Investigating the Impact of Static Roadside Advertising on Drivers' Situation Awareness

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ABSTRACT

Roadside advertising has the potential to create a crash risk for drivers as it may distract attention from driving at critical times. In an on-road instrumented vehicle study, we examined if and how static advertising billboards affect drivers' situation awareness across different driving environments. Nineteen fully licensed drivers drove an instrumented vehicle around a 38 km urban test route comprising freeway, busy urban retail and arterial road sections. The route contained a number of static billboards. Drivers provided continuous verbal protocols throughout the drive. Results indicated that the structure and content of drivers' situation awareness was not appreciably affected by the billboards in any of the road environments examined. Drivers focused their attention on the billboards when driving demand was low, such as when driving on the freeway with light to moderate traffic, in lower speed zones, or when stationary. However, when drivers were required to perform a manoeuvre or driving demands increased, drivers directed less attention to the billboards and focussed their awareness on the immediate driving task. This suggests that drivers can, at least under some conditions, effectively self-regulate their attention to billboards when required to focus on the immediate traffic or driving situation.

Keywords: *Driver distraction; Situation awareness; Roadside Advertising; Billboards; On-road study*

1. INTRODUCTION

Driving is becoming progressively more complex and drivers more distraction prone due to both in-vehicle (e.g., technologies) and external (e.g., road signs, advertising) factors. Driver distraction, defined as the “diversion of attention away from activities critical for safe driving towards a competing activity” (J. D. Lee, Young, & Regan, 2009, p 34), is acknowledged internationally as a growing threat to road safety (WHO, 2011). In Australia, distraction has been reported as a contributing factor in 14 percent of serious crashes resulting in hospital attendance (McEvoy, Stevenson, & Woodward, 2007), and in 10 percent of fatal and 18 percent of injury crashes in the US (NHTSA, 2015).

Distractions arising from outside the vehicle constitute a significant proportion of distraction – related crashes. In the US, up to 30 percent of police-reported distraction-related crashes are linked to external sources (Stutts, Reinfurt, Staplin, & Rodgman, 2001). Among the various external sources of distraction present in the road environment, roadside advertising represents a source that, by its very nature, is designed to attract drivers’ attention. Unlike directional and information-based roadside signage, which can provide wayfinding, information on road conditions and hazards and road safety messages, billboards are highly conspicuous due to their size, colour and their close proximity to roadways. In particular, digital billboards have been suggested to be a potential source of distraction given that their movement and flicker can involuntarily capture drivers’ attention (Abrams & Christ, 2003; Roberts, Boddington, & Rodwell, 2013). Given their attention-grabbing properties, it is reasonable to posit that billboards could distract drivers’ attention from the driving task and negatively impact driving behaviour. Indeed, basic visual search research conducted in laboratories indicate that the presence and decreased proximity of distractors increases reaction time to a target stimulus (Johnston & Cole, 1976; Pashler, 1987); suggesting that roadside advertising could disrupt drivers’ ability to detect driving-relevant information and objects in the road environment.

While some crash-data based studies have shown a correlation between roadside advertising and higher crash rates (e.g., Farbry, Wochinger, Shafer, Owens, & Nedzesky, 2001; Wallace, 2003), others have found no correlation (e.g., Yannis, Papadimitriou, Papantoniou, & Voulgari, 2013). Indeed, there is currently no direct, conclusive evidence that roadside advertising plays a significant causal role in distraction-related crashes (Roberts et al., 2013). However, there is a range of evidence from simulation and on-road research suggesting that roadside advertising can negatively impact a range of more subtle behavioural indicators (Wachtel, 2009).

Research conducted in a controlled simulated environment has demonstrated that drivers can look at roadside advertising too frequently and for too long (Crundall, Van Loon, & Underwood, 2006). Crundall et al., for example, found that drivers in their study spent, on average, almost half a second looking at raised level advertising billboards and close to one second looking at street level billboards. To put this into perspective, the authors found that drivers spent less time looking at potential driving hazards in the same region. Other researchers have also shown that time spent looking at roadside advertising is detrimental to safe driving (Edquist, Horberry, Hosking, & Johnston, 2011; M. S. Young et al., 2009). In particular, drivers' lateral (Young et al., 2009) and longitudinal control, as well as their reaction times to driving events (Edquist et al., 2011), have been demonstrated to be adversely affected by the presence of advertising billboards.

Research conducted in real traffic conditions largely support simulator study findings regarding visual attention. Dukic et al. (2013), for example, found that the middle-aged Swedish drivers in their instrumented vehicle study made more frequent and longer glances toward electronic billboards than standard road signs. On average, drivers in their study spent 2.25 seconds fixating on electronic billboards while driving during the day, compared to an average of 0.87 secs for other traffic signs. The dwell times for the electronic signs is almost double what was found in Crundall et al.'s (2006) simulator study for static street level billboards and suggests that the changing display on electronic billboards may attract drivers' attention for longer. It is also interesting to note that glances away from the forward roadway of more than two seconds increased crash and near-crash risk by at least two times that of normal, undistracted driving (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006).

Both simulation and on-road research shows that the impact of roadside advertising on driver behaviour is likely to vary depending on the characteristics of the billboard (Crundall et al., 2006; Wallace, 2003). More specifically, the impact of roadside advertising on driving behaviour has been found to increase when the billboard is positioned at street level rather than raised, or when it is located at curves or junctions (Crundall et al., 2006) and the content of the images are emotion laden (Trick, Brandigampola, & Enns, 2012). The impact can also vary across type of display (static or dynamic; S. E. Lee, McElheny, & Gibbons, 2007), with rapidly changing or moving stimuli, in particular, appearing to exacerbate the effects of roadside advertising both in terms of capturing visual attention and degrading driving performance (Belyusar, Reimer, Mehler, & Coughlin, 2016; Decker et al., 2015; Dukic et al., 2013).

Based on the results of previous research, roadside advertising has been shown to negatively impact a range of driver behaviours, including visual attention, reaction time, and lateral control. Another aspect of driver behaviour, shown to be impacted by driver distraction (e.g., Steven J. Kass, Cole, & Stanny, 2007; Strayer & Fisher, 2015; K. L. Young, Salmon, & Cornelissen, 2013), but that has not been examined in relation to roadside advertising is situation awareness (SA).

Driver SA is defined as activated knowledge, regarding road user tasks, at a specific point in time (P. M. Salmon, Stanton, & Young, 2012). To safely navigate dynamic road environments, drivers must perceive and attend to relevant information and use this to anticipate and react to changes and events in the environment to avoid conflicts with objects and other road users; that is, drivers must achieve and maintain adequate SA (Gugerty, 2011). Achieving SA involves a range of cognitive processes including perception and pattern recognition (S. J. Kass, Herschler, & Companion, 1991), attention and comprehension (Steven J. Kass et al., 2007; Wickens & Hollands, 2000), and decision-making (Endsley, 1995; Ma & Kaber, 2005). Engaging in distracting activities that compete for these same cognitive resources can lead to a breakdown in drivers' SA and, ultimately, impaired driving performance and hazard detection (Kass et al, 2007). Directing visual and cognitive attention toward roadside advertising rather than to surrounding road and traffic information could, therefore, result in a breakdown in driving-related SA and, ultimately, to drivers missing critical information regarding a change in the traffic situation that could lead to a collision.

The current study examined, in an on-road context, how static advertising billboards affect drivers' situation awareness in different driving environments: freeway, retail area and arterial road. In particular, we aimed to identify if the presence of billboards impacts on drivers' awareness of the behaviour of other road users or events occurring in the roadway, and in particular if drivers miss safety-critical elements in the environment in the vicinity of billboards (e.g. other drivers, pedestrians, traffic signal changes). Driver SA was modelled through propositional networks, which were constructed based on a content analysis of the verbal protocols provided by participants while driving a pre-defined urban test route. Network-based analysis of driver SA, drawn from verbal protocols, represents SA as information 'elements' and the relationships between them (Walker, Stanton, & Salmon, 2011). Thus, the method provides a comprehensive picture of driver SA that reflects breakdowns in SA due to perceiving fewer information elements in the driving environment, as well as failures of drivers to integrate these perceived elements into a situational model.

2. METHOD

2.1 Participants

A total of 19 fully licensed drivers (males = 12), provided complete and useable data sets. Drivers ranged in age from 22 to 47 years (M = 30.8, SD = 8.0), had held a valid licence for 2-30 years (M = 12.8, SD = 8.2) and drove between 1 and 100 hours each week (M =16.0, SD = 23.5). Participants reported that 70% of their weekly travel was for private purposes.

Participants were recruited through a weekly on-line Monash University newsletter and were compensated for their time and travel expenses. The study was approved by the Monash University Human Research Ethics Committee.

2.2 Materials and Equipment

2.2.1 On-Road Test Vehicle (ORTeV)

The study was conducted using MUARC's On-road Test Vehicle (ORTeV). The ORTeV is an instrumented GM Holden Calais sedan with automatic transmission and is equipped to simultaneously collect vehicle-related and roadway scene data and record driver-vehicle interactions. A discrete V-Box data logger records vehicle speed, GPS location, longitudinal acceleration and deceleration, steering variation and total distance travelled. Four unobtrusively mounted cameras capture forward and rear roadway views, each spanning 90 degrees. Video data of the driver's facial expressions and their interactions with the cockpit (see Figure 1) are also recorded. Audio data from inside the vehicle are captured via small ceiling mounted microphones. A small hand-held dictaphone was also placed in the vehicle as a backup for audio recordings.

A smart phone was mounted on windscreen to the left of the driver, above the centre fascia. This provided voice-guided navigation information to drivers throughout the driving route. A tracking program installed on the phone also streamed real time GPS data to the experimenters, allowing online monitoring of each driver's progress along the driving route.

[INSERT FIGURE 1 ABOUT HERE]

2.2.2 Verbal Protocol Analysis

Drivers' situation awareness of the driving environment was measured using Verbal Protocol Analysis (VPA). VPA is commonly used to investigate the cognitive processes associated with complex task performance and has been used previously as the input to SA modelling procedures in various domains, including road transport (Walker, Stanton, & Young, 2007; K. L. Young et al., 2013). Drivers in the current study were instructed to maintain a continuous dialogue of their internal thoughts related to their journey. These included general thoughts about where the driver is positioning their vehicle and why; thoughts about the road environment, road condition, road signs or billboards, road signals, other road users, what they are doing, how that relates to the driver and what actions they are taking and intend to take. It was emphasised that drivers' thoughts and behaviours should be a true reflection of what they would usually be thinking and doing as they drive. Drivers received training on the VPA task in a desktop driving simulator and while driving a practice route around the University campus. In total, the VPA training took approximately 30 minutes.

Drivers were directed to verbalise what they were doing and seeing, but not explain or rationalise their behaviour, in order to minimise the effect of the verbal protocols on driving performance. 'Think-aloud' concurrent verbalisation tasks such as VPA, where participants merely provide verbal expression of their thoughts and actions without describing or explaining their behaviour, has been shown in a 94 study meta-analysis to have no significant effects on objective task performance (Fox, Ericsson, & Best, 2011).

2.2.3 Driving Route

The 38km test route encompassed sections of freeway (motorway) driving (13 km; speed limit 80km/h – 100km/h); busy retail shopping areas (3.8 km; speed limit 40km/h to 60km/h) and arterial roads (17 km; 60km/h to 70km/h). The route took approximately 50 minutes to complete. Each section contained a range of static billboards so that the influence of roadside environment could be examined.

Extensive piloting was conducted to optimise the route in terms of exposure to billboards and ease of navigation for the driver. The study was constrained to a specific three-week period to coincide with the rotation cycle of the billboards, ensuring the same advertising was presented to each driver. Further, all test drives within this three-week period were performed on a weekday commencing at either 10am or 1.30pm to avoid peak traffic conditions outside of these times.

2.3 Procedure

Participants completed a single 2-hour session that included laboratory components and the on-road drive. On arrival at the MUARC driving laboratory, participants provided informed consent for the study and completed a demographic questionnaire (age, gender, length of licence, year licence obtained and average hours spent driving for work and for personal purposes per week).

Participants were then trained in the VPA. A brief overview of the procedure was provided to participants, and then demonstrated on a static simulator. Participants then practised the VPA on a simulated route. The laboratory training took approximately 10 to 15 minutes.

Participants were then escorted to the ORTeV, where they completed a brief test route around campus accompanied by the experimenter. This allowed participants to become familiar with the ORTeV and also served as on-road VPA training. This lasted for approximately 10 to 15 minutes. The experimenter then explained the driving route, started the GPS tracking programme and set up the satellite navigation. The experimenter left the vehicle once the participant was ready to begin the drive to avoid the potential for observer bias. Participants were not informed about the true nature of the study until the session had concluded so as to not prime them to focus on roadside advertising. Upon return, the participant was met by the experimenter and taken back to the simulator laboratory. Here they completed a post-drive interview lasting approximately 10 minutes that sought qualitative information regarding drivers' observations of the billboards.

2.4 Data Analysis

A range of vehicle-based measures were collected during the on-road study, including speed, brake pressure and steering angle. Only a handful of statistically significant differences in the driving measures were revealed across the billboard and control segments, and these indicated that the presence of billboards did not have a negative impact on driving performance. The vehicle-based data are not discussed further in this paper; however, the reader is referred to Young et al. (2015) for a summary of the vehicle findings.

For the purpose of the current paper, 10 static billboards were analysed across a total of 12 driving segments that contained three distinct driving environments: freeway, retail area and arterial road. Table 1 displays the location of the six billboard sections and the six matched control sections that contained no billboards.

[INSERT TABLE 1 ABOUT HERE]

VPA data were parsed into discrete segments (400 metres) surrounding each billboard of interest, as well as for corresponding control sections with no billboards, but similar driving conditions to the billboard segments (e.g. same speed limit and number of road lanes). For the billboard sections, data were extracted from 200 metres before to 200 metres after each billboard. This was the minimum approach distance to a) allow enough time to capture sensible VPA data and, b) the minimum visibility distance for the billboards (due to road curvature, trees or buildings). The 200 metre section after each billboard was examined to account for any delays in discussion of the billboard during VPA, while also ensuring that subsequent billboards were not visible. This allowed at least 10 seconds of VPA in the highest speed zones, which was sufficient to capture any residual discussion of the billboards.

Network analysis was used to describe and analyse participants' SA. The verbal protocols provided were first transcribed verbatim and then a content analysis of each transcript was performed using the text analysis software Leximancer™. Leximancer™ automates the creation of networks by extracting themes, concepts and their associated links from the verbal transcripts in a five step process: conversion of raw text data, concept identification, thesaurus learning, concept location, and mapping (i.e. visual representation of network). Leximancer™ has been used successfully in previous studies to create networks representing the SA held by different road users during on-road studies (Paul M. Salmon, Lenne, Walker, Stanton, & Filtness, 2014; Walker et al., 2011; K. L. Young et al., 2013). The networks produced comprise concepts, or 'information elements', and the links between them. For example, *'vehicle'* has *'slowed'* its *'speed'*; *'traffic light'* is *'red'*. This process produced one 'master' network for each of the 12 billboard and control sections examined. Each master network included data for all 19 participants combined. Agna^{TM} network analysis software was then used to interrogate the content and structure of each network using various network metrics.

3. RESULTS

The 12 SA master networks were analysed using the *density*, *diameter* and *sociometric* status metrics to compare the structure and content of the SA networks across the billboard and control sections and also across the three road environments.

3.1 Network Structure: Density and Diameter

Density is a measure of the overall interconnectivity of the SA network in terms of the number of links between the information elements (concepts). Network density values range from 0 (no concepts are connected) to 1 (every concept is connected to every other concept). Thus, higher values indicate a richer set of links between concepts and enhanced SA. The density values for the 12 SA networks are presented in the left column of Table 2. For all three road types (expect the arterial intersection), the density or interconnectedness of the networks was higher in the control sections compared to the billboard sections; however, the differences observed were marginal. This suggests that the level of connectedness within drivers' SA networks did not differ appreciably in the presence of billboards in any of the environments examined.

[INSERT TABLE 2 ABOUT HERE]

Diameter is used to analyse the connections and path lengths between concepts within a network. With regard to SA, lower diameter scores are indicative of more enhanced SA because the routes through the network are shorter and more direct. Greater diameter values are indicative of lower SA because there are more concepts per pathway through the network (Walker et al, 2011). The mean diameter values for the 12 SA networks are presented in the right column of Table 2. The diameter scores were low and similar across the billboard and control sections, suggesting that the concepts contained in the SA networks were well integrated, and did not differ appreciably in the presence of billboards.

In summary, the structure of the SA networks were similar across the billboard and control sections for all three road types. Both the density and diameter metrics suggest that the participants' networks contain a moderate number of concepts with well integrated links between them. However, it is possible that the presence of billboards may change the *content* rather than the *structure* of drivers' SA networks.

3.2 Network content: shared, unique and key concepts

The analysis of network content involved identifying and comparing the shared concepts (i.e., present in both the billboard and control master networks) and unique concepts (i.e., present only in one master network) across the matched billboard and control networks for each of the freeway, retail and arterial road environments. The sociometric status metric was then used to identify the relative importance of the shared concepts to drivers' SA in the matched billboard and control segments, as well as the key information elements underpinning SA.

Sociometric status provides a measure of how busy or important a concept is relative to the total number of concepts within the network and, therefore, indicates which concepts have more prominence in driver SA under each condition. Concepts with high sociometric values are highly connected to other concepts in the network, while concepts with low values often reside in the periphery of the network and are not well connected with other concepts.

3.2.1 Freeway Roadside and Overpass SA Networks

Table 3 displays the key shared and unique concepts that formed part of drivers' SA in the freeway roadside and overpass billboard and control networks. For the roadside networks, many of the key concepts that formed driver SA were unique to either the billboard or control segments. Only five key concepts were shared across the two road segments, suggesting that driver SA surrounding the roadside billboard was comprised of different information elements to that in the control segment.

During the control segment, drivers' awareness was heavily focussed around their vehicle speed and the speed limit, with key concepts being '*reduced'*; '*slowed'*; '*down'*; '*limit'*; *'(speed) sign'*; '*80km (per hour)*; and '*speed'*. Drivers' awareness during the control segment was also focused on the behaviour of surrounding vehicles (e.g. '*merged'*; '*car'*; '*front'*). However, surrounding the roadside billboard, the 'Transformers' billboard appeared to be a key focus of the drivers' awareness, with the concepts *'billboard'*; '*advertising'*; '*Transformers'*; and *'look'* featuring prominently. Other concepts that formed a part of drivers' awareness surrounding the roadside billboard were those relating to preparing to exit the freeway further ahead (e.g., *'left'*; *'lane'*; *'Yarra'*; *'Boulevard'*). In the vicinity of the billboard, drivers were also aware of their speed and the speed limit, although less so than during the control segment. This suggests that drivers were able to maintain an awareness of driving-related tasks and information despite the billboard featuring heavily in their awareness, although this aspect of driving-related awareness appeared reduced relative to the control segment.

The master network concept map for the roadside billboard segment is contained in Figure 2. Not surprisingly, the 'Transformers' node was most closely related to the concepts of 'advertising' and 'road', indicating that drivers were closely associating the billboard with advertising. The 'billboard' node was most closely related to the concepts of 'ahead' and 'car', confirming that drivers were aware of surrounding traffic surrounding the billboard.

[INSERT FIGURE 2 ABOUT HERE]

Finally, during the control segment, drivers' awareness appeared more focused on the forward roadway, whereas awareness was more focussed to the left (or the nearside) during the billboard segment (which was also off the left side of the road). This is likely a combination of drivers directing their attention towards the billboard, but also towards moving left in preparation to exit the freeway.

Comparisons of the sociometric status of shared concepts across the billboard and control networks revealed that, surrounding the roadside billboard, information elements associated with drivers' position on the road were more prominent than they were in the control network. This is evident by the concepts *'left'* and *'lane'* having a higher sociometric status in the billboard network. This result is likely to be due to drivers moving to the left in preparation to exit the freeway, but may also reflect that drivers' attention was focused toward the left where the roadside billboard was located. During the control segment, vehicle 'speed' was most prominent, which may reflect that drivers were required to reduce speed from 100 km/h to 80 km/h shortly before entering the control segment.

[INSERT TABLE 3 ABOUT HERE]

For the freeway overpass networks, many of the key concepts that formed driver SA were unique to either the overpass billboard or control networks. Only four key concepts were shared, suggesting that driver SA surrounding the overpass billboard was comprised of different information elements to that in the overpass control segment.

In the control segment, drivers' awareness was heavily focussed on vehicle speed and the speed limit, with key concepts being '*cameras'*; '*change'*; '*down'*; '*limit'*; '*sign'*; and '*speed'*. In the overpass billboard segment, the concepts related primarily to the drivers preparing to exit the freeway at Yarra Boulevard, with key concepts being '*boulevard'*; '*checking'*; '*exit'*; '*indicating'*; and '*slip'*. Interestingly, concepts related to speed were largely absent in the overpass billboard network. '*Billboard'* did not appear as a concept in the overpass billboard network. Indeed, only one driver reported the billboard in their verbal protocols, indicating that, compared to the roadside billboard, the overpass billboard featured less in drivers' awareness.

Comparison of the sociometric status of four shared concepts across the overpass billboard and control networks revealed that, surrounding the overpass billboard, information elements associated with road position were more prominent, with the concepts '*left'*; '*lane'* and '*road'* having a higher sociometric status. This result is likely due the fact that drivers were preparing to exit the freeway immediately after the billboard segment and is unlikely to be related to the billboard given that it was located centrally on an overpass bridge. The concept '*coming*' featured more prominently in the control network. This concept was heavily related to speed reduction (e.g., speed coming down) and confirms the greater focus on speed in this section of roadway.

3.2.2 Retail Area 60 km/h and 40 km/h SA Networks

Table 4 displays the key shared and unique concepts that formed part of drivers' SA in the four 60 km/h and 40 km/h retail billboard and control networks. The 60 km/h retail networks contained a similar number of shared and unique concepts, suggesting that driver SA in the billboard and control segments was made up of some of the same information elements. During both segments, drivers' awareness was focussed heavily on other road users, with key concepts including '*car*'; '*cyclist*'; '*truck*'; '*tram*'; and '*pedestrian*'. Many of these concepts were closely linked with concepts such as '*looking*'; '*clear*'; '*ahead*'; and '*behind*', indicating that drivers were focussed on monitoring the actions and behaviour of other road users. Although mentioned by two drivers, the two billboards did not form a key feature of drivers' SA. Rather, drivers appeared to be devoting attention to negotiating other road users.

While the information elements that made up driver SA were similar across the billboard and control networks, drivers appeared more focussed on speed during the billboard segment, with concepts unique to this segment being '*slow*'; '*slowly*'; and '*speed*'. This is likely to be due to road works in this section of the drive that were not present in the control segment. A comparison of the sociometric status of the 10 shared concepts confirmed that, the information elements that drivers were focussed on were similar across the billboard and control segments and that a key focus was on '*traffic*' and '*cars*' in '*front*', '*ahead*' or to the '*left*'.

[INSERT TABLE 4 ABOUT HERE]

In the 40 km/h retail networks, there were a large number of shared concepts and relatively few unique concepts, suggesting that driver SA in the billboard and control segments was made up of very similar information elements. Similar to the 60 km/h retail segments, during both 40 km/h retail segments drivers' awareness centred heavily around monitoring other road users' behaviour, with key concepts including '*car*'; '*cyclist/bike*'; '*truck*'; '*tram*'; '*pedestrians*'; '*people*'; '*looking*'; '*ahead*'; and '*behind*'.

The two billboards in the billboard segment were revealed as a key element of SA for two drivers. This is in contrast to the 60 km/h retail area where the billboards did not form a key component of SA for any drivers. One explanation for this discrepancy is that drivers may have had more opportunity, or may have been more inclined to focus on the billboards in the slower speed zone. The absence of road works in the 40 km/h billboard segment may have also contributed to the greater focus on the billboards. A comparison of the mean sociometric status of the 17 shared concepts across the billboard and control networks confirmed that the key information elements focussed on were highly similar across the two segments, with a key focus on the '*traffic*', '*cars*' and '*pedestrians*' '*ahead*'. Examination of the master network concept map for this segment reveals that the 'billboard' node was most closely linked with the concepts of 'front' and 'car', indicating that drivers maintained awareness of other traffic and were focusing attention forwards in the vicinity of the billboards.

3.2.3 Arterial Intersection and Midblock SA Networks

The key shared and unique concepts that formed part of drivers' SA in the four arterial intersection and midblock billboard and control networks are displayed in Table 5. With respect to the arterial intersection networks, there were a similar number of both shared and unique concepts, suggesting that driver SA in the billboard and control networks was made up of similar information elements. During both segments, drivers' awareness was centred heavily around the negotiating intersection and the traffic lights, with key concepts including '*intersection*'; '*waiting*'; '*slowing*'; '*light*'; '*green*'; and '*red*'. Monitoring other traffic at the intersection was also a key focus of awareness, with key concepts being *'cars'*; *'traffic'*; and *'trucks'*.

Although the two billboards at the arterial intersection did appear as a key concept in the network, they were only mentioned by one driver who was stopped at the traffic lights at the time. The billboard concept was most closely linked to the concepts 'looking' and 'front', which is not surprising given that the billboard was located directly in front of the driver. None of the drivers who proceeded through the intersection without stopping made mention of the billboards. This suggests that drivers may have more opportunity, or may be more inclined to focus on the billboards when stationary.

A comparison of the mean sociometric status of the 11 shared concepts across the billboard and control networks revealed that the key information elements that drivers focussed on were highly similar across the billboard and control segments, with a key focus on the '*traffic*', '*cars*' and '*lights*' '*ahead*'. This is not surprising given that all but one driver did not report noticing the billboard.

[INSERT TABLE 5 ABOUT HERE]

During the arterial midblock billboard segment, drivers' awareness was focussed on monitoring other vehicles and maintaining lane position, with key concepts being '*keeping*'; '*lanes*'; and '*traffic*'. Drivers were also focussed on vehicle speed and the speed limit, with concepts such as '*signs*'; '*slowing*'; and '*speed*'. During the control segment, drivers' awareness centred primarily on other roads users, with key concepts being '*pedestrians*'; '*looking*'; '*behind*' and '*left*'. Drivers were also focussed on the signalised pedestrian crossings that were contained within the control segment; however, speed did not appear to be a key focus.

In contrast to the arterial intersection, the two billboards in the midblock segment did not form part of drivers' situation awareness. In fact, the billboards in this segment were not mentioned by any drivers. Coupled with the finding that the arterial intersection billboards were only mentioned when stationary, the midblock results suggest that drivers tend to ignore or at least focus less on billboards when travelling at speed.

The sociometric status of the seven concepts shared across the midblock arterial billboard and control segments confirmed that, in the control segment, information elements associated with traffic lights were more prominent than they were in the billboard segment, with the concepts '*lights*' and '*green*' having a higher sociometric status in the no billboard network. This result is due the fact that there were two signalised pedestrian crossings located in the midblock control section. In the billboard section, monitoring other vehicles and maintaining lane position was a key focus, with the concepts '*traffic*' and '*lane*' having the highest sociometric status scores.

4. DISCUSSION

Using an instrumented vehicle and driver verbal protocol analysis, this study sought to examine if and how static advertising billboards affect drivers' situation awareness (SA) across different driving environments: freeway, busy urban retail area and arterial roads. Achieving and maintaining good SA is critical for safe driving and may play an important role in explaining how the presence of roadside advertising leads to driving performance decrements under some conditions.

The network analysis results indicate that the presence of static billboards did not appreciably alter the structure of drivers' SA in any of road environments examined. More specifically, the level of interconnectivity between the information elements extracted from the driving environment did not differ when drivers were driving in the vicinity of static billboards. Given the repeated-measures design of the study, it is not completely unexpected that SA network structure was similar across the billboard and control segments, because the basic building blocks of SA (i.e., how information is integrated) are heavily influenced by an individual's cognitive capacity, strategies and schema. Thus, it is possible that the presence of roadside advertising, and being distracted in general, may not affect so much *how* drivers' achieve SA, but rather what environmental elements they sample and focus on to achieve SA (i.e., the content of SA).

Analysis of drivers' SA network content revealed that, while the billboards did form a key aspect of driver SA in some situations, this appeared to be heavily moderated by the level of driving demand experienced. That is, there was a strong trend for drivers to mention the billboards in their verbal protocols only when driving demands were low, such as when travelling on the freeway in medium density free-flowing traffic or when stationary at traffic lights. For example, compared to the freeway roadside billboard that occurred on a segment of the freeway where driving demand was relatively low, the freeway overpass billboard (located where driving demand was higher) was mentioned far less by drivers in their verbal protocols. Given that both billboards were similar in content (Transformers movie versus a Foxtel advert featuring Iron Man) the content of the billboards is unlikely to play a role in the different levels of attention given to each. Rather, the difference in attention paid to both billboards may be because the roadside billboard was larger and, thus, more likely to attract attention, and/or because the drivers were required to exit the freeway shortly after the overpass billboard and preparation for this manoeuvre appeared to be dominating their attention and, thus, their SA.

Drivers directing relatively less attention towards roadside advertising in higher workload driving conditions may be due to an unconscious attentional narrowing as a result of increased driving demand. However, it may also point to a form of driver self-regulation, whereby drivers adapt their visual and cognitive attention in relation to billboards, paying more attention to them when driving is less demanding and paying less attention when driving demand increases (e.g., when exiting a freeway). This explanation is congruent with the findings of a number of research studies that have examined the impact of static and electronic billboards on driver behaviour and attention and found that billboard-related distraction appears to be regulated by drivers across different road environments and levels of driving demand (e.g., Decker et al., 2015; M. S. Young et al., 2009). A recent study by Metz and Krüger (2014), for example, found that when searching for directional information on traffic signs, drivers paid virtually no attention to the supplementary static signs advertising services available at a highway service area. They concluded that drivers were able to, through top-down control of attention, ignore the irrelevant supplementary sign information when tasked with finding specific direction information.

Importantly, the presence of static roadside advertising did not appear to alter drivers' awareness of safety-critical elements of the road environment, such as the behaviour of other road users or of changes to traffic conditions (e.g., road works or speed limit and traffic light changes). This was confirmed by the billboard-related concepts, when they did appear in the networks, being closely linked to concepts such as 'car', 'front' and 'ahead'. The only notable difference in drivers' awareness of safety-relevant information was that, in the freeway environment, drivers appeared less focussed on their speed and the speed limit in the segments containing the billboards, compared to the control segments. Overall, the results suggest that, while the presence of roadside advertising may have changed some aspects of the content of driver SA, it did not alter drivers' awareness of safety-critical road information. Rather, drivers appeared capable of ignoring the driving-irrelevant information presented by the billboards when driving demands increased and maintaining their awareness of events occurring in the roadway.

This study had a range of limitations that should be considered when interpreting the findings. First, although no observers were present in the vehicle, participants were aware that they were being video and audio recorded and this may have changed their driving behaviour in favour of driving in a safer manner. This may have resulted in the drivers focusing a greater amount of attention on driving-related tasks and less on driving-irrelevant objects such as billboards. A further limitation was that, as with all on-road studies, certain elements of the driving environment could not be controlled (e.g., weather, traffic density), and these may have differed across participants and the billboard and control sections, despite every effort being made to match these segments and have them as spatially close as possible so that factors such as traffic density and road geometry were comparable. Nonetheless, it cannot be ruled out that some of the changes observed in driver SA across the billboard and control segments may have been due to factors unrelated to the roadside advertising.

Similarly, while providing a high level of ecological validity, the on-road nature of the study meant that certain features of the billboards that might affect behaviour could not be controlled for or manipulated. These features included billboard location, content, size and placement height. It is, therefore, not known if drivers' ability to self-regulate their attention in relation to billboards would remain the same under varying billboard content or locations.

Finally, it was assumed that if the billboards, or other roadway features were not mentioned in the verbal protocols that drivers were not focussing their attention on these elements or were not aware of them. However, it is also possible that drivers may not have verbalised their awareness of the billboards, or other road and environmental features, because there simply was not enough capacity for them to report this information at the time or because some elements that underpin driver SA are not amenable to verbal reporting. While this limits the extent to which firm conclusions can be drawn regarding the presence of billboards on *reducing* drivers' awareness of certain driving-related information, it is possible to postulate about how billboards may or may not *change* what information elements become a more salient aspect of driver SA. Indeed, the fact that participants chose to report the driving-related information over the billboards, suggests that the driving-related aspects of the environment were given priority over the, arguably more salient billboards, and were a more key aspect of SA, in some instances.

Drivers will continue to be exposed to an increasing volume and range of roadside advertising. Continued research efforts are therefore required to establish how drivers' ability to achieve and maintain SA is affected by the type, placement and content of advertising signage. In particular, future research should examine a wider range of roadside advertising characteristics, including billboard content, size, height and location to determine if, and how, these aspects influence the impact of billboards on driver SA. In particular, the impact of electronic billboards on driver SA should be established given that they have been found to attract drivers' attention more frequently and for longer periods.

5. CONCLUSIONS

Rather than static roadside advertising influencing driver SA, the level of driving demand in the current study appeared to influence whether and how much attention drivers directed to the billboards. Drivers focused attention on billboards when driving demands were low, such as when driving on the freeway with light to moderate traffic or when stopped at traffic lights. However, when drivers were required to perform a manoeuvre or driving demands increased, drivers tended to direct less attention to the billboards, suggesting that, at least under the conditions examined, drivers can self-regulate their attention to billboards and essentially ignore them when required to focus on the immediate traffic or driving situation.

ACKNOWLEDGEMENTS

This project was funded through The Australian Government Researcher's in Business Initiative, with funds received from the Commonwealth of Australia and iOM Pty Ltd. Dr Young's contribution to this article was part funded by her Australian Research Council (ARC) Discovery Early Career Researcher Award (DE160100372). We thank Nebojsa Tomasevic for his assistance with the ORTeV.

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Figure 1: The four scenes captured by the camera set-up in the ORTeV

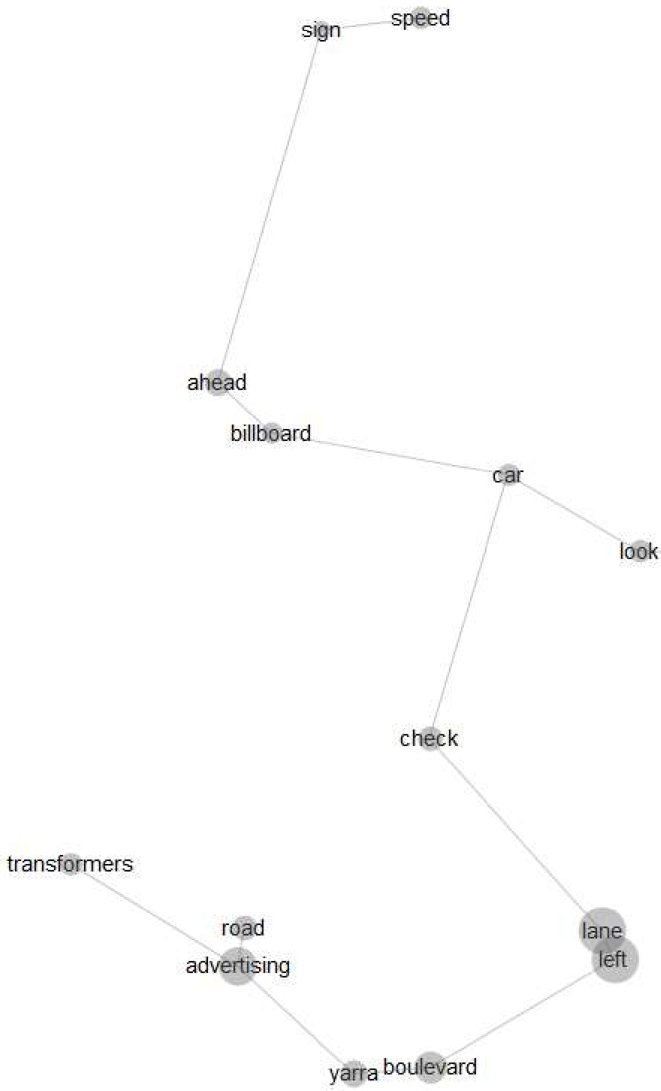

Figure 2: Master network concept map for the 400m freeway roadside billboard segment

Table 1 Billboard and equivalent control sections selected for analysis

Billboard / Control	Section Description	Billboard content
Control	Freeway – overpass	-
Billboard	Freeway – roadside (1 Billboard)	Transformers
Control	Freeway – roadside	-
Billboard	Freeway – overpass (1 Billboard)	Foxtel
Control	Retail area – 60 km/h	-
Billboard	Retail area – 60 km/h (2 Billboards)	3AW & Soliman vs. Sturm
Control	Retail area – 40 km/h	-
Billboard	Retail area – 40 km/h (2 Billboards)	Mancave storage & Masterchef
Control	Arterial – midblock	-
Billboard	Arterial – midblock (2 Billboards)	Origin Energy & Oakleigh Grammar
Control	Arterial – intersection	-
Billboard	Arterial – intersection (2 Billboards)	Seek & RACV

Table 2. Network density and diameter values across the distracted and undistracted drives

Section No.	Section Description	Density	Diameter
1	Control Freeway overpass	0.55	3.0
3	Billboard Freeway roadside	0.48	3.0
2	Control Freeway roadside	0.35	2.0
4	Billboard Freeway overpass	0.30	4.0
6	Control Retail 60 km/h	0.41	3.0
5	Billboard Retail 60 km/h	0.38	2.0
8	Control Retail 40 km/h	0.44	3.0
7	Billboard Retail 40 km/h	0.42	3.0
9	Control Arterial midblock	0.31	3.0
10	Billboard Arterial midblock	0.26	4.0
12	Control Arterial intersection	0.42	3.0
11	Billboard Arterial intersection	0.70	3.0

Table 3 Shared and unique concepts and sociometric status across the freeway roadside and overpass billboard and control networks

Unique concepts - Billboard segment	Unique concepts - Control segment	Shared concepts				
		Concept	Billboard		Control	
			Count*	SMS**	Count	SMS
Roadside Billboard						
Advertising (2)	80km (4)	Car	4	1.07	2	0.92
Ahead (5)	Down (9)	Lane	6	4.0	5	0.15
Billboard (5)	Front (1)	Left	7	4.0	3	0.15
Boulevard (3)	Hit (1)	Sign	3	0.53	4	0.31
Check (4)	Limit (4)	Speed	5	1.07	10	3.08
Look (3)	Merged (1)					
Road (3)	Reduced (2)					
Time (2)	Safe (1)					
Transformers (6)	Slowed (1)					
Truck (3)						
Yarra (3)						
Overpass Billboard						
Ahead (2)	Cameras (3)	Coming	3	0.13	4	2.4
Behind (4)	Change (2)	Lane	8	2.4	3	1.0
Boulevard (11)	Down (3)	Left	7	2.0	3	1.4
Car (5)	Limit (8)	Road	6	1.6	4	0.8
Checking (2)	Sign (7)					
Emergency (2)	Speed (11)					
Exit (5)	Truck (4)					
Indicating (3)						
Keeping (3)						
Slip (7)						
Vehicles (2)						
Zone (2)						

Numbers in parentheses indicate number of participants who had unique concept in SA network
*Number of drivers who had shared concept in their SA network
**SMS = sociometric status

Table 4 Shared and unique concepts and sociometric status across the 60 km/h and 40 km/h retail billboard and control networks

Unique concepts - Billboard segment	Unique concepts - Control segment	Shared concepts				
		Concept	Billboard		Control	
			Count*	SMS**	Count	SMS
60 km/h retail area						
Coming (5)	Behind (7)	Ahead	10	2.2	9	1.2
Cyclist (4)	Clear (5)	Car	16	6.7	14	3.6
Green (12)	Crossing (4)	Front	11	2.0	10	2.0
Lane (6)	Lights (4)	Left	10	3.0	12	2.7
Looking (6)	Moving (6)	Pedestrians	8	0.9	5	0.4
Pull (8)	Parked (5)	Road	7	1.1	5	1.1
Slow (7)	Sign (7)	Street	3	0.7	6	0.7
Slowly (5)	Slowing (5)	Traffic	13	3.5	8	1.4
Speed (8)	Truck (5)	Tram	7	0.9	8	0.1
Stopped (5)	Walking (3)	Turning	7	1.2	8	1.4
Straight (6)						
40 km/h retail area						
Billboard (2)	Bike (5)	Ahead	10	2.3	10	3.0
Cross (6)	Green (14)	Behind	5	0.6	7	1.0
Cyclist (3)	Lane (6)	Car	12	3.2	12	3.5
Lady (3)	Park (11)	Coming	4	0.8	9	1.6
Speed (6)	People (8)	Crossing	8	1.5	7	1.5
Turning (5)	Red (8)	Down	8	0.9	9	1.7
	Signal (2)	Front	10	2.5	7	1.1
	Street (7)	Left	11	2.5	8	1.8
	Waiting (5)	Light	9	1.0	14	3.6
		Looking	3	0.5	6	0.9
		Pedestrians	10	2.6	11	1.4
		Road	15	2.7	11	2.6
		Sign	8	1.1	7	1.4
		Slow	7	1.7	6	0.9
		Traffic	11	2.5	9	1.1
		Tram	6	0.7	6	1.0
		Truck	8	0.5	7	0.6

Numbers in parentheses indicate number of participants who had unique concept in SA network
*Number of drivers who had shared concept in their SA network
**SMS = sociometric status

Table 5 Shared and unique concepts and sociometric status across the arterial intersection and midblock billboard and control networks

Unique concepts - Billboard segment	Unique concepts - Control segment	Shared concepts				
		Concept	Billboard		Control	
			Count*	SMS**	Count	SMS
Arterial intersection						
Billboard (1)	Limit (4)	Ahead	7	1.8	6	1.1
Coming (5)	Road (7)	Behind	7	1	3	0.1
Intersection (4)	Sign (5)	Cars	8	2.5	5	0.9
Lanes (3)	Slowing (2)	Front	7	2	4	0.3
Moving (5)	Speed (6)	Green	10	2.5	7	0.8
Slow (4)	Straight (4)	Lane	9	2.1	7	0.9
Truck (3)		Left	8	1.4	11	1.4
Trucks (3)		Light	10	3.3	8	1.4
Turning (4)		Looking	4	1.2	3	0.8
Waiting (4)		Red	7	2.4	4	0.6
		Traffic	6	1.8	5	1.5
Arterial midblock						
Guy (3)	Behind (4)	Ahead	4	0.8	6	1.5
Keeping (4)	Coming (2)	Cars	4	0.5	5	1.4
Lanes (3)	Faster (3)	Front	3	0.5	5	0.4
Look (4)	Left (9)	Green	3	0.8	8	1.5
Signs (3)	Looking (4)	Lane	7	1.2	6	1.3
Slowing (2)	Pedestrian (3)	Lights	2	0.8	6	2.5
Speed (5)	Red (5)	Traffic	6	1.1	7	0.9
	Road (9)					
	Stopped (3)					
	Straight (2)					
	Turning (2)					

Numbers in parentheses indicate number of participants who had unique concept in SA network
*Number of drivers who had shared concept in their SA network
**SMS = sociometric status