# Development and Validation of a Naturalistic Driver Distraction Evaluation Tool

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## ABSTRACT

This paper describes the development and validation of a PC-based Naturalistic Driver Distraction Test designed to measure simulated driving performance while the driver is performing a secondary task. The paper discusses the logic behind the development of the test, including the principles that were used to guide its design, as well as the results of a pilot validation study. The findings from this study were consistent with previous research and theory and were consistent with those obtained with the LCT. The results did, however, highlight a number of refinements that were necessary to improve the utility of the test.

## KEYWORDS

Driver distraction; Design and evaluation, Test development

## BACKGROUND

A wide range of driver assistance, information, communication and entertainment systems are entering the vehicle market at a rapid rate. While these systems have the potential to assist drivers in performing the driving task, the potential for these systems to divert drivers' attention from driving and degrade performance and safety has been noted in the research literature [1]. It is vital that this potential trade-off between assisting the driver and distracting the driver is established experimentally prior to systems entering vehicle fleets, so that modifications can be made to their design or use-restrictions imposed while driving.

A commonly used approach to examine safety trade-offs involves evaluating driving performance while the driver interacts with in-vehicle systems and devices, using surrogate driving tests. Surrogate driving tests simulate and assess one or more aspects of the driving task. They are typically implemented in a laboratory environment and provide a simple, cost-efficient, reliable and valid method for evaluating the demand of IVIS (In-Vehicle Information Systems) and ADAS (Advanced Driver Assistance Systems) in the early design phase. The most commonly used surrogate driving tasks for IVIS evaluation are the Peripheral Detection Task (PDT), the visual occlusion technique and the Lane Change Test [2-4].

The appeal of many existing evaluation tests is that they are inexpensive and are quick and easy to use. However, they do have a number of limitations. These relate primarily to methodological issues that limit the extent to which the test results can be generalised to real-world driving. First, these tests are often uni-dimensional; that is, they only measure or provide information on one aspect of driving performance (e.g. lane deviation). Research shows that the effects of distraction manifest across a number of different driving performance measures, including speed, car following distance, lane keeping and reaction time, among others [5]. Thus, use of a test that only provides information on only one or two aspects of driving performance, may have limited application to real world driving and lead to inaccurate or compromised assessments of the safety implications arising from use of the system under review. Secondly, the targets or events used in existing tests are often predictable, both in terms of their presentation rate and the response required. As a result, drivers can rapidly develop expectations that a particular response is required when a recognised target stimulus is presented. It is likely that driver responses to such predictable events are not representative of responses observed while driving in a real-world dynamic environment [4].

As part of a research program with the Automotive Cooperative Research Centre and General Motors Holden there was an identified need to develop a more ecologically valid, less predictable and multi-dimensional test for evaluating IVIS systems, but one that is also simple and quick to use and does not require expensive equipment. To this end, the Naturalistic Driver Distraction Test was developed. The remainder of this paper presents an overview of test development and validation.

## TEST DEVELOPMENT

The Naturalistic Driver Distraction Test is a PC-based driving task that measures simulated driving performance while the driver is performing a secondary task; whether this is interacting with an in-vehicle device or performing another everyday task while driving. This test is designed primarily to evaluate IVIS such as infotainment systems, but also nomadic devices such as mobile phones, MP3 players and Personal Digital Assistants (PDA). It is not designed to evaluate effects in relation to the use of ADAS when driving. Further, the test has been designed to evaluate prototype or completed systems, rather than systems that are in the early concept phase. It is also envisaged that the test could be used to examine other forms of driving impairment, such as fatigue or alcohol consumption. However, only the validity and sensitivity of the test as a method to evaluate the effects of secondary task performance has been examined to date.

The design of the Naturalistic Driver Distraction Test's driving scenario is described in detail below, but first, the principles used to guide the design of the test are discussed.

### Guiding Principles

The Naturalistic Driver Distraction Test development was governed by three guiding principles that would ensure that this test provided functionality not provided by existing tools. Principles 1 and 2 derived primarily from requirements of the end user community, that being automotive designers and researchers in the first instance, while the third was more a research-driven principle that addressed the need to better capture real-world distractions in a test environment.

***Ease of application***

The test was designed to be simple enough to be used and interpreted by a range of people, from system designers who may have little human factors training, through to researchers who may have extensive human factors knowledge. The test was also designed to be quick to use and require minimal time and expense to set up. The hardware set-up can, for example, be based on a standard PC equipped with suitable graphics cards, three screens and a gaming steering wheel.

***Versatility***

The test was designed to be versatile. That is, it can be used in a range of testing environments and by a wide range of people with an interest in the development of safe and non-distracting interfaces The test is designed specifically for a PC-platform and for use in a laboratory environment; however, it could also be implemented in other environments; for example, in conjunction with a vehicle cockpit mock-up or in a driving simulator. The test is not designed to replace existing evaluation tests or more advanced driving simulators, but rather to compliment these by supporting the design process. Indeed, many of the existing surrogate measures can be used in conjunction with the naturalistic driving test, such as visual occlusion goggles, the PDT and the Sternberg method.

***Applicability to real world driving***

Importantly, the test was designed to overcome a number of well-known limitations of existing surrogate driving tests. In particular, it has been designed to provide a more realistic driving environment with expected and unexpected events and tasks that occur in everyday urban driving. It also automatically records the effects of secondary task performance on a number of safety-critical driving performance indicators and provides these results in an easy to use format.

**Driving Scenario Design**

The Naturalistic Driver Distraction Test was programmed using driving simulation software developed by Eca Faros. The test consists of a 6.6km (approx) urban driving environment. The simulated roadway comprises a straight undivided road with two lanes of travel in each direction. The dimensions of the road lanes, road markings and roadside signs match to scale, the dimensions of arterial roads, markings and signs set out in the Australian Standard 1742.1 [6], the Road Design Guidelines Part 3 [7] and the Traffic Engineering Manual Vol. 2 [8]. The simulated drive contains four speed zones, 40 (school zone), 60, 70 and 80 km/h zones. There are four 60 km/h zones, which constitute approximately 3.9km of the drive. There is one 40 km/h school zone, which is about 500 m in length, and one 70 km/h and one 80 km/h zone, each of which are 1.1km in length.

The test drive is divided into 6 separate segments, each 1.1 km in length and containing a signalised intersection in the middle. The number and length of segments was chosen to keep duration of the under 15 min in accordance with guiding principles. The drive segments have been designed so they can be easily re-arranged and placed in any order. This allows multiple configurations of the drive to be designed, minimising the impact of learning effects if multiple trials are conducted. An example design schematic for one drive segment is contained in Figure 1.

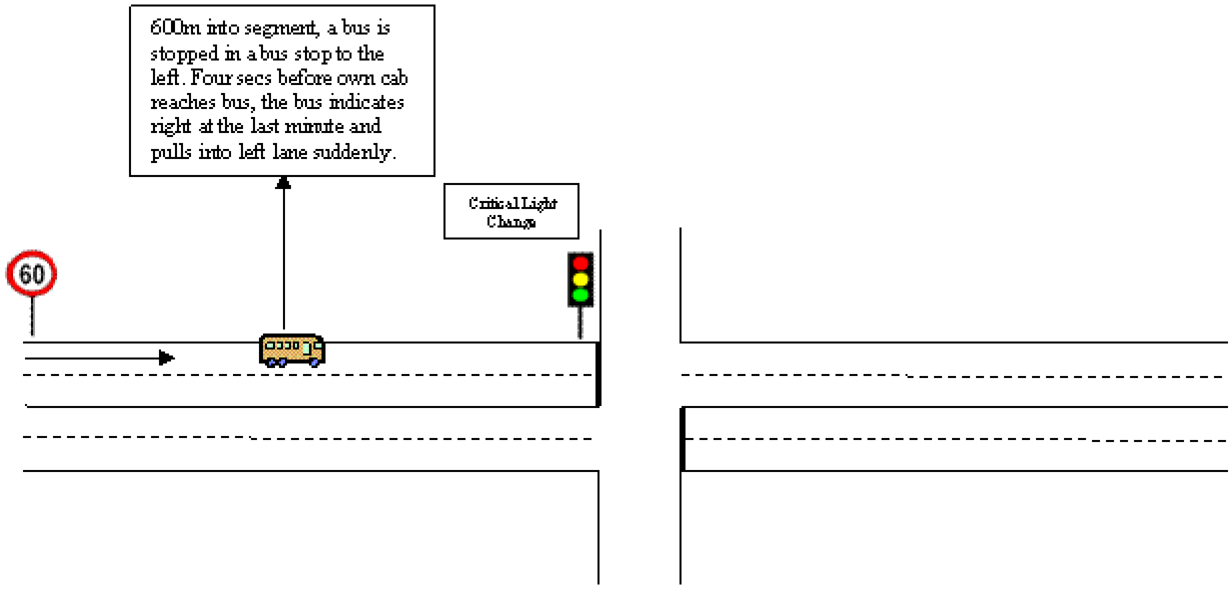


**Figure 1.** Drive segment containing the bus event and a critical light change

Drivers are required to maintain their speed and position on the road using standard vehicle controls including: a steering wheel and foot pedals for braking and acceleration. Start and stop signs are placed at the start and the end of the drive to signify to the driver when the test has commenced and ended. Drivers are instructed to drive in the left lane, unless directed by signs to move into the right lane, and not to pass or overtake other vehicles.

Throughout the drive, drivers encounter a number of expected (e.g. changing traffic lights) and unexpected events (e.g. pedestrians walking onto road or the sudden braking of a lead vehicle). These events are discussed in greater detail in the following section.

**Driving Scenario Events**

Each of the six drive segments outlined above contains a number of expected and unexpected events. A list of the events contained in the test is displayed in Table 1 and a screen shot of the bus event is contained in Figure 2. A number of expected events occur at regular, predictable intervals throughout the drive and are events for which the required course of action is clear to the driver (i.e., adjust speed to new limit, stop at traffic light, follow vehicle at safe distance). There are also unexpected events that occur at irregular intervals throughout the drive. These are critical in nature (i.e., they require a rapid response by the driver) and the type of action required is not always immediately apparent to drivers (e.g., whether they should brake or swerve or accelerate). Both event types were included in the test as expectancy is a critical factor influencing drivers' reaction times [9].

The events contained in the test were selected for a number of reasons. Firstly, they are realistic events of the type that occur in everyday driving; that is, they involve key elements of safe driving and draw upon fundamental psychological constructs including speed and distance perception, hazard detection, perception and response, and gap selection. Secondly, the events include typical crash scenarios (e.g. rear-end and lane change/merge) for which driver distraction has been identified as a common causal factor [10,11]. The third and final reason is that the events are aimed at capturing those driving performance measures that have been shown to be affected by dual-task performance, such as speed-control, reaction-time and car-following behaviour [5]. Importantly, the test-drive contains events experienced by drivers in urban driving environments.

In addition to the expected and unexpected events, the test-drive also contains a number of 'control' events that are similar in nature to the unexpected events, but do not require any evasive action to be taken by the driver (i.e., pedestrians walking on the side of the road, cars waiting to turn from side streets). These control events were intended to reduce the predictability of the measured events, thereby addressing guiding principle 3 - Applicability to real-world driving.

**Table 1.** Events included in each drive segment ('U' denotes an event that is Unexpected, 'E' denotes an Expected event)

| Drive Segment | Event | Description |
|---|---|---|
| **1** | Car following event (E) | Test car catches a slower lead car and follows it for 1km |
| | Lead vehicle braking event (U) | Lead car brakes suddenly at a rate of 5 m/sec$^2$, and turns left down side street |
| | Traffic light change (E) | Traffic light remains green |
| **2** | Critical traffic light change (U) | Traffic lights change from green to amber within the decision dilemma zone |
| **3** | Pedestrian event (U) | Pedestrian on left steps out suddenly onto the road on a collision path with the test vehicle, but then stops and returns to the kerb |
| | Traffic light change (E) | Traffic light changes to green early (100 metres) |
| **4** | Bus event (U) | When the test vehicle is 4 sec away, a bus at a stop indicates right at the last second and pulls into the left lane suddenly |
| | Critical traffic light change (U) | Traffic lights change from green to amber within the decision dilemma zone |
| **5** | Motorcycle event (U) | Motorcycle suddenly turns right out of a side road into the path of the test vehicle without yielding and accelerates off quickly |
| | Critical traffic light change (U) | Traffic lights change from green to amber within the decision dilemma zone |
| **6** | Roadwork (merge right) event (U) | Drivers are warned that the left lane ends (50 m beforehand) and that they have to merge |
| | Gap acceptance event | When turning right drivers are required to select a safe gap in a continuous stream of oncoming vehicles. Every third gap is safe |
| | Traffic light change (E) | Traffic light remains green |

**Figure 2.** Bus event from the driver's perspective.

### Driving Performance Measures

The test automatically records a number of driving performance measures that have been shown to be sensitive to distraction, including measures of speed; Standard Deviation of Lane Position (SDLP); car following distance (time headway); reaction time to expected and unexpected events; response type to these events (e.g. brake, swerve). Specific performance measures have been defined for each event in the test.

## TEST PILOT VALIDATION

As part of the test development process, a pilot validation study was undertaken. This study had three main objectives: to establish that the test worked properly from an operational perspective; to examine its sensitivity to surrogate visual and cognitive tasks of varying complexity; and to compare if the results of the distraction test were consistent with those obtained on another commonly used evaluation tool - the Lane Change Test (LCT). The LCT was used as a comparison test because it has been widely used in IVIS evaluation and produces a range of driving measures that can be compared to those obtained with the distraction test.

## Materials and Methods

### *Participants*

Twenty-seven drivers participated in the study. Sixteen of the participants were male and 11 were female. The mean age for the group was 24.4 yrs (SD = 3.0 yrs). All participants held a valid full drivers license (except one who was still on a probationary license) and the mean age at which they started driving (gained their probationary license) was 19.3 yrs (SD = 2.6 yrs).

### *Driving Tasks*

The driving simulations were run on a desktop PC, using a single 19” LCD monitor. The visual scene included only a forward-view with an integrated rear-view mirror (see Figure 2 above). Participants sat in a height-adjustable chair at a table on which the display and steering-wheel were mounted. The chair and pedals were positioned to approximate those of a real vehicle.

In addition to the Naturalistic Driver Distraction Test, participants also completed trials with the LCT.

#### *Lane Change Test (LCT)*

The LCT [2] is a simple driving simulation comprising a 3,000 metre straight three-lane road. Test participants drive along at a constant system-set speed of 60 km/h. The drivers are instructed with regard to lane-change manoeuvres by 18 signs that appear on each side of the road at regular intervals. The lane-change signs appear every 150 metres, on average. The six possible lane changes that can be made by drivers (e.g. from the middle to left-lane, or from the right to middle-lane) are counterbalanced across trials to avoid learning effects. Drivers are required to complete this test (primary task) while interacting with an in-vehicle device (secondary task).

### *Secondary tasks*

Two surrogate distracter tasks were employed – the Surrogate Reference Task (SuRT) (visual/manual) and mathematical problem-solving, each with two levels of difficulty. Surrogate secondary tasks were used in the current experiment because their difficulty level can be easily manipulated.

#### *Visual secondary task*

The SuRT is a visual-manual task. Participants were required to visually search for the larger target circle among visually similar distracter circles (visual demand) and then select the portion of screen containing the target (manual demand). Two difficulty levels of this task were presented – easy and difficult. The difficulty level was manipulated by varying the size of the distracters so that they were closer in size to the target circle and by increasing the number of selector bars on screen. The visual task was semi self-paced, whereby the participants could take as much time as needed to make their selection, but the software controlled when the next circle display was presented. The SuRT was presented on a laptop which was located on the table to the left of the driver, within 30 degrees (horizontal and vertical) of their normal field of view and within easy reach.

*Cognitive secondary task*

The cognitive task used, the mathematical problem-solving task, involved basic addition and also had two levels of difficulty – easy and hard. Random numbers were read aloud to the participant (through a headset) using DirectRT software. For the easy level, the participant was asked to add 5 to the number and say their response out loud. For the difficult level, participants were required to add 7. The task was semi self-paced, whereby participants were given as much time as needed to respond to each problem (self-paced), however, the system presented the next problem immediately after a response had been given (system-paced).

Errors and response times on the secondary tasks were automatically recorded by the SURT and DirectRT software.

### *Procedure*

The experiment was run over two sessions. Upon arrival at the first session, participants were requested to sign a consent form once it had been established that the explanatory statement had been read and understood, and any questions answered. Participants then completed a brief demographic questionnaire.

The driving (Distraction Test and the Lane Change Test) and secondary (Visual and Cognitive) tasks were explained. Participants were given practice with the secondary tasks and static baseline data were collected for each level of task-difficulty while not driving.

Depending on the counterbalanced order, participants then completed the test-trials using either the Distraction Test or the LCT. Each of these test-trials involved a practice drive and then six trial runs. The six trial runs included two baseline runs (driving only) at the start and end of the trial, and four dual-task runs: visual easy, visual hard, cognitive easy, cognitive hard. In the second session, participants completed the test trials using the driving test that was not used in the first session.

The presentation of the LCT and Distraction Test was counter-balanced across participants, as was the order in which the visual and cognitive secondary tasks were presented.

Before each test drive, participants were given the instruction to: “Please concentrate your attention on driving safely, but do not ignore the secondary tasks”.

## RESULTS AND DISCUSSION

A number of driving performance measures were recorded and analysed for the Naturalistic Driver Distraction Test. The results for a number of these measures were inconclusive and subsequently form the basis for a number of refinements that should improve the validity of the test. Only the results from the Naturalistic Driver Distraction Test will be reported here. Where relevant, reference will be made to how the results compared to those of the LCT. All driving performance measures were analysed using a one-way repeated-measures ANOVA with five levels (baseline, visual easy, visual hard, cognitive easy, cognitive hard).

### *Mean speed*

A one-way ANOVA confirmed that mean speed differed significantly across the five task conditions, $F(3,17)=5.214$, $p<0.01$ (see Figure 1 below). Paired samples t-tests confirmed that with the exception of the ‘visual easy’ versus the baseline condition, all differences in mean speed were statistically significant ($p < .05$). This finding is consistent with previous research, which has demonstrated a tendency for drivers, who are engaged in secondary tasks, to reduce their mean speed [e.g., 12-15]. Such behaviour is thought to be a compensatory response, whereby distracted drivers attempt to lower their overall risk by reducing their speed. As expected, the harder of the distracter tasks, particularly the "visual hard" task, were associated with the lowest mean speeds. This suggests that, as the demands of secondary tasks increase, drivers reduce their speed to compensate.

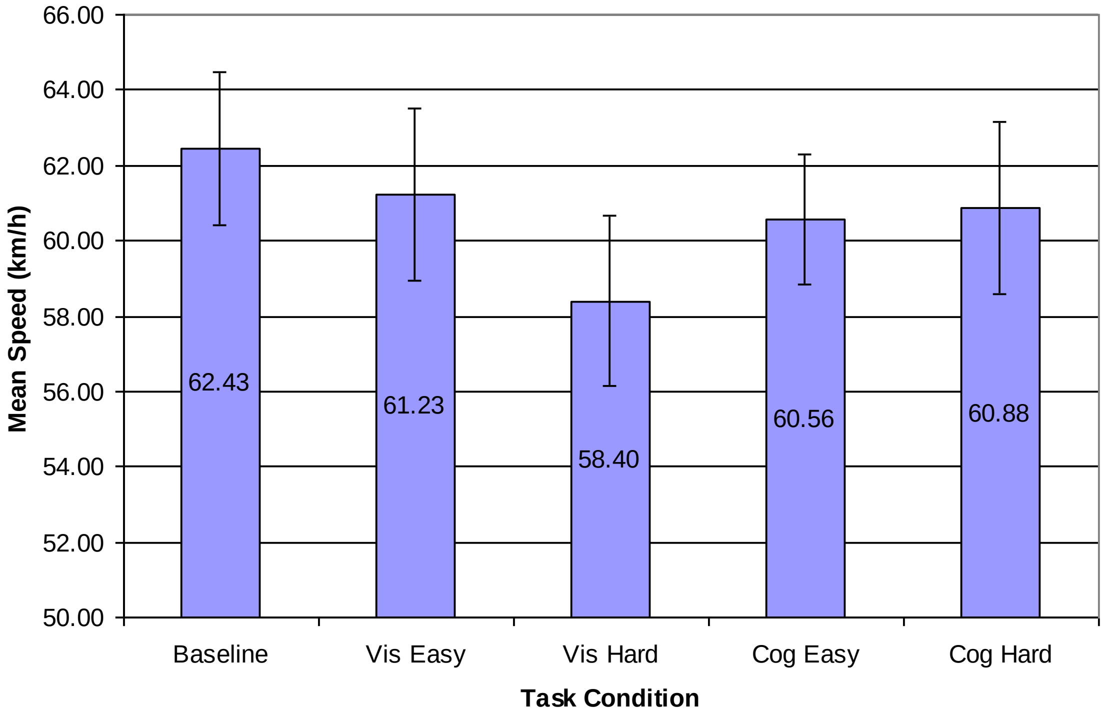


***Figure 1.*** *Mean speed and standard error (bars) for each condition tested using the Naturalistic Driver Distraction Test*

### *Standard deviation of speed*

A similar pattern of behaviour was evident for the standard deviation of speed data, with significant differences evident across task conditions $F(3,52)=5.792$, $p<0.01$. Post-hoc tests revealed that the baseline condition had the highest variability in speed and this was significantly higher than all the dual-task conditions ($p < .05$). Unlike the mean speed, this result is less consistent with past research, which typically shows that speed variability increases when distracted compared to a similar situation where the driver is not distracted [e.g., 13,16]. The statistical significance between these means in the current study is so small, however, that the differences in speed variability are at most only marginal.

### *Standard deviation of lane position*

The standard deviation of lane position (SDLP) results were particularly promising. Significant differences in SDLP were found across task conditions, $F(2,6)=11.14$, $p<0.001$. As seen in Figure 2, SDLP was highest when drivers were performing the visual secondary tasks. This proved significantly higher than both cognitive conditions and the baseline condition ($p<.05$). Furthermore, the 'visual hard' condition was significantly higher than the 'visual easy' condition. This suggests that the more demanding the visual task, the greater the effect on drivers' lateral control. The standard deviations of lane-position for the two cognitive tasks were not significantly different to the baseline condition, suggesting that the cognitive secondary tasks had little or no effect on drivers' ability to maintain their lateral position on the road. The SDLP data from the distraction test were similar in terms of the pattern and direction of changes to those of the mean lane deviation results obtained with the LCT. The results also are consistent with past research in this area. Specifically, a number of research studies have shown that cognitive secondary tasks have little effect on lane-keeping ability and that moderate levels of cognitive load can even lead to more precise lateral control, by reducing lane-position variation. Visual load, in contrast, has been shown to increase lane keeping variation [17,18].

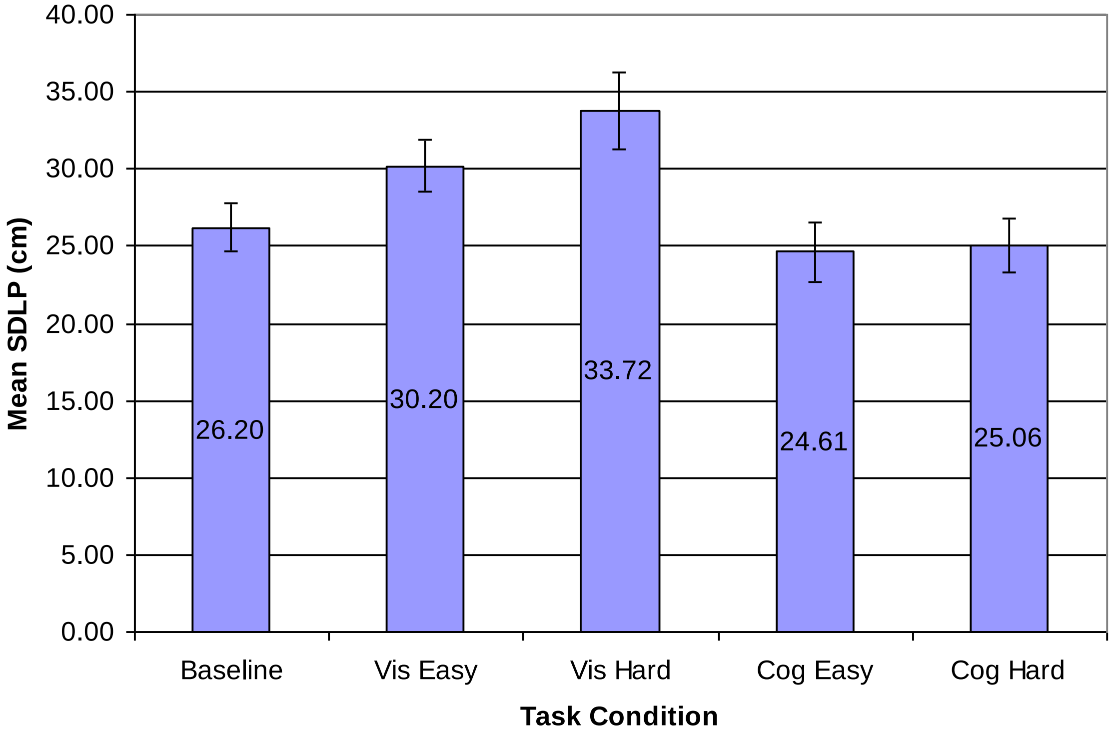


***Figure 2**. Mean SDLP and standard error (bars) for each condition tested using the Naturalistic Driver Distraction Test*

### *Mean number of lane excursions*

A similar pattern of results were found when examining the mean number of lane-excursions, as shown in Figure 3 below. The number of lane excursions (where any part of the vehicle was outside the correct lane) made differed significantly across task conditions, $F(2, 11)=12.85$, $p<0.001$. The highest number of lane-excursions was found in the two visual conditions, which were significantly higher than both cognitive conditions and the baseline condition ($p<.001$).

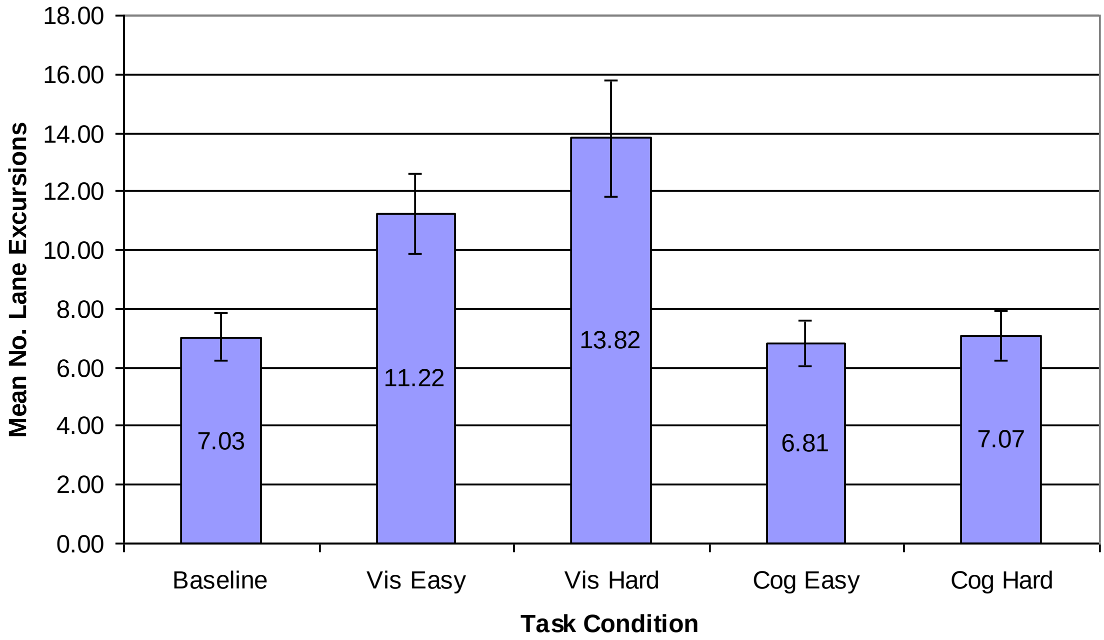


***Figure 3.*** *Mean number of lane excursions and standard error (bars) for each condition tested using the Naturalistic Driver Distraction Test*

### *Brake reaction time to unexpected events*

Drivers' reaction-times to four of the unexpected events (bus, lead vehicle, pedestrian and motorcycle) were investigated across the driving conditions. The results were inconclusive, with no significant differences in mean brake reaction-time to the motorcycle, pedestrian or lead braking-vehicle events found across the baseline and the four dual-task conditions. A significant difference in reaction time was found for the bus event ($F(4,80)=5.76$, $p<0.001$), whereby reaction-time was significantly slower in the baseline condition than all other conditions ($p<.010$). These results are not consistent with previous research: Previous findings have found that reaction times to events occurring in the periphery are increased when drivers are distracted, [15,19,20].

## CONCLUSIONS

The Naturalistic Driver Distraction Test was designed to incorporate a variety of different scenarios that are realistic and likely to occur in everyday real-world driving. Furthermore, many of these scenarios are known to be associated with distraction-related crashes. The driving performance measures captured by the Distraction Test are known to be affected by dual-task performance, such as speed-control, reaction-time and car-following behaviour.

Overall, the pilot validation study shows very promising results. In many cases these results corroborate previous research findings and theories, particularly the findings relating to measures of speed and lateral control. The findings were also consistent with those obtained with the established Lane Change Test, with many of the driving measures obtained with the two tests showing a similar direction and magnitude of change across the baseline and dual-task conditions. Importantly, this suggests that the Distraction Test is sensitive to the different effects of visual and cognitive distraction, as well as secondary tasks that vary in their level of demand. There are, however, a number of refinements that need to be made in order to improve the validity of the test, particularly in relation to the reaction time measures. The suggested refinements include: the use of three display screens to increase the field of view and improve the presentation of the unexpected events and tasks such as gap-acceptance; and, reprogramming the traffic-light phases so that the amber light is triggered at a more critical point for the driver when in the decision dilemma-zone. Further work with the test should focus on determining how these refinements affect the validity of the Distraction Test, but also on how the test performs with real IVIS tasks rather the surrogate tasks used in this study. Further work is also needed to examine if the test offers greater functionality and sensitivity to distraction than the current surrogate measures.

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## REFERENCES

1. Young, K.L., Regan, M., and Hammer, M., (2003), *Driver distraction: A review of the literature*. Monash University Accident Research Centre, Clayton, Victoria.
2. Mattes, S., and Hallen, A. (2008). Surrogate distraction measurement techniques: The Lane Change Test. In Regan, M. Lee, J.D., & Young, K.L. (Eds.). Driver distraction: theory, effects and mitigation. Broca Raton: CRC Press.
3. Foley, J.P. (2008). Now you see it, now you don't: Visual occlusion as a surrogate distraction measurement technique. In Regan, M. Lee, J.D., & Young, K.L. (Eds.). Driver distraction: theory, effects and mitigation. Broca Raton: CRC Press.
4. Victor, T.W., Engström, J., and Harbluk, J.L. (2008). Distraction Assessment methods based on visual behaviour and event detection. In Regan, M. Lee, J.D., & Young, K.L. (Eds.). Driver distraction: theory, effects and mitigation. Broca Raton: CRC Press.
5. Young, K.L., Regan, M., and Lee, J.D. (2008). Measuring the effects of driver distraction; direct driving performance methods and measures. In Regan, M. Lee, J.D., & Young, K.L. (Eds.). Driver distraction: theory, effects and mitigation. Broca Raton: CRC Press.
6. Standards Australia, (2003), Manual of uniform traffic control devices. Part 1: General introduction and index of signs. Standards Australia International, Sydney, Australia
7. VicRoads, (2002), Road Design Guidelines Part 3. Cross Section Elements. VicRoads, Kew, Victoria
8. VicRoads, (2006), Traffic Engineering Manual Volume 2. Signs and markings. VicRoads, Traffic and Transport Integration Department, Kew, Victoria
9. Evans, L. (2004). *Traffic Safety.* Science Serving Society, Bloomfield Hills, MI.

10. Eby, D.W, and Kostynuik, L.P. (2004). Crashes and driver distraction: A review of databases, crash scenarios, and distracted-driving scenarios. Deliverable 1. SAVE-IT Project.

11. Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D., and Ramsey, D. J. (2006). *The impact of driver inattention on near-crash/crash risk: an analysis using the 100-Car Naturalistic Driving Study data.* Virginia Tech Transportation Institute, Blacksburg, Virginia.

12. Briem, V., Hedman, L. R. (1995). Behavioural effects of mobile telephone use during simulated driving. *Ergonomics* 38, 2536-2562.

13. Burns, P. C., Parkes, A., Burton, S., Smith, R. K., and Burch, D. (2002). *How dangerous is driving with a mobile phone? Benchmarking the impairment to alcohol*. TRL Limited.

14. Rakauskas, M.E., Gugerty, L.J., and Ward, N.J. (2004). Effects of naturalistic cell phone conversation on driving performance. *Journal of Safety Research, 35,* 453-464.

15. Tornos, J.E.B., and Bolling, A.K. (2005). Mobile phone use – Effects of hand-held and hands-free phones on driving performance. *Accident Analysis and Prevention, 37,* 902-909.

16. Green, P., Hoekstra, E., and Williams, M. (1993). *On-the-road tests of driver interfaces: Examination of a route guidance system and a car phone*. University of Michigan Transport Research Institute, Washington, D.C.

17. Engstrom, J., Johansson, E., and Ostlund, J. (2005). Effects of visual and cognitive load in real and simulated motorway driving. *Transportation Research Part F, 8,* 97-120.

18. Greenberg, J., Tijerina, L., Curry, R., Artz, B., Cathey, L., Grant, P., Kochlar, D., Kozak, K., and Blommer, M. (2003). Evaluation of driver distraction using an event detection paradigm. *Journal of the Transportation Research Board* No 1843.

19. Langer, P., Holzner, B., Magnet, W., and Kopp, M. (2005). Hands-free mobile phone conversation impairs peripheral visual system to an extent comparable to an alcohol level of 4-5g 100ml. *Human Psychopharmacology* 20, 65-66.

20. Patten, C.J.D., Kircher, A., Ostlund, J., and Nilsson, L. (2004). Using mobile telephones: Cognitive workload and attention resource allocation. *Accident, Analysis and Prevention, 36,* 341-350.