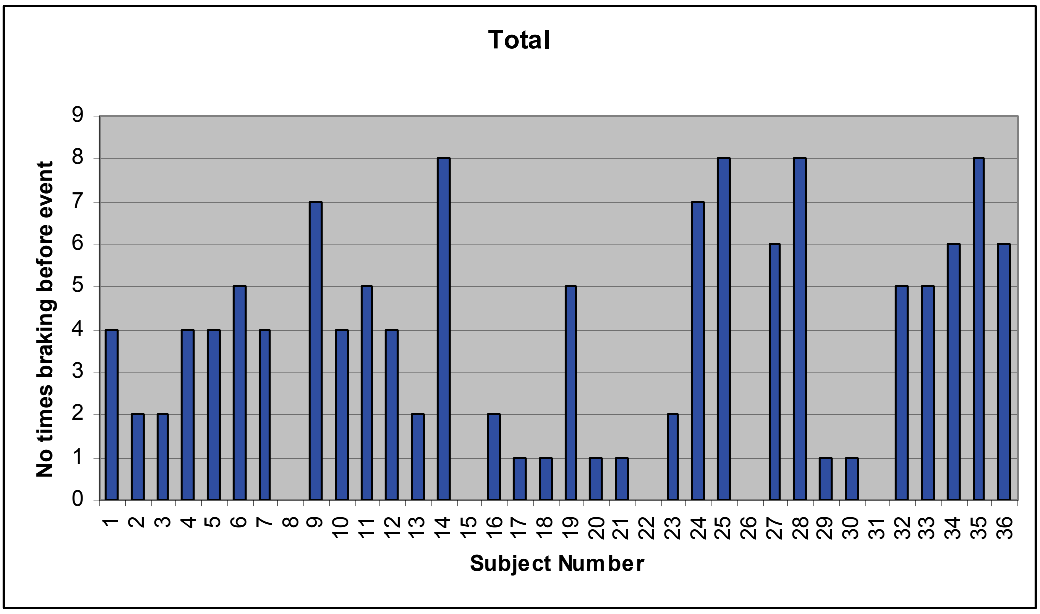

Figure A-8. Summary of Braking Prior to Event Start

	Pedestrian Emerging from the Left		Pedestrian Emerging from the Right		Car Emerging from the Left		Car Emerging from the Right		Car Emergency Braking	
Run	Average Reaction Time (sec)	Sample Size	Average Reaction Time (sec)	Sample Size	Average Reaction Time (sec)	Sample Size	Average Reaction Time (sec)	Sample Size	Average Reaction Time (sec)	Sample Size
1st	0.8	19	0.9	11	0.8	22	0.9	9	1.3	18
2nd	0.7	15	0.8	9	0.7	12	1.1	4	1.2	16
3rd	0.7	10	0.6	2	0.7	15	0.5	1	1.2	17

Table A-7. Reaction Time Summary and Effect of Familiarity

The table above compares the average reaction times of all drivers based on the event type and simulator run number. The highlighted cells above show that the sample size is too low for any meaningful assessment of the change in reaction times; however, the table does appear to show some significance on shorter reaction times when the driver is on their second or third session in the simulator. It is also worth noting that for the events where either the pedestrian or car emerged from the right, the sample sizes are low and drops off quickly with subsequent sessions in the simulator.

A.3 Summary

The design of this simulator study was such that a limited number of test subjects were required to react to five different events in three separate routed sessions. The aim of the study was to establish the effects that a brake assist system would have on the stopping distance and time of the vehicle. One further difficulty with the results was the system used to inform drivers of whether they needed to speed up or slow down. This could potentially results in an early release of the accelerator pedal, or early and low pressure application of the brakes.

While reaction times could be determined from this study, it has to remain questionable as to whether the design of the trials accurately reflects how drivers react in real life. With each test subject being exposed to 15 different emergency situations, it is clear that they will become familiar with these events. It is therefore likely that they will be at a much heightened level of alertness and potentially have a pre-planned reaction to these emergencies.

The time to brake application can be used as a lower estimate, or optimistic time, for driver reaction time. The time between the initial release of the accelerator pedal to the application of the brake pedal can still be used with some degree of confidence.

Data related to events where the driver had already released the accelerator pedal, but had not yet applied the brakes makes in difficult to determine if they were already beginning to react slightly before the event start. It is also difficult to establish whether they may have already been covering the brake pedal prior to the event start.

85th percentile reaction times for pedestrians emerging from the left or right of 1.0 seconds would appear to be in agreement with other research, where the stimulus is clear and straight forward. The general range used in accident investigation of 0.7 to 1.5 seconds, and I would opt for the lower to middle point of this range if the pedestrians were clearly visible approaching the road before actually creating the emergency situation.

For cars emerging from the right, the sample size is extremely low, as most drivers perceived the need to brake before the vehicle entered into the main road. When the emergency situation was vehicle emerging from the left, there were much fewer instances of “early” driver reaction. Average reaction times in this case were 0.9 second and again consistent with other research when the driver has additional warning prior to the vehicle emerging into the main road.

The reaction times to a vehicle in front applying emergency braking results in much longer times for the driver to release the accelerator pedal, although once release the rest of the reaction appears consistent with the other emergencies. One possible reason for this is that while the brake lights would have been visible, there would be no immediate indication of the level of braking being applied by the vehicle in front.

This study has highlighted a number of the issues that all researchers face when attempting to determine driver reaction times. In real life, a driver would have no preconceived idea that they will be faced with an emergency situation within a set time period. Attempts have been previously made in by researchers conducting physical tests that require a driver to undertake a completely different task and, after stating the task has finished, present them with an emergency situation. While this is probably more realistic than informing the driver of the aims of the trials, the simulated emergency events on a real road still have to be designed in such a way that there is no possibility of an accident. If the simulated event uses foam blocks, for example, then a driver may not react appropriately as they would to a small child. Within this study, a car simulator was used instead of physical tests, however, although subjects were not informed of the trials aims, repeated emergency situations will obscured the driver reaction time data recorded.

Appendix B. Gantry Collapse Simulator Trial

B.1 Introduction

An investigation took place to examine the type and time of reaction, using 24 participants, to a gantry collapsing in front of drivers within a simulated motorway environment. In the simulation, the gantry was designed to collapse after the nearside support (positioned off the carriageway) was hit by a large white saloon car, when either 150m or 200m in front of the vehicle being driven by the test subject. The drivers' response to the incident was then recorded, with the study measuring a number of variables. Each participant had only one drive through the event, thus preventing anyone becoming familiar with the scenario.

In order to ensure that the gantry collapse was realistic and would fall in a genuine manner, tests previously conducted on the test track at TRL were used to define the input for the simulator.

Each participant drove for 12.2 miles in general traffic, when the saloon car they were following "*drifted left across the hard shoulder and off the motorway, striking the support strut in the verge and causing it to detach from the ground and transom*" (Reed, 2005), leaving no nearside support for the transom . The transom is the horizontal part of the gantry as shown in Figure B-1 below. The driver was then free to react in the manner they deemed appropriate for the situation, with their reaction time being measured from the time that the car hit the gantry. The previous study[1] uses the time that the driver should have reacted from as the start of the data; however, I understand that this is actually two frames when the car collides with the gantry, which leads to a discrepancy of up to 0.5 second for the reaction.

After the gantry had fully collapsed and was resting on the verge as shown in Image 1, there was still plenty of room for the participants' vehicle to pass underneath the gantry as long as they remained on the carriageway. This may have affected how a driver would react and whether they would attempt to continue and pass under the gantry or anticipate further collapse and stop.

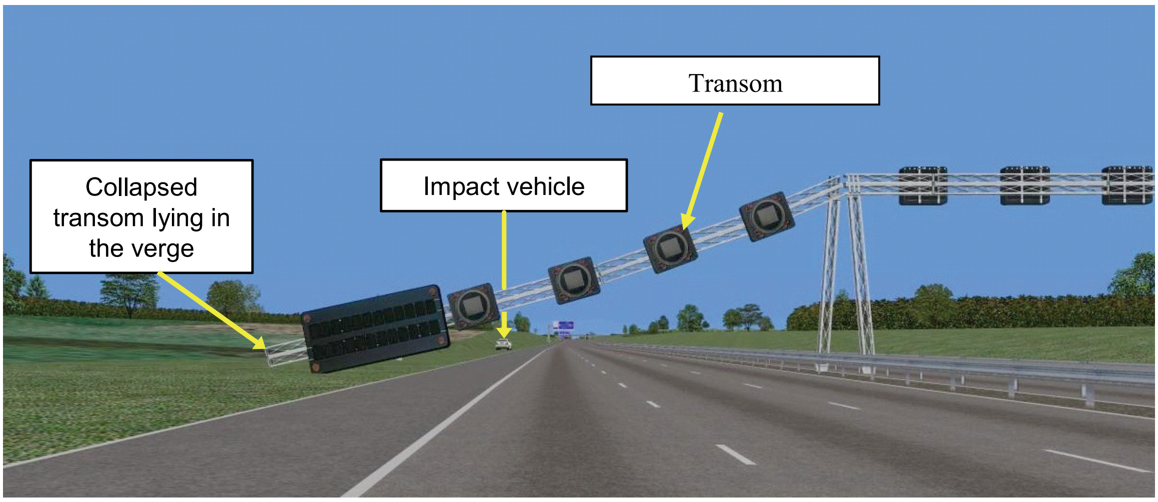

Figure B-1. Fully Collapsed Gantry

B.2 Results of Simulator Trial

Although the previous study looked at driver reaction times with regards to age and distance from the gantry when the car left the carriageway, this report has mainly focused on all drivers' behaviour for accelerator pedal release, point of brake application and the steering response to the gantry collapsing.

Drivers have been separated into two different categories, the younger 17-44 years and the older 45+ years, these are represented in the Table B-1 as Age 1 and 2 respectively, and later referred to as Group 1 and Group 2.

From the raw data provided, the time to apply the brake from gantry collapse, the time to release the accelerator pedal and, in some cases, the time to steer the vehicle towards the outside lane were calculated (Table B-1). The highlighted values in table B-1 show the first reaction for each driver and whether this reaction was steering or braking.

Driver	Age	Time to Apply Brake from Start of Data	Time to Apply Brake from Gantry Collapse	Time Difference Between Accelerator and Brake	Time to Start Steering	Time to Release Accelerator	Quickest Time to React
1	2	1.45	1.28	0.50	N/A	0.77	1.28
2	1	N/A	N/A	N/A	0.46	0.90	0.46
3	2	1.60	1.48	1.02	1.42	0.45	1.42
4	1	1.45	1.33	0.88	1.08	0.45	1.08
5	1	1.35	1.27	0.98	N/A	0.30	1.27
6	2	1.50	1.33	N/A	0.50	Does not apply Accelerator	1.33
7	2	2.10	1.95	1.15	N/A	0.80	1.95
8	2	2.45	2.34	1.40	1.50	0.95	1.50
9	1	1.80	1.68	0.98	N/A	0.70	1.68
10	2	1.40	1.30	0.90	1.93	0.40	1.30
11	2	N/A	N/A	N/A	1.45	1.0	1.45
12	1	N/A	N/A	N/A	N/A	Slight reduction	N/A
13	2	1.0	1.18	0.73	N/A	0.45	1.18
14	1	1.55	1.45	1.0	N/A	0.45	1.45
15	1	1.25	1.15	0.90	1.85	0.25	1.15
16	1	N/A	N/A	N/A	1.15	Accelerates after incident	1.15
17	1	1.75	1.60	1.30	1.38	0.30	1.38
18	2	N/A	N/A	N/A	1.30	1.15	1.30
19	2	1.65	1.15	1.0	N/A	0.15	1.15
20	2	1.30	1.17	0.87	2.17	0.30	1.18
21	1	1.55	1.45	0.85	N/A	0.60	1.45
22	1	1.90	1.80	1.35	3.05	0.45	1.80
23	1	1.45	1.35	0.80	2.25	0.55	1.35
24	2	2.85	2.75	0.85	1.60	1.90	1.60

Table B-1a. Data Collected and Calculated (All Times in Seconds)

	Time to Apply Brake from Gantry Collapse	Time Difference Between Accelerator and Brake	Time to Start Steering	Time to Release Accelerator
Average	1.53	0.97	1.54	0.63
15th Percentile	1.18	0.83	1.08	0.30
50th Percentile	1.35	0.94	1.45	0.45
85th Percentile	1.84	1.22	2.15	0.95

Table B-1b. Data Collected and Percentiles Calculated (All Times in Seconds)

The data calculated was then assessed based on the two age groups and split into the two age groups to observe any difference in reaction for the younger and older drivers, for all variables (Tables B-2 and B-3).

	Time to Apply Brake from Gantry Collapse	Time Difference Between Accelerator and Brake	Time to Start Steering	Time to Release Accelerator
Average	1.45	1.00	1.60	0.50
15th Percentile	1.29	0.85	1.01	0.30
50th Percentile	1.45	0.98	1.38	0.45
85th Percentile	1.66	1.24	2.33	0.67

Table B-2. Younger Group Reaction Times

	Time to Apply Brake from Gantry Collapse	Time Difference Between Accelerator and Brake	Time to Start Steering	Time to Release Accelerator
Average	1.59	0.94	1.48	0.76
15th Percentile	1.17	0.75	1.31	0.35
50th Percentile	1.32	0.90	1.48	0.77
85th Percentile	2.21	1.13	1.91	1.08

Table B-3. Older Group Reaction Times

B.3 Analysis

B.3.1 Time to Apply the Brake

The first reaction that has been examined in this report was the time to apply the brake after the gantry collapse, and therefore only includes participants who applied the brake. The 50th percentile response time for the older participants to apply the brake is less than those for the younger group by 0.13 seconds, however, it can be seen that there is a greater variance in brake reaction times for the older group, with the 85th percentile time being much greater than for the younger group. These variations can be seen in Figure B-2 below, with the marker representing the 50th percentile, and the lower and upper limits of the line representing the 15th and 85th percentile respectively.

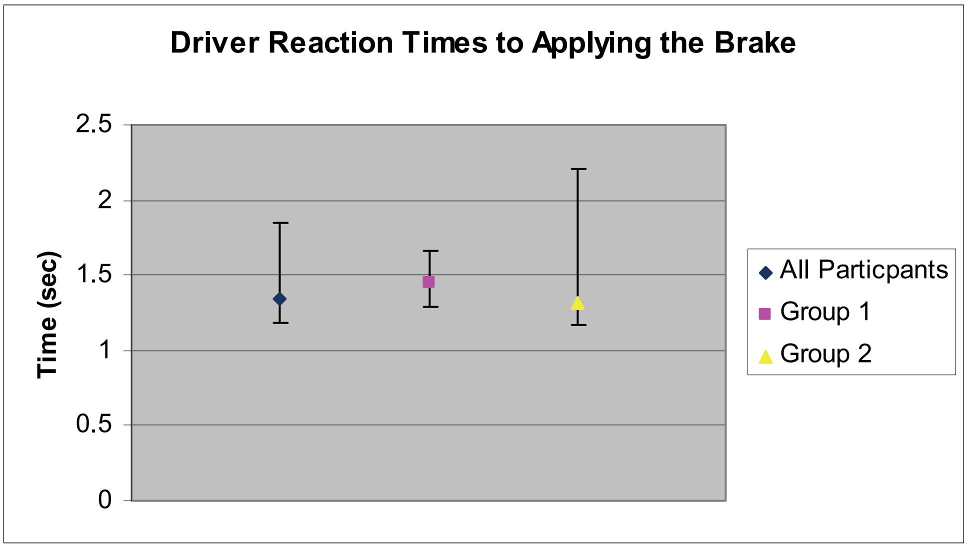

Figure B-2. Driver Reaction Times to Applying the Brake.

The graph also shows that the majority of participants that applied the brake did so within 1.5 seconds of the saloon car hitting the gantry. The spread in brake reaction time between the 15th percentile and the 85th percentile for Group 1 was 0.37 second compared to Group 2 of 1.04 seconds.

B.3.2 Time to Release Accelerator Pedal

The time it took participants to release the accelerator pedal follows the same trend as the time it took to apply the brakes, except the variance within each age group is less. Out of the 24 participants, 88% released the accelerator pedal at a time after the gantry was impacted, which means that 12%, or 3 participants, did not. This could be a combination of not reacting at all, or simply the driver had already release the accelerator pedal prior to the vehicle in front striking the gantry.

It can be seen from Figure B-3 that the accelerator is released within 0.95 second for the 85th percentile of all participants, with an average time of 0.63 seconds, taken from Table B-1b. Driver 24, however, took 1.9 seconds to release the accelerator pedal.

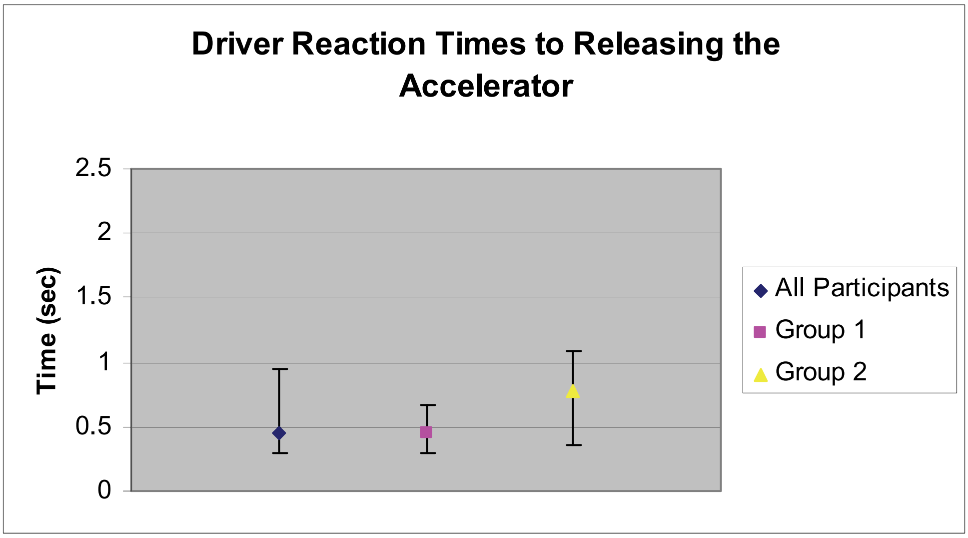

Figure B-3. Driver Reaction Times to Releasing the Accelerator.

B.3.3 Time Difference Between Releasing Accelerator and Applying the Brake

The time it took for a driver to apply the brakes after releasing the accelerator pedal did not depend on whether they were going to stop the vehicle or steer away. The 50^{th} percentile for the whole group was 0.94 seconds, ranging from 0.83 seconds to 1.22 seconds, 15^{th} percentile and 85^{th} percentile respectively.

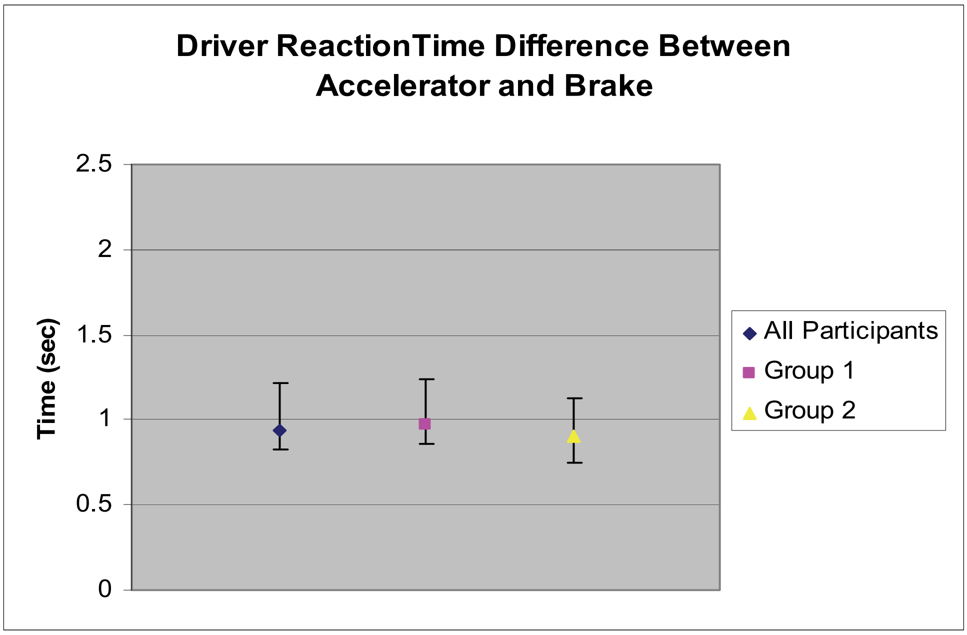

Figure B-4. Driver Reaction Time Difference between Accelerator and Brake.

It can be observed from Figure B-4 that an average Group 2 applied the brake after releasing the accelerator pedal in a shorter amount of time than Group 1.

B.3.4 Time to Apply Steering

The final reaction that was observed was the time taken to steer the vehicle away from the gantry, this was calculated by applying a minimum displacement of 1m to show significant steering. Therefore Figure B-5 only shows the reactions for 15 participants. Unlike the braking reaction times, the difference in reaction time within the younger age group (Group 1) for the steering response was much greater than for the older group, with the difference between the 50^{th} and 85th percentile being 0.95 for Group 1 and 0.43 for Group 2.

Figure B-5. Driver Reaction Times to Steering

Figure B-5 also shows that the majority of participants, who applied a steering reaction, did so within 2.15 seconds, with a 50th percentile of 1.45 seconds. This graph shows the participants who have steered as a reaction. However, no distinction is made as to whether this was the first or second reaction.

B.3.5 Comparison of First Reactions

From the results already observed within this report it is clear that every driver will react in a different way depending on what they individually think is the best method and this chosen action will be completed within different reaction times.

The reaction time used in this study has been taken from time of the gantry impact to the first time that the driver starts to make a physical effort to control the vehicle, this being either brake application (where the foot needs to be moved), steering the car away from the falling section of the gantry (Figures B-6 and B-7). These graphs show how each specific driver reacted to the gantry collapse, some drivers applied the brake as well as steering, while driver 12 does not appear to react at all. The average time for a driver of either age group to first apply some physical reaction by steering or braking was 1.35 seconds, where 64% of drivers applied the brakes, while 36% applied steering first. Those people who applied the brake did not necessarily stop the vehicle, with only 47% of this group bringing the vehicle to a halt before reaching the gantry.

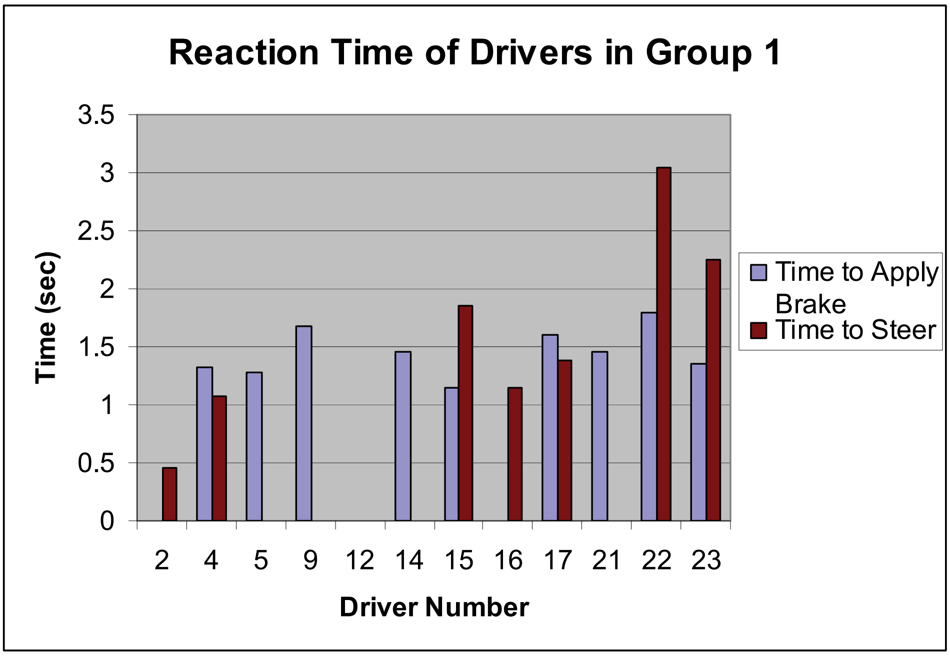

Figure B-6. First Reaction Times of Drivers in Group One.

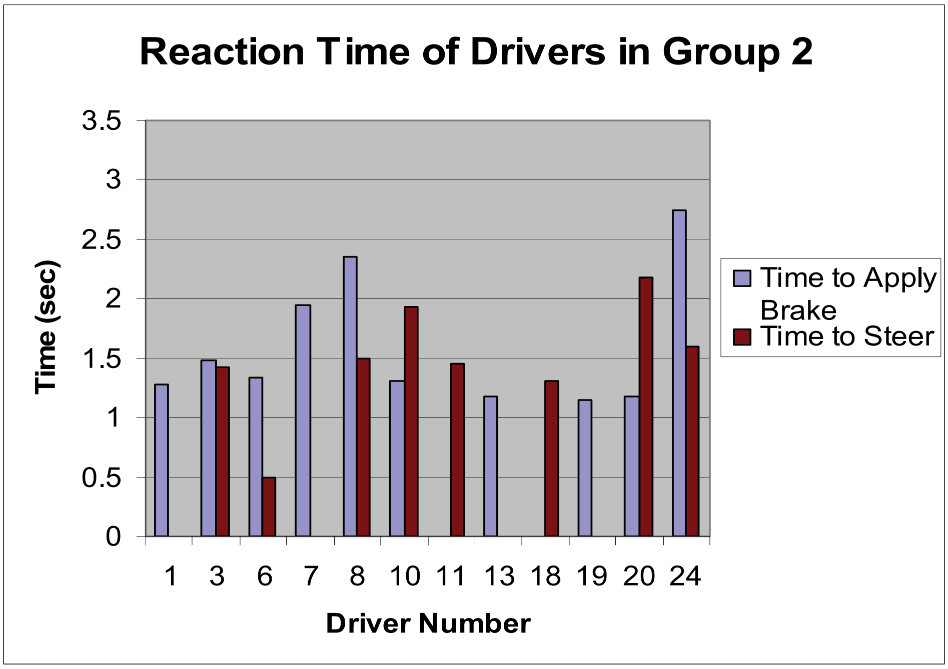

Figure B-7. First Reaction Times of Drivers in Group Two.

The reaction time of those who applied the brakes as their first reaction can be observed in Figure B-8. The 50th percentile for all participants was 1.23 seconds, in the range of 1.17 to 1.70 seconds, 15th and 85th percentile respectively.

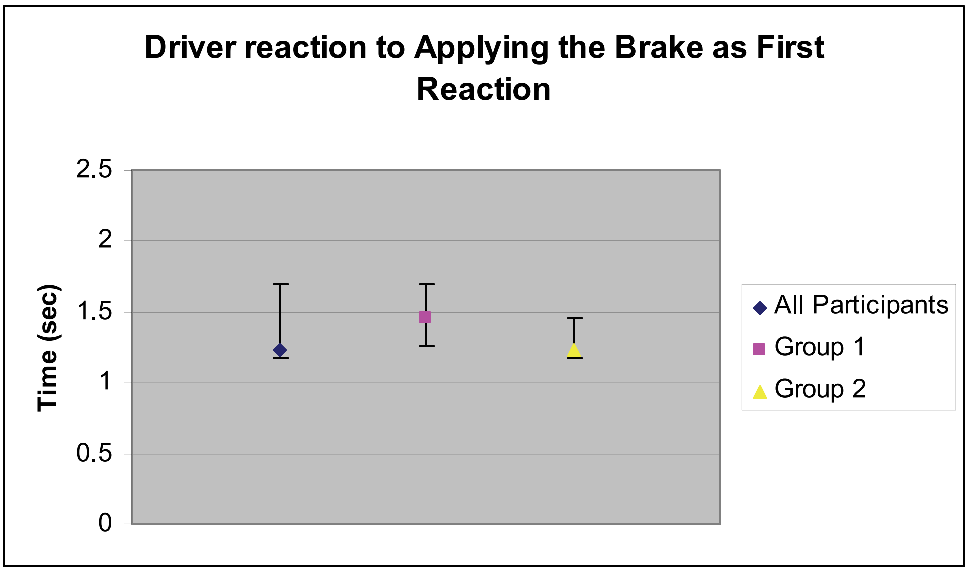

Figure B-8. Driver Reaction Times to Braking as First Reaction

The average reaction time of all participants to start steering as a first reaction is faster than those who applied the brakes, Figure B-9. However, the 50th percentile for all participants is 1.34 seconds, and for Group 2 is 1.44 seconds, which is slower than the time taken by participants who applied the brakes as their first reaction. Group 1 had faster 50th reaction time when steering. The 15th and 85th percentile of all participants are also faster by a minimum of 0.22 second.

This difference in reaction times could have been because applying steering is a faster response for a driver to undertake, as there is no additional time for the driver to move part of their body to undertake a steering response. Braking requires the driver to move their foot from the accelerator to the brake pedal, whereas a driver generally already has their hands on the steering wheel.

Figure B-9. Driver Reaction Times to Steering as First Reaction

Figures B-8 and B-9 show the initial reaction times for all participants. It was originally thought that further assessment by age group could have been undertaken, however, some data sets were left with as little as four drivers.

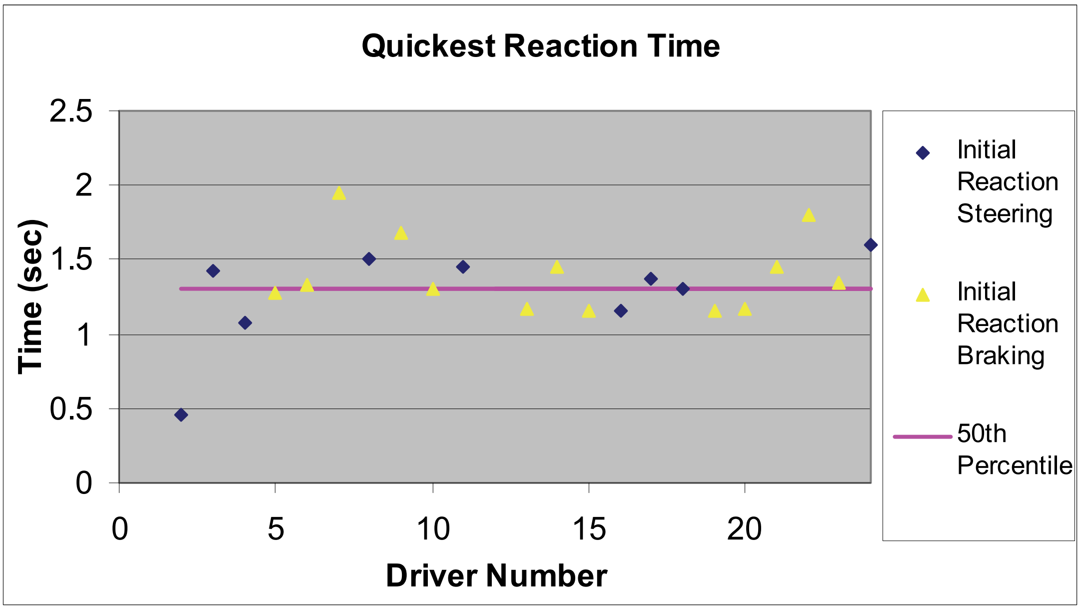

Figure B-10. Driver's Initial Reaction Times with 50th Percentile Line.

Figure B-10 shows the first reaction times for drivers, distinguishing between braking and steering response to the gantry collapse. The 50th percentile line was calculated and displayed at a time of 1.3 seconds.

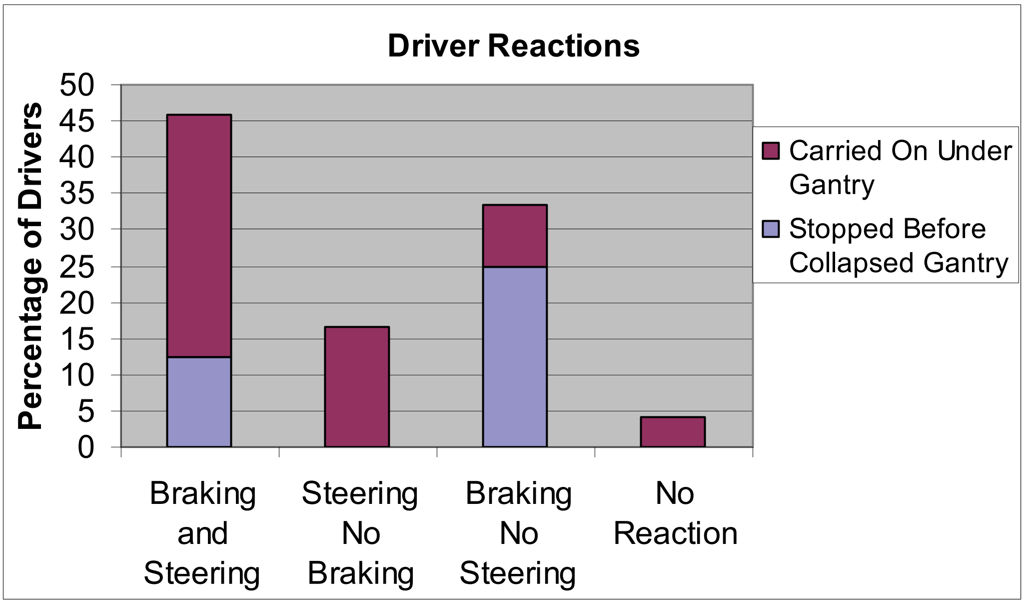

Figure B-11. Percentage of Driver's Reactions.

The simulator trial was designed in such a manner that all drivers should have enough the time to stop the vehicle before the gantry collapsed if they wished to do so.

However, out of the 24 drivers, only 9 stopped the car before it reached the gantry, 19 drivers did apply the brakes either as a first or second reaction, meaning that a high percentage either did not stop their vehicle in time, or made the decision that it was safe to drive beneath the fallen gantry.

From figure B-11, it can be seen that 75% of those that only applied the brakes stopped before the collapsed gantry. 17% of drivers did not apply the brakes at any stage, and instead manoeuvred across the road continuing under the gantry. The main reaction was to brake and sometimes steering

(79%), but within these participants only 38% felt it necessary to stop the vehicle before reaching the collapsed gantry.

B.3.6 Comparison of Driver Reactions

After releasing the accelerator pedal, the brakes were applied as a first reaction in 13 cases and on average this took participants 0.97 seconds, with all drivers being within +/- 0.5 seconds of this value. Some of the drivers did not apply the brakes after the gantry collapsed; however, some of these did, instead, steer and change lanes, and therefore this should be observed as a reaction to the gantry collapsing.

Five of the remaining participants released the accelerator pedal and then applied steering before any other action, moving towards the outside lane of the motorway (where the clearance beneath the gantry was greatest) within 1.6s. One other driver did not react to the gantry collapse in anyway, Figure B-12.

Five other participants' first reaction was to steer away from the gantry collapse, which was done before releasing the accelerator pedal. Four steered the vehicles causing lateral movement of over 1.5m, three of which switched lanes moving on average 4.5m away from the collapsed side of the gantry. This can be observed in Figure B-12, where Driver 2 has moved the vehicle 4.8m away from the gantry whilst continuing to drive.

Drivers undertaking this high level of steering had reaction that were generally faster, than those who applied the brakes, with the fastest reaction being as low as 0.46 (table B-1) compared to the fastest reaction time of 1.15 seconds for those who applied the brakes as their first reaction.

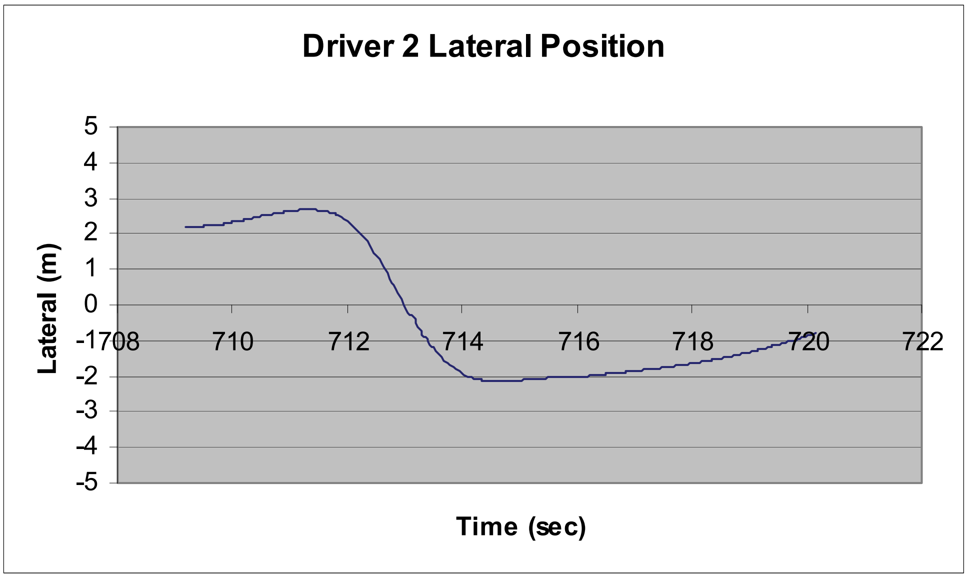

Figure B-12. Driver 2 Lateral Position across the Motorway.

Figure B-13 shows how participant number 24 reacted to the gantry collapse. The driver varies the lateral position of the car rapidly, travels under the collapsed gantry and then rapidly stops. This is observed at approximately 709 seconds where the lack of normal steering control can be seen by the horizontal line up the graph.

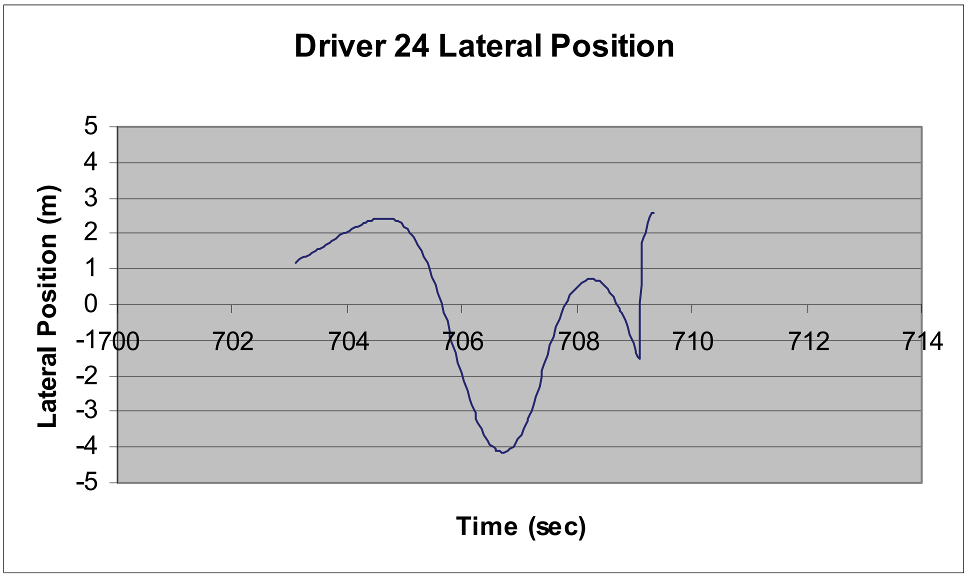

Figure B-13. Driver 24 Lateral Position.

Driver 12, however, does not appear to react in any specific way, see figure B-14. The brakes were not applied there was no significant lateral movement, maximum of 0.5m, and the driver only slightly released the accelerator pedal before then increasing the acceleration again to drive under the gantry.

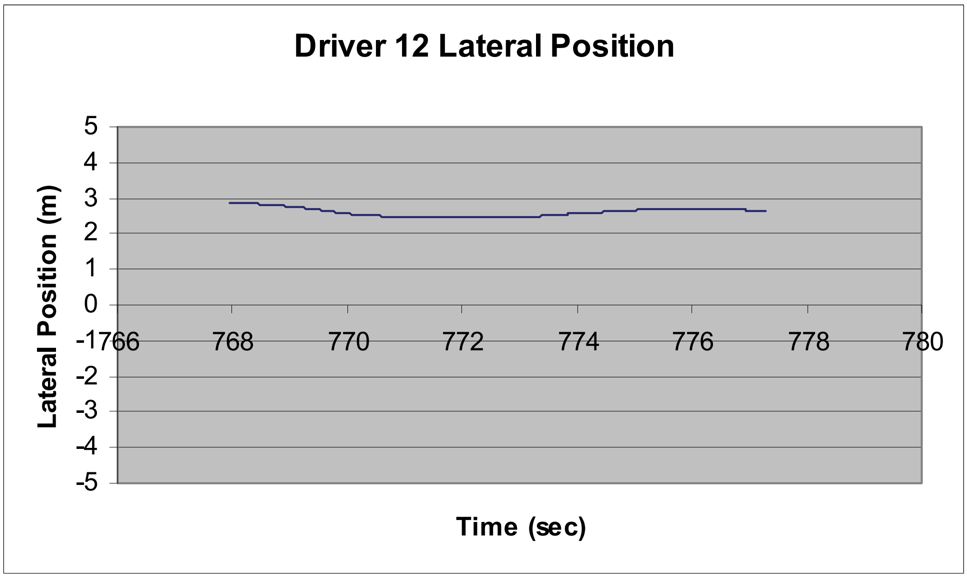

Figure B-14. Driver 12 Lateral Position.

The way in which Driver 5 and 21 reacted to the gantry collapse was very different as can be seen in figures B-15 and B-16, although neither of these drivers significantly changed their lateral position. Driver 5 applied their foot to the brake very hard but then the perceived danger appears to have decreased and he no longer felt the need to stop. However Driver 21 also applied their foot to the brake hard, but slowly released the pressure and the car eventually came to a standstill.

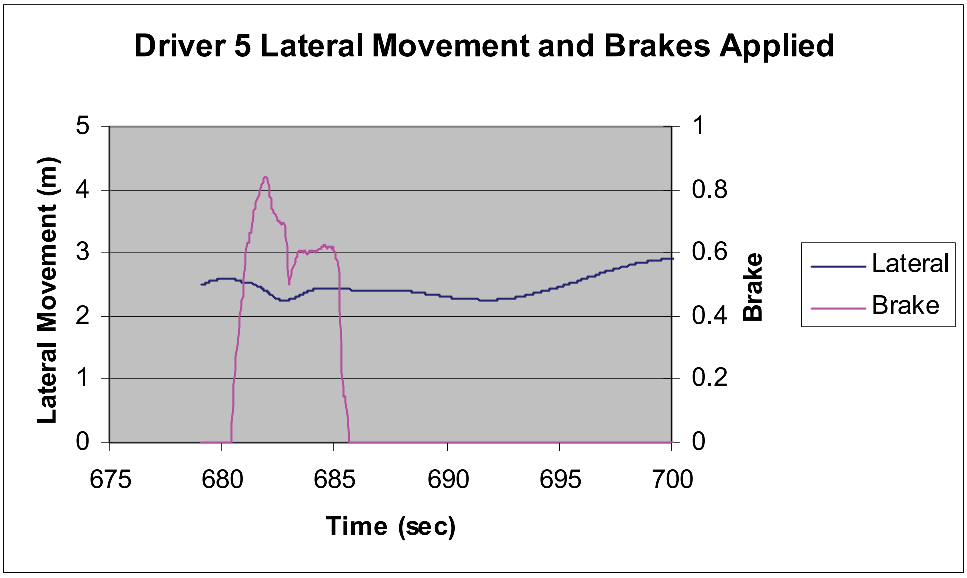

Figure B-15. Driver 5 Lateral Movement across the Motorway and the Level of Braking.

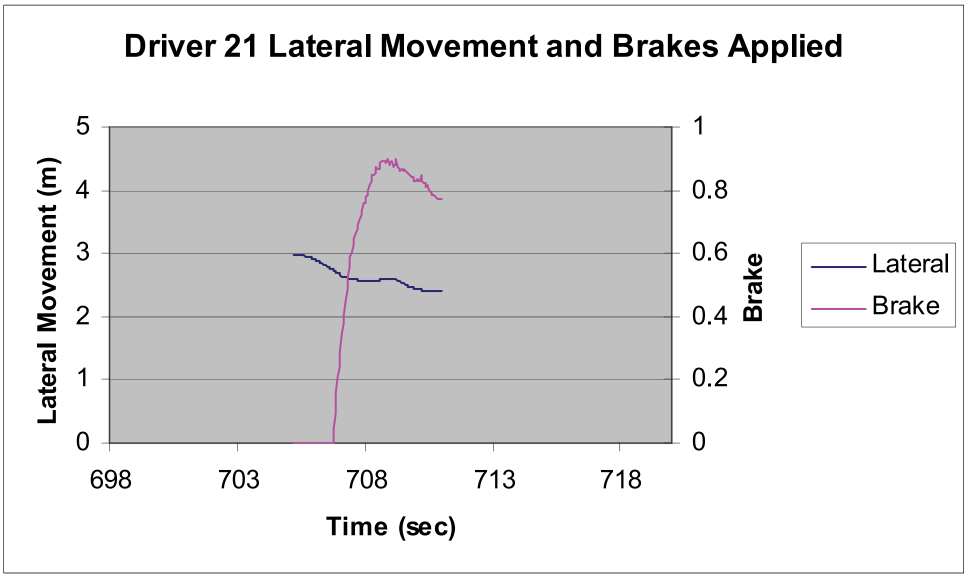

Figure B-16. Driver 21 Lateral Movement across the Motorway Level of Braking.

B.4 Summary

It must be taken into account that the participants may have been in a ‘state of alert’ after watching the leading vehicle drift off the road sometime before the hitting the gantry, see Figure B-16.

These tests have shown that to a particular unfamiliar event, drivers can react in a number of different ways or not at all. All of the calculations in this report have used the initial impact into the gantry as the first possible time to react, however, this could vary as the participants could have begun their reaction when the car drifted off the road, or they may not have begun to react until the gantry starts to fall in front of them. A driver may have reacted differently in a real world situation where the amount of danger to themselves and others dramatically increases, and the probability of a driver being able to do an emergency stop on a motorway or swerve into another lane without causing an accident decreases.

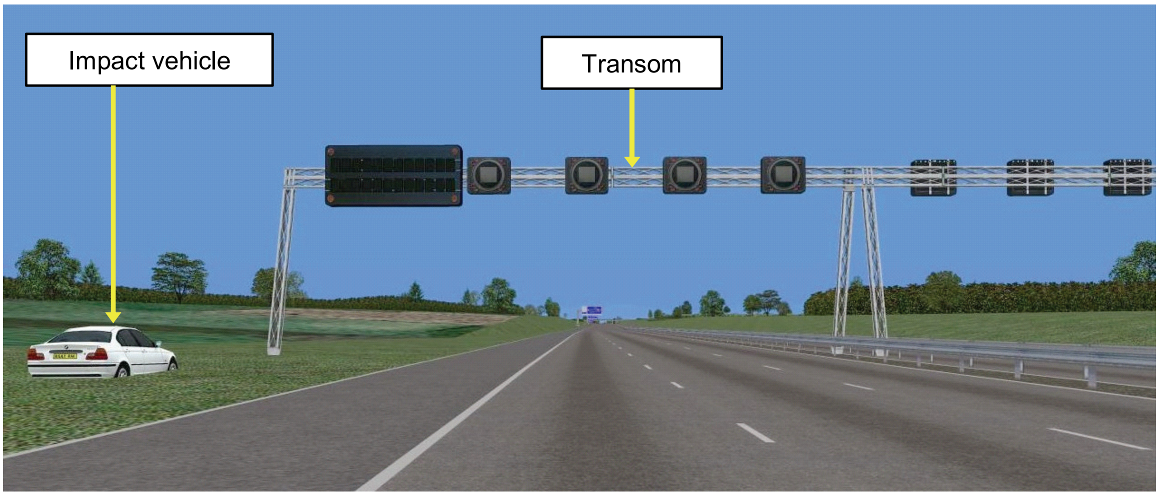

Figure B-16. The large white saloon car Drifting off the Motorway.

The results have shown that 88% of the participants released the accelerator after the saloon car collided with the gantry and therefore were aware of the incident, the remaining 12% were either not applying the accelerator at the point of collision or had very slightly reduced the amount of pressure then increased it again. This makes it difficult to determine whether they reacted to the event or not.

In the initial gantry collapse project, using the simulator was part of a larger scale project, and therefore the sole aim was not to assess driver reaction times to an unfamiliar event. Therefore, while additional participants would have allowed better statistical analysis, this study does offer useful data on how drivers react, by braking, steering or both to what would be generally an unexpected and unfamiliar event. The analysis in this report will provide a useful comparison to other studies involving more familiar events.

Appendix C. Unexpected Stationary Vehicle Simulator Trial

C.1 Introduction

The main simulator trial was designed to assess whether drivers can determine the difference in vehicle performance when using either standard or performance fuels. The trials involved each driver (48 in total) completing five separate runs over the same route while altering the acceleration and response rates of the simulator vehicle. In each run there were different expectations on the driver, with some of the runs designed to apply a time pressure, where overtaking was required and other runs where there was no time pressure and no overtaking possible. The performance modification was categorised as either standard or high acceleration modes, where the high acceleration is 8% faster. The accelerator pedal had either normal or low responsiveness, with the low responsiveness meaning the accelerator pedal has a 1.5 second delay before the engine responded. Of the 48 drivers in the trial, all were male, and half were members of a performance fuels club.

In addition to the main aim of the trial, a separate investigation was piggy backed on the study to see investigate how drivers would react to driving around a gentle bend of radius 529m and being confronted by a stationary car in their path.

While the main study consisted of 48 participants, only 26 were used in the driver reaction study as these were the only drivers who had the stationary vehicle on the final run, whilst under a time pressure with vehicle to overtake.

The simulated environment was daylight in a rural setting on a two lane carriageway in a national speed limit area. The stationary vehicle was close to the nearside kerb and did not have any lights illuminated. It was a black 1995 model Mercedes SLK, and was aligned with the left hand side of the road facing in the same direction as the driver’s direction of travel.

In order to calculate the necessary information, the first possible point of perception had been calculated from the simulator as 12597.5m from the start of the event, and the car was fully visible when the driver had travelled at total distance of 12606.9m. Therefore, each driver had 203.4 metres of visibility to the stationary car in which to attempt to avoid a collision. Any driver reactions that occurred prior to this were excluded from the calculations.

C.2 Results of Simulator Trial

The data collected for each driver consisted of many variables including the accelerator pedal position before and after the delayed response (scenario dependent), steering wheel input, brake pedal application, road radius, x and y acceleration, x position, distance headway, time remaining, distance travelled, speed, lateral position. The majority of this data was collected for the main study.

For the driver reaction time study, Tables C-1a and C-1b show the time taken to release the accelerator pedal, the time to apply the brake and the time to apply steering, all of which were measured from the first possible point of perception. The time difference between the accelerator pedal release and brake pedal application was calculated. For each of the reaction events listed, average, 15th, 50th and 85th percentiles were calculated.

Tables C-2a and C-2b are similar to Tables C-1a and C-1b, with the difference being that they display the distances associated with the various reaction events from the first possible point of perception.

The times and distances displayed in the following tables assume the maximum visibility distance related to the point when the vehicle first partially becomes visible. If reaction times and distances were measured from the point the whole vehicle becomes visible, then the maximum distance in which to react reduces to 194 metres.

The values shown in brackets in Table C-2b relate to the distance the driver was from the stationary car when undertaking a specific task and are used subsequently in this report.

The driver highlighted is the only driver who stopped before reaching the stationary vehicle. All other drivers steered around it without stopping.

Test Subject Number	Driver Number	Time to Release Accelerator	Time to Apply Brake	Time Difference Between Accelerator and Brake	Time to Start Steering
1	1	2.50	3.20	0.70	0.45
3	2	1.65	1.85	0.20	Steering Not Applied[1]
4	3	1.65	1.75	0.10	5.00
6	4	3.10	3.35	0.25	5.05
7	5	1.70	3.25	1.55	5.00
9	6	5.00	5.85	0.85	6.20
13	7	Released Before Visible[2]	Brake Not Applied[3]	N/A	4.70
14	8	Released Before Visible[2]	2.25	N/A	5.50
16	9	4.05	4.75	0.70	4.85
19	10	1.80	2.15	0.35	4.30
20	11	3.15	3.35	0.20	4.10
22	12	2.10	2.10	0.00	4.05
24	13	1.60	2.20	0.60	4.45
25	14	4.90	Brake Not Applied[3]	N/A	5.15
27	15	4.55	4.80	0.25	4.20
28	16	Released Before Visible[2]	4.35	N/A	5.35
30	17	2.9	3.80	0.9	5.60
31	18	Released Before Visible[2]	2.60	N/A	6.50
32	19	5.65	6.50	0.85	6.40
33	20	2.50	3.70	1.20	6.30
34	21	Released Before Visible[2]	4.60	N/A	5.10
35	22	3.00	3.45	0.45	8.25
37	23	4.80	5.25	0.45	7.35
38	24	2.30	2.50	0.20	4.45
40	25	3.05	3.45	0.40	4.45
46	26	3.95	Brake Not Applied[3]	N/A	4.25

Table C-5a. Data Collected and Calculated (All Times in Seconds).

[1] The participant did not apply any steering.
[2] The accelerator was released before first possible point of perception.
[3] The participant did not apply any braking.

	Time to Release Accelerator	Time to Apply Brake	Time Difference Between Accelerator and Brake	Time to Start Steering
Average	3.13	3.52	0.54	5.08
15th Percentile	1.70	2.17	0.20	4.23
50th Percentile	3.00	3.35	0.45	5.00
85th percentile	4.80	4.79	0.87	6.34

Table C-1b. Data Collected and Percentiles Calculated (All Times in Seconds).

Test Subject Number	Driver Number	Distance to Release Accelerator	Distance to Apply Brake	Distance Covered Between Accelerator and Brake	Distance to Start Steering
1	1	88.4	114.1	25.7	14.2
3	2	45.2	50.7	5.5	Steering Not Applied[4]
4	3	68.6	72.8	4.2	174.1
6	4	98.7	107.1	8.4	159.0
7	5	56.6	106.8	50.2	158.4
9	6	107.1	126.2	19.1	134.0
13	7	Released Before Visible[5]	Brake Not Applied[6]	N/A	145.3
14	8	Released Before Visible[5]	73.5	N/A	163.7
16	9	112.7	132.3	19.6	135.1
19	10	73.4	87.4	14.0	166.8
20	11	125.7	133.6	7.9	162.8
22	12	89.1	89.1	0.0	165.7
24	13	63.7	86.9	23.2	164.6
25	14	119.1	Brake Not Applied[6]	N/A	125.7
27	15	167.1	176.3	9.2	154.0
28	16	Released Before Visible[5]	117.5	N/A	142.6
30	17	85.4	111.6	26.2	161.0
31	18	Released Before Visible[5]	82.8	N/A	174.8
32	19	139.1	160.4	21.3	157.9
33	20	65.1	96.3	31.2	157.2
34	21	Released Before Visible[5]	136.4	N/A	150.8
35	22	85.4	98.0	12.6	181.7
37	23	107.2	117.2	10.0	157.4
38	24	90.9	98.7	7.8	164.8
40	25	93.6	105.8	12.2	135.6
46	26	133.3	Brake Not Applied[6]	N/A	143.4

Table C-2a. Data Collected and Calculated (All Distances in Metres).

[4] The participant did not apply any steering.
[5] The accelerator was released before first possible point of perception.
[6] The participant did not apply any braking.

	Distance to Release Accelerator	Distance to Apply Brake	Distance Covered Between Accelerator and Brake	Distance to Start Steering
Average	96.0 (107.4)	107.9 (95.5)	16.2	150.0 (53.4)
15th Percentile	65.1 (138.3)	84.0 (119.4)	7.1	135.4 (37.3)
50th Percentile	90.9 (112.5)	106.8 (96.6)	12.6	157.9 (45.5)
85th percentile	125.7 (77.7)	133.2 (70.2)	25.9	166.1 (68.0)

Table C-2b. Data Collected and Percentiles Calculated (All Distances in Metres).

Each column for the times and distances presented in Tables C-1b and C-2b should be taken in isolation. It can be seen, for the 50th percentile response, that the distance covered by the vehicle between releasing the accelerator pedal and applying the brake is not the actual difference between the distances where the accelerator pedal was released and the brake pedal applied. This is because the same drivers will no always appear in the same percentile response group.

C.3 Data Analysis

The data shown in Tables C-1a and C-2a has been used to produce a number of graphs to show the variation in driver reactions based on accelerator pedal release, brake pedal application and steering wheel application. Superimposed onto these graphs are the lines designating the 15th, 50th and 85th percentile responses.

It should be noted that the sample of drivers consisted solely of men, aged between 25 and 73 years, and the results may not be a true representation of the population as a whole.

Additionally, the speeds of the drivers immediately prior to the first point of perception may be in excess of that which they would normally driver due to the nature of the main trial, with the imposed time constant.

C.3.1 Reaction to Release the Accelerator Pedal

Out of the 26 drivers in the sample, 19 released the accelerator pedal as a first reaction to the stationary vehicle, after it became visible. These varied in time (Figure C-6), ranging between the fastest reaction of 1.6 seconds and the slowest reaction of 5.65 seconds. Of the 7 remaining, 5 were not applying any force to the accelerator pedal when the stationary vehicle first became visible. The 50th percentile response for all of these drivers was 3.0 seconds. .

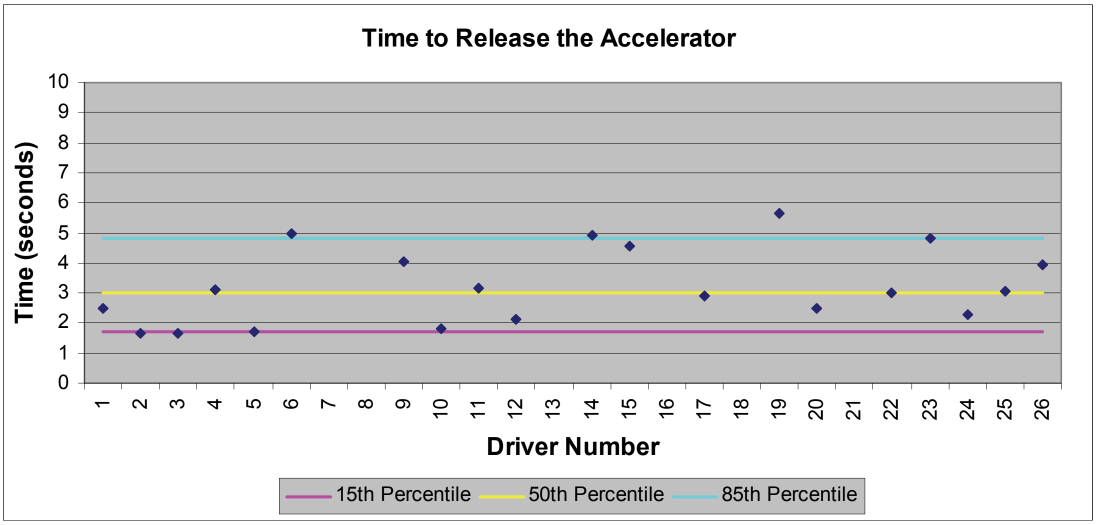

Figure C-6. Time to Release the Accelerator Pedal from First Possible Point of Perception.

The figure above shows driver responses based on time; however, the speed of the vehicle will determine how close they were to the stationary vehicle when this reaction occurred. The distance relationship has been assessed below.

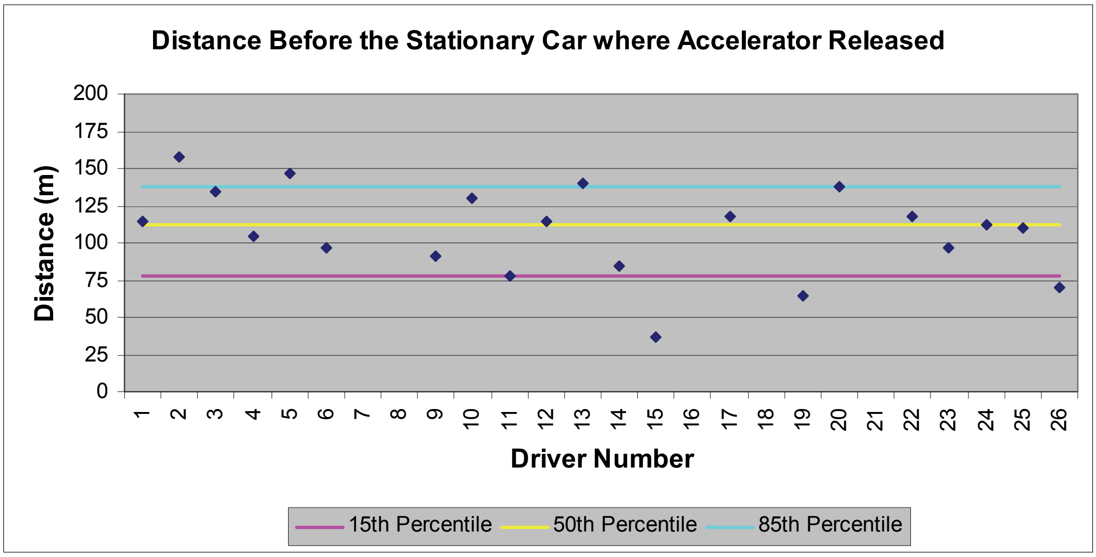

Figure C-7. Distance Before the Stationary Vehicle where the Accelerator pedal was Released.

There is a wide variation in the distance away from the stationary car when the participants released the accelerator pedal (Figure C-7). These range from as close as 36.3m to as far away as 158.2m, with a 15th percentile response of 77.7m and 85th percentile response of 138.3m. It should be noted that the 15th, 50th and 85th percentile distances do not directly relate to the times in Figure C-1, as Figure C-2 distances relative to the stationary vehicle.

C.3.2 Reaction to Apply the Brake

Out of the 26 drivers that have been analysed, only three did not apply any braking following the first visibility of the stationary vehicle.

The 50th percentile response for brake application was 3.35 seconds after the first possible sight of the stationary vehicle, travelling, on average, 107.9m before slowing.

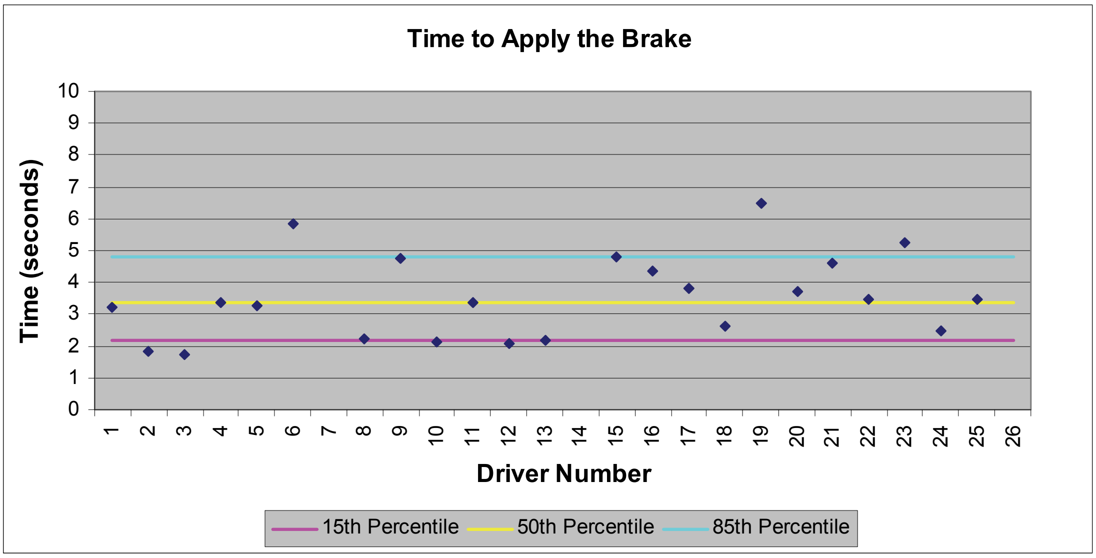

Figure C-8. Time to Apply the Brake from the First Possible Point of Perception.

Figure C-8 shows that Driver 6 took 5.85 seconds to apply the brake after the first possible point of perception, and although this is longer than nearly all of the other drivers, Figure C-9 shows that he was still 77m away from the stationary vehicle, which may not have provided adequate space for him to stop prior to the location of the stationary vehicle had he been prevented from overtaking. This was the case with 5 drivers in the sample

Driver 15 reacted slightly quicker than Driver 6 to apply the brake, but this was when only 27.1m away. At his speed of 83mph, it would take him approximately 100m to stop at full brake application and therefore a collision would have ensued if it was not possible to overtake

These highlight the issue between the brake reaction time and the travelling speed of the car, and also the fact that drivers may not perceive the need to brake in order to avoid a collision. Therefore, the brake reaction times analysed must be considered in the context of the study.

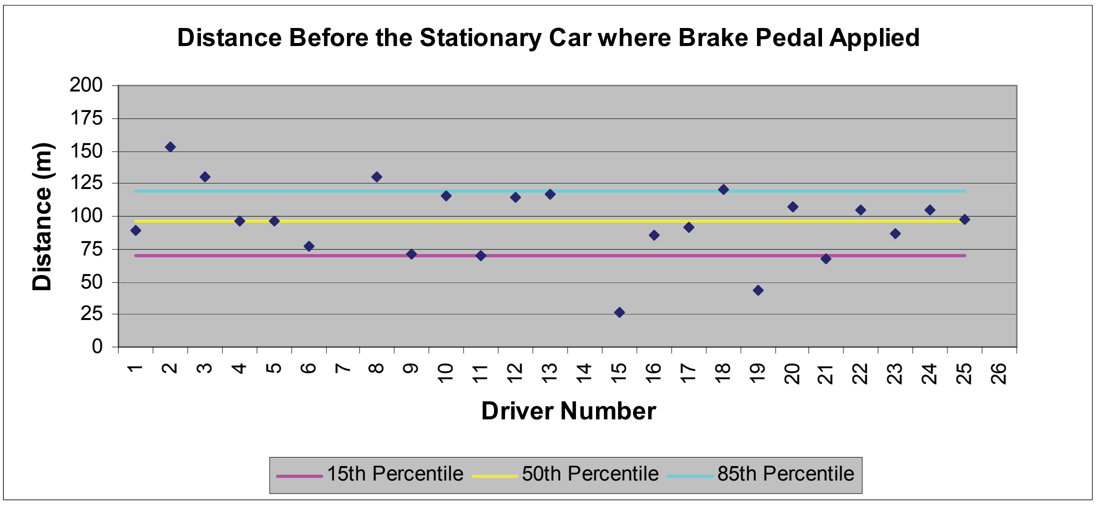

Figure C-9. Distance before the Stationary Car where the Brake Pedal was Applied.

C.3.3 Difference between Accelerator Release and Applying the Brake

The time and distance difference between releasing the accelerator and applying the brake was calculated from the raw data. 19 drivers reacted by releasing the accelerator pedal before applying the brake. It was not possible to calculate this value for the other 7 drivers as there was either no information associated with accelerator pedal release (5 drivers) or the driver did not apply the brake pedal (2 drivers). Figure C-10 displays the reaction time data for the 19 drivers in this subset, utilising the same scale on the Y-axis for consistency. To assist clarity Figure C-10 is repeated (Figure C-11) with a lower maximum time value.

The 85th percentile response for all drivers who released the accelerator and applied the brake was 0.87 second with only 3 drivers taking longer than this.

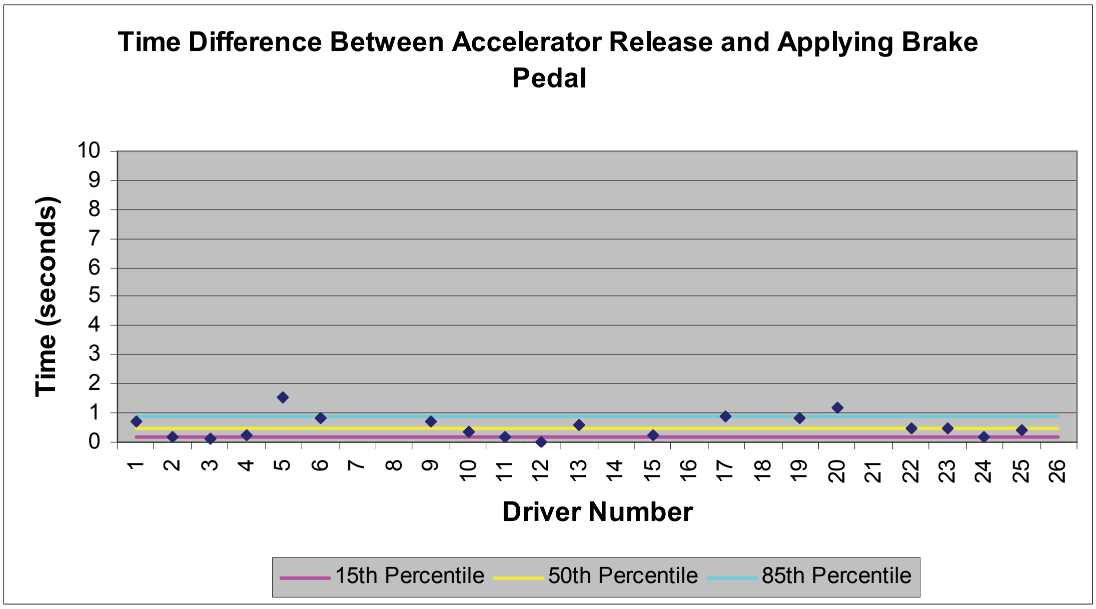

Figure C-10. Time Difference between Releasing the Accelerator and Applying the Brake Pedal.

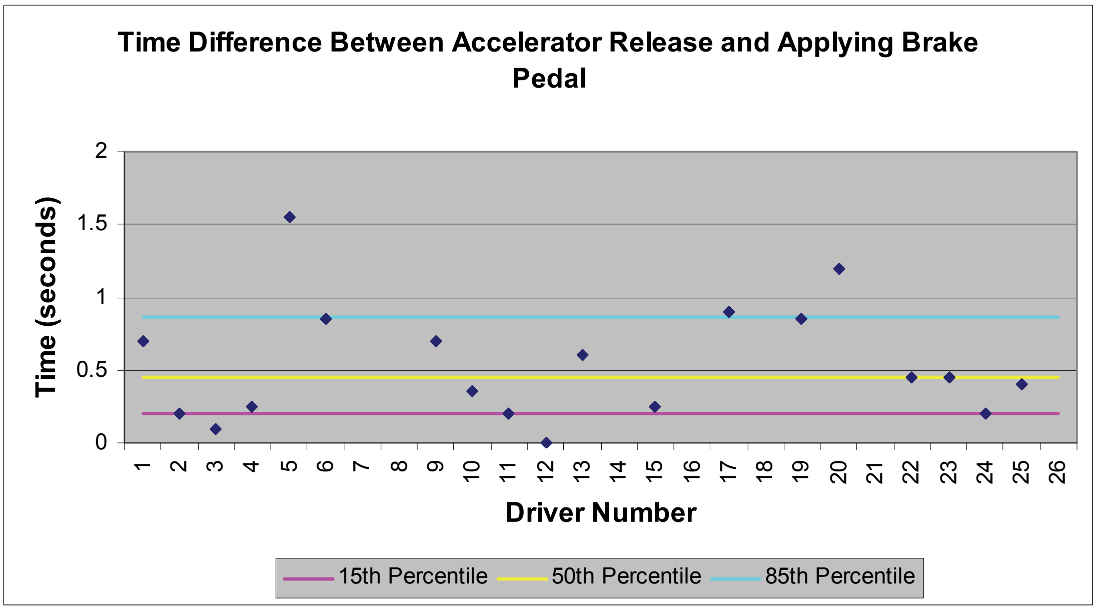

Figure C-11. Time Difference between Releasing the Accelerator and Applying the Brake Pedal (note shorter time scale on y-axis).

Overall, it could be said that the times the participants took were greater than one would expect in a true emergency situation.

Interestingly, the data shows that Driver 12 (from the performance fuel Club) took no time at all between releasing the accelerator pedal and applying the brakes (Figure C-12). This is not consistent with a normal driver releasing the accelerator pedal and applying the brake pedal, and can only be achieved by left foot braking or operating the brake and accelerator pedal at the same time with the same foot.

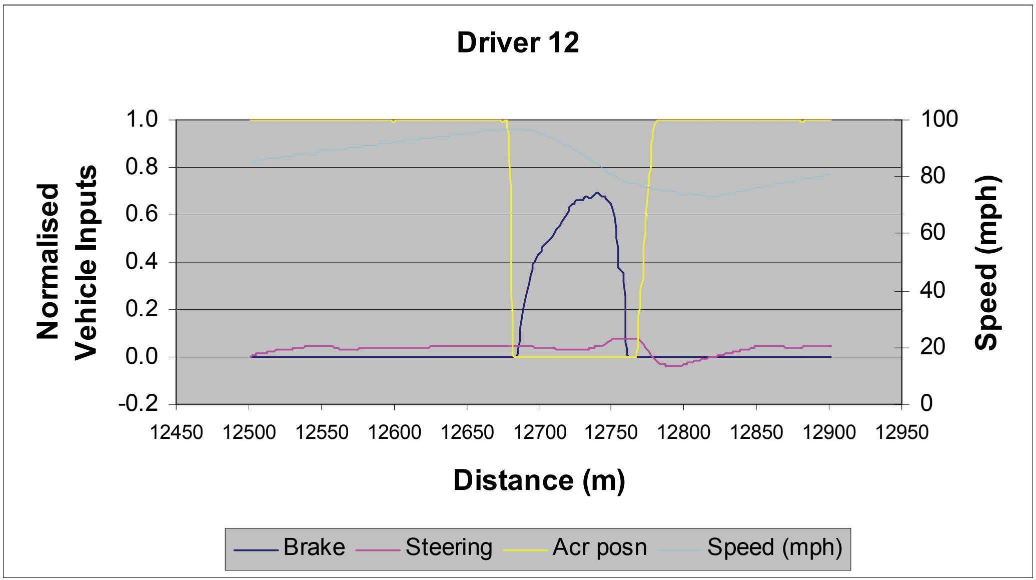

Figure C-12. Driver 12, Accelerator Response, Braking Response, Steering Input and Speed.

Figure C-13 shows a magnified version showing where the accelerator pedal was released and the brake applied, as well as showing the brake being released and the accelerator applied again almost immediately. At the onset of braking, the driver was travelling at approximately 96mph and only slowed down to 73mph when overtaking the stationary vehicle.

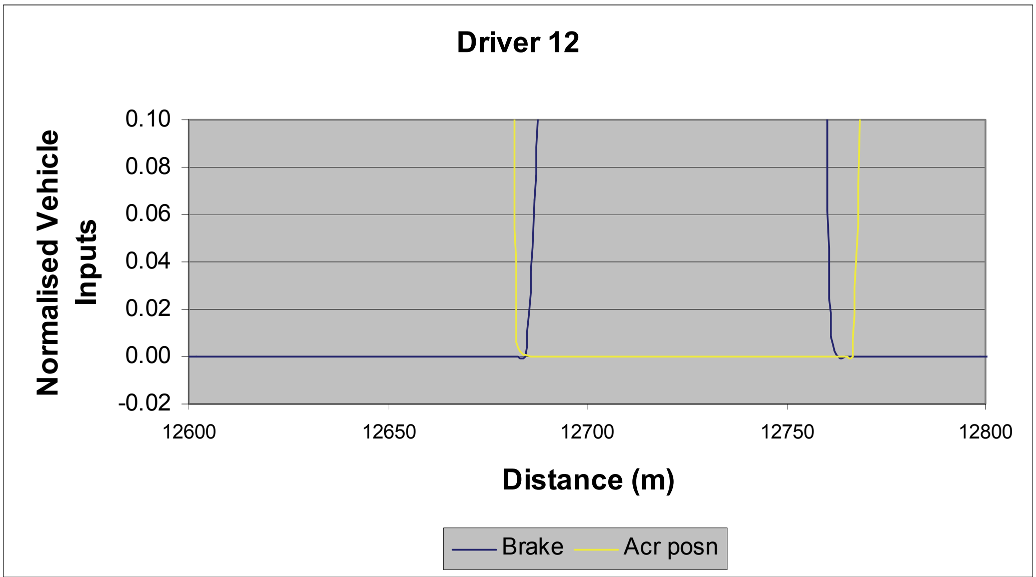

Figure C-13. Driver 12, Accelerator Response, Braking Response, Steering Input and Speed.

The distance that each driver covers while moving their foot from the accelerator pedal to brake pedal is a combination of the time taken and the speed the vehicle is travelling, and therefore results in a similar pattern of data points as the time profile.

These results also show that one driver, travelling at approximately 70 mph, covered a distance of 50 metres after releasing the accelerator and before applying the brake pedal.

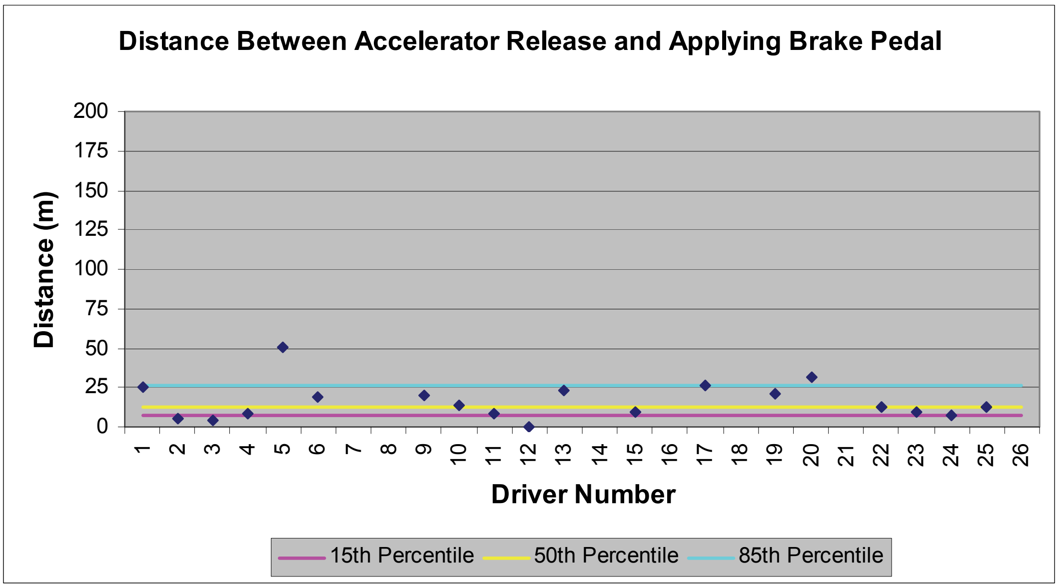

Figure C-14. Distance Difference between Releasing the Accelerator and Applying the Brake Pedal.

C.3.4 Reaction to Apply Steering

The additional study was designed in such a way that it would possible for drivers to be able to steer around the stationary vehicle without coming into conflict with traffic travelling in the opposite direction. It could therefore be expected that all 26 drivers would safely steer around the vehicle and continue to the end of the route; however, Driver 2 did not, and stopped before he reached the stationary vehicle.

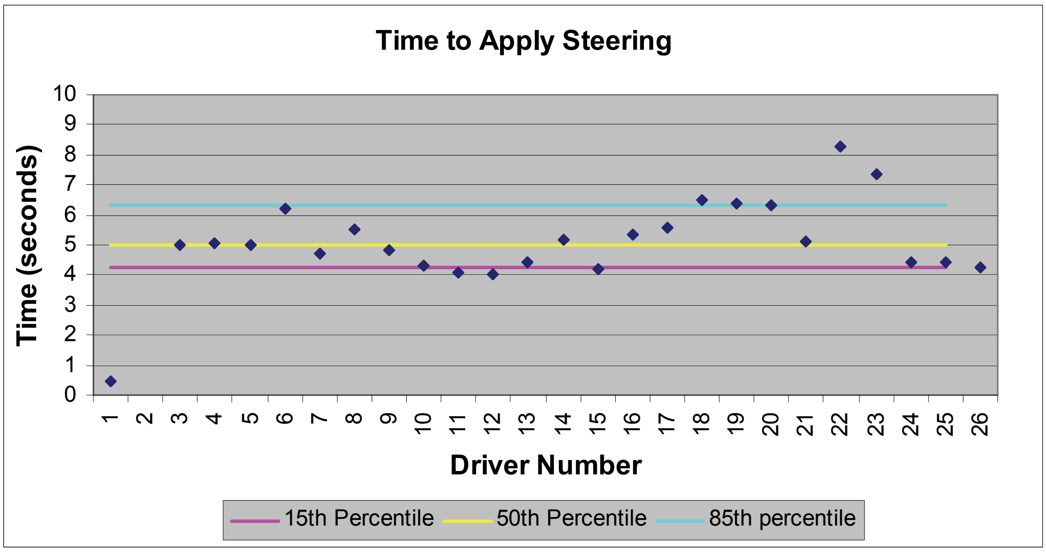

Figure C-15. Time to Apply Steering from the Possible Point of Perception.

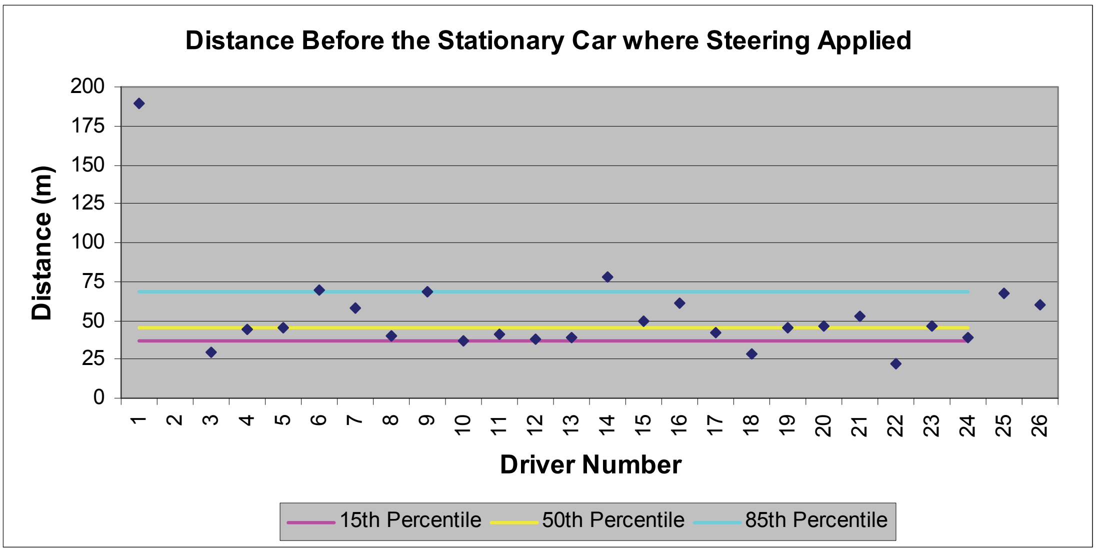

Figure C-16. Distance before the Stationary Car where Steering was Applied.

The majority of participants applied steering within 4.23 and 6.34 seconds of the stationary vehicle coming into view, with the longest time being 8.25 seconds after the first possible point of perception, with this driver steering when only 21.7m away.

Due to Driver number 2 stopping before reaching the stationary vehicle, he has been left out of the calculations. The 50th percentile response for the remaining sample to begin steering around the stationary vehicle was when 45.5m away.

Driver 1 seems to react very quickly (after 0.45 seconds and when 198.2m away from the stationary car), but this was after the vehicle became visible. The steering response was seen to be a significant steering input and it was therefore deemed to be a reaction to the stationary vehicle. This will be looked at in further detail later.

Driver 23 appears to take quite a long time to apply any steering following the first possible point of perception, this being 7.35 seconds. However, comparing this to the distance that he was from the stationary car, he was 46m away, which was a response very close to the 50th percentile for all drivers.

C.3.5 Driver Age

The graph below (Figure C-17) shows the time to apply the brake for all drivers, where the drivers have been arranged in order of age to observe any direct comparison.

A simple linear trend line through the data shows there to be a generally increase in the time taken to react with increasing age. However, this is only a general trend and it can be seen that individual drivers perform considerably better or worse than other drivers of a similar age.

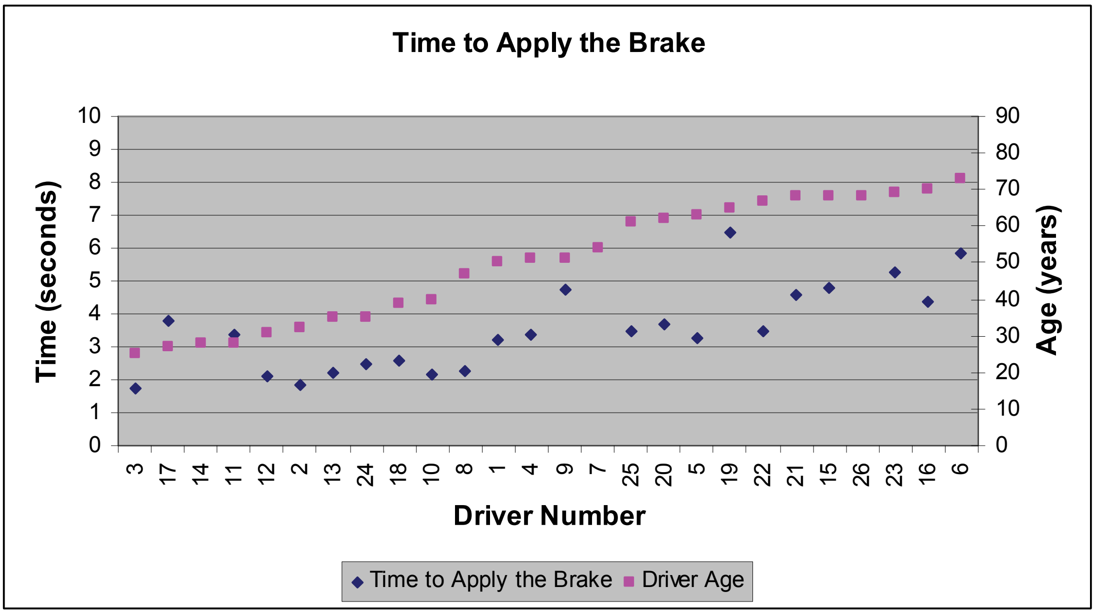

Figure C-17. Time to Apply the Brake from First Possible Point of Perception with regards to Age.

Taking the two extremes of age, it could be seen that Driver 6, who was 73 years old, took 5.85 seconds to apply the brake, and Driver 3, who was 25 year old, only took 1.75 seconds to apply the brake. However, comparing these results to Driver 20, 62 year old, who took 3.7 seconds to apply the brake and Driver 17, 27 year old, who took as long as 3.8 seconds to apply the brake, it can be seen that the increase in age does not always correspond to an increase in time to apply the brake.

Table C-3 shows the average times for the different reactions, segregated into three age groups. The table includes data from all drivers who undertook a specific action and does not only represent the first reaction.

	Age Group: 20 to 40	**Age Group: 41 to 60**	**Age Group: 61 +**
Average Time to Release Accelerator (seconds)	2.45	3.22	3.99
Average Time to Apply the Brake (seconds)	2.48	3.39	4.52
Average Time to Apply Steering (seconds)	4.84	5.03 (4.11)	5.71

Table C-3. Average Time for Each Age Group.

The average time for a driver in the age group of 20 to 40 to release the accelerator was 2.45 seconds, and increases with increasing age, taking 3.99 seconds for the oldest age group. A similar trend is apparent with the time to apply the brakes.

Likewise, the average time for applying steering for those in the 20 to 40 years old age group is 4.84 seconds, increasing to 5.03 seconds for those in the 41 to 60 years old group, and increasing again for the final age group to 5.71 seconds. The number that is shown in brackets for the age group 41 to 60 is the average reaction time with Driver 1's reaction of 0.45 seconds removed, as it may bias the sample. This shows that there is no longer a linear trend with age, with the middle age group applying steering earlier than the other two groups.

C.3.6 Additional Analysis

In an attempt to gauge the style of driving of the participant, the lateral acceleration of the vehicle through the bend, immediately prior to any reaction, was calculated.

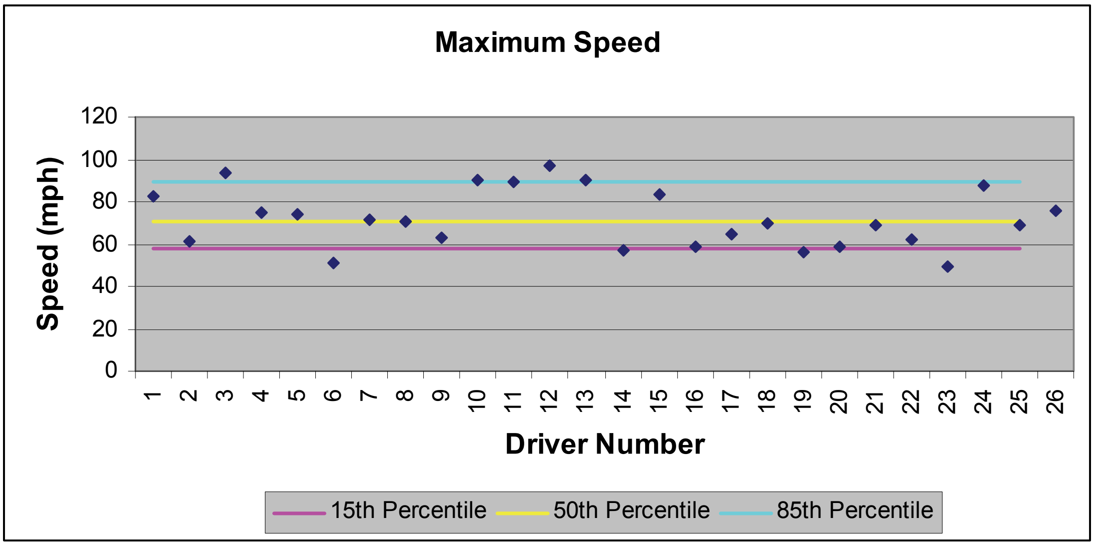

Figure C-18. Maximum Speed for Each Driver.

With information on the vehicle's speed (Figure C-18) and the lateral acceleration utilised by the driver (Figure C-19), it is possible to estimate the level of driver aggressiveness through the bend. The maximum level before loss of control would be approximately 8 ms^{-2}, and based on the speeds travelled at in this study, a level in excess of 3 ms^{-2} would have been uncomfortable for a normal driver. The graph below (Figure C-19) shows that 6 drivers are either above or very close to this value.

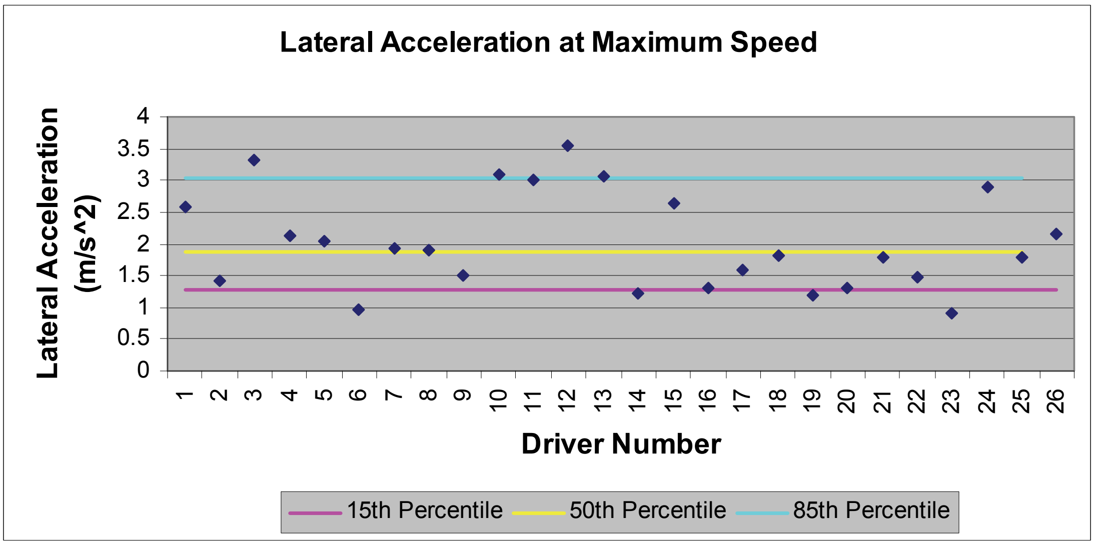

Figure C-19. Lateral Acceleration for Each Driver at Maximum Speed.

The graph below (Figure C-20) shows the speed difference when the drivers applied the brake and when they released the brake. The speed difference illustrates the severity of brake application, whether this is was by means of pressing firmly to slow the vehicle down or to slightly tap the brakes which may have been deemed as sufficient if the drivers speed is low.

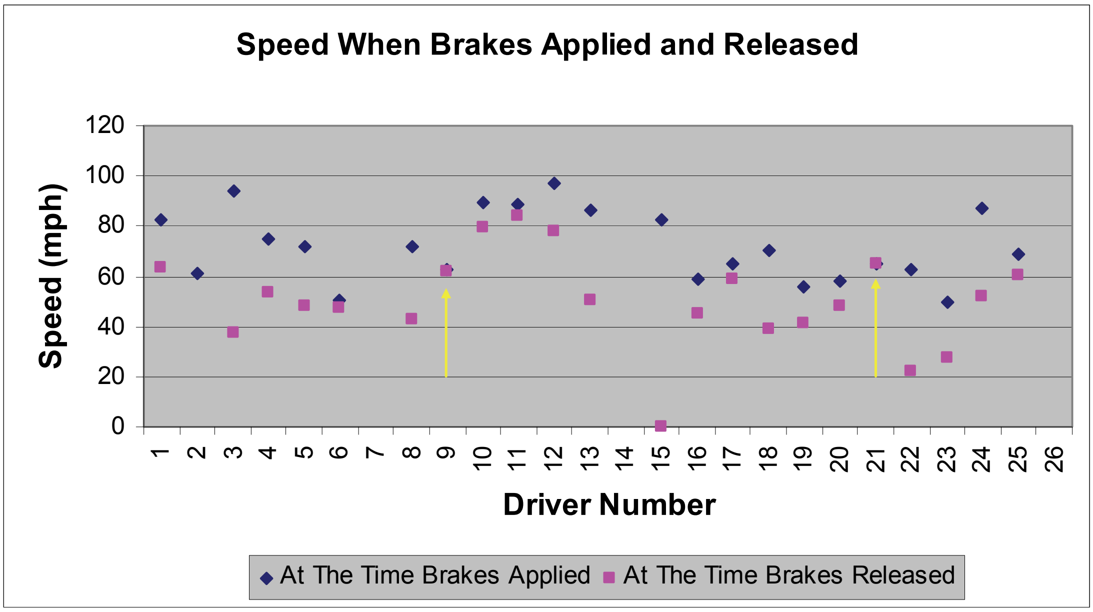

Figure C-20. Speed When Brakes Applied and Released, for All Drivers.

The arrows highlight Drivers 9 and 21, as these are the drivers whose speed difference is so small that only one point can be seen. These drivers have therefore only slightly braked and continued to drive at 61.6mph and 64.6mph respectively. However, Driver 15 can be seen to have applied the brakes firmly decreasing his speed from 85.2mph to 0.01mph as he passes the stationary vehicle.

Driver 2 does not have a time when the brake pedal was released due to him bringing the car to a halt before the stationary vehicle; this has been signified by no magenta square on the figure below (Figure C-20).

C.4 Specific Driver Behaviour

From the information acquired it is possible to look at the different reactions and order of reactions for individual drivers. It is clear that the majority of drivers took their foot off the accelerator, applied the brake, and then steered around the stationary car. A typical example is Driver 5 (Figure C-21, actions shown by arrows), who releases the accelerator at 1.7 seconds, when 146.8m from the stationary car, then firmly applies the brake at 3.25 seconds which brings his speed down from approximately 73mph to 48mph. Steering is then applied at 5.0 seconds as the brake pedal is released, followed by a phase of acceleration as he moved past the stationary car slowly increasing his speed again.

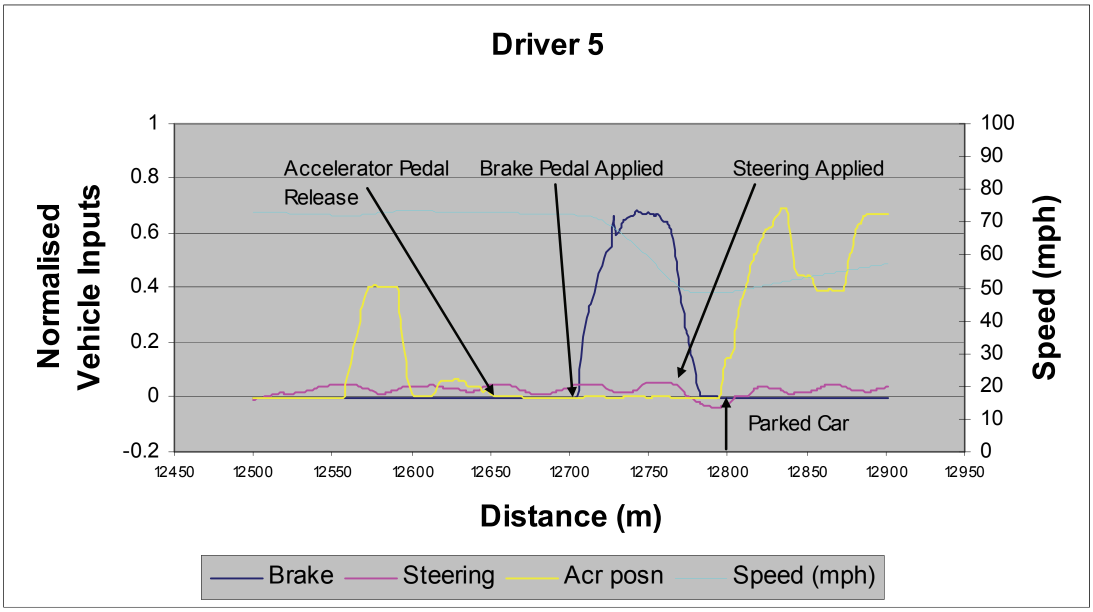

Figure C-21. Driver 5, Accelerator Response, Braking Response, Steering Input and Speed.

However, the data shows that there were 7 drivers who did not release the accelerator as a first reaction, and subsequently 4 drivers applied the brake as a first reaction. This is because they had already released the accelerator when exiting the previous bend, and therefore before the point of possible perception. The remaining 3 drivers applied steering as a first reaction.

Driver 7 (Figure C-22) does not react to the stationary car by releasing the accelerator pedal after the first possible point of perception or apply the brakes. Since the accelerator was not applied whilst approaching the stationary vehicle, the speed of the vehicle slowly decreases by approximately 5mph to manoeuvre around the stationary vehicle. This driver is one of the drivers whose first reaction was to apply steering, at a time of 4.7 seconds after the first possible point of visibility and when 58.1m away from the stationary vehicle.

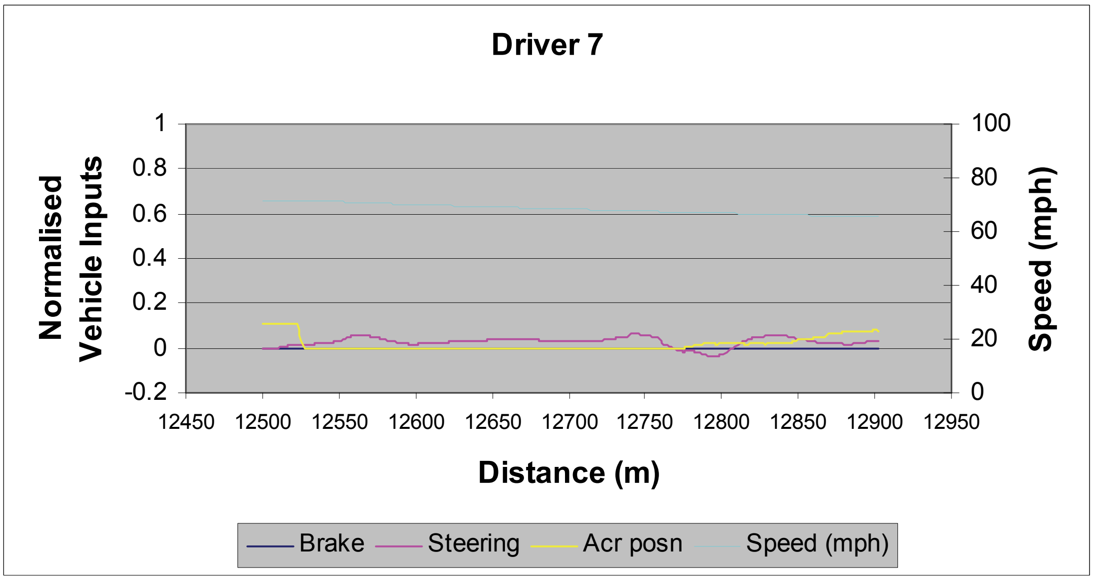

Figure C-22. Driver 7, Accelerator Response, Braking Response, Steering Input and Speed.

The graph below (Figure C-23) shows the response for Driver 2. It can be observed that this driver comes to a standstill before the stationary vehicle. This driver's data for steering has not been used in the analysis in this report due to the steering input being after the car had stopped, and is a result of simulator error.

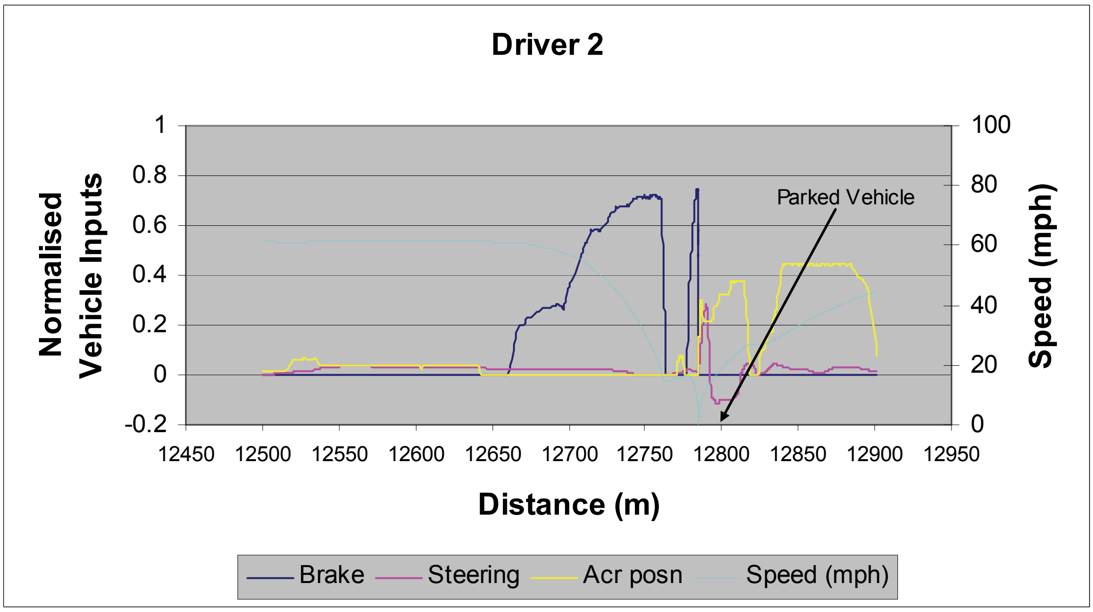

Figure C-23. Driver 2, Accelerator Response, Braking Response, Steering Input and Speed.

C.5 Summary

This study was complied by piggy backing onto a trial which was designed to determine whether drivers can tell the difference in performance between standard fuels and performance fuels.

The trial confronted a group of participants with a stationary vehicle in their path on their fifth run, having already completed four runs with no such vehicle present. It can therefore be said with some confidence that the drivers were unaware of the stationary vehicle being placed in the simulation and any reaction they undertook would be an unexpected but familiar event.

26 out of the 48 drivers had a stationary vehicle on run 5, with no lights illuminated, which was positioned along the left hand side of the road on a gentle bend of radius 529m. The drivers proceeded around the bend, where the first point of visibility of the stationary vehicle was at 12597.5m from the trial start. When the participant approached the stationary vehicle, it was safe to steer into the opposing traffic lane as there were no cars travelling in the opposite direction.

The bend before reaching the first point of visibility was relatively gentle, and with the car positioned at 12800.9m, this gave the participants 203.4m, and at least 4.7 seconds (travelling at the maximum speed of the drivers which is 97.1 mph) after the first point of visibility to react. This was a suitable distance and amount of time and all drivers should have been able to react and stop or manoeuvre around the stationary car.

All drivers reacted to avoid the stationary vehicle. Out of all 26 drivers only one driver stopped the vehicle prior to reaching the stationary car; all of the other drivers slowed down to varying degrees but deemed it safe to continue past the stationary car.

The general trend of all drivers was to release the accelerator, apply the brake and then steer around the vehicle, 58% of drivers completed these actions in this order. 96% of drivers steered around and continued past the stationary vehicle and one driver (4%) stopping before the vehicle.

The fastest reaction time seen in this investigation was from Driver 1 whose first reaction was to apply steering to the vehicle at 0.45 seconds after the first possible point of perception. It was also possible to determine the longest reaction times for those who reacted either by steering, applying the brake or releasing the accelerator. These times were 8.25 seconds, 6.50 seconds and 5.65 seconds respectively.

For the drivers who released the accelerator pedal, the average reaction time was 3.1 seconds, with the 15th and 85th percentile responses being 1.7 and 4.8 seconds respectively.

The average brake reaction time was 3.5 seconds after first visibility, with a 15th percentile response time of 2.2 seconds and an 85th percentile response of 4.8 seconds.

The reaction to steer was much longer and generally as the vehicles needed the stationary car and therefore it is very unlikely that the action was an emergency response.

The time it takes to switch from accelerator pedal to brake pedal was shown to be slightly greater than would be expected from a true emergency, ranging from 0.0 second to 1.55 seconds. These reactions illustrate that the drivers distinguish the stationary vehicle as a hazard they are approaching. However, the amount of braking that is applied varies greatly from driver to driver.

Drivers in this trial did not have a speedometer to tell them the speed they were travelling at, often resulting in them exceeding the speed limit. Throughout the entire study, at a point 200m before the stationary car, 77% of the participants exceeded the national speed limit, and 65% exceeded 65mph, which could be due the drivers being under time constraints. This restriction on the amount of time they have complete the run may have led to them paying more attention and driving faster than they would have done while out driving in an everyday situation.

Various other issues with the data have been observed with this trial that would need to be understood when using the figures calculated. Even though a good driver age range had been used for the trial, most drivers tended to be at either ends of the scale and not at the average age. There was also no young and inexperienced drivers or drivers older than 73. Another issue is that all the drivers were male; this does therefore not represent the population.

Appendix D. Driver Fatigue

D.1 Introduction

A study was undertaken to assess the effects that different drinks had on the levels of driver fatigue, including measuring their reaction time at various points in the simulator trial.

The trial used three different drinks in order to determine whether varying the amounts of caffeine and glucose consumed would have an effect on fatigue and hence the reaction times. During the trials, the drivers were unaware of which of the three drinks they had taken. The drinks consisted of a control drink, which was simply water with colouring added to enable it to look the same as the others, a level one drink (water, 60g glucose and 25mg caffeine) and a level 2 drink (water, 60g glucose and 40mg caffeine). The driver was tested for approximately 1 hour each day, over three separate days in the simulator as well as an initial practice session and on each day had a different one of the drinks, unaware of which drink they had consumed. The order of the drinks was not the same for each participant.

Once the familiarisation session had been completed, the participants drove through four different scenes, each one containing a reaction time task. The reaction time tasks consisted of a red bar appearing on the simulated environment in front of the driver and the drivers were informed to flash their headlights when this appeared.

The first reaction task took place during the first motorway section, after approximately 44.5km of the 60km segment. The road then changed into a curved section of road, which was a two lane road with a speed limit of 60mph. This section lasted for 19 km and contained reaction task two. After this, the drivers were instructed to follow the car in front of them at a set distance on the motorway they have now rejoined. There were chevrons marked on the road at the beginning of this section, which were then removed for a significant amount of this section of road, before being replaced again at the end to allow the participants to judge and assess their distances. The car in front would vary its speed between 50mph and 70mph and this section lasted for 23km, containing reaction task three. Reaction task four was in the last section of the trial which was a further motorway section extending for 25km in normal traffic.

The participants undertook all of the study trials shortly after lunchtime where the levels of fatigue are known to increase. The driving they were required to complete was uninteresting and unchallenging, thus adding to fatigue, with no radio playing in the vehicle.

D.2 Results and Analysis

Due to the trial assessing various fatigue indicators, a large amount of data was gathered; however, only a small proportion of this was relevant to driver reaction times. The pertinent data was extracted and compiled into tables to show the average, 15th, 50th and 85th percentile reaction times. These variables consisted of the speed at which the participants were driving, the average headway within the following section, the reaction times for four reaction tasks and the drink they had consumed prior to driving. If a reaction had not taken place within 5 seconds of the red bar appearing, no reaction time was recorded.

D.2.1 Vehicle Speed

The speed at which a driver travelled during the trials was used to determine whether anything could be ascertained as to the level of alertness and general driving behaviour.

It can be seen from the following tables that, on average, the driver's average speed on each section of road was at or above the speed limit. No account has been taken of the drink type consumed by each participant.

All Runs	**Average**	**15th Percentile**	**50th Percentile**	**85th Percentile**
First Motorway Section	78	71	78	89
Curved Road	60	59	61	62
Second Motorway Section	77	67	75	90

Table D-6a. Results for all runs and all drivers. (All speed in mph)

First Motorway Section	**Average**	**15th Percentile**	**50th Percentile**	**85th Percentile**
Run 1	81	74	80	89
Run 2	80	72	80	89
Run 3	79	71	77	89

Table D-1b. Results for the first motorway section for all drivers. (All speed in mph)

Table D-1a shows the (average) fastest travelling speed, by the drivers throughout the entire trial, was when driving the first motorway section. The range for all three runs for this section was 71 mph to 89 mph, for the 15th and 85th percentile responses, with little variation noted across the three separate runs (Table D-1b).

Curved Road	**Average**	**15th Percentile**	**50th Percentile**	**85th Percentile**
Run 1	60	58	60	61
Run 2	60	60	61	61
Run 3	61	60	61	62

Table D-1c. Results for the curved road section for all drivers. (All speed in mph)

The speed for the curved section increased very slightly from Run 1 to Run 2, and from Run 2 to Run 3. The reason for the lower vehicle speed in this section (Curved Section) compared to the average speeds of approximately 80 mph for the 'normal motorway section' is unknown; however, this may due to the perceived severity of the curve, although a driver would not received direct feedback from the vehicle in relation to the lateral acceleration.

Second Motorway Section	Average	15^{th} Percentile	50^{th} Percentile	85^{th} Percentile
Run 1	77	66	77	85
Run 2	78	70	75	90
Run 3	77	66	74	90

Table D-1d. Results for the second motorway section for all drivers. (All speed in mph)

The speeds on the second motorway section can be seen in Table D-1d, and are slightly slower, on average, than the first motorway section, although on Run 3 the 85^{th} percentile speed increased very slightly by 1 mph. This may be as a direct result of driver fatigue.

D.2.2 Headway

As with the speed analysis above, no attempt has been made at this stage to assess driver's performance based on drink type. On the section of road where a driver had to maintain a set headway, not speed data was produced. Therefore it is this headway data that has been assessed below.

Following	Average	15^{th} Percentile	50^{th} Percentile	85^{th} Percentile
Run 1	88	50	84	125
Run 2	77	47	72	99
Run 3	79	49	67	113
All Runs	81	49	76	114

Table D-2. Results for the following section for all drivers. (All distance in m)

The headway distance between the participant's vehicle and the vehicle they were following varied considerably from driver to driver. In the first run of the trial these distances ranged from a 15^{th} percentile of 50m to 85^{th} percentile 125m (Table D-2). The average headway for all the runs in this section was 81m. The headway distance for each driver in a particular run varied considerably, as the lead vehicle's speed was constantly varied, having the effect of either increasing or decreasing the headway if the participant did not react.

D.2.3 Reaction Times

During each of the sections, the drivers were asked to react to the appearance of a red bar on the screen in front of them by flashing their headlights. The tables below present the reactions times based on the run number (to assess any familiarisation) irrespective of drink type. To recap, reaction task 1 (RT1) was the first motorway section, reaction task 2 (RT2) was on the curved road section, reaction task 3 (RT3) was to maintain a headway and reaction task 4 (RT4) was the second section of motorway.

Run 1	Average	15th Percentile	50th Percentile	85th Percentile
RT1	1.16	0.82	1.04	1.30
RT2	1.19	0.96	1.15	1.43
RT3	1.00	0.80	1.00	1.34
RT4	1.14	0.83	1.07	1.54
All RT	1.12	0.86	1.05	1.38

Table D-3a. Results for run one for all drivers. (All time in seconds)

Table D-3a shows that, on average, the reaction time recorded during task three (RT3) was the quickest. The averages of all of the other reaction tasks were within 0.2 second greater than this. While the same can be said for the 15th and 50th percentile responses, at the 85th percentile level, reactions in task one appeared to be quickest.

Overall, drivers were seen to react (by flashing their headlights) in a time of 0.86 to 1.38 seconds for the 15th and 85th percentile groups. As these times relate to a driver's first experience of the reaction time task, they are likely to represent a more accurate response.

Run 2	Average	15th Percentile	50th Percentile	85th Percentile
RT1	1.11	0.81	1.08	1.45
RT2	1.01	0.72	0.99	1.28
RT3	0.82	0.52	0.86	1.12
RT4	1.09	0.77	0.94	1.41
All RT	1.01	0.70	0.94	1.30

Table D-3b. Results for run 2 for all drivers. (All time in seconds)

In Run 2, it was seen that the average reaction times (RT1 to RT4) all reduced, and it was still evident that the reaction times in task three were the fastest, this being (on average) 0.82 second, which was 0.18 second quicker than during Run 1. Reaction task two also has the same decrease from Run 1 from 1.19 seconds to 1.01 seconds.

The average reaction times for the different reaction tasks range from 0.82 second for reaction time three to 1.11 seconds for reaction time one, which is slightly greater than the average reaction time range seen for Run 1.

For this run (Run2), the 15th percentile and 85th percentile for all reaction times was 0.70 second and 1.30 seconds respectively, giving a range of 0.6 second, which is slightly greater than for Run 1.

Run 3	Average	15^{th} Percentile	50^{th} Percentile	85^{th} Percentile
RT1	0.97	0.72	0.93	1.23
RT2	0.95	0.58	0.90	1.28
RT3	0.95	0.82	0.93	1.02
RT4	0.99	0.71	0.95	1.21
All RT	0.97	0.70	0.93	1.24

Table D-3c. Results for run 3 and for all drivers. (All time in seconds)

The table above shows the reaction times for Run 3. The average reaction times on Run 3 were generally lower than for the two earlier runs and also much closer together, with the variation being just 0.04 seconds. This could be due to the fact the drivers are expecting the red bar to appear at a specific point and are therefore ready to flash the lights no matter which task they are undertaking at the time. Such a factor is likely to be an artefact of the study as the red bar always appeared at the same point in each of the tasks.

The 15^{th} and 85^{th} percentile range of reaction times for all four tasks were 0.70 and 1.24 seconds respectively, a spread of 0.54 second, which is slightly more than Run 1 but slightly less than on Run 2.

All Runs	Average	15^{th} Percentile	50^{th} Percentile	85^{th} Percentile
RT1	1.08	0.75	1.03	1.32
RT2	1.05	0.77	1.01	1.29
RT3	0.92	0.67	0.90	1.19
RT4	1.07	0.77	0.99	1.41
All RT	1.03	0.75	0.97	1.30

Table D-3d. Results for all runs and all drivers. (All time in seconds)

Table D-3d collates the results for all three runs. It shows that, on average, reaction task three resulted in the shortest reaction time (0.92 second), while overall an average reaction time of 1.03 seconds was found. The 15^{th} and 85^{th} percentile range of reaction times for all four tasks, and all three runs were 0.75 and 1.30 seconds respectively.

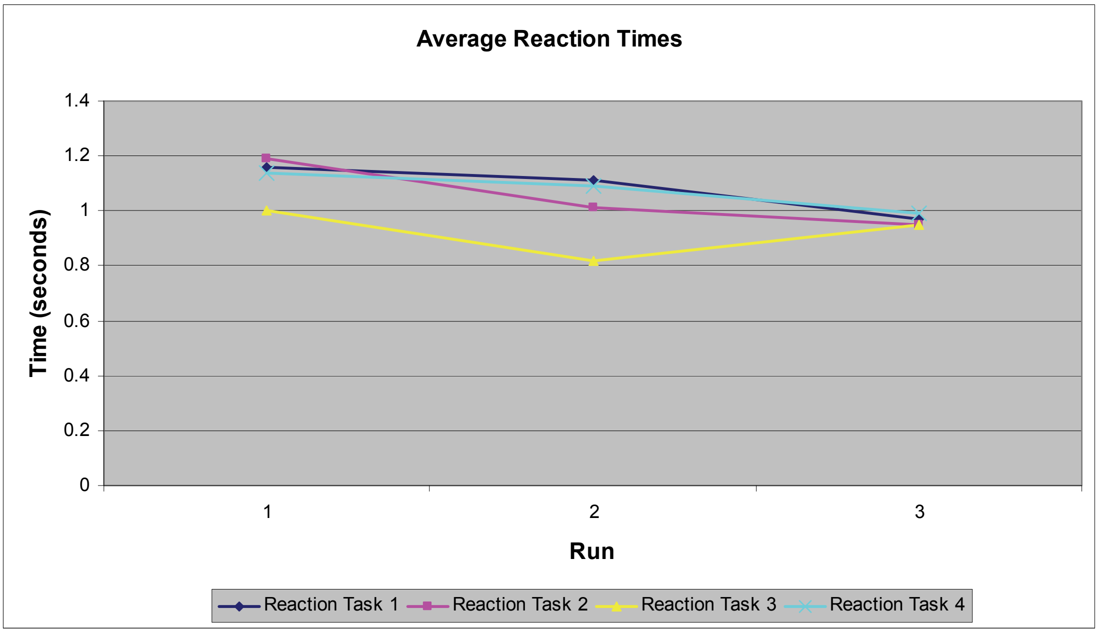

Figure D-24. The average reaction times for all drivers and all runs.

Figure D-24 shows that, apart from reaction task three (where the participants were required to follow the vehicle in front at a set distance), the time taken to flash the headlights from the appearance of the red bar decreases with increasing run number. The decrease in reaction times could be for many reasons, one of which is that the drivers were becoming more familiar with the simulator trial and may be more aware of the red bar appearing, thus reducing their reaction time.

It should be noted that the drivers in these trials will have their hands close to the controls (and may even have their hand on the control) ready to flash the lights and therefore this may decrease any reaction time associated with movement. In a normal driver emergency braking manoeuvre, the driver has to move their foot from the accelerator pedal to the brake pedal which could take a more time.

The following three graphs (Figures D-2, D-3 and D-4) show the time taken to flash the headlights to the appearance of the first red bar (which occurs during section one whilst driving along the motorway), separated into whether the driver was on Run 1, 2 or 3. It can be observed from these figures that some drivers reacted very differently on every run, whereas others consistently reacted in around the same time.

As an example, Driver 7 was seen to consistently react quickly during each run, whilst also becoming faster, 0.68 second, 0.55 second and 0.42 second respectively.

Driver 1 had very different reaction times across the three runs. While the reaction time increased with increasing run number (Run 1 2.75s, Run 2 1.5s and Run 3 1.1s) each reaction time was still in excess of the 50^{th} percentile response across all runs.

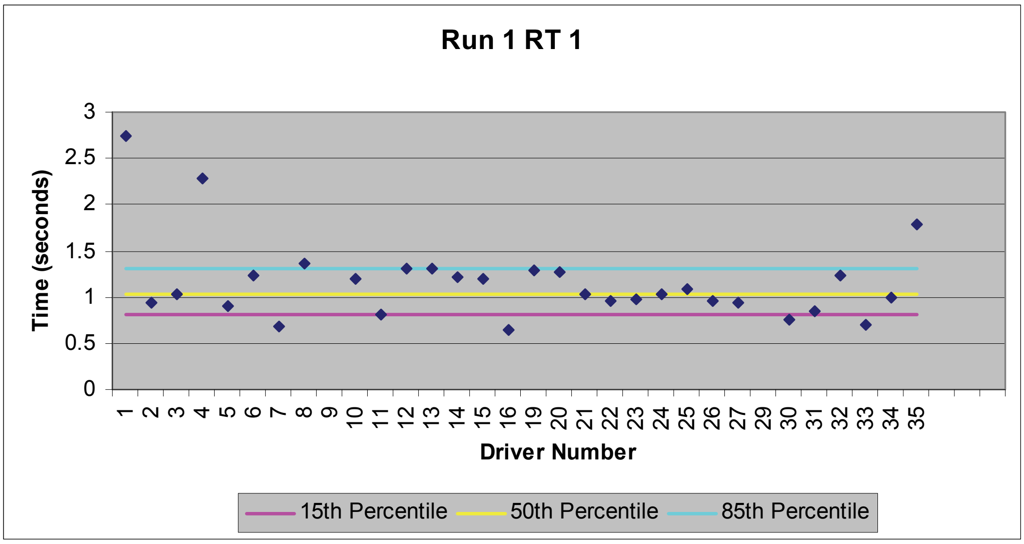

Figure D-2. Reaction Time for Reaction Task One of all Drivers for Run 1.

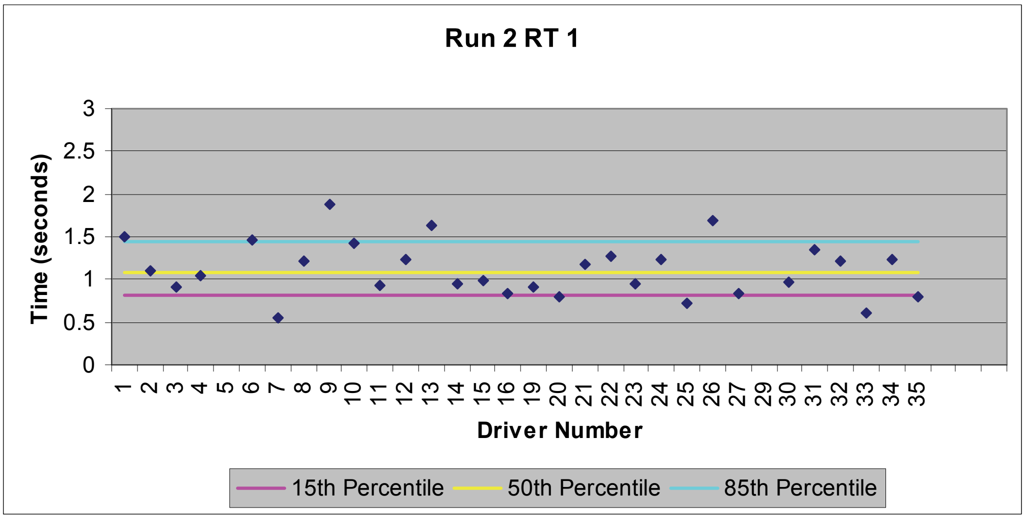

Figure D-3. Reaction Time for Reaction Task One of all Drivers for Run 2.

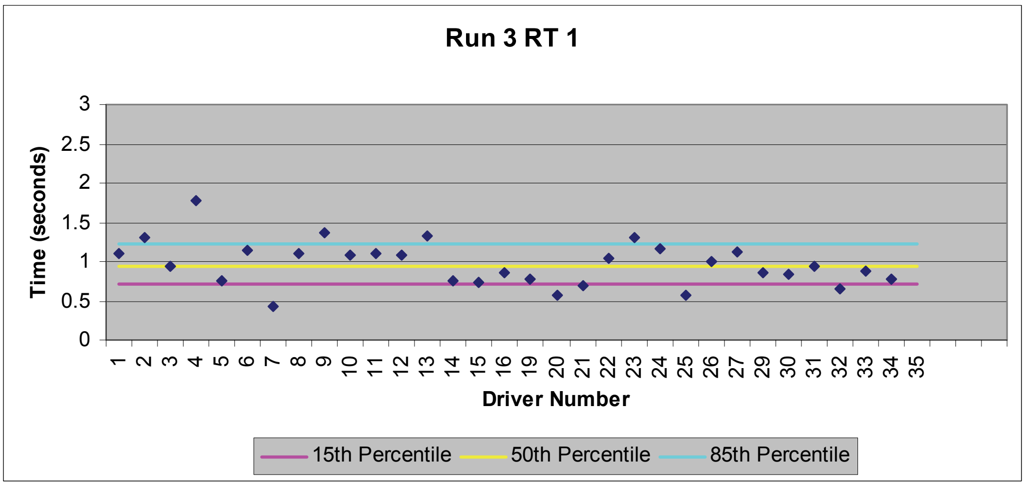

Figure D-4. Reaction Time for Reaction Task One of all Drivers for Run 3.

D.2.4 Analysis of Gender

The data for all three separate runs was combined, and then split by gender and reaction task. The tables below show the average, 15th, 50th and 85th percentile reaction times for male and female drivers.

Male	Average	15th Percentile	50th Percentile	85th Percentile
RT1	1.02	0.74	0.97	1.24
RT2	0.97	0.56	0.96	1.20
RT3	0.89	0.60	0.90	1.02
RT4	1.06	0.70	0.95	1.40
All RT	0.99	0.70	0.93	1.24

Table D-4a. Results for all reaction time tasks for male drivers. (All time in seconds)

Female	Average	15th Percentile	50th Percentile	85th Percentile
RT1	1.12	0.79	1.07	1.37
RT2	1.10	0.80	1.04	1.31
RT3	0.95	0.77	0.94	1.24
RT4	1.08	0.80	1.03	1.41
All RT	1.07	0.78	1.00	1.34

Table D-4b. Results for all reaction time tasks for female drivers. (All time in seconds)

A comparison between male and female drivers showed that male drivers were, on average, faster for every run and every reaction task (Tables D-4a and D-4b). The greatest difference in the average reaction time was for Run 1, where the male's average reaction time was 1.02 seconds and the female was 1.12 seconds. While this difference is significant in statistical terms, in accident investigation, a 0.1 second variation is very low.

The male group's 15th to 85th percentile reaction time range for all runs and all reaction tasks was between 0.70 second and 1.24 seconds, and the similar range for the female group was between 0.78 second and 1.34 seconds.

D.2.5 Drink Type

The trial was to determine the influence of a drink on the level of driver fatigue. Since each drink was randomly distributed across each of the three runs (Figure D-5), it is likely that the trends found in the data so far are related to some kind of driver familiarity, and not related to the drink consumed.

Drink 1 was the control, Drink 2 contained 60g Glucose and 25mg of Caffeine and Drink 3 contained 60g Glucose and 40mg of Caffeine.

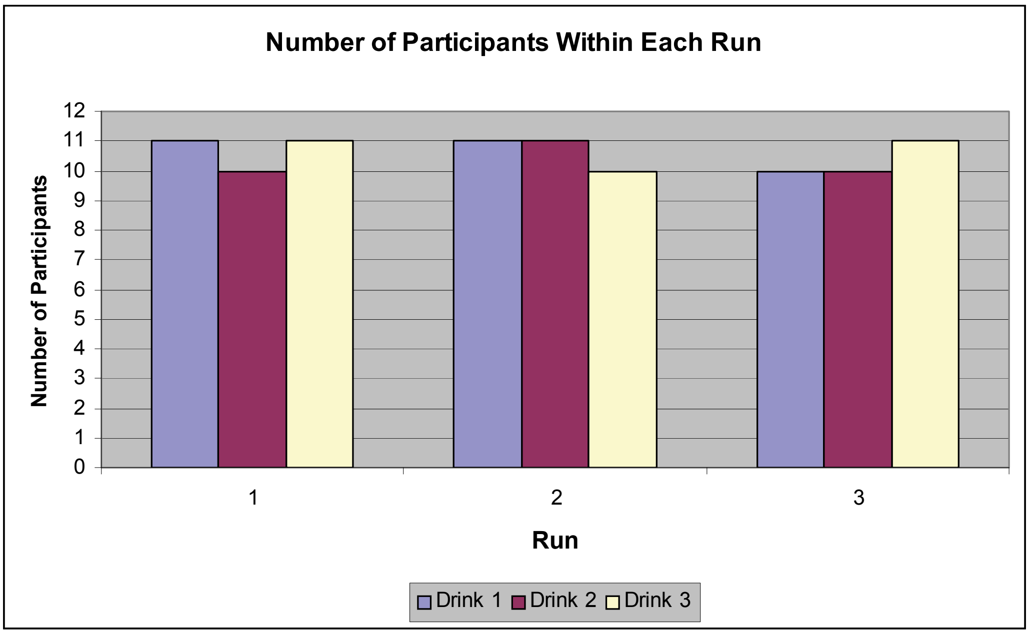

Figure D-5. Distribution of Participants by Drink and Run Number

This section considers the type of drink consumed, together with the run number it was consumed on. This leads to some small sample sizes in the data, and it must therefore be carefully considered.

The tables below show the different reaction times for the tasks with regards to the drink type consumed. The number in brackets is the participant sample size in each data set, which can be seen to range from 7 to 11. The reaction times in the tables are averages. The 'All' dataset for each run number combines together the 4 reaction events for each driver.

Drink 1	RT1	RT2	RT3	RT4	All
Run 1	1.11 (10)	1.11 (11)	1.01 (10)	1.23 (11)	1.12 (42)
Run 2	1.16 (11)	1.00 (11)	0.75 (10)	0.98 (11)	0.98 (43)
Run 3	1.09 (10)	1.18 (10)	0.94 (10)	1.13 (10)	1.09 (40)
All	1.12 (31)	1.09 (32)	0.90 (30)	1.11 (32)	1.06 (125)

Table D-5a. Average reaction times for Drink 1. (All time in seconds)

Table D-5a shows the reactions times for Drink one. The shortest reaction time for all runs was 0.90 second (reaction task 3) with the average reaction time across all runs and tasks of 1.06 seconds for Drink one.

Drink 2	RT1	RT2	RT3	RT4	All
Run 1	1.17 (9)	1.14 (9)	1.01 (7)	1.05 (9)	1.09 (34)
Run 2	1.11 (9)	1.05 (11)	0.81 (10)	1.18 (11)	1.04 (41)
Run 3	0.84 (11)	0.75 (11)	1.02 (10)	0.92 (11)	0.88 (43)
All	1.02 (29)	0.97 (31)	0.94 (27)	1.05 (31)	1.00 (118)

Table D-5b. Average reaction times for Drink 2. (All time in seconds)

Reaction task 3 was also the quickest with Drink two, with the average across all runs of 0.94 second. The average reaction time for Drink two, across all reaction tasks and runs was 1.00 second, 0.06 second faster than for Drink one.

Drink 3	RT1	RT2	RT3	RT4	All
Run 1	1.19 (11)	1.31 (11)	0.99 (10)	1.21 (11)	1.16 (43)
Run 2	1.07 (10)	0.98 (10)	0.92 (9)	1.12 (10)	1.02 (39)
Run 3	0.99 (10)	0.92 (10)	0.90 (8)	0.93 (10)	0.94 (38)
All	1.09 (31)	1.08 (31)	0.94 (27)	1.06 (31)	1.04 (120)

Table D-5c. Average reaction times for Drink 3. (All time in seconds)

Tables D-5c shows the reactions times for Drink three. The average reaction time from all runs and all reaction tasks was 1.04, 0.04 second slower than Drink 2, but 0.02 second faster than Drink 1.

Generally, for Drinks two and three the average reaction time for all reaction tasks decreased the more runs completed. This was not the case with Drink one where the average reaction times decreased from Run 1 to Run 2, but then increased between Run 2 and Run 3.

The reaction times for each drink type varied by up to 0.4 second, depending on run number; however, there does not appear to be any simple relationship between the reaction task and the run number. Reaction task three can be seen to be consistently the fastest reaction, increasing slightly between drinks one and two (0.90 to 0.94) and remaining constant between drinks two and three. There are a number of reasons why this task may have the fastest reaction time, one of which could be due to the drivers already being in a heightened level of alertness as they are concentrating on maintaining a headway to the vehicle in front.

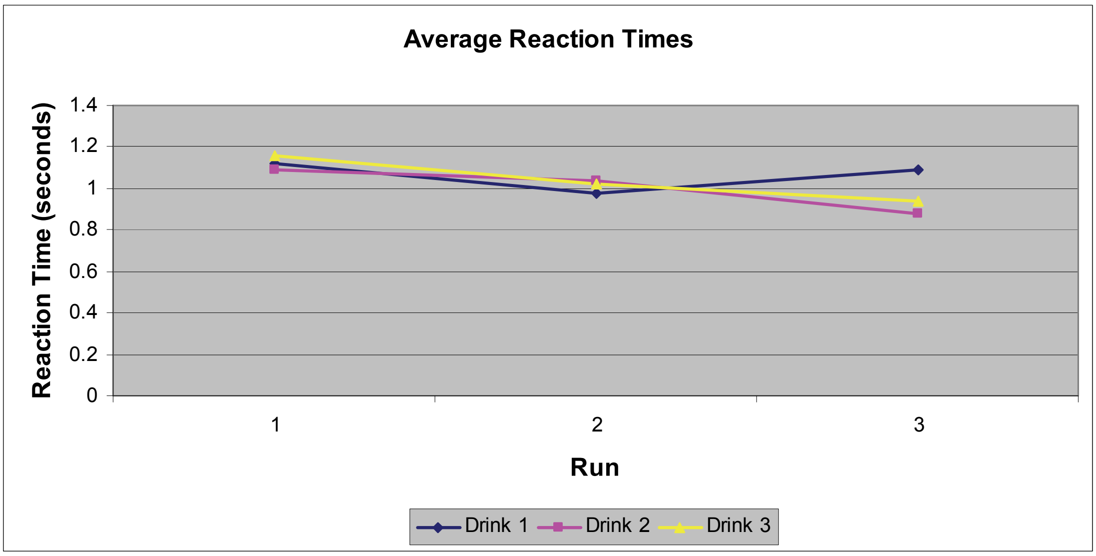

Figure D-6. The average reaction times for all runs and all tasks.

Figure D-6 shows that the variation in reaction times in the data sets makes it very difficult to determine any correlation between individual runs and drink consumed. The figure shows that the reaction times for drinks two and three reduce with increasing run number; while the same cannot be said for Drink one.

D.3 Summary

The aim of the trial was to determine the effect of drink on driver fatigue levels. The participants were instructed to drive in the simulator for approximately one hour, consisting of 60km on a motorway, 19km on a curved road section, 23km following a vehicle in front at a fixed headway and a final 25km motorway driving. During each of the four stages of the drive, the participants were informed that at some point a red rectangular bar would appear in front of them. On seeing the red bar, the drivers were asked to flash their headlights as soon as they could.

Overall, the data acquired during this trial showed that, irrespective of drink and task type, the average reaction time was 1.03 seconds, this being 1.12 seconds for Run 1, 1.01 seconds for Run 2 and 0.97 second for Run 3. The 15th percentile response for all runs was 0.75 second and an 85th percentile response of 1.30 seconds.

The general trend seen for reaction tasks one, two and four was for a decrease in reaction time with increasing run number. However, reaction task three showed a reaction time decrease between Runs 1 and 2, and an increase between Runs 2 and 3. This type of trend highlights a level of driver familiarity with the trials and possibly their heightened level anticipation around the time where the red light appears.

The data was analysed by male and female groups, which showed that males had faster reaction times than females, but by just an average of 0.08 second. The 15th percentile response time for males was 0.70 second, while it was 0.78 second for females. The 85th percentiles were 1.24 seconds and 1.34 seconds for males and females respectively.

The effect of the different types of drink consumed by the participants was also analysed; however, little correlation was found between runs, reaction task and drink consumed. On average, the change between Drink one and two resulted in a decreased in reaction from 1.06 seconds to 1.00 seconds, but with the further increase in caffeine (Drink 3) the reaction time increased slightly to 1.04 seconds.

It should be noted that the reaction times in this study relate to a driver having to flash their headlights to the presence of a red rectangular bar. Therefore, the identification and decision stages of a perception-reaction time need to be considered before using any reaction time included in this study.

Driver reaction times to familiar but unexpected events

The *Driver reaction times to familiar but unexpected events* study was undertaken as part of the TRL re-investment program to promote internal research. The study was designed to take advantage of existing data collected during previous trials in the CARSIM, together with bespoke studies designed to be integrated into new trials.

In collision investigation, it is the perception and response of a driver to a familiar, but unexpected event (such as the sudden movement of a pedestrian crossing from behind a parked vehicle) that is of considerable importance when reconstructing an incident for criminal or civil proceedings.

The reaction times measured in the trials in this TRL study, appear to be consistent with the work of Olson, partially because of the nature of the definition of Olson's reaction time range. Instead of taking the range as fixed, the collision investigator needs to understand how the range was calculated and whether a particular event needs the range to be modified, such as when the detection and identification phases may have been undertaken before a particular hazard enters the road.

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