

## **Advertising billboards impair change detection in road scenes**

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### **Abstract:**

Throughout Australia and much of the world, roadside advertising by means of billboards is commonplace - but potentially distracting for drivers. As yet, there is little research into which specific aspects of driving performance might be affected by the presence of such advertising billboards. To investigate this, the present experiment used the 'change detection' paradigm to examine how billboards affect visual search and situation awareness in road scenes. In a controlled experiment, inexperienced, older, and comparison drivers searched for changes to road signs and vehicle locations in static photographs of road scenes. On average, participants took longer to detect changes in road scenes that contained advertising billboards. This finding was especially true when the roadway background was more cluttered, when the change was to a road sign, and for older drivers. The results are consistent with the small yet growing body of evidence suggesting that roadside advertising billboards impair aspects of driving performance such as visual search and the detection of hazards, and therefore should be more precisely regulated in order to ensure a safe road system.

### **Keywords:**

Roadside advertising, visual clutter, driver distraction, road environment

### **Introduction**

Advertising billboards are seen in road environments around Australia. They are highly conspicuous, and thus are a potential distraction for drivers. Road authorities are coming under increasing pressure from outdoor advertising companies to allow the erection of more billboards along roadsides, so it is important to understand the likely effects of adding billboards to various road environments. Previous research has shown that billboards attract visual attention (Beijer, Smiley, & Eizenman, 2004; Lee, McElheny, & Gibbons, 2007; Smiley, Smahel, & Eizenman, 2004), and that the presence of billboards correlates with higher crash rates (Cairney & Gunatillake, 2000; Farby, Wochinger, Shafer, Owens, & Nedzesky, 2001). However, apart from Johnston and Cole's (1976) laboratory study (which found that advertisements impaired peripheral detection) there has been little work on which aspects of driving performance might be affected by billboard presence.

A large proportion of the sensory input used by drivers is visual, and visually conspicuous items such as billboards are most likely to interfere with visual processing tasks (Wickens, 2008). These include such driving subtasks as searching for road signs, noticing hazards, and maintaining situation awareness of nearby vehicles using visuospatial working memory. A laboratory task that emulates these driving tasks is the 'change detection' paradigm, when the changes to be detected are relevant to driving.

For example, to detect a change in a vehicle, an observer must be aware of other road users and notice any (potentially hazardous) changes to the situation. To detect a change in a road sign, an observer must search the scene to locate and recall all the road signs. Change detection time has been found to correlate with at-fault errors in a simulated driving task (Lees, Sparks, Lee, & Rizzo, 2007).

The present study examined detection of changes to vehicles and road signs in the presence and absence of billboards. It was hypothesized that drivers would have more difficulty detecting changes in scenes with billboards present. Because road signs are less conspicuous than vehicles, we expected that billboards would have the greatest effect on detection of changes to road signs. The road scenes also contained different levels of visual clutter, to determine how a complex background interacted with the presence of the conspicuous billboards. Previous research using the change detection paradigm has found that experienced drivers were better than inexperienced drivers at detecting new vehicles (Famewo, Trick & Nonnecke (2006), while older drivers take longer to detect changes in road scenes (McCarley et al (2004). The present experiment therefore included drivers who had less than one year's experience of unsupervised driving, and drivers over 65 years old, as well as a comparison group of experienced, young to middle-aged drivers; it was hypothesised that the inexperienced and older drivers would take longer to find changes than the comparison drivers.

**Method**

*Participants.*

A group of forty-five participants (23 males and 22 females) were recruited from the university community and nearby senior citizens' clubs. The inexperienced driver group consisted of fifteen drivers aged 18-25 who had less than one year of experience in driving unsupervised, the older driver group comprised fifteen drivers aged over 65 years who held full driver's licences, and the comparison driver group consisted of fifteen drivers aged 25-55 who held full licences. Table 1 has further characteristics of participants in each group.

**Table 1. Participant Characteristics**

Group	Proportion of males	Mean age	Mean driving experience	(Self-estimated) Mean distance driven
Inexperienced	7/15	19.3 years	0.4 years	2,700 km/year
Comparison	4/15	34.8 years	14.6 years	10,500 km/year
Older	12/15	73.0 years	52.7 years	15,600 km/year

*Apparatus and stimuli.*

Participants viewed photographs of road scenes on a 15-inch LCD screen at a distance of approximately 60cm. The photographs thus subtended 14 degrees horizontally x 11 degrees vertically of visual angle at the participant's eye.

Stimuli were 96 pairs of photographs taken from the perspective of an automobile driver on arterial roads around Melbourne, Australia. The road environments ranged from suburban main streets to multilane highways to provide varying levels of background clutter; the levels of 'built' and 'designed' clutter were classified according to Edquist (2008). Built clutter includes factors such as shopfronts along the road and high buildings on each side. Designed clutter refers to the number of road signs and markings ('high' = more than three in one photograph). For each pair of photographs, one of the pair was modified such that a car, a road sign, or some other item was missing or its size changed. There were 40 pairs in which a vehicle appeared or disappeared, including 16 pairs with billboards and 16 pairs without billboards matched for the level of background clutter (the other eight pairs were not matched and are not analysed here). Likewise, there were 40 pairs in which a road sign was the appearing and disappearing object, including 16 which had billboards and a further matched 16 without billboards. The stimulus set also included eight pairs of photographs in which a billboard was the object that appeared and disappeared, and eight pairs of photographs with some other non-driving related object changing.

*Procedure.*

Figure 1 shows the sequence for each trial. So that all participants started scanning from the same place for each scene, each trial began with a fixation cross at the centre of the screen. After one second the computer displayed the first picture in the pair for 400ms, then a grey screen for 100ms, then the second picture for 400ms, then the grey screen for 100ms, then back to the first picture. This pattern repeated for 45 seconds, or until the participant responded by pressing the space bar. Participants then used the mouse to indicate the location of the changing object. Ten practice trials were completed before commencing the experiment. The experiment was self-paced so that participants could take a break between trials. The order of the scenes was randomised.

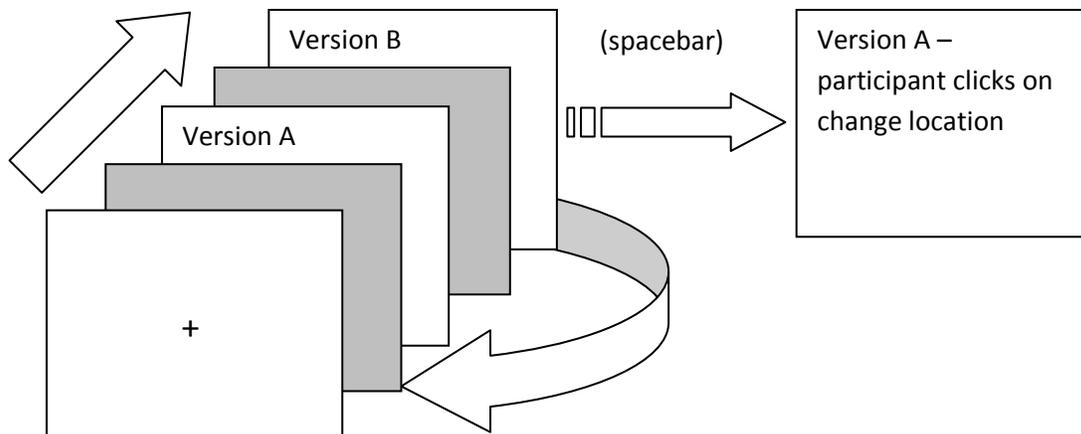


Figure 1. Procedure for change detection 'flicker' task.

## Results

Trials on which the participant responded incorrectly were excluded from the analysis, as they did not reflect the time taken to accurately detect the change (errors comprised less than 2% of the data from each group; of 2880 total responses, there were 17 errors on scenes with billboards and eight errors on scenes without billboards, so there was no time-accuracy tradeoff). Outliers in the response times were replaced by the mean plus 3.29 times the standard deviation for each cell, rounded down to the nearest integer, in order to improve normality. A mixed-model ANOVA was performed, with age/experience group as a between-subjects factor, and presence or absence of billboards, level of built clutter, level of designed clutter, and type of object that changed as within-subjects factors.

There was a significant main effect of the presence of billboards; participants took longer to detect the change in scenes containing billboards. Presence of billboards interacted significantly with built clutter, and with designed clutter; in both cases, the effect of billboard presence on time to detect change was larger for scenes with high clutter. There was also a three-way interaction between billboard presence, built clutter and designed clutter,  $F(1, 42) = 21.85, p < .001, \eta^2$  (effect size) = .34. Pairwise comparisons between scenes with billboards and scenes without billboards were performed for each combination of high or low built and designed clutter. Mean times to detect change and 95% confidence intervals for each of these combinations are shown in Figure 2.

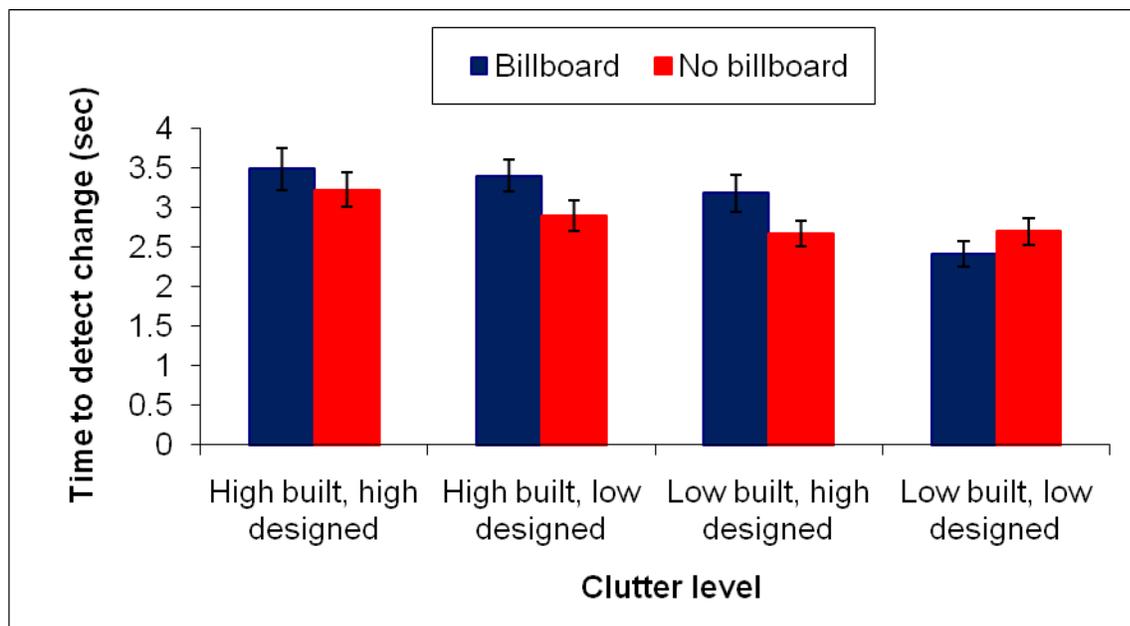


Figure 21. Effect of billboards by level of built and designed clutter (bars represent 95% CIs).

When both built and designed clutter were high, adding billboards did not have a significant effect on time to detect change,  $t(44) = 1.94, p = .059$ . When built clutter was

high but designed clutter was low or vice versa, drivers took longer to detect changes in scenes with billboards than in scenes without billboards (high built, low designed  $t(44) = 5.10, p < .001$ ; low built, high designed  $t(44) = 5.81, p < .001$ ). When both built and designed clutter were low, drivers were faster to detect changes in scenes with billboards,  $t(44) = -3.82, p < .001$ .

Although the interaction of billboard presence and change type was not significant, there was a significant three-way interaction between presence of billboards, type of change and level of designed clutter,  $F(1, 42) = 8.95, p < .01, \eta^2 = .18$ . Analysis of each change type separately (see Figure 3) revealed that the interaction of billboard presence with designed clutter was not significant for changing cars,  $F(1, 42) = 1.68, p > .1, \eta^2 = .04$ , but was significant for changing signs,  $F(1, 42) = 9.23, p < .01, \eta^2 = .18$ . For the changing sign pairs with billboards, the effect of designed clutter on time to detect change was significant,  $F(1, 42) = 41.23, p < .001, \eta^2 = .50$ . However it was not significant for the changing sign pairs without billboards,  $F(1, 42) = 2.90, p = .1, \eta^2 = .06$ .

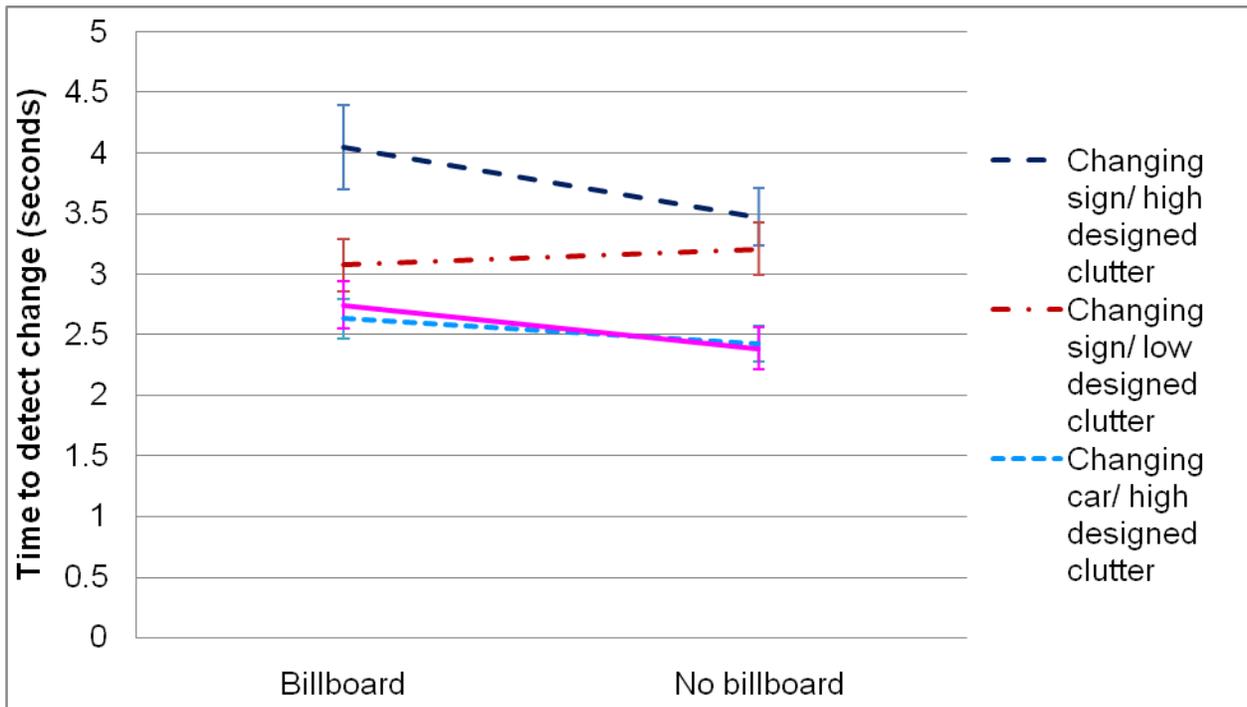


Figure 3. Billboard effect for changes to signs and cars at high and low designed clutter (bars represent 95% CIs).

In addition to significant main effects for age/experience group and change type, as well as a two-way interaction between these variables, there was also a significant three-way interaction between presence of billboards, type of change and age/experience group,  $F(2, 42) = 5.19, p = .01, \eta^2 = .20$ . Analysis of each change type separately revealed that the interaction of billboard presence with age group was not significant for changing cars,  $F(2, 42) = 2.33, p > .1, \eta^2 = .10$ , but was significant for changing signs,  $F(2, 42) = 3.77, p < .05, \eta^2 = .15$ . Mean detection times for each change type are shown in Figure

4. For the changing sign pairs with billboards, the effect of age group on time to detect change was significant,  $F(2, 42) = 13.69, p < .001, \eta^2 = .50$ . Dunnett's post-hoc t-test showed that the older drivers took significantly longer to detect changes than the comparison group did ( $p < .001$ ) while the inexperienced drivers could not be differentiated from the comparison drivers ( $p > .5$ ). For the changing sign pairs without billboards, the effect of group on time to detect change was larger,  $F(2, 42) = 43.45, p < .001, \eta^2 = .67$ . Not only were the older drivers significantly slower ( $p < .001$ ), but the inexperienced drivers were significantly faster than comparison drivers ( $p < .05$ ).

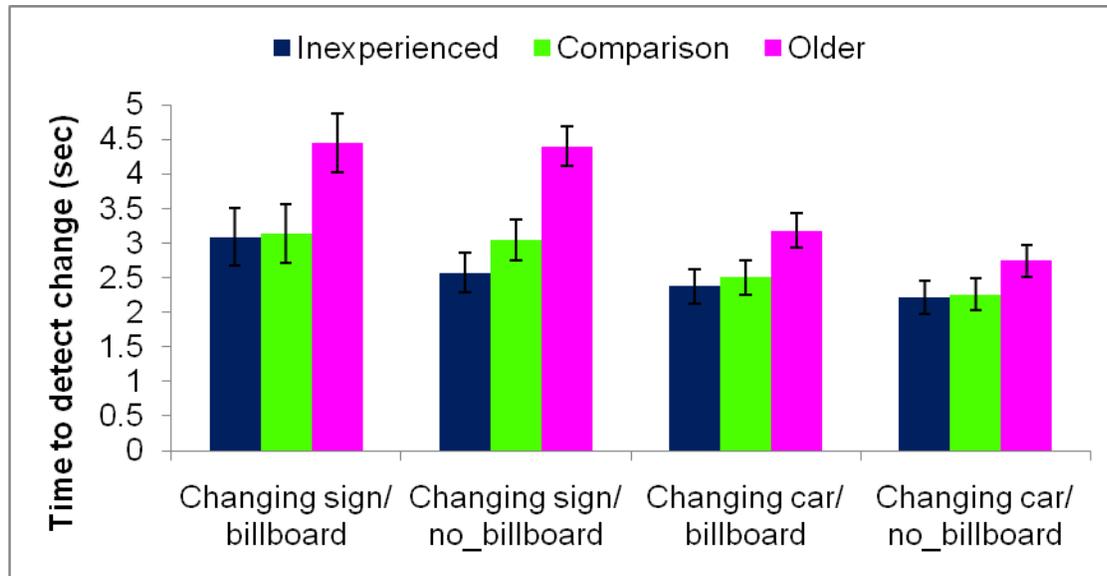


Figure 4. Effect of billboards for each age group on time to detect changes to signs and vehicles (bars represent 95% CIs).

## Discussion

The finding that the presence of billboards increases time to detect changes is an important one. This result lends support to the idea that billboards can automatically attract attention when drivers are engaged in other tasks, delaying their responses to other aspects of the environment. The effect of billboards was particularly strong in scenes where response times are already lengthened by high levels of built or designed clutter. This is particularly concerning, as road scenes with high levels of built and/or designed clutter are just the sort of busy, commercial, high traffic environments where billboards are most often erected.

In the low clutter scenes, billboards did not impair response times; in fact responses were faster in scenes with billboards than in scenes without. This unexpected and inconsistent finding cannot be explained by the size or eccentricity of the changes in these photographs. Further research is required to explain this effect. However it should be noted that the difference between billboards and no billboards in this category was smaller than in the other categories, and the overall effect is for billboards to delay responses.

As expected, detection of road signs was particularly affected by competing search targets such as other road signs (i.e. high designed clutter) and billboards. High levels of sign clutter and billboard presence had a multiplicative effect on time to detect changing signs. This suggests that in road scenes with many traffic control devices and billboards competing for attention, some road signs simply will not be perceived. This suggestion is supported by the results of recent driving simulator experiments, which have found that advertising billboards affect both recall of road signs (Ewing & Dumbaugh, 2009), and response to road signs (Edquist, Horberry, Hosking, & Johnston, 2011), perhaps due to changed fixation patterns and increased mental workload (Young & Mahfoud, 2007).

There was also an interesting interaction with age group. Older drivers seem to have an extra long response time in the most difficult condition. This is consistent with other research (e.g. Ball, Beard, Roenker, Miller, & Griggs, 1988) showing that older drivers are more sensitive than others to task difficulty effects. To reduce the effects of these long response times on road safety, road signs could be made easier to see. Measures to achieve this might include increasing their size and conspicuity, removing background clutter, and restricting roadside advertising and other non-driving-related signage.

The present study is limited in that it did not include a driving task, merely a surrogate measure for visual subtasks required during driving. However, the results are consistent with a mounting body of evidence showing that billboards on roadsides attract attention and impair aspects of driving performance. In light of these findings, it would seem sensible that road safety authorities take a precautionary approach. Horberry, Regan and Edquist (2009) argue that rather than waiting until it can be proven beyond doubt that roadside advertising is responsible for a particular collision, road authorities should regulate billboards to minimise the probability of interference with driving.

The change detection paradigm is useful for driving research, as it depends on many of the same visual attention processes necessary for safe driving. Some may question whether the 'flicker' technique used here is too artificial to provide useful real-world results, as it depends on the brief blank screen between the two versions of the picture to erase the normal motion cues of a change. However the results of such experiments are consistent with other experimental paradigms showing that we do not perceive as much of the world as we think that we do (see Simons, 2000, for a review of this literature). Change blindness and related inattention blindness techniques allow us to examine visual perception more closely. Other techniques from the visual attention literature that could be used in driving research include the 'mud splash' technique, in which one conspicuous change masks a simultaneous change. This technique could be used to examine whether changing billboards distract attention from safety related changes in the road scene. Such research would be especially useful given the growing popularity of dynamic billboards, which are capable of changing instantaneously from one image to another. There is currently debate about how often such changes should be permitted to occur, and further research such as the experiment proposed here could elucidate the safety effects of frequent changes.

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