Citation:

Effects of multitasking and intention-behaviour consistency when facing yellow traffic light uncertainty

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Keywords: Driving, intersections, yellow traffic lights, response bistability, multitasking, intention-behaviour consistency.
We examined the effects of multitasking on resolving response bistability to yellow traffic lights using the performance metrics of reaction time and stopping frequency. We also examined if people’s actual behaviours, measured by implicit foot pedal responses, differed from their intentions along these factors, as measured by explicit verbal commands. In a dual-task paradigm, participants responded to random traffic light changes, presented over a static background photograph of an intersection, using either foot pedals or verbal commands while simultaneously identifying spoken words as either ‘animals’ or ‘artefacts’ via button pressing. The dual task condition was found to prolong reaction times relative to a single task condition. In addition, verbal commands were faster than the foot pedal responses and conservativeness was the same for both types of responses. A second experiment, which provided a more dynamic simulation of the first experiment, confirmed that conservativeness did not differ between verbal commands and foot pedal responses. We conclude that multitasking affects a person’s ability to resolve response bistability to yellow traffic lights. If one considers that prolonged reaction times reduce the amount of distance available to safely stop at intersections, this study underscores how multitasking poses a considerable safety risk for drivers approaching a yellow traffic light.
Introduction

There is widespread confusion about the expected response to a yellow traffic light (Jensen, 2011). This is exacerbated by the legal provision in many jurisdictions that permit a driver to cross a yellow light if they do not have the distance available to safely stop (Marusek, 2014). Response bistability is defined as the simultaneous elicitation of two response associations (Wood, Chouinard, Major, & Goodale, 2017). Unlike red and green lights that designate a single motor response (Templeton & Franklin, 1992), yellow lights denote ‘stop’ and ‘go’ as two different possibilities, which compete to be executed into a motor action. Cisek and Kalaska (2005) shed some light as to how this might happen at a neurological level. Following the presentation of a visual stimulus specifying two competing actions, different sets of neurons in certain motor areas of the cortex fire to a visual stimulus with only one set continuing to fire after an action is selected. At intersections, the presence of two possible responses to a yellow light creates a dilemma zone. The dilemma zone is the time or distance range within the yellow light phase where stopping or proceeding appear equally risky (Gugerty et al., 2014). A slow, reckless, or uncertain response by a driver encountering this dilemma can be disastrous. Rear-end collisions may occur if a driver stops too suddenly. On the other hand, a driver may collide with side traffic if they continue through the lights and have insufficient time to clear the intersection. Thus, it is crucial that drivers resolve this dilemma with a rapid and decisive response that is most appropriate for the situation.

The examination of a person’s frequency of stopping responses when confronted with a yellow traffic light can provide insight into whether they have a tendency to make conservative or liberal decisions. Conservativeness is defined as a tendency to make the stop response, thereby minimising the probability of making a risky intersection crossing, while liberalness is the reverse. A conservative bias would be indicated by a comparatively higher
threshold for accepting a ‘go’ signal at a yellow traffic light and a liberal bias indicated by a lower threshold (Lynn & Barrett, 2014; Stanislaw & Todorov, 1999). Research suggests that response bistability increases the risk of indecisive and reckless decisions. Elmitiny, Yan, Radwan, Russo, and Nashar (2010) demonstrated how increases in red traffic light violations transpire when yellow traffic light onsets occur within the dilemma zone: the distance where equal numbers of drivers stop and go. Fewer red traffic light violations happen to drivers who are more conservative, with a tendency to stop when seeing a yellow traffic light. Consequently, a need exists to evaluate the contributing factors that increase conservativeness in normal drivers, which will in turn reduce red traffic light violations. The present investigation examined the effects of multitasking and intention-behaviour consistency when facing yellow traffic light uncertainty. Next, we will discuss multi-tasking and intention-behaviour consistency.

Multitasking and intention-behaviour consistency are closely associated with two important driving performance metrics: reaction time (Brookhuis, Waard, & Mulder, 1994) and conservativeness as indexed by stopping frequencies. Namely, more conservative drivers stop more frequently under ambiguous situations. Multitasking is defined as the concurrent handling of more than one task (Salvucci & Taatgen, 2008) using rapid reorientation between tasks (‘task switching’; Rubinstein, Meyer, & Evans, 2001). Intention-behaviour consistency describes the degree of difference between what individuals report intending to do in a driving situation, as indicated by explicit responses, and their actual behaviour, as indicated by implicit responses. Intentions can be expressed as verbal responses (Nyberg et al., 2001).

There is overwhelming evidence that multitasking negatively impacts response speed. In particular, phone use while driving is problematic due to its prevalence (Kidd, Tison, Chaudhary, McCartt, & Casanova-Powell, 2016). A meta-analysis by Caird, Willness, Steel, and Scialfa (2008) found phone use triggered a mean reaction time increase of 250 ms. A
further meta-analysis by Caird, Johnston, Willness, Asbridge, and Steel (2014) revealed texting degraded performance even further, adding 260 ms. Accordingly, the mobile phone use is estimated to increase a driver’s vehicle accident risk fourfold (Redelmeier & Tibshirani, 1997). Multitasking may also affect the content of driver decisions. Increased errors and response variation are observed in many driving simulation studies (Hancock, Lesch, & Simmons, 2003; Harbluk, Noy, Trbovich, & Eizenman, 2007; Just, Keller, & Cynkar, 2008). Notably, a naturalistic study by D. L. Strayer, Watson, and Drews (2011) observed that drivers using mobile phones were ten times more likely to fail to stop appropriately at a stop sign at a four-way intersection. However, a substantial gap in research still exists on the impact of multitasking on performance during intersection crossings. Specifically, it is unknown whether or not the response bistability produced from yellow lights exacerbates performance decline beyond previous mean estimates.

Multitasking can be operationalised using a dual task. A dual task is the addition of a secondary task while participants perform a primary task (Koch & Tsuchiya, 2007). Dual task interference is quantified by how much accuracy and reaction time are affected while participants perform two tasks compared to only one (Luck, 1998; Pashler, 1994). The Central Bottleneck Theory (Welford, 1952) posits that only one task is able to be efficiently processed at a time by a central, amodal processing area (Dux, Ivanoff, Asplund, & Marois, 2006). Performance on tasks higher in automaticity are typically expected to be less affected by a dual task (Logan, 1979) as they are theorised to exert less processing demands (Wickens & McCarley, 2008). Problematically, different task modalities (i.e. vocal, manual, visual) may utilise parallel processing (Hazeltine, Ruthruff, & Remington, 2006) and have mode-specific storage (Saults & Cowan, 2007), potentially limiting interference. However, evidence points to some overlap in selection processes for spoken and manual responses (Xue, Aron, & Poldrack, 2008) and bottlenecks when responding to auditory and visual stimuli (Harbluk et
al., 2007). For this study, we had participants manually identify with button pressing an auditory presented stimulus as either an ‘animal’ or ‘artefact’ from dictated wordlists by Rossion and Pourtois (2004) during a simulated driving task towards an intersection. This was carried out to establish whether or not a secondary task would affect the manner the participants respond to traffic lights.

Participants in our experiments responded to traffic lights using either foot pedals, which they have had many years of experience doing, or by verbal commands, which is not the typical way drivers respond to traffic lights. The purpose of this manipulation was to examine intention-behaviour consistency; namely, is what we explicitly ‘say we do’ the same as what we implicitly ‘actually do’ while driving?

Research has established that motor responses and speech are valid representations of implicit and explicit processing (Goddard, Kahn, & Adkins, 2015; Lupyan & Ward, 2013; Schall, 2009). As the natural way of controlling a vehicle, foot responses are an intuitive representation of actual driver behaviour (Goddard et al., 2015). On the other side, verbalisation is thought to implicate a greater degree of higher-order cognitive processing (Schall, 2009) and is more likely to operate within conscious awareness (Lupyan & Ward, 2013). Accordingly, verbal responses are found to lag motor responses by 150 to 300 ms (Castiello & Jeannerod, 1991; Castiello, Paulignan, & Jeannerod, 1991), well beyond the conservative 50 ms needed to neuromuscularly execute a vocalisation (Gracco & Abbs, 1987). This does not mean that explicit responses are confined to reflect declarative knowledge but rather they require additional computational power and can operate independently from those that are more implicit (see Stanley & Krakauer, 2013, for an excellent discussion).

Research suggests that more explicit verbal responses will be more conservative. Explicit verbal commands are more cognitively penetrable (Evans, 2008; Wilson, Lindsey, & Schooler, 2000) – cognitive penetrability being defined as the degree to which thinking can
influence a behaviour – and more susceptible to modification by social expectation (Stokes, 2013). Careful driving is expected of drivers. As a result, drivers asked to self-report will tend to do provide a desirable report (Lajunen, Corry, Summala, & Hartley, 1997; Lajunen & Summala, 2003). As implicit foot pedal responses are less cognitively penetrable, we would expect riskier and more liberal responses by foot pedal responses than by verbal commands. In other words, participants will explicitly ‘say’ how they are expected to act and will implicitly ‘do’ how they typically respond while driving.

With this mind, we carried out two experiments to examine the effects of multitasking on resolving yellow light response bistability and to evaluate if people’s actual behaviours, measured by implicit foot pedal responses, differed from their intentions, as measured by explicit verbal commands. Our first experiment (the static multitasking experiment) isolated and compared responses to changes in traffic lights over a static background while our second experiment (the dynamic simulated intersection approach experiment) compared responses in a more realistic simulation of an yellow light approach. The two experiments served to establish ecological validity. The first allowed us to examine multitasking and intention-behaviour consistency in a highly controlled manner with the use of static images. However, driving is a dynamic not a static process. Therefore, we re-examined some aspects of experiment 1, specifically intention-behaviour, in a more dynamic setting to see if our findings might converge under a more realistic simulation.

Our first hypothesis was that multitasking would slow reaction times and hamper conservative decision making, which are both important for accident prevention when people are confronted with a yellow traffic light specifying two possible actions. We also had a second hypothesis whereby people’s responses would be less conservative, more decisive and less affected by dual-task interference when they respond implicitly with foot pedals than when they respond explicitly by verbal commands.
2. Methods

Experiment 1: Static multitasking experiment

The experiment took approximately thirty minutes to complete.

Participants

Thirty (19 males and 11 females, age range: 18-57, mean = 28.3) adults participated in experiment 1. All participants reported to have at least three years of experience driving a motor vehicle. Two females were excluded from the analysis due to a recording failure of the foot pedals and two males were excluded from the analysis due to insufficient quality of verbal recordings, leaving a total sample size of 26 participants (17 males and 9 females, age range: 18-57, mean = 27.7). The participants were recruited from the La Trobe University community. Participants reported to be right-handed and have normal or corrected-to-normal vision, which were advertised inclusion criteria. Individuals were excluded from participation if they had a history of neurological or psychiatric disorders, were susceptible to epileptic seizures, migraines or headaches, or required prescribed psychotropic medication or medication that could cause drowsiness. All participants provided informed written consent and all procedures were approved by La Trobe University’s human research ethics committee.

Driver background questionnaire

This was a 6-item self-report survey related to participants’ driving history (Appendix A). This survey was created to gain information about key factors identified from previous studies to
influence driving performance, such as years of driving experience (Langford, Methorst, & Hakamies-Blomqvist, 2006), regular driving exposure (McGwin, Chapman, & Owsley, 2000), vehicle accidents in the last 6 months (West, French, Kemp, & Elander, 1993), recent ‘near misses’ in the last 6 months (Korner-Bitensky, Kua, von Zweck, & Van Benthem, 2009), and detected driving offense by police or camera in the last 6 months (Rothengatter, 1982). To maximise the response rate, questions only required yes / no responses and were worded to avoid any perceived admission of guilt (Coutts & Jann, 2011).

Apparatus

Stimuli were presented on a Display++ LCD Monitor (Cambridge Research Systems) using E-Prime 2.0 (Psychology Software Tools Inc., 2012) and a Dell Precision 3610 desktop computer (Fig. 1). As illustrated in Fig. 2, four traffic light photographs were used to simulate traffic light changes and elicit responses. Light colours and a fixation point to reduce eye movements (Legge & Campbell, 1981) were added to an original image (provided courtesy of cardriving.com.au) using Adobe Photoshop CC (Adobe Systems, 2015). The task involved a two-alternative forced choice (2AFC) task, with participants asked to give “go” or “stop” responses verbally or using foot pedals as the blank light randomly transitioned to either a green, yellow or red light. Participants had a three second countdown before each task and the light changed after three seconds. A total of 25 trials were presented: ten trials of red lights and ten trials of green lights were presented in line with Pelli and Bex (2013) and Montag and Wilber (2003), and five trials of yellow light transitions were presented to reflect their comparatively lower occurrence in real-life driving and to heighten response bistability by preserving their less frequent occurrence. Three types of responses were collected: foot pedal, verbal, and button responses. Foot pedal responses were recorded with a Thrustmaster ENZO.
Ferrari FFB steering wheel package, used in past driver behaviour studies (Bartlett et al., 2007; Vural et al., 2009). E-Prime recorded on-line the reaction times and the type of responses (i.e. “accelerator” or “brake”) made by the participant. Verbal responses were collected by E-Prime for 10 seconds at a sample rate of 44,000 Hz for off-line analysis thorough a Shure WH20XLR head-worn microphone. Dual task stimuli were delivered by E-Prime via Logitech headphones and button responses were recorded on-line using E-Prime’s Model 200a Serial Response Box (Psychology Software Tools Inc, 2003).

*Animal-artefact identification task*

This identification task used items taken from the Rossion and Pourtois (2004) dataset (available: [http://wiki.cnbc.cmu.edu/Objects](http://wiki.cnbc.cmu.edu/Objects)), which are coloured versions of the original Snodgrass and Vanderwart (S&V) objects (Snodgrass & Vanderwart, 1980). We select items from this dataset because the degree of familiarity in the general population for each item is published and well-established (Rossion & Pourtois, 2004). Four lists of 13 artefacts and 12 animals were taken (Appendix B), with artefacts and animals paired according to familiarity scores – which is an important consideration given that familiarity can confound reaction time (Glass, Cox, & LeVine, 1974). As exhibited in Appendix C, mean familiarity scores were consistent between each wordlist. A one-way ANOVA confirmed no significant differences in familiarity scores between the four wordlists, $F(3,99) = .02, p = .996$ (see Appendix C for means and standard deviations of each wordlist). All wordlist items were converted to audio, using the text to speech function in TextEdit (Apple Computers, 2014, Version 1.10). We also created audio recordings of these wordlists, with the words played backwards to create new sets of stimuli for the single task condition. This reverse scrambling was done using in-house scripts written in Matlab (Mathworks, Natick, Massachusetts, USA). Presenting
incomprehensible stimuli during the single task controlled for the effects of the presence of sound (Ma, Hwang, & Lin, 2009).

To increase accuracy and precision, E-Prime’s Model 200a Serial Response Box (SRB) was used to capture animal-artefact identifications via button pressing. A keyboard or mouse lacks reaction-time precision due to hardware quality (Plant, Hammond, & Whitehouse, 2003), delays caused by operating systems (Plant & Turner, 2009), and interferences arising from other hardware components (i.e. video card; Plant, Hammond, & Turner, 2004). The SRB eliminates this variability by recording the response time before sending it to the computer. Struthers (2015) reports that the SRB exhibits superior millisecond latency ($M = 2.38, SD = 0.70$) over either a keyboard ($M = 15.02, SD = 2.53$) or a mouse ($M = 21.91, SD = 5.15$), resulting in more accurate and precise measurements and fewer trials required to achieve good sensitivity (Breakwell, 2006; Li, Liang, Kleiner, & Lu, 2010).

Procedures

Following completion of the demographic and driver background questionnaire, participants then proceeded to the main experiment. Participants each completed four conditions: (1) foot pedal responses with single task, (2) foot pedal responses with dual task, (3) verbal commands with single task, and (4) verbal responses with dual task. The order of tasks was counterbalanced across participants using the Latin square method. This was done to prevent order effects. The sequence of events for any given trial was as follows. Participants were first presented with a blank traffic light. As seen in Fig. 2, a spoken word from an animal-artefact wordlist was played through the headset during the transition of the black traffic light to a random light colour (red, yellow, or green). Participants responded either verbally (“go” or “stop”) or with the foot pedals (“accelerator” or “brake”) using their right foot. This was done
either as a single or dual task. In the single task condition, participants would perform this task while listening to the auditory recordings of the scrambled words. In the dual task condition, participants would perform this task while listening to the intact auditory recordings of animal and artefact words while they classified them into their appropriate categories by pressing buttons on the SRB with their right hand (button 1: artefact; button 2: animal). Each trial would end after both responses had been made or five seconds had passed, whichever was fastest. A three second break occurred between each trial. Participants completed 25 trials per condition and the order of trials was randomly generated by E-Prime. Participants were instructed to respond naturally to the traffic lights as they would when driving and return their foot to the floor after each trial was completed. Participants were instructed to respond to the traffic light first and then make the animal-artefact identification. Although this interference task is uncommon while driving, it conceivably taxes people in ways similar to those that are sometimes, and should not be, performed while driving, such as pressing keys on a mobile phone in response to speech.

Statistical analyses

Reaction times and the type of responses made by the participant were determined manually on a trial-by-trial basis from the verbal recordings using in-house scripts written in Matlab (Mathworks, Natick, Massachusetts, USA). For each individual, median reaction times for the foot pedal, verbal, and button responses were calculated for each condition, which is a measure that is less sensitive to outliers than means (Ratcliff, 1993). This was decided instead of removing outliers to avoid ‘double dipping’ (Motulsky, 2014) and because the typical ±2 SD indicator can itself be affected by outlying variables (Leys, Ley, Klein, Bernard, & Licata, 2013). The percentage of stop responses made by participants was also calculated for each of
the different conditions. The average and standard deviation for these different dependent variables are presented in the Results.

Given our objective was to examine how different factors influence responses to yellow traffic lights, the rest of the statistical analyses were restricted to making comparisons between yellow traffic light conditions and how the overall performance in these conditions was related to driving history. Furthermore, as expected, there was little variability in stop frequencies for red and green traffic lights (see Results) to allow for appropriate use of parametric statistics. Variance in the data is an assumption that must be met for analysis of variance (ANOVA) and calculating Pearson correlation coefficients ($r$). ANOVA was performed with Task (Single vs. Dual) and Response Modality (Foot Pedals vs. Verbal) as within-subject factors. Separate ANOVAs were performed for the reaction times and the stopping frequencies as the dependent variable.

Last, we determined the effects of Age, Frequency of Driving, Experience, Driving Offenses, Near Misses and Accidents on reaction times and stopping frequencies during task performance collapsed across the different yellow light conditions. To this end, we calculated Pearson correlation coefficients ($r$) that tested whether or not Age, Frequency of Driving, and Experience correlated with the overall reaction times and stopping frequencies across the yellow light conditions. We also performed unpaired t-tests with Welch’s corrections to account for unequal variance to compare reaction times and stopping frequencies between participants with and without driving offences, near misses, and accidents in the last 6 months. Unless specified otherwise, reported $p$ values were corrected for multiple comparisons and statistical significance was evaluated in reference to the conventional alpha level of .05 for two-tailed tests.
Experiment 2: Dynamic simulated intersection approach experiment

The experiment took approximately an hour to complete. The participants in this experiment completed the same driver background questionnaire as experiment 1.

Participants

Eight participants completed the experiment. Compared with experiment 1, there was a larger proportion of male ($n = 6$) than female ($n = 2$) participants and the average age was three years higher ($M = 31.25$, $SD = 12.06$).

Apparatus

The same apparatus from experiment 1 was used for experiment 2. As illustrated in Fig. 3, stimuli were created using a single, nine second video clip of an approach of an intersection. The approach was at 60 km/hr and no other traffic was on the road. Using the method of constant stimuli (Urban, 1910), we added ten yellow light onsets post-production to the video clip that were estimated to encompass the dilemma zone. As shown in Appendix D, the range of light changes was set between 1.3 to 4.5 seconds, with eight equal intervals between. Static type 1 dilemma zone calculations of Zhang, Fu, and Hu (2014) were used as a reference point in order to ensure that the dilemma zone would be present in the intervals we used. This interval range was broadly consistent with other estimations of the dilemma zone (Bonneseon, Middleton, & Zimmerman, 2002; Elmitiny et al., 2010; Rakha, El-Shawarby, & Setti, 2007). The yellow light duration time was four seconds in duration, as this is the duration time Australia regulates for 60km/h zones (Levasseur & Akcelik, 2014). An extra second was also
added to account for mean perceptual reaction times found by Goh and Wong (2004). Intervals were rounded to one decimal place to accommodate the 25fps frame rate used in the video. A video with no traffic light change was presented as a catch trial.

**Procedures**

Participants completed the simulated intersection approach task twice, using foot pedals ("brake" or "accelerator") and verbal commands (vocalising "go" or "stop"). Participants were instructed to respond naturally to the traffic lights as they would when driving and return their foot to the floor after each trial was completed. Following the participant’s response, the video terminated. Participants were shown each of the eleven videos ten times during each of the two conditions, with 220 clips presented in total. To control for any carry-over effects, half the sample completed the verbal command condition first and the other half completed the foot pedal condition first. The order of the trials was randomly generated by E-Prime. Following the participant’s response, the video terminated.

**Statistical analyses**

In each participant, we created a psychophysical curve for each type of response: verbal commands and foot pedal responses. The number of stop responses made by participants was recorded for each of the ten conditions (excluding the catch-trial). For each participant, the frequency of stop decisions was converted into a probability ($P$) of stopping for each light colour, represented as a digit between 0 and 1. Yellow light responses had a probability between consistent stop-responses at red lights and consistent go-responses at green lights.
Therefore, it was possible to convert the green, yellow and red light responses into psychophysical curves using the following logistic function:

\[ P(x) = \frac{e^{b_0 + b_1x}}{1 + e^{b_0 + b_1x}} \]

Where \( b_0 \) and \( b_1 \) are coefficient estimates based on an initial general linear model (binary logit) fit. From this function, the PSE was calculated as \( P = .5 \), with a lower PSE values signifying that a participant chose stop responses more frequently. This was taken to represent conservativeness of decision making, as a conservative decision-maker was theorised to stop more frequently when confronted with a yellow light. Additionally, we calculated the bistability width (\( \omega \)) as:

\[ \omega = P_{75} - P_{25} \]

Where \( P_{25} \) and \( P_{75} \) correspond to \( P = .25 \) and \( P = .75 \) respectively. In this case, the bistability width (\( \omega \)) provides a measure of variability in decision making, with higher \( \omega \) values signifying greater uncertainty by the participant. We took this to represent decisiveness, as a decisive decision maker was theorised to show less uncertainty. PSE and \( \omega \) values were entered in paired samples t-tests as the dependent variable.

Results

*Driver background questionnaire*
According to the questionnaire, the number of years that the participants reported driving a motor vehicle ranged between 3 to 37 years ($M = 11.38, SD = 9.08$). The participants also reported driving between 0 to 30 hours per week ($M = 9.69, SD = 7.17$). In the six months preceding study participation, a moderate number of participants reported a driving offence (Yes: 7; No: 19) and a near miss (Yes: 8; No: 18). A smaller proportion reported being in an accident (Yes: 4; No: 22).

Reaction times to the yellow traffic lights in the dual task

Descriptive statistics across all conditions, including red and green traffic light conditions, are presented in Tables 1 and 2. Given our objective was to examine how various factors might influence response bistability to yellow traffic lights, the Results will focus on statistical comparisons between yellow traffic light conditions and how performance in these conditions might correlate with driving history.

As expected, participants were slower to respond to the yellow traffic lights under dual compared to single task conditions (Main effect of Task: $F_{(1,25)} = 11.38, p = .002, \eta^2 = .313$, Fig. 4a). Contrary to expectations, participants were slower to respond to the yellow traffic lights when they responded with the foot pedals, as they would driving, compared to when they verbalised ‘go’ or ‘stop’, which are not conventional responses (Main effect of Response Modality: $F_{(1,25)} = 39.00, p < .001, \eta^2 = .609$, Fig. 4a). No interaction between Task and Response Modality was observed ($F_{(1,25)} = 0.12, p < .733, \eta^2 = .005$, Fig. 4a). Correlation analyses revealed that reaction times to the yellow traffic lights correlated positively with Age ($r_{(24)} = 0.58, p = .002$, Fig. 4b) and Experience ($r_{(24)} = 0.43, p = .027$, Fig. 4c) but not with Frequency ($r_{(24)} = 0.28, p = .168$). Reaction times did not differ between participants with and
without driving offences ($t_{(20)} = 1.33, p = .198, d = 0.32$), near misses ($t_{(7)} = 0.59, p = .574, d = 0.21$), or accidents ($t_{(3)} = 0.15, p = .891, d = 0.11$) in the last 6 months.

Stopping frequencies to the yellow traffic lights for the dual task

Stopping frequencies to the yellow traffic lights did not differ between the dual and single task conditions ($F_{(1,25)} = 0.77, p = .387, \eta^2 = .030$, Fig. 4d) nor did they differ while participants responded with the foot pedals versus saying ‘go’ and ‘stop’ ($F_{(1,25)} = 1.19, p = .285, \eta^2 = .005$, Fig. 4d). No interaction between Task and Response Modality was observed ($F_{(1,25)} = 39.00, p = 1.000, \eta^2 = .609$, Fig. 4d). Correlation analyses revealed that stopping frequencies to the yellow traffic lights did not correlate with Age ($r_{(24)} = -0.24, p = .236$), Experience ($r_{(24)} = -0.35, p = .080$), or Frequency ($r_{(24)} = 0.09, p = .653$). Stopping frequencies to the yellow traffic lights did not differ between participants with and without driving offences ($t_{(8)} = 0.39, p = .707, d = 0.17$), near misses ($t_{(9)} = 0.78, p = .455, d = 0.25$), or accidents ($t_{(3)} = 1.31, p = .273, d = 0.31$) in the last 6 months.

Classification reaction time during the dual task

During the dual task, participants were as fast in classifying objects with button pressing when they responded to the yellow traffic lights verbally than when they responded with the foot pedals ($t_{(25)} = 0.35, p = .732, d = 0.16$, Fig. 5a). Correlation analyses revealed that reaction times to the yellow traffic lights correlated positively with Age ($r_{(24)} = 0.41, p = .036$, Fig. 5b) and Experience ($r_{(24)} = 0.45, p = .022$, Fig. 5c) but not with Frequency ($r_{(24)} = -0.06, p = .787$). Reaction times did not differ between participants with and without driving offences ($t_{(12)} =
0.54, \( p = .599, d = 0.20 \), near misses (\( t_{(11)} = 0.34, p = .741, d = 0.16 \)), or accidents (\( t_{(4)} = 0.70, p = .521, d = 0.23 \)) in the last 6 months.

Classification accuracy during the dual task

During the dual task, participants were more accurate in classifying objects with button pressing while they responded to the yellow traffic lights verbally compared to when they used the foot pedals (\( t_{(25)} = 2.98, p < .001, d = 0.48 \), Fig. 5d). Performance in classifying objects was almost 10% worse than with the foot pedals. Correlation analyses revealed that classification accuracy did not correlate with Age (\( r_{(24)} = 0.25, p = .225 \)), Experience (\( r_{(24)} = -0.35, p = .084 \)), or Frequency (\( r_{(24)} = 0.32, p = .111 \)). Classification accuracy did not differ between participants with and without driving offences (\( t_{(11)} = 0.24, p = .813, d = 0.14 \)), near misses (\( t_{(18)} = 0.66, p = .517, d = 0.23 \)), or accidents (\( t_{(6)} = 0.12, p = .911, d = 0.10 \)) in the last 6 months.

Experiment 2: Dynamic simulated intersection approach experiment

Background driver questionnaire

Participants completing experiment 2 had an average of three more years driving experience compared to those in experiment 1 (\( M = 14.50 \) years, \( SD = 11.95 \)) but drove a similar number of hours per week (\( M = 8.25, SD = 9.47 \)).

Index of conservativeness and decisiveness for the simulated intersection
Analysis of PSE and ω values did not detect significant differences between foot pedal and verbal responses, and did not support the hypothesis that people make more conservative responses while responding explicitly than implicitly. Namely, differences between the PSE of foot pedal ($M = 1.86, SD = 0.21$) and verbal ($M = 1.84, SD = .22$) responses were not statistically significant, $t(7) = .26, p = .799, d = 0.09$. Likewise, differences between the ω values of foot pedal ($M = 0.57, SD = 0.52$) and verbal ($M = 0.54, SD = .42$) responses were also not statistically significant, $t(7) = .50, p = .632, d = 0.18$.

Discussion

Experiment 1 assessed the effects of multitasking on yellow traffic light responses and tested whether or not a discrepancy existed between intentions and behaviour while experiment 2 explored further if people differed in the relative conservativeness of their responses when making implicit or explicit responses in a more dynamic situation. The second experiment differed from the first in two ways: (1) there was no multitasking and (2) we attempted to study conservativeness in a more realistic setting.

We hypothesised that multitasking would hamper fast and conservative decision-making for both foot pedal and verbal responses, and that foot responses would be more implicit and less disrupted than the verbal responses. We hypothesised that explicit responses would be more conservative than implicit responses. The first hypothesis was partially supported. Multitasking prolonged reaction times across response modalities. Our second hypothesis was not supported. No differences were observed in the degree of conservativeness in the responses made between the foot pedal and verbal commands in both experiments. The convergence in results between experiments affirms a degree of ecological validity to experiment 1, which is considerably less realistic than experiment 2. It is unlikely that the
convergence between experiments arose from a lack of power. The effect sizes reported for conservativeness between foot and verbal responses are miniscule in both cases (experiment 1: \(\eta^2 = .005\); experiment 2: \(d = 0.09\)) and would not be detected with reasonable sample sizes. Last, the foot responses were not less disrupted than the verbal responses in the dual task in experiment 1. Contrary to expectations, the foot responses were slower than the verbal responses in the dual task.

In the ensuing discussion, we expand on four key findings: (1) the slower responses to yellow traffic lights while multitasking, (2) the faster responses in verbal commands relative to foot responses, (3) the lack of effects of response modality on conservativeness, and (4) the age effects observed on reaction times and stopping frequencies. We end our paper by discussing the implications of these key findings on future technological applications.

**Key finding 1: Responses to yellow traffic lights are disproportionately slower while multitasking**

Our results complement a large body of evidence cataloguing the deleterious effect of multitasking while driving (Caird et al., 2014; Caird et al., 2008). This was evident in the slower reaction times during the dual task conditions (Fig. 4a; Table 1). Reaction time increases caused by distracted driving have substantial practical implications. For example, Carney, McGehee, Harland, Weiss, and Raby (2015) reviewed dashboard cameras from 1,691 crashes of drivers aged between 16 and 19 and determined that distraction was implicated in 60% of the crashes, tremendously exceeding government estimates. Their analysis also revealed slower reaction times when emergency braking was implicated in a considerable proportion of rear-end collisions. Although increases in reaction times cannot be asserted to have caused the collisions, it certainly added to the probability of one occurring. Had those drivers not been
distracted and had additional time and distance to brake, it is conceivable that many of these collisions could have been avoided.

In our study, participants classified, by button pressing, auditory presented words of animals and man-made artefacts. Although this is not something one typically does while driving, our results reveal how the manipulation was successful in creating interference. Auditory tasks are commonly used to approximate mobile phone use (Harbluk et al., 2007). However, given such approximations are typically conservative (Caird et al., 2008), the observed effects are likely not inflated. Rather, the true effects of multitasking are probably greater because drivers commonly engage in substantively more complex multitasking than the dual task performed by participants in this study. For example, drivers self-report using GPS devices (Lee, Forlizzi, Hudson, & Jun, 2014), eating (Irwin, Monement, & Desbrow, 2014), and even reading a newspaper (AA Insurance, 2014) as well as changing clothes (Hurwitz et al., 2015) while driving. These real-life multitasking activities are concerning when one considers only comparatively minor amounts of additional cognitive load are required to significantly increase reaction time, as demonstrated by our study. In many jurisdictions, legislation prohibits drivers using electronic devices, primarily focusing on drivers making physical contact with the device (Victorian Government, 2009). Consequently, in these jurisdictions, there is a distinction between illegal ‘hands on’ use of devices and legal ‘hands free’ devices (i.e. Bluetooth car phone systems). However, rather than simply campaigning against ‘eyes off the road’ (AMTA, 2015), the cognitive impairment caused by multitasking should be equally considered, given it is similarly debilitating (David L. Strayer, Drews, & Crouch, 2006).

Key finding 2: Verbal commands are faster than foot pedal responses
The implicitness of foot responses were posited to produce greater speed due to their conceivable automaticity (Shine & Shine, 2014). Research is clear that increasing task automaticity by mass practice leads to faster reaction times (Scheel, 2010; Schneider & Chein, 2003; Schumacher et al., 2001). However, foot pedal responses were found to be slower than verbal responses while making yellow light responses (Fig. 4a; Table 1). A contributing factor may have been the travelling difference between starting position and the foot pedal, however this is necessary for effective braking. It may also be the case that performing a routine response may decrease vigilance, may encourage mind-wandering, which can hamper the initiation of efficient, automatic systems and increase reaction times (Cerezuela, Tejero, Chóliz, Chisvert, & Monteagudo, 2004; Chapman, Ismail, & Underwood, 1999; Lajunen et al., 1997; Sullman & Taylor, 2010). Reaction times differences were greatest between foot pedal and verbal responses when responding to yellow lights (Table 1). Given that responding to a yellow traffic light appropriately requires a certain degree of attention and cognitive supervision (Blaser & Shepard, 2009), both of which depend on vigilance, a driver operating on “autopilot” is more likely to react more slowly and perhaps more inappropriately than one driving more carefully.

Inattentive states have consistently been shown to be sub-optimal compared with focused attention (i.e. ‘alertness’ and ‘vigilance’) on measures of reaction times and accuracy (Campagne, Pebayle, & Muzet, 2004; Lisper, Laurell, & Van Loon, 1986). This is because attention is able to decrease external noise (Lu & Dosher, 1998) and reduce the attended objects’ signal intensity (Marisa Carrasco, Penpeci-Talgar, & Eckstein, 2000; Yeshurun & Carrasco, 1999). Beyond this, attention is argued to accelerate the rate of information processing (M. Carrasco & McElree, 2001), Conversely, inattention diminishes the driver’s ability to notice critical changes in the road environment at intersections (Caird, Edwards, Creaser, & Horrey, 2005; Knowles & Tay, 2002). The practical implications of slower foot responses are concerning because people actually use their feet as opposed to making verbal
commands when controlling vehicles in the real world. Thus, our findings raise questions about whether or not a more cognitively supervised modality, such as voice-control, might be safer for controlling vehicles.

Across all light conditions (yellow, red and green), the foot pedal responses recorded in our study demonstrated more variability in reaction times than the verbal responses (see the standard deviations report in Table 1). We offer two explanations. First, the greater spread in reaction times for the foot pedal responses may reflect different levels of driving experience across participants. It is conceivable that there would be less variability in more experienced drivers. Conversely, given that people do not typically operate vehicles using their voice, one would expect similar variability across different levels of driving experience. Second, participants could have chosen to be more decisive when making verbal responses. It is conceivable that explicit responses are more likely to reflect a conscious rule and be less influenced by other ongoing mental operations than by more implicit responses. However, fast heuristic-driven responses can come at the cost of reduced flexibility in decision making and the risk of prematurely ‘seizing’ or ‘fixating’ on incorrect answers (Kruglanski & Webster, 1996; Smith, 1995). Loss of flexibility can lead to dangerous adaptive strategies (Etienne, Marin-Lamellet, & Laurent, 2013). The converse of this trade off may be evident in the classification task. Unlike traffic light responses, there were no differences between verbal and button press reaction times in the classification task (Table 2; Fig. 5a). However, verbal classifications were significantly more accurate than button presses (Fig. 5d). Flexibility is crucial to real-world driving scenarios, as they are a unique and potentially subject to rapid changes (A. C. Stein & Dubinsky, 2011) and the driver needs to strike an optimal balance of speed and accuracy. Further research is needed to establish and quantify the presence of the speed-accuracy compromise in yellow traffic light decisions to ascertain the conditions under
which to drivers may resort to inflexible and rigid decision-making in a complex and changeable road situation.

**Key finding 3: Response modality did not impact conservativeness.**

What people said they would do while driving was found to be the same as what they actually did. No difference was found between stopping frequency between foot pedal and verbal responses (Fig. 4a). However, a limitation was that possible social influences that might motivate liberal responses were not taken into account. Although social influence was initially hypothesised to create conservative decisions, it may be that, for some participants, social influence promoted liberal decision making (i.e. they were more likely to go rather than stop at a yellow light). The most applicable self-serving motivation is the motivation to finish the task quickly. In real-life driving situations, reckless decisions occur as drivers compete for space as a function of time. Driver self-report studies demonstrate how violations are often incurred when trying to get somewhere in a hurry (Gras et al., 2006; Hatfield & Job, 2006). Further self-serving motivations that may inspire liberal decision-making include the desire to raise social status through risk-taking (Møller & Gregersen, 2008), manage sense of threat (Taubman Ben-Ari, Florian, & Mikulincer, 2000), and alleviate frustration (Shamoa-Nir & Koslowsky, 2010). Further research may benefit by attempts to capture these motivations using predictors of reckless driving, such as the Driver Behavior Questionnaire (Wishart, Freeman, & Davey, 2006).

Another consideration is that implicit foot pedal responses may have been more cognitively penetrable than initially predicted, and influenced by pro-social motivations (Ferguson & Bargh, 2004; Perugini, Conner, & O'Gorman, 2011; van Baaren, Holland, Kawakami, & van Knippenberg, 2004). A study that ingeniously combined both these ideas is
by Valdesolo and DeSteno (2008), which found that explicit hypocritical judgments about other participant’s behaviour was eliminated under a dual task. This suggested that explicit self-serving judgments were overridden by implicit pro-social attitudes. Taken collectively, explicit and implicit responses were consistent in conservativeness. However, more sensitive measures should be used to test if divergent motivations underpin either response type.

**Key finding 4: Middle aged and more experienced drivers are slower and less likely to stop.**

Our results also revealed that more experienced drivers and older drivers tended to be slower. Reaction times increased as a function of experience (Fig. 4c) and age (Fig. 4b). In opposition to this finding, earlier research suggests that more experienced drivers will perform faster when making implicit decisions and when facing uncertainty. In tandem with this, middle aged drivers tend to be more experienced and so are commonly considered as safer. This is because experience is tied to automaticity. More experienced drivers have a lower crash risk (BITRE, 2013) and exhibit greater task automaticity, evidenced by faster reaction times and better performance under dual task conditions (Sagberg & Bjornskau, 2006). On the other hand, recently licensed drivers, who are in the process of automatising driving tasks, have the highest crash risk (McCartt, Shabanova, & Leaf, 2003). Nevertheless, more experienced drivers were found to be slower and were not found to be more conservative than less experienced drivers.

We offer two explanations for the slower reaction times of middle aged and more experienced drivers. First, experienced drivers may have been more susceptible to inattention due to the routine nature of our paradigm. As explained earlier, the more routine a task is, the less vigilant one becomes, which diminishes attention. Responding to a traffic light is more routine for a more experienced driver than it is for a less experienced driver. Second, the effects of age could have contributed to slower reaction times in the more experienced drivers given
that processing speed and visual processing abilities may decline with age (Owsley et al., 1998; Stutts, Stewart, & Martell, 1998). Furthermore, middle aged drivers may avoid driving in conditions they feel uncomfortable in (Ball et al., 1998) and not overestimate their abilities (Marottoli & Richardson, 1998), reducing their exposure to challenging driving conditions which is needed to facilitate learning and growth. This is in opposition to the tendencies of younger drivers to overestimate their driving ability (Groeger & Brown, 1989) and exhibit impulsive, risky, and thrill-seeking behaviour (Steinberg, 2007). Further research is needed to develop strategies to mitigate declines in processing speed in middle aged drivers and protect experienced drivers against the effects of inattention blindness.

Implications for technological applications

Our findings are informative for the implementation of new technologies that are currently used to improve driver safety. Three relevant technological developments that are relevant to yellow light responses are intersection collision warning systems (ICWS), signal timing of traffic lights, and voice control car systems.

ICWS provide in-car warnings to drivers, alerting them to an imminent intersection collision (Belz, Robinson, & Casali, 1999; Chang, Lin, Hsu, Fung, & Hwang, 2009; Chen, Cao, & Logan, 2011), which has the potential to reduce right angle, or ‘t-bone’, collisions. These systems are currently in development and yet to be integrated into mass-market vehicle manufacturing. ICWS warning systems commonly use auditory warnings as a means of reducing visual load (Yan, Xue, Ma, & Xu, 2014). However, our study found that the addition of meaningful, single-word auditory stimuli significantly prolonged reaction times (Fig. 4a). In an immanent collisions situation, the additional auditory stimuli may prolong reaction times if
the driver has already seen the hazard. Further research is suggested to assess whether or not ICWS increases reaction times and whether or not it is effective while drivers are multitasking.

The study lends further support for the use of dynamic yellow light phase times. Traffic lights in many countries use algorithms that extend the yellow light phase for times of day when traffic is heavy or there is inclement weather. Yellow light phase times are hugely important because time may be a driver’s single greatest resource when crossing an intersection. Standardised phase times are problematic because drivers regularly exceed speed limits at intersections (David, 2015) and because of the panoply of individual and situational factors that potentially exacerbate response bistability (Zhang et al., 2014). Dynamic equations, on the other hand, change the phase time based on the anticipated presence of risk factors, such as environmental factors that reduce drivers’ ability to perceive the lights and decelerate, as well as anticipated approach speeds (McGee et al., 2012). Our study found significant reaction times differences when responding to traffic lights when drivers were multitasking (Table 1; Fig. 4a), older (Fig. 4b), and more experienced (Fig. 4c). These differences may mean the standardised time is insufficient at particular intersections for some drivers. If the time is insufficient, the dilemma zone expands, leading more drivers to emergency brake or make risky crossings (H. S. Stein, 1986). For this reason, trends in the United States, Canada, and Germany are toward dynamic kinematic formulas for determining phase times (McGee et al., 2012). Exploration of the increased use of these formulas recommended to mitigate against the significant variability of reaction times between drivers.

Verbal interfaces, such as Siri, Google Assistant, and Amazon Alexa are increasingly embedded into phones and vehicles. Verbal interfaces offer a way of reducing button pressing while driving (Greengard, 2015). As evident in our study, verbal responses conferred a performance advantage as they were faster than foot pedal responses (Table 1; Fig. 4a) and facilitated more accurate classifications in the dual task (Fig. 5d). Verbal interfaces may
mitigate against the negative effects of multitasking and increase driving efficiency. Tentative evidence that vehicle speech interfaces can lead to more consistent driving (Barón & Green, 2006) complements these findings. However, D. L. Strayer, Turrill, Coleman, Ortiz, and Cooper (2014) and Cooper, Ingebretsen, and Strayer (2014) note that verbal interfaces can create high cognitive demand for drivers due to imperfect reliability and driver inexperience with the technology, however verbal interfaces are constantly improving. Further research is needed to confirm the effectiveness of verbal interface systems for reducing driver distraction, and facilitating higher response speeds and consistency while driving.

Closing remarks

In conclusion, the study demonstrates that multitasking prolongs reaction times to yellow traffic lights and that explicit verbal responses are faster than implicit foot pedal responses. The primary implication of this study is that multitasking can increase risk for drivers navigating intersections, with performance decline resulting from lower levels of additional cognitive load than undertaken during real-world multitasking. The performance increases observed for explicit responses requires further observation. More sensitive measures are required to ascertain effects of top-down motivations on yellow light responses. Recommendations for public policy include: (1) adopting dynamic equations for determining yellow light duration, (2) restrictions against multitasking that take into account the cognitive impairment of multitasking, (3) investment be made to research the viability of in-vehicle ICWS systems, and (4) investment be made to promote improvement in voice-command car systems.
Acknowledgements

The authors would like to thank the School of Psychology and Public Health at La Trobe University and the Australian Research Council (DP170103189) for providing financial support for this study.

Open Practices Statement

The data reported in this paper are available upon request. None of the experiments were preregistered.

References


in the pacific northwest. *Journal of Transportation Safety and Security*, 00-00. doi:10.1080/19439962.2014.997329


Fig. 1. Testing station. Stimuli were presented using a (a) Dell Precision 3610 desktop computer and (b) Display++ LCD Monitor (Cambridge Research Systems), used for its high 120Hz refresh rate (Ghodrati, Morris, & Price, 2015). Pedal responses were recorded with a (c) Thrustmaster ENZO Ferrari FFB steering wheel package, used in past driver behaviour studies (Bartlett et al., 2007; Vural et al., 2009). Verbal responses were recorded using a (d) Shure WH20XLR head-worn microphone, used in past studies to record for off-line analysis (Kang, Yun, & Seong, 2011; Miyata & Kudo, 2014). Dual task stimuli were delivered via (e) over-ear Logitech headphones, with responses recorded using a (f) Model 200a Serial Response Box (Psychology Software Tools Inc, 2003).
Fig. 2. Trial events for experiment 1. A trial began with the participant seeing the image of a blank traffic light to the left. The image was set to transition to randomly present one of images to the right: the red light, yellow light, or green light. Slide transitions and audio stimuli from dual task were simultaneously occurred after three seconds, with a varying stimulus onset time (jitter) of 300-600ms to reduce predictability. Participants were required to respond verbally (“go” or “stop”) or with foot pedals (brake or accelerator).
Fig. 3. Sequence of events for experiment 2. In this trial, a yellow light change is scheduled to occur 3.08 seconds prior to the intersection crossing. Panel (a) shows 3.0 seconds into the trial when the traffic light is still green. Panel (b) shows the light yellow 5.0 seconds into the trial and panel (c) shows the light red 7.0 seconds into the trial. Participants were required to respond verbally ("go" or "stop") or with foot pedals (brake or accelerator).
Fig. 4. Driving performance during the yellow traffic light conditions in experiment 1. The figure provides a summary of the main findings with regards to the effects of dual task on driving performance. Panel (a) shows that average reaction times during the dual and single task conditions while participants gave their responses verbally (yellow bars) or used the foot pedals as they normally would while driving (orange bars). Main effects of Task and Response Modality were observed. Panels (b) and (c) shows linear correlations of the aggregated reaction times increasing as a function of Age (b) and Experience (c). Panel (d) shows how frequently participants stopped. Error bars represent SEMs.
Fig. 5. Classification performance during the yellow traffic light conditions in experiment 1. The figure provides a summary of the main findings with regards to performance on the object classification task. Panel (a) shows that average reaction times in providing manual button responses while participants also responded to yellow traffic lights verbally (yellow bars) or with the foot pedals (orange bars). Panels (b) and (c) shows linear correlations of the aggregated reaction times increasing as a function of Age (b) and Experience (c). Panel (d) shows how accurate the participants were at the object classification task while also responding to the yellow traffic lights verbally (yellow bars) or with the foot pedals (orange bars). Participants were significantly worse in the latter relative to the former condition. Error bars represent
SEMs.
Table 1. Descriptive statistics for driving performance in experiment 1.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Average Reaction Time (ms)</th>
<th>Standard Deviation Reaction Time (ms)</th>
<th>Average Stop Frequency (%)</th>
<th>Standard Deviation Stop Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Task, Verbal Response</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Light</td>
<td>498.30</td>
<td>86.96</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Red Light</td>
<td>520.70</td>
<td>96.51</td>
<td>99.62</td>
<td>1.96</td>
</tr>
<tr>
<td>Yellow Light</td>
<td>499.03</td>
<td>88.77</td>
<td>82.31</td>
<td>36.80</td>
</tr>
<tr>
<td>Single Task, Foot Response</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Light</td>
<td>502.75</td>
<td>96.21</td>
<td>2.69</td>
<td>7.24</td>
</tr>
<tr>
<td>Red Light</td>
<td>562.79</td>
<td>79.79</td>
<td>93.46</td>
<td>12.31</td>
</tr>
<tr>
<td>Yellow Light</td>
<td>593.46</td>
<td>86.82</td>
<td>79.23</td>
<td>34.17</td>
</tr>
<tr>
<td>Dual Task, Verbal Response</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Light</td>
<td>694.63</td>
<td>157.84</td>
<td>3.46</td>
<td>6.29</td>
</tr>
<tr>
<td>Red Light</td>
<td>692.82</td>
<td>148.34</td>
<td>97.69</td>
<td>6.52</td>
</tr>
<tr>
<td>Yellow Light</td>
<td>674.90</td>
<td>136.19</td>
<td>85.38</td>
<td>29.15</td>
</tr>
<tr>
<td>Dual Task, Foot Response</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Light</td>
<td>695.87</td>
<td>193.17</td>
<td>6.92</td>
<td>10.87</td>
</tr>
<tr>
<td>Red Light</td>
<td>688.35</td>
<td>176.83</td>
<td>91.54</td>
<td>11.56</td>
</tr>
<tr>
<td>Yellow Light</td>
<td>756.33</td>
<td>246.41</td>
<td>82.31</td>
<td>30.11</td>
</tr>
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</table>

Table 2. Descriptive statistics for classification performance in experiment 1.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Average Reaction Time (ms)</th>
<th>Standard Deviation Reaction Time (ms)</th>
<th>Average Accuracy (%)</th>
<th>Standard Deviation Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dual Task, Verbal Response</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Light</td>
<td>1264.49</td>
<td>276.63</td>
<td>96.54</td>
<td>6.29</td>
</tr>
<tr>
<td>Red Light</td>
<td>1226.25</td>
<td>239.27</td>
<td>91.54</td>
<td>11.56</td>
</tr>
<tr>
<td>Yellow Light</td>
<td>1294.55</td>
<td>292.28</td>
<td>95.38</td>
<td>10.29</td>
</tr>
<tr>
<td><strong>Dual Task, Foot Response</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Light</td>
<td>1325.41</td>
<td>312.85</td>
<td>88.41</td>
<td>11.14</td>
</tr>
<tr>
<td>Red Light</td>
<td>1271.95</td>
<td>321.94</td>
<td>90.09</td>
<td>12.16</td>
</tr>
<tr>
<td>Yellow Light</td>
<td>1317.22</td>
<td>343.76</td>
<td>85.58</td>
<td>17.57</td>
</tr>
</tbody>
</table>
Appendix A

Driver Background Questionnaire.

1. Approximately how many years driving experience do you have? __________

2. Approximately how many hours would you regularly spend driving per week? __________

3. Have you experienced a vehicle accident in the last 6 months that has made you more cautious or less confident while driving? Y/N

4. Have you experienced a ‘near miss’ in the last 6 months that has made you more cautious or less confident while driving? Y/N

5. Have you had a driving offence detected by police or automated cameras in the last 6 months. Y/N
## Appendix B

### Dual Task Wordlists

**Table B.1**

*Wordlists for Animal-Artefact Identification Task*

<table>
<thead>
<tr>
<th>List 1</th>
<th>List 2</th>
<th>List 3</th>
<th>List 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bed</td>
<td>Book</td>
<td>Chair</td>
<td>Door</td>
</tr>
<tr>
<td>Finger</td>
<td>Hand</td>
<td>Nose</td>
<td>Table</td>
</tr>
<tr>
<td>Toe</td>
<td>Glass</td>
<td>House</td>
<td>Key</td>
</tr>
<tr>
<td>Leg</td>
<td>Lips</td>
<td>Pants</td>
<td>Pen</td>
</tr>
<tr>
<td>Sweater</td>
<td>Bread</td>
<td>Ear</td>
<td>Eye</td>
</tr>
<tr>
<td>Foot</td>
<td>Lamp</td>
<td>Pencil</td>
<td>Shoe</td>
</tr>
<tr>
<td>Socks</td>
<td>Tree</td>
<td>Watch</td>
<td>Arm</td>
</tr>
<tr>
<td>Bottle</td>
<td>Cup</td>
<td>Sun</td>
<td>Thumb</td>
</tr>
<tr>
<td>Car</td>
<td>Glasses</td>
<td>Ruler</td>
<td>Apple</td>
</tr>
<tr>
<td>Pot</td>
<td>Shirt</td>
<td>Belt</td>
<td>Cigarette</td>
</tr>
<tr>
<td>Coat</td>
<td>Leaf</td>
<td>Scissors</td>
<td>Flower</td>
</tr>
<tr>
<td>Frying Pan</td>
<td>Hanger</td>
<td>Knife</td>
<td>Orange</td>
</tr>
<tr>
<td>Tomato</td>
<td>Truck</td>
<td>Banana</td>
<td>Blouse</td>
</tr>
<tr>
<td>Dog</td>
<td>Cat</td>
<td>Bird</td>
<td>Cow</td>
</tr>
<tr>
<td>Chicken</td>
<td>Horse</td>
<td>Rabbit</td>
<td>Duck</td>
</tr>
<tr>
<td>Fly</td>
<td>Butterfly</td>
<td>Rooster</td>
<td>Fish</td>
</tr>
<tr>
<td>Ant</td>
<td>Mouse</td>
<td>Snail</td>
<td>Sheep</td>
</tr>
<tr>
<td>Bee</td>
<td>Donkey</td>
<td>Pig</td>
<td>Squirrel</td>
</tr>
<tr>
<td>Goat</td>
<td>Frog</td>
<td>Turtle</td>
<td>Swan</td>
</tr>
<tr>
<td>Owl</td>
<td>Fox</td>
<td>Caterpillar</td>
<td>Deer</td>
</tr>
<tr>
<td>Monkey</td>
<td>Lion</td>
<td>Eagle</td>
<td>Lobster</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>-------</td>
<td>---------</td>
</tr>
<tr>
<td>Elephant</td>
<td>Peacock</td>
<td>Bear</td>
<td>Camel</td>
</tr>
<tr>
<td>Penguin</td>
<td>Gorilla</td>
<td>Zebra</td>
<td>Giraffe</td>
</tr>
<tr>
<td>Raccoon</td>
<td>Snake</td>
<td>Alligator</td>
<td>Ostrich</td>
</tr>
<tr>
<td>Sea Horse</td>
<td>Skunk</td>
<td>Tiger</td>
<td>Seal</td>
</tr>
</tbody>
</table>

* Words in Wordlists 1 and 2 were reversed for use in the single task condition.*
Table C.1. Mean Familiarity Scores for Wordlists in Animal-Artefact Identification Task (n = 25).

<table>
<thead>
<tr>
<th>Condition</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>List 1</td>
<td>3.81</td>
<td>1.26</td>
</tr>
<tr>
<td>List 2</td>
<td>3.85</td>
<td>1.19</td>
</tr>
<tr>
<td>List 3</td>
<td>3.83</td>
<td>1.20</td>
</tr>
<tr>
<td>List 4</td>
<td>3.78</td>
<td>1.21</td>
</tr>
</tbody>
</table>
Table D.1. Times and Distances from the Intersection when Yellow Traffic Light Onsets Occur During the Simulated Intersection Approach

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time from the intersection (seconds)</td>
<td>1.3</td>
<td>1.7</td>
<td>2.0</td>
<td>2.4</td>
<td>2.7</td>
<td>3.1</td>
<td>3.4</td>
<td>3.8</td>
<td>4.1</td>
<td>4.5</td>
</tr>
<tr>
<td>Distance from the intersection (meters)</td>
<td>21.7</td>
<td>27.6</td>
<td>33.5</td>
<td>39.4</td>
<td>45.4</td>
<td>51.3</td>
<td>57.2</td>
<td>63.1</td>
<td>69.1</td>
<td>75.0</td>
</tr>
</tbody>
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