Influence of Cue Utilisation and Driver Distraction on Performance in a Driving Simulator

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Abstract

Driver distraction is a significant road safety concern, especially with the increasing prevalence of mobile phone engagement while driving. Various individual differences may predict the extent to which individuals' are effected distraction. Cue utilisation, which is the capacity to extract and apply task relevant cues to make cognitive judgements about a situation, is one individual difference that has not been considered in this context. This study assesses the relationship between cue utilisation and the ability to manage distraction within a simulated driving context. Thirty-five qualified drivers completed an online assessment of cue utilisation within a driving context, and a simulated driving task involving two scenarios. During the 'no distraction' scenario, participants navigated an urban area complying with Australian road rules. During the 'distraction' scenario, participants drove a comparable route and in addition, read and verbally responded to a series of text messages. For each scenario, driving performance and perceived cognitive workload was measured. Results demonstrated that greater cue utilisation capacity was not associated with superior driving performance, but was associated with a higher perceived cognitive workload in the absence of a distraction. The outcomes of this study contribute to knowledge of driver distraction and its relationship with cue utilisation.

Declaration

This thesis contains no material which has been accepted for the award of any other degree of diploma in any University, and, to the best of my knowledge, this thesis contains no material previously published except where due reference is made. I give permission for the digital version of this thesis to be made available on the web, via the University of Adelaide's digital thesis repository, the Library Search and through web search engines, unless permission has been granted by the School to restrict access for a period of time.

Signature: Date: 01/10/2019

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Contribution to Project

The design and development of this study was a collaborative process between the supervisor and the student. However, the design of the individual driving and distraction tasks, as well as the data collection (for the main study and associated manipulation checks) were undertaken by the student.

Influence of Cue Utilisation and Driver Distraction on Performance in a Driving Simulation

Introduction

Driver distraction is a significant road safety concern, especially with the technologically advanced motor vehicles currently available that make it easier for drivers to engage in non-driving related activities (Ma & Kaber, 2005). Driver distraction has been defined as “the diversion of attention away from activities critical for safe driving towards a competing activity” (Lee, Young, & Regan, 2008, p. 31). With less attention being directed towards driving, the likelihood of driver error and corresponding road accidents increase (Ma & Kaber, 2005), for all road users.

The consequences of driving while engaged in secondary, distracting tasks (such as speaking on a mobile phone) can be innocuous (such as missing the intended exit from a freeway) or more severe (such as a collision; Young & Salmon, 2012). The ways in which performance is effected include, but are not limited to, longitudinal (Strayer & Drews, 2004) and lateral control (Reed & Green, 1999), reduced situational awareness (Lee & Strayer, 2004; Young, Salmon & Cornelissen, 2013), and diminished reaction time (Burns et al., 2002). In their review of the effects of driver distraction in Australia, Young and Salmon (2012) found that driver distraction, unsurprisingly, increased chances of driver error, with the indication that participation in a secondary task was a contributing factor in approximately 23% of road accidents or near-accidents resulting from driver error. Even devices which have been specifically designed for use while driving, have shown to pose a threat to driver safety which is at least as great as engaging in activities that have not been adapted (Chisholm, Caird & Lockhart, 2008; Hosking, Young & Regan, 2009; Tsimhonit, Smith & Green, 2004).

Various activities that are often a source of distraction while driving have been identified in the literature and their impact on driving performance assessed. Due to the proliferation of mobile phone use when driving, there has been considerable attention given to its impact. For example, Consiglio, Driscoll, Witte and Berg (2003) conducted a simulated driving experiment which found that drivers' breaking response was negatively affected by mobile phone use. Similarly, it was found that drivers undertaking a visual distraction task were more likely to make errors when than drivers' who are not engaging in a distraction (Young, Salmon & Cornelissen, 2013). The impact of mobile phone use on driver performance overall is a consistent finding in the literature and highlights the numerous consequences which can result from mobile phone use (e.g., Alm & Nilsson, 1994; Jin, Xian, Niu & Bie, 2015; Yekhshatyan, 2010), therefore emphasising that this use has a significant effect on the performance of drivers across circumstances.

Mobile phone use represents much of distraction on the roads, however, there are various aspects of this use that can be distracting. A substantial portion of the driver distraction literature examining mobile phone use, has focused on the effects of phone calls made and received during driving (Horberry et al., 2006). These studies have shown making and receiving phone calls leads to decreased overall performance resulting from decreased reaction time (Haigney, Taylor & Westerman, 2000). It has also been found that individuals demonstrate a decrease in speed and a resulting increased margin for error in their driving, in order to participate in a phone conversation (Horberry et al., 2006).

However, Caird, Johnston, Willness, Asbridge and Steel (2014) proposed that sending and receiving text messages while driving could be more of a distraction than talking on the phone in the same context. Similarly, Hosking, Young and Regan (2009) investigated the effects of sending and retrieving text messages on driving performance, particularly for young novice drivers. They found that the time spent looking away from the road while text messaging was approximately 400% greater than when not text messaging. Additionally, Hosking et al. (2009) reported an increase in variability in lane position of up to approximately 50%, a missed lane change increase by 140%, and a lead vehicle following distance increase by up to approximately 150% when participants were engaged in text messages while driving. Even simply having a phone present or expecting a text message has been found to be a distraction, in that drivers are likely to glance towards or check the phone consistently (Caird et al., 2014).

Another aspect of mobile phone use that causes distraction is the use of hand-held or hands-free devices. While hands-free devices are often marketed as being much safer than hand-held devices (Virginia Tech, 2019), research suggests that the two approaches may both be similarly detrimental to driver performance. Burns et al. (2002) found that using a hand-held mobile phone while driving resulted in a 50% slower response to hazards than when not in use. Haigney et al. (2000) demonstrated that hands-free mobile phone use resulted in significant negative effects on driving performance. Therefore, it is clear that almost all tasks associated with a mobile phone while driving (making or receiving a call, sending or receiving text messages, reading text messages, or simply glancing at your phone) result in detrimental effects on driver performance.

While the previous literature discussed highlights the objective performance effects of engaging in mobile phone use, drivers have reported that their perception of subjective workload differs across distraction tasks, with mobile phone use being one of the top influences on increased subjective workload. Hornberry et al. (2006) conducted a study to examine the effects of concurrent in-vehicle tasks on driver distraction, performance and perceptions of workload. Significant differences were found for both objective performance and subjective workload, with the no distraction condition reporting the lowest subjective workload rating and recording the highest performance scores, followed by the mobile phone distraction (Hornberry et al., 2006). Therefore, suggesting that performing coinciding in-vehicle tasks can degrade performance, likely as a result of an increase in cognitive workload.

Working memory is the system which temporarily stores and uses information obtained in connection with cognitive tasks (Miller, 1956). It has the capacity to hold four (plus or minus two) pieces, or ‘chucks’ of information at a time (Cowan, 2001) and as such, is a finite resource. Workload, defined as the association between the resources required to execute a task and the resources available to the individual undertaking the task (Spector & Jex, 1998), is measured on a continuum of high to low. A low workload task is characterised by a demand for fewer cognitive resources, while a high workload task requires most, if not all of an individual’s cognitive resources (Spencer & Jex, 1998). It has been shown that when an individual attempts to engage in too many activities simultaneously, or a single task is of a high workload, there is a risk that the tasks will exceed the number of cognitive resources available in working memory. As a result, we struggle to allocate our resources and inevitably end up dedicating more resources to one task over another, either the primary or secondary task (Nicholson et al., 2009). Therefore, when engaging in activities that requiring the use of more cognitive resources than are available, performance is likely to be affected. For example, when first learning to drive, the task is cognitively challenging as the skill has only just development. A novice driver may find it challenging to engage in a conversation and drive simultaneously, as it exceeds the limit of their cognitive resources. However, after the driver’s skills develop, engaging in a conversation and driving simultaneously becomes easier as driving will require fewer resources as proficiency increases.

The extent to which distraction tasks result in the degradation of performance is dependent upon several factors, including the demands of the driving task, the demands of the distraction task or distractor, the process of resource allocation between the two tasks, the type of attentional resources required, individual differences, and the time of exposure (Drews, Yazdani, Godfrey, Cooper, & Strayer, 2009; Lerner, Singer & Huey, 2008). While there are many forms that driver distraction can take, a distraction typically consists of some combination of visual, verbal, motor and cognitive requirements, most of which are also required to complete the primary task of driving (Drews, Yazdani, Godfrey, Cooper, & Strayer, 2009). The extent of a distraction's effect on driving performance is a result of which of these types of resources are required by the task.

The impact of text messaging on driving has been found to be much greater than the impact of taking a phone call. Arguably, this is a result of differences in the attentional resources that are required for both tasks. Specifically, text messaging utilises motor, visual and cognitive resources, while a hands free phone call only requires verbal and cognitive resources (Drews et al., 2009). Further, engaging in text message interactions while driving is a dual-task combination which requires the concurrent performance of two independently performed tasks, each with distinct and separate objectives. This likely results in less resources available for each task and consequent diminished performance (McIsaac, Lamberg & Muratori, 2015). In some cases the secondary task, for example receiving a text message, is unexpected and is a momentary interruption to the primary task; driving, increasing cognitive demand as attention is shifted from the primary task to the new stimuli. In this context, the interruption acts as a disruption to attention and the cognitive resource allocation process, as it, at least momentarily, requires the individual to establish what has drawn their attention away from the primary task, before cognitive resources can be reallocated (Plummer, Grewal, Najafi & Ballard, 2015).

The impact of distraction on performance and subjective workload varies, but individual differences, such as experience, age and familiarly, might be predictive of this impact. One such difference is cue utilisation, which has yet to be explored in this context. Conceptually, cues are thought to be associations which exist between environmental features and events within long term memory (LTM; Brunswik, 1955), allowing for the rapid retrieval of information from Long Term Memory (LTM) to working memory. Almost all behaviours will require environmental cues to be selected and processed accordingly. For example, when driving, seeing the brake lights of a car is the feature, and the associated knowledge that the car is going to slow down and stop is the event. These associations are formed on the basis of experience or deliberate practice, wherein the repeated pairings of features and events in the environment strengthens the relationship within the LTM. Once cues have been integrated in LTM, their function is to simplify the navigation of complex situations and occurrences by directing attentional resources towards the necessary aspects of the situation, and advocate appropriate responses based on past experience. As a result, rapid decisions can occur as the associations are nonconsciously retrieved from LTM automatically. Subsequently, as experience develops in a specific domain (e.g., driving) individuals develop an extensive and nuanced network of cues pertaining to different events. This allows them to respond quickly to situations as they can match current situations to previously experienced ones in LTM, and the extent to which we effectively use cues predicts how many resources we have available to manage potential distractions.

The capacity to apply domain specific associations in the form of cues, is referred to as cue utilisation (Wiggins, Brouwers, Davies & Loveday, 2014). A high capacity for cue utilisation allows the individual to access information stored in their LTM, freeing up their working memory for potential distractions or unexpected changes (Falkland, Wiggins, & Westbrook, 2019). Cue utilisation from this broad perspective is involved in all information processing experiences (Olson, 1978).

The process of cue utilisation can be understood through Brunswik’s (1955) Lens Model (Figure 1). In this model, cues are depicted as a mediating factor between the actual situation (e.g., a car about to stop) and the perceived situation on the part of the individual (e.g., the car is not going to stop). The individual perceives the situation based on their present environmental cues (e.g., a green light ahead and steady traffic flow, indicating the car will continue on). Some cues used may be more or less diagnostic of the situation. It proposes that the determination of which cues are activated and have influence on behaviour is a result of the similarities between the current environment and features stored in memory. Therefore, the main premise of the Brunswik's Lens model is that cues are used to assess a situation, and the these cues are selected on the basis of past experience and as a result may vary in how predictive they are of the present situation.

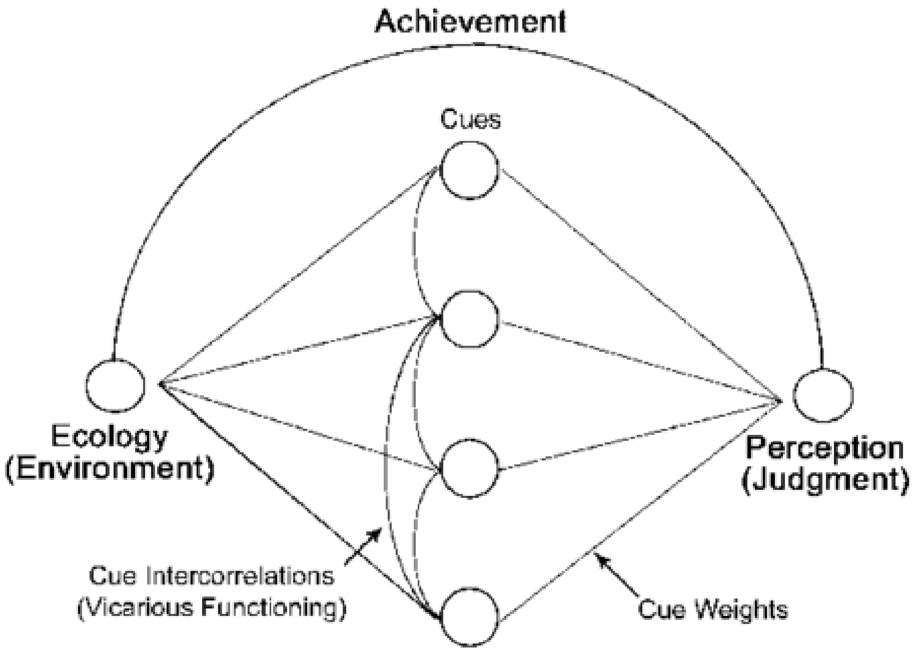

Figure 1. Brunswik's Lens Model (modified; Wigton, 2008).

Cue utilisation has been associated with superior performance based on the presumption that it reduces the cognitive demands placed on working memory (Ericsson & Kintsh, 1995). Consequently, it can be suggested that performance of those demonstrating a greater capacity for cue utilisation would be to a higher standard than that of individuals demonstrating a lesser capacity for cue utilisation. Through their experiments determining the effects of cue utilisation capacity on a novel rail control task, Brouwers et al. (2016) demonstrated that participants with a higher cue utilisation ability were faster in their performance, even when asked to completed a secondary task. Therefore, an examination of the relationship between cue utilisation and performance on other specialised tasks, may help to further develop the understanding of how cue utilisation influences the process of completing a task, the resulting performance and the influence of various individual differences.

The retention of domain-specific associations in long-term memory has been found to be associated with decreases in cognitive load. Greater cue utilisation capacity, specifically in relation to the utilisation of domain-specific cues, could therefore account for a lower subjective workload (Wiggins et al., 2017). Patten et al. (2006) suggested that reductions in cognitive load increase the number of residual resources available, therefore enabling these attentional resources to be directed at secondary tasks. Reductions in cognitive load when completing a high workload task, are thus likely to be the result of the use of cues, a largely nonconscious and automatic process. Consequently, consistent with Patten et al.'s (2006) proposition, the use of cues reduces cognitive load and frees up working memory so that additional tasks can be completed if needed. Therefore, theoretically, those with a greater capacity for cue utilisation within the domain of driving, would arguably be able to manage distractions better than those with a lesser cue utilisation capacity, due to the availability of cognitive resources.

A previous study investigated the relationship between cue utilisation and distraction on a low workload task and examined whether distractions, when presented during a low workload environment, impact novel task performance, as a function of cue utilisation capacity (Trigg, 2016). It was found that there was no significant difference in performance between the distraction and no distraction conditions, as well as between the performance of participants with higher or lower cue utilisation capacities (Trigg, 2016). It could be argued that the use of a low workload task might explain why differences were not found between cue utilisation levels, distraction and performance on the novel task. Therefore, while there was no difference found in a low workload task paired with a distraction between individuals with a greater capacity for cue utilisation and individuals with a lesser capacity for cue utilisation, it could be argued that there would be a difference in a high workload task requiring the use of more cognitive resources and thus forcing participants to retrieve cue association from their LTM when available.

In contrast, there is only one study that has addressed the relationship between cue utilisation and performance in other high workload contexts. Falkland, Wiggins and Westbrook (2019) conducted a study examining the role of cue utilisation in the management of interruption during a high workload task (a train control simulation). Their study was based on the theory that interruptions are deleterious to performance due to the imposition of cognitive demands that they have on the limited resources of working memory (Klingberg, 2000). It was demonstrated that participants with lower levels of cue utilisation demonstrated a greater decline in performance following exposure to interruptions, while participants with higher levels of cue utilisation maintained a comparable performance standard. Arguably, this result could be explained by participants with lower levels of cue utilisation having less cognitive resources available to dedicate to the interruptions. Falkland, Wiggins and Westbook (2019) also note that the detrimental impact of interruptions appears to be a result of the nature of the activity engaged in during the distraction, rather than distraction from the primary task itself. As driving is arguably a higher workload task in comparison to the train control simulation employed in Falkland et al. (2019), it could be postulated that a similar association may be found between cue utilisation and driver distraction, however the cues utilised vary and therefore the relationship needs to be investigated.

The Current Study. This study aimed to determine whether a relationship exists between cue utilisation capacity and distraction, when looking at performance on a simulated driving task. It looked to determine whether an individual’s capacity for cue utilisation impacts the extent to which they are distracted by the use of a mobile phone during a simulated driving task. It was hypothesised that participants will demonstrate superior driving performance during a simulated driving scenario completed in the absence of a mobile phone based distraction, compared to a comparative simulated driving scenario paired with a mobile phone based distraction (H1). Further, it was hypothesised that participants will demonstrated a greater perceived cognitive workload during a simulated driving scenario in the absence of a distraction, compared to a relative simulated driving task paired with a mobile phone based distraction task (H2).

It was hypothesised that participants with a greater cue utilisation capacity will perform better on a simulated driving task in the absence of a mobile phone-based distraction task, compared to participants with a lower cue utilisation capacity (H3). Furthermore, it was hypothesised that participants with a greater cue utilisation capacity will demonstrate superior performance on a simulated driving task when completing a simultaneous distraction task, compared to participants with a lesser cue utilisation capacity (H4).

It was hypothesised that participants with a greater capacity for cue utilisation will perceive the simulated driving task in the absence of a mobile phone-based distraction to be of a lower cognitive workload than participants with a relatively lesser capacity for cue utilisation (H5). Finally, it was hypothesised that participants with greater cue utilisation capacities will report the simultaneous driving and distraction tasks as requiring a lower mental workload compared to those with lesser cue utilisation capacities (H6).

2. Method

2.1. Design

This study comprised a 2 (Cue Utilisation Typology: Greater, Lesser) x2 (Driving Scenario: Distraction, No Distraction) mixed design, with cue utilisation typology as the between-groups variable and distraction as the within-groups variable. Participants were classified with either higher or lower cue utilisation based on an assessment of cue utilisation

(EXPERTise 2.0) within the domain of driving. The distraction scenario required participants to engage in a secondary task while completing the simulated driving task, as opposed to the 'no distraction' scenario which was completed in the absence of a distraction task. Performance on the simulated driving tasks and a subjective measure of cognitive workload (NASA-TLX) were the dependent variables for the analyses.

2.2. Participants

Participants comprised 34 students and members of the general public who were recruited from the University of Adelaide's online participant recruitment system (SONA) and through snowball and convenience sampling, respectively. Participants were predominately female (58.8%), ranged in age from 18 to 25 years (M = 21.03, SD = 2.69), and their driving experience ranged from 2 to 108 months (M = 43.72, SD = 26.05). All participants held an Australian Drivers Licence, were fluent in English and had normal or corrected-to-normal vision. Participants were also required to be under the age of 25 with a maximum of 9 years driving experience to control for exposure to driving which enabled comparative assessments of cue utilisation (Brouwers, Wiggins, & Griffin, 2018; Sturman, Wiggins, Auton, & Loft, 2019). While an exclusion criterion included any previous experience with the Simworx SX06DTS driving simulator, no participants reported such experience, and therefore, no participants were excluded from the analyses.

2.3. Materials

2.3.1. Driving Performance Task. The simulated driving scenarios (distraction, no distraction) were performed using the Simworx SX06DTS driving simulator which is equipped with a steering wheel, brake, accelerator and indicator set in front of three 24-inch computer screens (Figure 3). The simulator contains a bank of scenarios aimed at teaching novice drivers new driving skills, and these scenarios have been shown to be an accurate representation of real-world driving and its requirements (Simworx, 2013). However, one limitation of using the

Simworx driving simulator was that it does not possess to capability to manually create driving scenarios.

Figure 2. SIMWORX SX06DTS Driving Simulator

During the driving performance task, participants were required to complete two scenarios (one which was completed in the absence of a distraction task, one which was paired with a distraction task). These two driving scenarios were selected from the simulator's task battery. It was critical that the two scenarios selected were comparative in difficulty to ensure that any differences in performance between the 'no distraction' and 'distraction' scenarios could be attributed to the distraction manipulation, rather than the difficulty of the scenario itself. To establish this, a manipulation check was conducted which is described in section 2.3.1.3.

The first scenario (which was completed with 'no distraction') required participants to navigate an urban area fitted with road-related encounters, such as traffic, pedestrians, intersections and signage (see Figure 4). Adhering to the road rules, the scenario took approximately 8 minutes to complete. The second scenario (which was paired with a 'distraction' task) selected was comparative to the first in performance requirements and completion time, however it differed in appearance (see Figure 5). For both driving scenario, participants were instructed to comply with the instructions provided by the simulator's in-built navigation system which guided them around a moderately trafficked area, using visual and verbal directions, for approximately eight minutes.

Participants completed the first simulated driving scenario in the absence of a distraction. In contrast, the second simulated scenario was completed at the same time as a distraction task (described in section 2.3.1.2). To ensure that the distraction task devised sufficiently limited participants' cognitive resources and simulated a plausible real-world distraction, without extinguishing the participants ability to undertake the driving task, a second manipulation check was undertaken.

Figure 3. Screen shot depicting part of the 'no distraction' scenario

Figure 4. Screen shot depicting part of the 'distraction' scenario

2.3.1.2. Distraction Task. As mobile phones are a very common form of driver distraction, the distraction task utilised a mobile phone to receive text messages. Participants were instructed that during this driving scenario, they would be receiving sporadic text messages on an iPhone 6s that was placed in a cradle at the top of the middle screen. They were not told how frequently or at what intervals these messages would arrive. Participants were told that when they heard (via an audible message tone) or saw (via the mounted iPhone) a message arrive, they must immediately read and respond to the message verbally to the researcher.

Within this eight minute driving scenario, there were seven text messages sent to participants, each consisting of a short question (such as 'What day of the week is it?' see Appendix A for the full list) presented at one-minute intervals throughout the simulated driving module (Figure 6). The questions were modelled after those used in a study on driver distraction and performance by Hosking, Young and Regan (2009). These researchers found this style of questions to be an effective and representative distraction utilising a range of mental resources, including perceptual, cognitive and verbal, all of which are required for driving.

Figure 5. iPhone mounted on the Simworx Driving Simulator for use during the distraction task

2.3.1.3. Manipulation Check for Scenario Comparability. This manipulation check was undertaken to ensure any performance differences between the ‘distraction’ and ‘no distraction’ scenarios was attributable to the distraction manipulation, and not variances in the scenarios. Six South Australian drivers licence holders participated in the manipulation check. The sample was primarily female (83.3%), comprised individuals between 18 and 25 years of age (M = 22, SD = 1.63), and were all fluent in English. Participants were asked to complete three Simworx simulated driving scenarios; a belief practice scenario to familiarise themselves with the simulator (approximately 6 minutes), followed by the two driving scenarios under comparison, and without distraction. After the completion of each scenario, participants were asked to complete the NASA-TLX as a measure of subject workload pertaining to each scenario. The two driving scenarios were presented to participants in a counterbalanced order to account for practice effects, and the manipulation check took participants approximately 30 minutes each.

For the simulated driving tasks, scores of performance on various sub-categories, including speed control, priority, signs, lane position and steering, were collated to create an overall driving performance score. For the NASA-TLX, ratings of perceived cognitive workload on seven levels for each scenario were aggregated to create a mean rating of perceived cognitive workload.

To compare objective driving performance between the two scenarios, a dependent samples *t*-test was run with overall performance on each driving scenario as the dependent variable. On average, there was no significant difference in driving performance on the first scenario (M = 7.39, SE = 0.67) when compared to the second scenario (M = 7.78, SE = 0.79), $t(5)$ = 0.36, p = 0.731, r = 0.16. While there were no objective performance differences between the two driving scenarios, a second dependent samples t-test was run with scores on NASA TLX for each scenario to examine whether the two scenarios differed in perceived cognitive difficultly. On average, there was no significant difference between perceived cognitive workload for the first scenario (M = 3.97, SE = 0.43) and the second scenario (M = 3.28, SE = 0.39), $t(5)$ = -1.99, p = 0.103, r = 0.67.

Taken in combination, these results suggest that the two driving scenarios selected were of comparable difficulty since there were no objective performance differences between the scenarios nor were they reported by participants as being subjectively different in mental workload. Therefore, one scenario was arbitrarily selected to be paired with a distraction task, where any performance differences could be confidently attributed to the distraction task rather than differences between the two scenarios.

2.3.1.4. Manipulation Check for Distraction Task. This manipulation check was required to confirm that the devised distraction task was sufficiently limiting on participants' cognitive resources. Five South Australian drivers licence holders participated in this manipulation check. All were proficient English speakers between the ages of 18 and 25 (M = 20.2, SD = 1.47) and the sample was predominantly female (60%). No participants who participated in the first manipulation check were allowed to participate in this manipulation check.

Participants were required to complete the two driving scenarios, which were previously established to be of equal difficulty. One had been arbitrarily selected to be completed in conjunction with the distraction task (here forth referred to as the ‘distraction’ scenario) and one was to be completed without a secondary task (here forth referred to as the ‘no distraction’ scenario). The order of the scenarios was counterbalanced between individuals to ensure that any performance differences between the scenarios was due to the relative difficulty of the distraction task, rather than the order of presentation. Following each scenario, participants were asked to complete the NASA-TLX as a measure of cognitive workload. In total, manipulation took approximately 30 minutes per participant.

Following the same procedure reported in the first manipulation check, overall performance scores for each driving scenario were created based on performance in various sub-categories, including speed control, priority, signs, lane position and steering. Mean NASA-TLX scores combined to create a mean rating of perceived cognitive workload for each scenario.

A dependent samples *t*-test with overall driving performance on each driving scenario (distraction, no distraction) as the dependent variable was run to compare driving performance between the two scenarios. On average, it was found that participants performed significantly poorer during the distraction scenario ($M = 5.00$, $SE = 1.35$) compared to the no distraction scenario ($M = 8.80$, $SE = 0.12$), $t(4) = -2.78$, $p = 0.05$, r = 0.81. A second dependent samples t-test was run with scores on NASA-TLX for each scenario to examine whether there were any differences in perceived cognitive difficultly. On average, participants reported significantly higher cognitive workload during the distraction scenario ($M = 3.59$, $SE = 0.33$) compared to the no distraction scenario ($M = 2.93$, $SE = 0.36$), $t(4) = 4.04$, $p = 0.016$, r = 0.89). In combination, these results demonstrate that objective performance and subjective workload were worse in the ‘distraction’ scenario when compared to the ‘no distraction’ scenario.

Therefore, it can be assumption that the distraction task substantially restricts the cognitive and visual resources required by the driving simulation, without outweighing the task completely.

2.3.2. Demographic Questionnaire. Participants were asked to complete a series of demographic questions indicating their age, gender, driving experience and driving simulator experience (see Appendix B).

2.3.3. NASA Task Load Index (NASA-TLX). The NASA-TLX is a multi-dimensional rating assessment which measures an individual's perceived cognitive workload of a task based on the average rating of six sub-scales; Mental Demands, Physical Demands, Temporal Demands, Perceived Performance, Effort and Frustration, measured on a 7-point Likert scale, from 1 (*Very Low Demand*) to 7 (*Very High Demand*) (NASA, 1986). The NASA-TLX has been assessed in a number of experimental tasks, including stimulated flight tasks, supervisory control simulations and laboratory-based tasks (Wierwille, 1984; Hauser, Childress & Hart, 1983). The Index has shown to have substantially less inter-rater variability than unidimensional workload rating scales (NASA, 1986).

2.3.4. Expert Intensive Skills Evaluation Version 2.0 (EXPERTise 2.0). EXPERTise 2.0 (Wiggins, Loveday, & Auton, 2015) is shell software program that evaluates participants' utilisation of cues during task-related activities. Typologies of behaviour that reflect a greater or lesser capacity for cue utilisation can be calculated based on performance across five tasks that require the utilisation of cues within a specific domain. The validity of EXPERTise 2.0 has been established in paediatric diagnosis (Loveday, Wiggins, Searle, Festa, & Schell, 2013), power control (Loveday, Wiggins, Harris, O'Hare, & Smith, 2013), and aviation decision making (Wiggins, Azar, Hawken, Loveday, & Newman, 2014). EXPERTise 2.0 has exhibited satisfactory test-retest reliability (Loveday, Wiggins, Festa, Schell, & Twigg, 2013; Watkinson, Bristow, Auton, McMahon, & Wiggins, 2018).

The software can be customised to assess cue utilisation in a specific domain or context. For this study, the Driving 'edition' was chosen as it assesses participants' application of cues within a driving context (Brouwers, Wiggins, Helton, O'Hare, & Griffin, 2016). The battery comprises five tasks; Feature Association Task, Feature Discrimination Task, Feature Identification Task, Feature Recognition Task and the Feature Prioritisation Task.

2.3.4.1. Feature Association Task (FAT). The FAT examines the degree to which an individual can distinguish relevant from irrelevant features (Falkland, Wiggins & Westbrook, 2019). Participants are presented with 19 pairs of feature-event words or phrases that relate to driving (including two practice items; see Appendix C). Each word pair, such as "fog" and poor visibility", is presented on screen for 1500ms and participants then rate their perceived relatedness of the terms using a 6-point Likert scale, from 1 (*Extremely Unrelated*) to 6 (*Extremely Related*). The mean variance is calculated for the ratings across the 17 scenarios where greater mean variance is associated with a greater level of cue utilisation (Morrison, Wiggins, Bond & Tyler, 2013).

2.3.4.2. Feature Discrimination Task (FDT). The FDT examines the extent to which an individual is able to identify the relative utility of features during a problem solving task (Wiggins, Whincup & Auton, 2019). In the Driving edition, participants are shown a written hypothetical driving scenario and given details surrounding the situation, including a map of the area, the plan driving route, the destination, how long it would take to get there and 3 alternative routes (see Appendix C). Participants are asked to choose which option is best suited to the scenario based on the details provided. Following this, the 14 features that were embedded in the task (e.g., time of day, meeting time, local radio reports) are presented and participants are asked to rate the degree to which each feature influenced their decision on a 10-point Likert scale, from 1 (*Not important at all*) to 10 (*Extremely Important*). A singular measure of variance is developed from the aggregated ratings and greater variance is presumed to be correlated with a greater capacity for cue utilisation (Pauley, O'Hare, & Wiggins, 2009).

2.3.4.3. Feature Identification Task (FIT). The FIT measures the extent to which an individual is capable of identifying target features within a complex array (Wiggins, Whincup & Auton, 2018). Participants were shown 22 (including one example item) photos of road scenes taken from the driver's perspective (see Figure 6) and were asked to select the area of the image which they consider to be of greatest concern, such as a cyclist, school zone or police horses. The speed that participants respond at is recorded (in milliseconds) and a lower response time is associated with greater capacity for cue utilisation (Loveday, Wiggins, & Searle, 2014).

Figure 6. Example road scene from the Feature Identification Task

2.3.4.4. Feature Recognition Task (FRT). The FRT assesses the accuracy with which an individual is able to make decisions based on their recognition of critical features (Wiggins, Whincup, & Auton, 2018). Participants are shown 22 photos of road scenarios (including one practice scenario) for 1000 milliseconds each. Participants then estimate the speed limit of the pictured road from a list of four options (see Appendix C for an example). Greater summed accuracy is expected to be associated with a higher capacity for cue utilisation (Wiggins & O'Hare, 2003).

2.3.4.5. Feature Prioritisation Task (FPT). The FPT assesses the degree to which an individual accesses task-related features, determined by analysing the order in which they obtain task-relevant information (Falkland, Wiggins, & Westbrook, 2019). Participants are presented with a brief driving scenario with specifics excluded, accompanying the scenario is a list of 17 drop down tabs (see Figure 7). Participants are given 60 seconds to access the information they consider important to determine the appropriate course of action. The ratio of pairs of features selected in the sequence they were presented is computed as a proportion of the total number of feature pairs selected throughout the task, as is consistent with previous EXPERTise 2.0 use (Wiggins, Whincup & Auton, 2018).

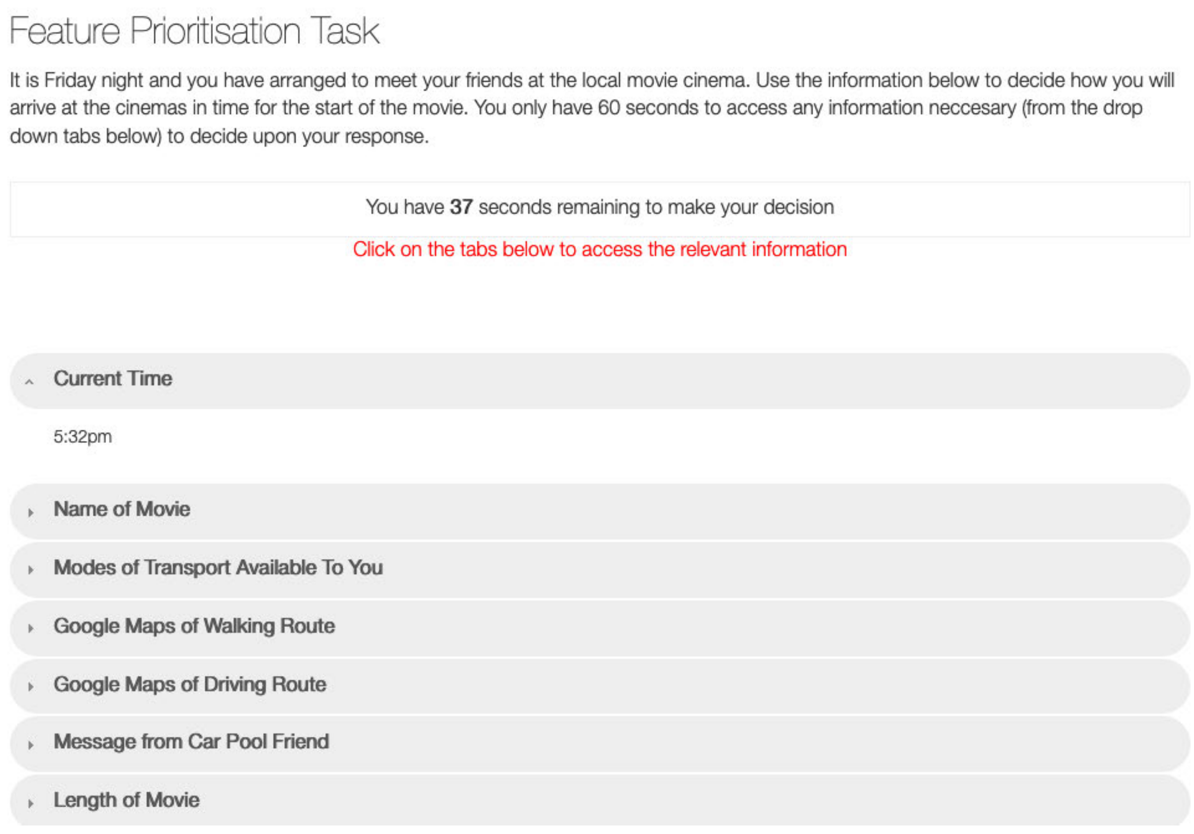

Figure 7. Example of drop-down menu from the Feature Prioritisation Task

2.4. Procedure

Ethics approval for this study was obtained from the University of Adelaide's Human Research Ethics Committee (reference code: H-2019-51 or 19/51; see Appendix D). Participants were tested individually in 60-minute sessions. Upon arrival, participants were provided with a verbal description of the study, and read and completed the participant information and consent forms digitally. Further, they were provided the opportunity to retain a hard copy of this paperwork. The demographic questionnaire and EXPERTise 2.0 test battery were then completed.

Participants then moved to the driving simulator and adjusted it to their comfort before beginning the six minute practice scenario, in which they familiarised themselves with the display and controls of the system. Participants then completed the 'no distraction' scenario where participants followed the simulator's navigation system around a moderately trafficked area for approximately 8 minutes. Immediately after completing the scenario, participants were given the NASA-TLX to complete with paper and pen. Following this, participants then completed the second simulated driving scenario ('distraction'). Participants again followed the simulator's navigation system around the simulated area, however, in this scenario, the simulation was completed while undertaking the distraction task. Again, participants completed the NASA-TLX immediately after completing this scenario.

3.0 Results

3.1. Overview of Analyses

The main objective of the present study was to determine whether the two typologies of participants, categorised on the basis of cue utilisation capacities measured using the EXPERTise 2.0 battery, differed in their driving performance during a distracted, and non-distracted simulated driving scenario. A secondary objective was to examine whether the cue utilisation typologies influenced perceived cognitive workload across two conditions of a driving task (‘distraction’, ‘no distraction’). The statistical analyses undertaken to address these aims consisted of two stages.

The first analysis stage involved confirming the two typologies of participants could be differentiated based on cue utilisation performance across the tasks encompassed in the EXPERTise 2.0 task battery. The purpose of the second stage of the analysis was to address the hypotheses. It assessed whether driving performance in a simulated driving scenario completed in the absence of a mobile phone based distraction, was superior to performance on a comparative simulated driving scenario paired with a mobile phone based distraction (H1). Further, it assessed whether participants demonstrated a greater perceived cognitive workload during a simulated driving scenario in the absence of a distraction, when compared to a relative simulated driving task completed in conjunction with a mobile phone based distraction task (H2). It was hypothesised that participants with a greater capacity for cue utilisation will demonstrate superior performance on a simulated driving task in the absence of a mobile phone-based distraction task, compared to participants with a lower capacity for cue utilisation (H3). It was also hypothesised that participants with a greater cue utilisation capacity will perform better on a simulated driving task when completing a simultaneous distraction task, comparative to participants with a lower cue utilisation capacity (H4). Further, it was hypothesised that participants with greater cue utilisation capacities will perceive the simulated driving task in the absence of a mobile phone-based distraction task to be of a lower cognitive workload than participants with lesser cue utilisation capacities (H5). Finally, it was hypothesised that participants with a greater capacity for cue utilisation will perceive the simultaneous driving and distraction tasks to be of a lower cognitive workload, when compared to those with a lower capacity for cue utilisation (H6).

3.2. Data Reduction

For the simulated driving tasks, scores of performance on various sub-categories, including speed control, priority, signs, lane position and steering, were recorded by the driving simulator, before being commuted into an overall performance score between 1 and 10, based on the relative weightings of each sub-category. This process was completed for each driving scenario ('distraction', 'no distraction').

For the NASA-TLX, ratings of perceived cognitive workload on seven levels for each distraction condition ('distraction', 'no distraction') were recorded on a 7-point Likert scale, from 1 (*Very Low Demand*) to 7 (*Very High Demand*). Data for the performance level was reverse coded, before the seven level scores were averaged, to create a mean rating of perceived cognitive workload for that condition.

The standard approach to data reduction for the EXPERTise 2.0 tasks was undertaken for this data (Bouwers, Wiggins, Helton, O'Hare & Griffin, 2016; Loveday, Wiggins, Harris, et al., 2013). For the Feature Identification Task, mean response latencies of the identification of critical features was computed across the 22 scenarios. For the Feature Recognition Task, the total number of correct responses was summed. For the Feature Association Task, the subjective ratings of the association between each feature-event pair was recorded, and then combined to form a single metric resulting from the mean variance of each participants' responses. For the Feature Discrimination Task, the ratings of utility for each of the 14 features was recorded on a 10-point Likert-scale from 1 (*not important at all*) to 10 (*extremely important*). A single metric of the variance of each response was then calculated from these ratings. For the Feature Prioritisation Task, the order in which information tabs were accessed was recorded. This information was used to create a ratio of sequential feature pairs accessed compared to the total feature pairs available in the FPT.

3.3. Covariates

Independent samples t-tests indicated that cue utilisation was not related to age, $t(32) = -1.702$, $p > 0.05$ nor driving experience in months, $t(32) = -0.721$, $p > 0.05$. A chi-squared test indicated that cue utilisation was also unrelated to gender, $X^2 (1) = 1.395$, $p > 0.05$. Therefore, it was not necessary to include covariates as potential explanatory variables in the main analyses.

3.4. Stage 1: Cue Utilisation Typologies (Cluster Analysis)

A *k*-means cluster analysis establishes groups, or 'typologies' on the basis of comparing performance across different tasks, so that the member of each group are the most alike to members of their 'in-group', and most dissimilar to members of the opposing or 'out-group' (Kaufman & Rousseeuw, 2009). In the current study, a *k*-means cluster analysis was carried out to establish whether participants could be classified into two clear typologies based on distinct levels of cue utilisation performance across the EXPERTise 2.0 tasks (Sturman, Wiggins, Auton, & Loft, 2019; Wiggins, Azar, et al., 2014). Before the cluster analysis could be conducted, however, raw scores for each of the five EXPERTise 2.0 tasks were converted to standardised *z*-scores. The results of the cluster analysis are summarised in Table 1, including the mean centroid values for each cluster on variables that comprise EXPERTise 2.0.

The cluster analysis yielded two distinct typologies representing participants who had relatively higher and lower capacities for cue utilisation. Cluster 1 contained 21 participants who recorded lower response latencies on the FIT, greater accuracy on the FRT, greater variance in the FAT and FDT and a relatively lower ratio in the FPT. Overall, this pattern of performance is reflective of participants who possess a relatively higher level of cue utilisation while responding to tasks within the domain of driving. The remaining 13 participants formed Cluster 2, who exhibited the opposite pattern of results, consistent with a lower level of cue utilisation. These two typologies underlay the subsequent analyses.

Table 1.

Centroid Values for Cue Utilisation Typologies

EXPERTISE 2.0 Tasks	Typology	
	Cluster 1 (Higher) (n = 21)	Cluster 2 (Lower) (n = 13)
Feature Identification Task (response latency)	-0.552	1.004
Feature Recognition Task (accuracy)	1.989	-1.966
Feature Association Task (variance)	1.163	-1.868
Feature Discrimination Task (variance)	0.343	1.788
Feature Prioritisation Task (ratio)	-0.042	1.183

3.5. Stage 2: Hypothesis Testing

3.3.1. Relationship between Cue Utilisation and Driving Performance. To examine the effect of distraction on driving performance in general (H1) and the relationship between cue utilisation capacity and driving performance (H3, H4), 2 (Cue Utilisation Typology; greater, lesser) x 2 (Driving Scenario; Distraction, No Distraction) mixed design ANOVA was conducted with cue utilisation typology as the between-subjects variable and driving performance as the dependent variables.

To address H1, the main effect of distraction was examined. A statistically significant within-subjects effect of distraction on overall performance was evident, $F(1, 32) = 32.312$, $p < 0.001$, $r = 0.709$, indicating that driving performance during the 'distraction' scenario (M = 4.907, SD = 2.116) was significantly poorer when compared to performance during the 'no distraction' scenario (M = 6.719, SD = 1.653), providing support for H1.

To address H3 and H4, the interaction between cue utilisation typology and driving performance was inspected. No statistically significant interaction was evident between cue utilisation cluster and driving performance, $F(1, 32) = 1.340$, $p = 0.100$, $r = 0.201$. This suggests there is no difference in performance between participants with relatively higher and lower capacities for cue utilisation during the distraction and no distraction scenarios, failing to provide support for H3 and H4.

3.3.2. Relationship between Cue Utilisation and Perceived Cognitive Workload.

To assess the relationship between cue utilisation capacity and perceived cognitive workload as specified in H5 and H6, a second 2 x 2 mixed factorial ANOVA was conducted, with cue utilisation typology (greater, lesser) included as the between-subjects factor, distraction scenario (distraction, no distraction) included as the within-subjects factor, and NASA-TLX scores as the dependent variable.

To address H2, the main effect of driving scenario on perceived cognitive workload was inspected. There was no main effect for the presence of distraction on perceived cognitive workload (H2), $F(1, 32) = 0.924$, $p = 0.344$, $r = 0.168$, indicating that participants found the 'distraction' driving scenario ($M = 3.638$, $SD = 0.807$) to be no more cognitively demanding than the 'no distraction' driving scenario ($M = 3.408$, $SD = 0.939$), providing no support for H2.

To address H5 and H6, the interaction between driving scenario and cue utilisation typology on perceived cognitive workload was inspected. A statistically significant between-subjects interaction was found between cue utilisation cluster and the 'distraction' scenario, $F(1, 32) = 6.966$, $p = 0.013$, $r = 0.423$. An inspection of means (see Figure 8) revealed that overall ratings of perceived cognitive workload did not differ for the 'distraction' scenario between cue typologies, which did not support H6. However, ratings did differ for the 'no distraction' scenario. During this scenario, participants with a greater capacity for cue utilisation rated the task as less cognitively demanding ($M = 3.147$, $SD = 0.784$) compared to participants with a relatively lesser capacity for cue utilisation ($M = 3.831$, $SD = 1.043$). This suggests that participants demonstrating a lower capacity for cue utilisation, found the driving task competed in the absence of a distraction to be more difficult than those demonstrating a higher capacity for cue utilisation, which is in support of the hypothesis.

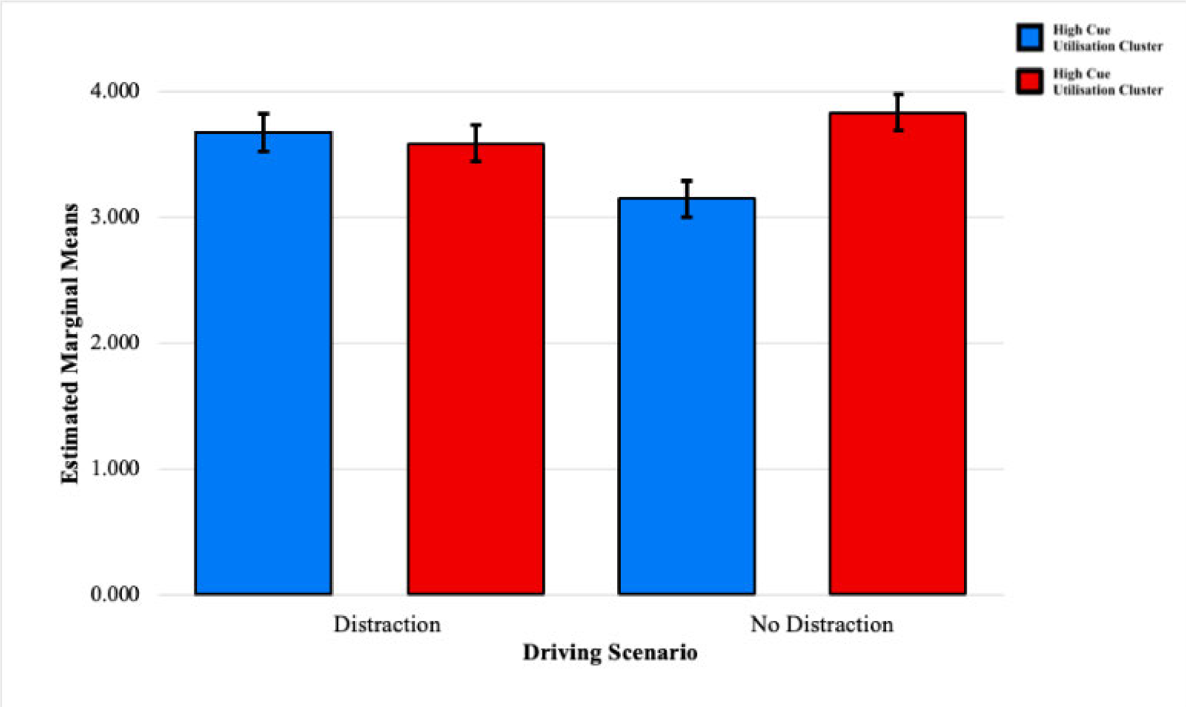

Figure 8. Mean perceived cognitive workload ratings (NASA-TLX scores) for each distraction scenario, clustered by relative cue utilisation capacity.

4. Discussion

This study was designed to explore whether cue utilisation capacity (greater, lesser), relates to stimulated driving performance in the presence and absence distraction. Further, the study aimed to assess whether cue utilisation capacity influenced perceived cognitive workload across the same two conditions of the driving task (‘distraction’, ‘no distraction’).

It was hypothesised that engaging in a secondary, distraction task alongside the initial task would be associated with decreased performance (H1), when compared to completing the initial task alone. The results provided support for this hypothesis, as participants overall driving performance was significantly poorer during the ‘distraction’ scenario, the simulated driving task paired with the distractor task, then during the ‘no distraction’ scenario, indicating that the presence of a distraction leads to a decline in performance. An increase in task elements or demands leads to an increase in the need for cognitive resources, and depending on the extent of this need, potentially putting a strain on the resources available at any point in time. This strain is evident in this finding, as the 'distraction' scenario required more cognitive resources for successful completion than the 'no distraction' scenario.

As the increase in task elements has associations with an increase in cognitive load, it was proposed that the participants would rate the 'distraction' scenario as being more cognitively demanding than the 'no distraction' scenario (H2). The results did not support this interaction, demonstrating that neither scenario was perceived as more or less cognitively demanding overall. Therefore, it can be concluded that participants found driving in the absence of a distraction and driving while reading and responding to text messages to be equally difficult. This was an interesting finding as the manipulation check (see section 2.3.1.4) conducted prior to this study demonstrated that the 'distraction' scenario was perceived as being of a higher cognitive workload than the 'no distraction' scenario. A potential explanation for this finding is that the two scenarios were counterbalanced during the manipulation, but were not in this case due to the sample size. Further, this findings is inconsistent with previous research in which in-vehicle distractions resulted in increased subjective workload when compared to conditions devoid of distraction (Horberry, Anderson, Regan, Triggs & Brown, 2005).

It was hypothesised that a higher capacity for cue utilisation is associated with superior performance on both the 'distraction' (H3) and 'no distraction' (H4) scenarios, independently, when compared to the association between performance and a relatively lower cue utilisation capacity. The findings did not support this hypothesis, indicating that cue utilisation capacity has no effect on driving performance in this context. Therefore, based on these results, it cannot be concluded that determining an individual's capacity for cue utilisation give insight into their potential for driving performance, in the presence or absence of a distraction. Previous research on the relationship between cue utilisation and performance has determined that increases in cue utilisation capacity lead to reduction in performance error and response latency (Brouwers, Wiggins, Griffin, Helton & O'Hare, 2017; Falkland & Wiggins, 2019). In contrast the present study found no statistically significant effect of these two constructs. There are two potential explanations for these opposing results. First, it could be argued that no empirical relationship exists between cue utilisation and performance, consistent with the findings of Trigg (2016). However, this is unlikely due to the number of significant findings indicating otherwise. The second, more likely, explanation is that the lack of support is a result of the present study itself, potentially resulting from the small sample size.

An analysis of the relationship between NASA-TLX scores and cue utilisation clusters revealed that while both higher and lower cue utilisation clusters found the 'distraction' scenario to be similarly cognitively demanding (H6), a relatively lower cue utilisation capacity was associated with a higher perceived cognitive workload for the 'no distraction' scenario (H5). Results supporting the effects of cue utilisation capacity on only one of the two scenarios could be due to the order in which the scenarios were presented. As the scenarios where not counterbalanced due to the sample size, the 'no distraction' scenario was the first scenario to completed by all participants. The 'no distraction' scenario alone was a challenging task and therefore it is possible that participants with a greater capacity for cue utilisation were able to identify and form relevant cue associations for the simulated driving task in general quicker than those with a lesser cue utilisation capacity enabling the quicker adaptation to the circumstances of the scenario. Further, the distraction task utilised in this study was relatively innocuous, and therefore may not have been difficult enough to sufficiently distraction participants from the driving task. As such participants cognitive resources were not overloaded and there were still additional resources available to be directed towards unexpected cues arising from the driving task. Participants with greater cue utilisation capacities were presumably using less cognitive resources for the driving task, leaving sufficient resources available for the distraction task. However, while participants with a lower capacity for cue utilisation may have used more cognitive resources relative to those with a higher cue utilisation capacity, the innocuous nature of the distraction task did not require the use of all more resources than were available. This accounts for the similar ratings of perceived cognitive workload for the 'distraction' scenario reported by both cue utilisation clusters.

4.1 Theoretical Implications

The outcomes of this study contribute to the growing theoretical understanding of cue utilisation, especially in relation to driving and driver distraction, a domain which had yet to be explored prior. A greater capacity for cue utilisation was found to be associated with a lower perception of cognitive workload of the driving task completed in the absence of distraction. Additionally, the presence of distraction has shown to increase human error, therefore demonstrating its detrimental effect on performance, despite drivers' lack of perception of this effect.

By understanding the effects of cue utilisation in the domain of driving, the role of cue utilisation in other everyday activities starts to become more apparent. Specifically, while it is known that cues play an important role in our understanding of, and participation in, our environments, the conclusions drawn in this study help to demonstrate the importance of cue utilisation capacity on the aforementioned understanding of and participation in the task or environment.

4.2 Practical Implications

The findings of the current study have practical implications for the development of safe-driving practices, both in the form of training and educational promotion. The implications of findings in support of the overall decrease in performance when a distraction is present (H1), combined with the lack of evidence for the perception of the same outcome (H2), is important to note. Specifically, while participants demonstrated the detrimental effects of a distraction in their performance outcomes, they did not demonstrate that they believed this to be the case, instead implying that they are unaware of effects the use of a mobile phone (as per the 'distraction' scenario) had. This has many implications for road safety practices. Evidence that individuals' performance decreases when engaging with a mobile phone but are unaware of this decline in performance, suggests that the likelihood of doing so in real-world driving circumstances is high. This is similar to findings surrounding the effects of drink driving on performance and the subjective perception that individuals' are able to perform comparably when intoxicated and when not, despite objective measures demonstrating the contradictory results (Xiaohua, Xingjian, & Jian, 2014). The resulting inferences that can be made regarding road safety practices indicate that more effective means of educating drivers, specifically those with less than 9 years driving as this was a parameter of the study, potentially need to be developed or reinforced.

While it is unlikely to be practical to incorporate cue utilisation evaluations into the training and assessment of all drivers, certain driving roles which require, or at least, are associated with the use of mobile phones or similar technology may benefit from cue-based training or testing. In particular, car services and taxi drivers may require the use of mobile phones and GPS technology to perform their job. In these cases, an assessment of cue utilisation capacity may be helpful in determining potential risk factors for potential employees, as well as the selection and training of these individuals. Alternatively cue-based training could be proffered to all as a means of improving performance and increase road safety. While no effect was found for cue utilisation capacity and performance in the presence of a distraction task in the present study, this may have been the result of methodological causes and the abundance of supporting literature pertaining to the effects of cue utilisation on performance, may warrant the implementation of these training programs. Similar training approaches have been put in place for workers in other high workload operational roles, such as rail control or aviation (Morrison, Wiggins, Bond & Tyler, 2013; Pauley, O'Hare, & Wiggins, 2009), and typically involve placing workers in simulated environments, much that used in this study, as a means of enabling the discovery of task-relevant cues. The outcomes of the current study provide the opportunity to note the merits of these training procedures and support their development within the domain of driving.

4.3 Limitations and Future Directions

Despite the outcomes of this study, there are limitations that could be addressed in potential future studies. As relationship between cue utilisation and driver distraction has not been previously investigated, this study serves as a preliminary study with many avenues for future directions. Although this study was conducted in a controlled environment using a simulator which has shown to closely emulate the factors of driving, in reality driving contexts and factors are dynamic and many in-vehicle and environmental influences, may be present that are unique to the circumstance and therefore were unable to be accounted for by the controlled and simulated environment of this study. Further, the driving simulator was incrementally different to a real-world car, because they were simulated and took place in an isolated environment. Therefore, despite the practice module used to familiarise with the simulator, being as comfortable with and performing as one would when driving typically is unlikely. Although the use of a simulator is a commonly used to generalise findings to real world environments, it is not a perfect comparison. As a result, future research may be targeted at assessing the effects evident (H1, H5) or lacking (H2, H3, H4, H6) in this preliminary, controlled-environment study, in real-world driving circumstances.

Further research may also benefit from looking at the relationship between cue utilisation and the specific aspects of driving performance separately. For example, speed control, lane position or sign use, may be individually associated with cue utilisation capacity despite the current study finding no significant association between performance and cue utilisation on the overall combination of these facets.

Performance and subjective cognitive workload measures were use in the current study to identify cognitive workload. However, it may be prudent to measure workload using the more objective physiological responses, such as brain response patterns and cerebral oxygenation, measured using Near Infrared Spectroscopy (NIRS; Sturman, Wiggins, Auton, Loft, Helton, Westbrook & Braithwaite, 2019). These measurement methodologies which unavailable for this study. The current study examined the association between cue utilisation and driver distraction, and the relationship between cue utilisation, physiological responses and driving performance has been investigated previously (Sturman, Wiggins, Auton, Loft, Helton, Westbrook & Braithwaite, 2019), however no research examining the relationship between physiological responses and driver distraction had been conducted. Therefore, this is an avenue of investigation that should be addressed in future research.

The small sample size obtained for this study may have limited the findings. Significant results were found for some of the proposed hypotheses, however, it is possible that the lack of significant effects found may have resulted from a lack of sufficient participants. Therefore, conducting a similar study using a larger sample size, one that potentially stems from a wider and more generalisable population, may be beneficial for future research in this domain.

4.4 Conclusion

The aim of this study was to determine whether cue utilisation capacity relates to differences in performance and perceived cognitive workload during a simulated driving task in the presence and absence of a distraction. The outcomes of this study suggest that a greater capacity for cue utilisation is not associated with better performance on a simulated driving task, in neither the presence nor absence of a distraction. Further, the results suggest that a higher capacity for cue utilisation was indicative of a decreased subjective perception of the cognitive workload of a driving scenario, however this was not evident in the presence of a distraction. Finally, the results demonstrate that the presence of a distraction results in a decrease in driving performance overall, however, it does not lead to an increase in subjective perceptions of cognitive workload. The present study proposes that future research focus on the relationship between cue utilisation and driver distraction, utilising varying distraction types and performance measures.

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Appendix A

Distraction task questions adapted from Hosking, Young and Regan (2009)

What day of the week is it?

What month is it?

What year is it?

What day comes after Tuesday?

What is the opposite of cold?

What state are we in?

What University is this?

What is the opposite of yes?

Appendix B

Demographic Questionnaire

Demographic Questions

Pre-Survey 1 (Demographics)

Please complete the following demographic questions.

Please specify your age *

Please indicate your gender *

- Male
- Female
- Other
- Prefer not to say

Do you have 20/20 or corrected (ie. Glasses or contacts) vision? *

- Yes
- No

Do you have any experience with a Simworx Driving Simulator? *

- Yes
- No

If yes, how much experience?

How many years and months have you had your drivers license (e.g., 4 years 3 months)? *

On average, how long do you spend driving each day?

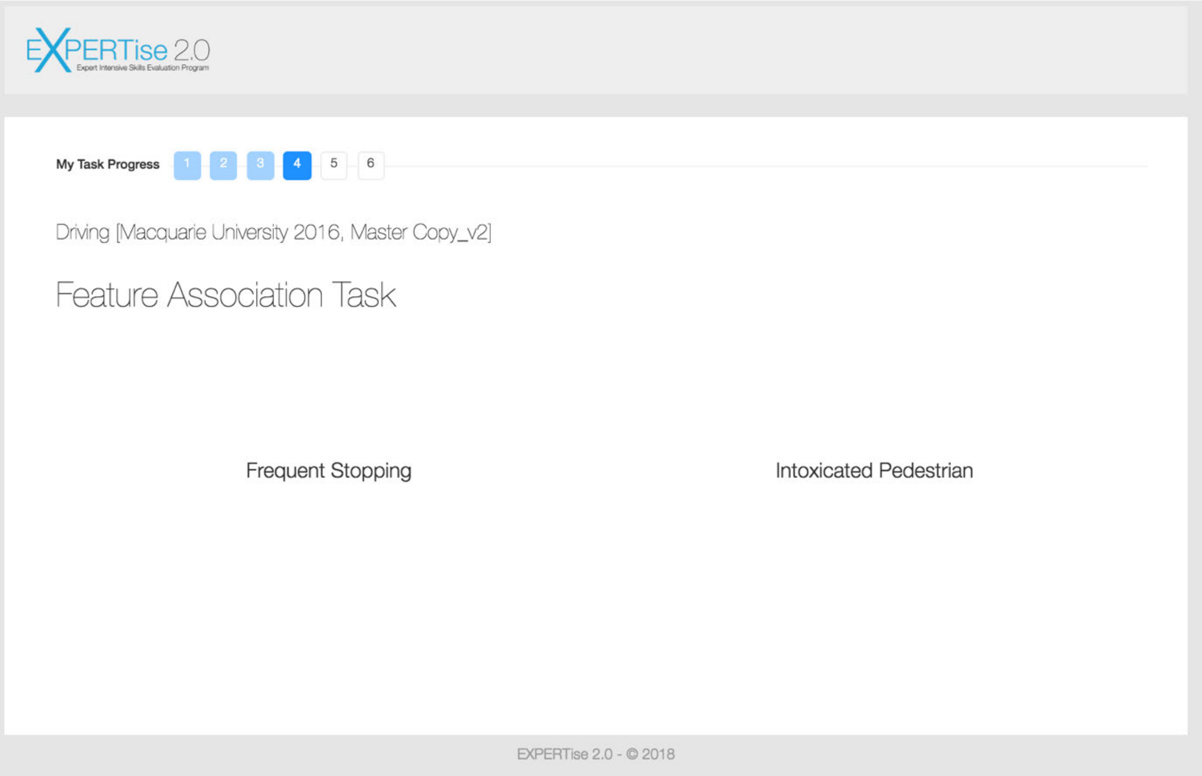
*

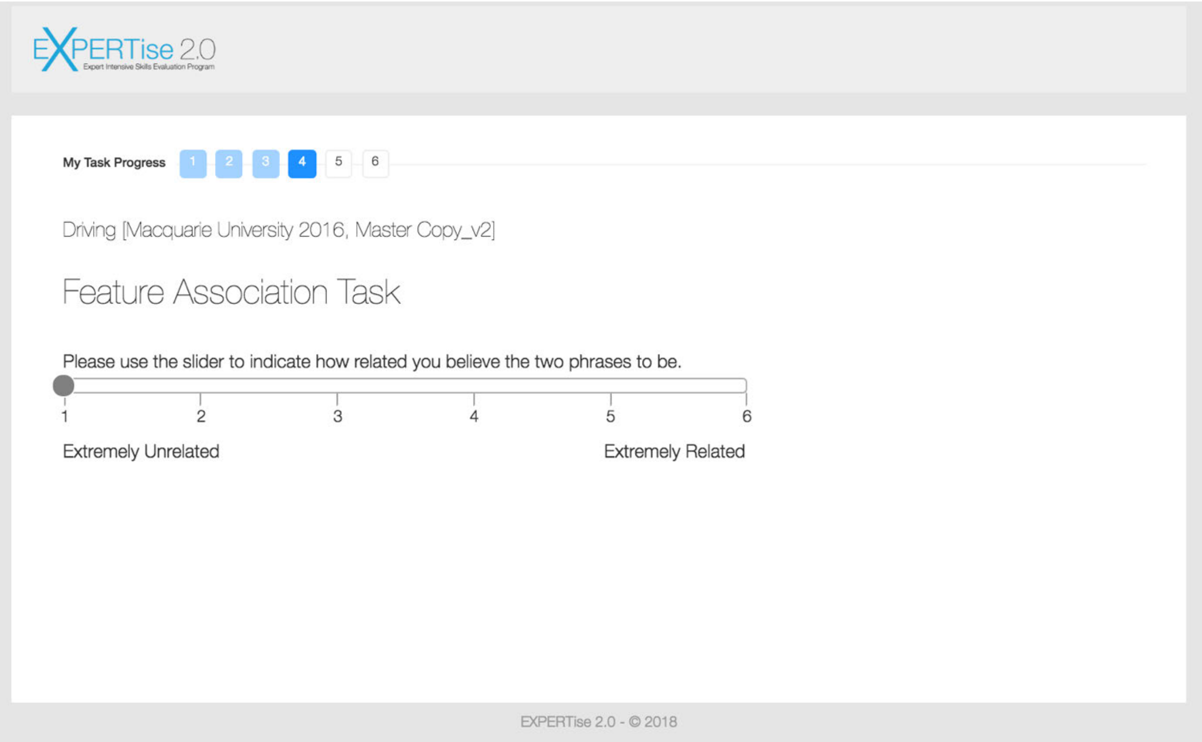
- Less than once per day
- Less than 30 minutes

Appendix C

EXPERTise Task Examples

Feature Association Task Example





Feature Discrimination Task Example

EXPERTise 2.0
Expert Intensive Skills Evaluation Program

My Task Progress 1 2 3 4 5 6

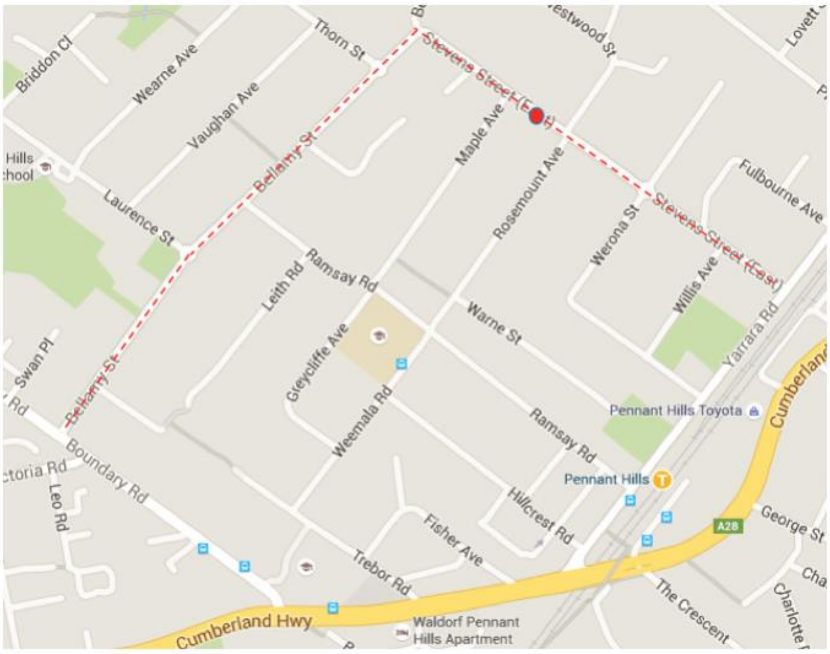
Driving [Macquarie University 2016, Master Copy_v2]

Feature Discrimination Task

You have a meeting to attend at 3.00pm and, under normal conditions, it takes 25 minutes to complete the 11 km route from your departure point. Your usual route takes you down Stevens St, on to Bellamy St, and then a right turn on to Boundary Road. You depart for your meeting at 2:30pm.

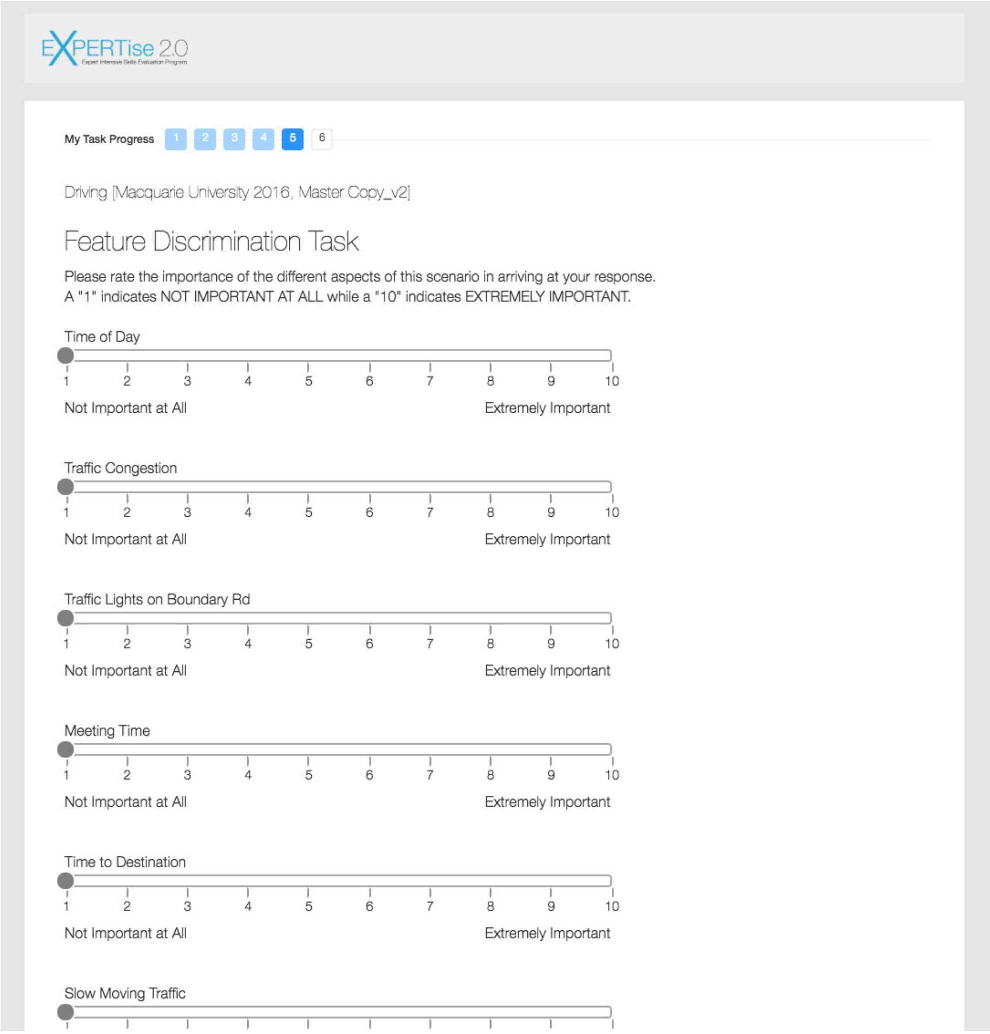
Approximately seven minutes (3 km) into the drive, there is a line of traffic stretching from the intersection of Bellamy St and Stevens Street that brings you to a stand still (indicated by the red circle on the Map). Although the traffic is moving, it is very slow.

You had been listening to the local radio and there was no mention of traffic congestion in this area. You are aware that there is a set of traffic lights on Boundary Rd than can cause traffic congestion on occasion. Some drivers are turning down Maple Ave, and you presume that they are taking Ramsay St to reach Bellamy St. However, there is no traffic light at this intersection. Other drivers are reversing their direction of travel, and you assume taking Yarrara Rd onto the Cumberland Highway and then intercepting Boundary Rd. Finally, other drivers are turning down Rosemount Ave and on to Weemala Rd. However, you know that there is no right turn possible at the end of this road on to Boundary Rd and that drivers will need to take Trebor Rd to turn on to the Cumberland Highway. You also know that, at this time of day, the Cumberland Highway is very busy.



Continue

EXPERTise 2.0 - © 2018



EXPERTise 2.0

Expert Intensive Skills Evaluation Program

My Task Progress 1 2 3 4 5 6

Driving [Macquarie University 2016, Master Copy_v2]

Feature Discrimination Task

Please rate the importance of the different aspects of this scenario in arriving at your response.
A "1" indicates NOT IMPORTANT AT ALL while a "10" indicates EXTREMELY IMPORTANT.

Time of Day

1 2 3 4 5 6 7 8 9 10

Not Important at All — Extremely Important

Traffic Congestion

1 2 3 4 5 6 7 8 9 10

Not Important at All — Extremely Important

Traffic Lights on Boundary Rd

1 2 3 4 5 6 7 8 9 10

Not Important at All — Extremely Important

Meeting Time

1 2 3 4 5 6 7 8 9 10

Not Important at All — Extremely Important

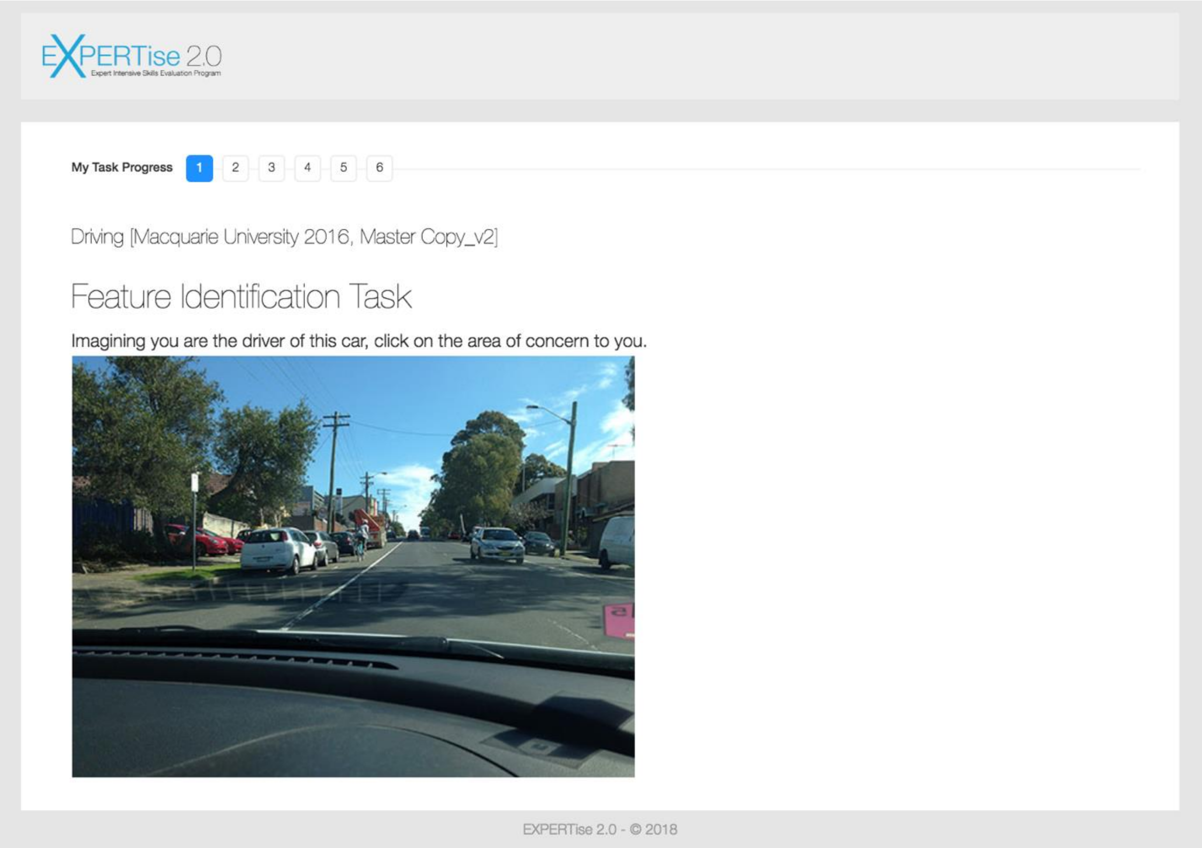
Time to Destination

1 2 3 4 5 6 7 8 9 10

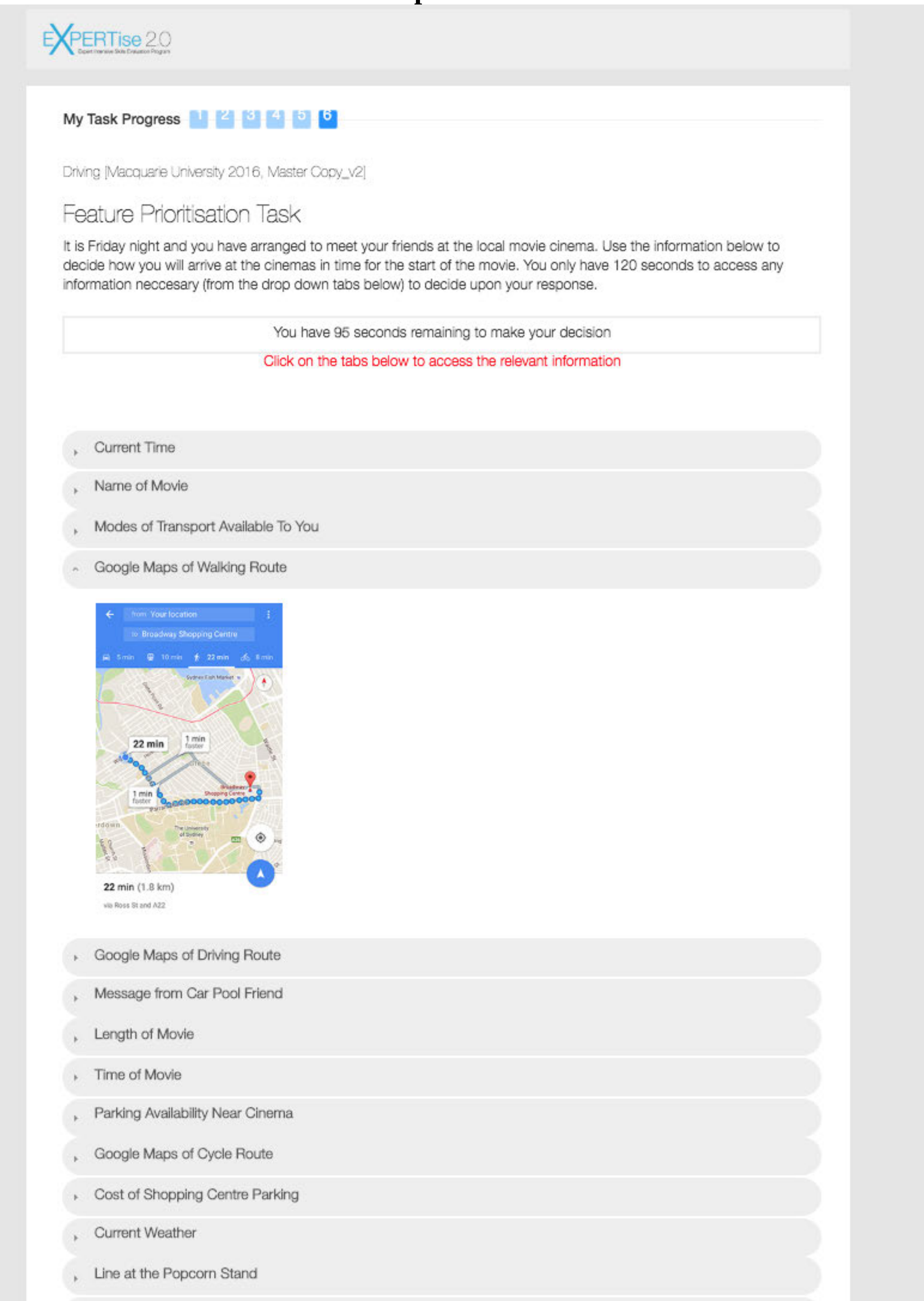
Not Important at All — Extremely Important

Slow Moving Traffic

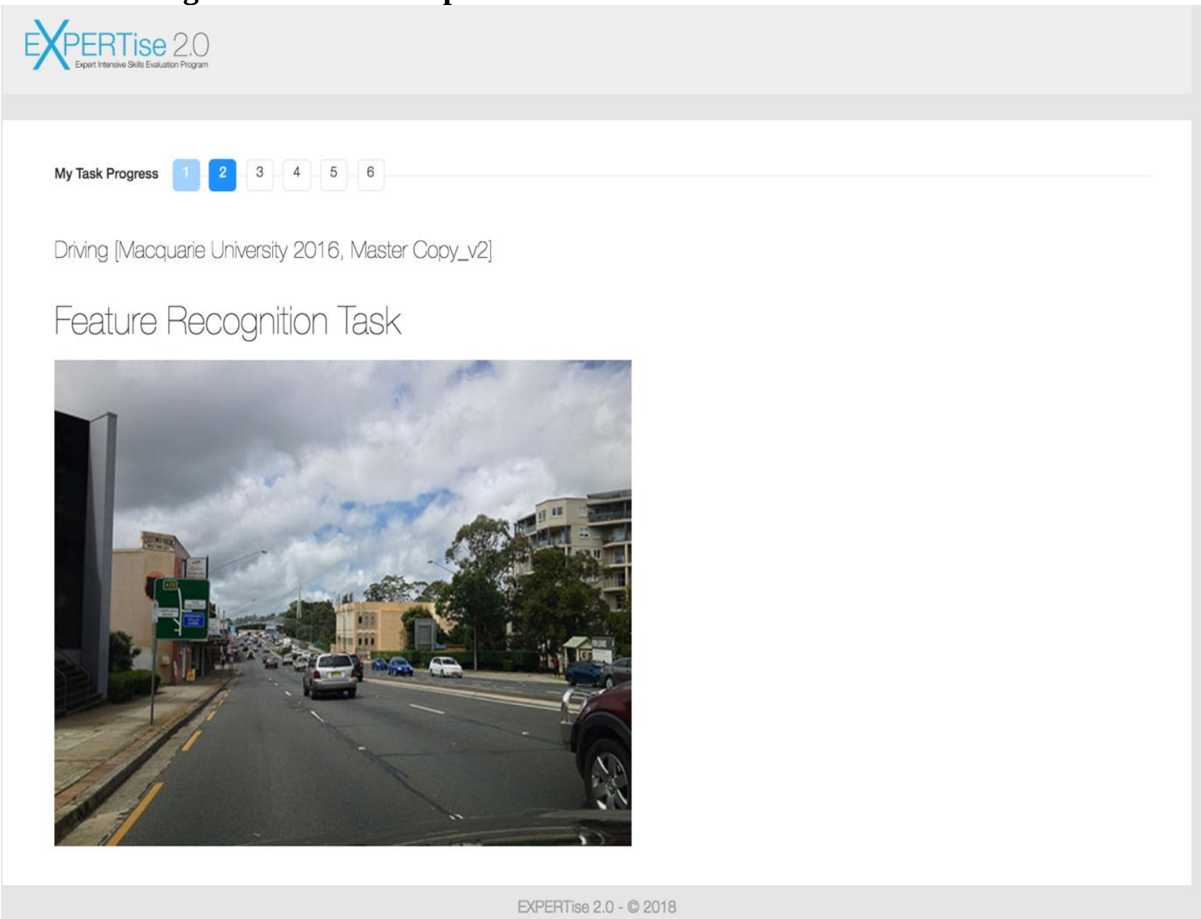
Feature Identification Task Example

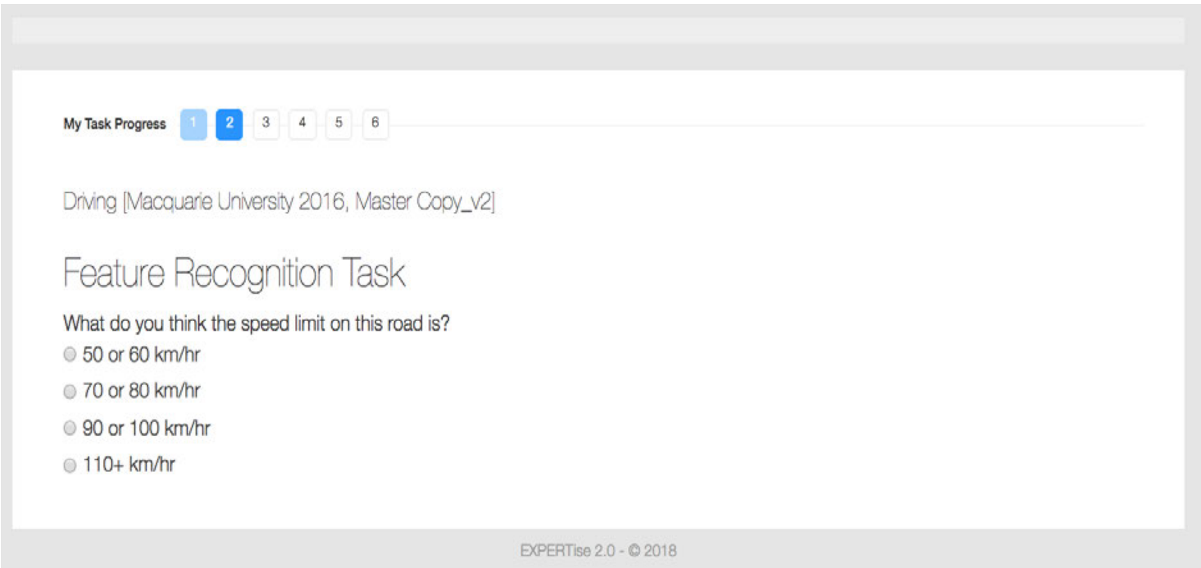


Feature Prioritisation Task Example



Feature Recognition Task Example





Appendix D

Ethics Approval Form

THE UNIVERSITY OF ADELAIDE AUSTRALIA

School of Psychology
University of Adelaide
North Terrace, Adelaide SA 5005
Ph. 61 8 8313 5693
Fax 61 8 8313 3770

School of Psychology: Human Research Ethics Subcommittee
Approval Sheet

Dear JAIME

The members of the subcommittee have considered your application:

Code Number: 19/51

Title:

THE RELATIONSHIP BETWEEN CUE UTILISATION AND DRIVER DISTRACTION DURING PERFORMANCE ON A DRIVING SIMULATOR

With [Student name, if applicable] CAMILLE DALGARNO

I am writing to confirm that approval has been granted for this project to proceed. Approval is granted to 12 months from the date specified below.

Yours sincerely,

[redacted]