Visual clutter in road environments - what it does, and what to do about it

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Abstract

Visual clutter in roadscapes, including roadside advertising, is increasing, and there is little research on the effect on driving performance. Research at the Monash University Accident Research Centre investigated the sources and effects of visual clutter. This paper describes a method for assessing the level of clutter in a road scene, and summarises MUARC research on the effects of high levels of visual clutter on visual and driving task performance. The finding that visual clutter impairs these tasks has implications for road design. Suggestions are provided for road engineers to improve this situation when designing and locating road signage and when approving roadside advertising.

Keywords

Visual clutter, roadside advertising, billboards, road signs**,** visual environment

Introduction

Driving on a typical major road is a complex activity, involving processing large amounts of visual information which continuously changes, and making decisions at speed. The amount of visual information in road environments is increasing, due to higher traffic density, more complex traffic management systems, increased commercial roadside development, and increasing pressure on road authorities to permit advertising next to major roads. With this increasing amount of visual information, the road environment is increasingly prone to 'visual clutter'.

There has been little research into how and to what extent visual clutter can compromise driver safety. Road authorities are forced to develop their guidelines around the visual appearance of the road and roadside environment based on engineering judgement, conventions and international standards (e.g. MRQ, 1). These guidelines are being increasingly challenged; for example in the area of roadside advertising, road authorities have been asked to provide evidence to defend their assumption that additional visual stimuli could impair driving performance.

A major research gap at the commencement of the project was a method to determine the level of clutter in scenes, both to use in research to ascertain the effects of visual clutter on driving, and to assess road environments to determine whether the level of visual clutter is acceptable. The present work therefore had two aims: first to develop a consistent rating method, and second to ascertain what effect visually cluttered environments have on driving performance.

Developing a taxonomy of visual clutter

Initial studies involved focus groups with drivers and a study in which drivers rated photographs of various road scenes. Based on the results of these studies, a taxonomy of sources of visual clutter was developed. Three types of visual clutter were identified:

1. 'Situational clutter', or traffic, includes all the moving objects on and next to the road that must be attended for safe driving (including pedestrians as well as other vehicles).
2. 'Designed clutter', or signage, includes all those objects that road authorities use to communicate with the driver, such as road markings, traffic signs and signals; these items must also be attended for safe driving.
3. 'Built clutter' includes all other potential sources of visual clutter: buildings and other infrastructure, shop signage, and advertising billboards. These objects may distract attention from the driving task and/or make the background visually complex.

Experiment 1: Validation of the visual clutter taxonomy

Aim: to validate the three-factor taxonomy of visual clutter sources against subjective ratings from drivers.

Method: 14 probationary drivers, 12 drivers aged over 65, and 13 experienced young to middle aged drivers watched 32 video clips of roads. Each road clip was classified (based on the identified sources of clutter) as high or low for each of built, designed, and situational clutter, leading to eight road categories. A balanced factorial design was used (with equal numbers of video clips in each category) to ascertain the relative effect of each type of clutter and any potential interactions. Drivers gave 3 ratings (on a scale of 1-10) during each of the 10-second long clips.

Results: High levels of built clutter significantly increased subjective ratings of visual clutter, ($F(1, 36) = 170.07$, $p < .001$, $\eta^2 = .83$). So did high levels of designed clutter ($F(1, 36) = 75.52$, $p < .001$, $\eta^2 = .68$), and situational clutter ($F(1, 36) = 212.97$, $p < .001$, $\eta^2 = .86$).

Conclusions: High levels of built, designed or situational clutter as specified in the taxonomy agree with subjective ratings. The taxonomy can therefore be used to classify the level of clutter in road scenes without requiring the collection of ratings from a group of observers (the previous method used in research on visual clutter).

Evaluating the effects of visual clutter

There are several pathways by which visual clutter might impair the performance of the driving task. Visual clutter in the form of background complexity impairs the selection of relevant information from the environment, which is required for hazard detection and maintaining situation awareness (Evans & Stevens, 2; Lee & Triggs, 3); and visual clutter in the form of irrelevant signage interferes with visual search for traffic signs (Shoptaugh & Whitaker, 4; Ho *et al*., 5; McPhee *et al*., 6). Both of these effects will increase the demands placed on the driver. The accumulated stress from performing a demanding task may in itself reduce the attentional resources of the driver (Hancock & Warm, 7). Visual clutter in the form of highly conspicuous objects may distract the driver and temporarily capture the driver's attentional resources (Theeuwes *et al*., 8). When the demands of the driving task exceed the driver's attentional resources for any of these reasons, driving performance is likely to be impaired.

The experiments summarised below tested the above hypotheses on the effects of visual clutter using a change detection task and a simulated driving task. As the literature on workload and divided attention suggests that certain drivers may be more vulnerable to the effects of visual clutter (Ball *et al*., 9; Ho *et al*., 5; Ponds *et al*., 10; Young & Stanton, 11), we also explored the differential effects of clutter on young novice drivers and elderly drivers as compared to fully licensed young to middle-aged drivers. Advertising billboards were a form of visual clutter specifically investigated both because of previous literature suggesting that they are likely to have an effect on driving performance (Johnston & Cole , 12; Cairney & Gunatillake, 13; Farbry *et al*., 14; Crundall *et al*., 15; Lee *et al*., 16), and because new technologies are making these objects increasingly of interest to road authorities.

Experiment 2: Effect of visual clutter on change blindness

Aim: To determine the effect of high levels of visual clutter on a visual task necessary for driving.

Method: 15 probationary drivers, 15 drivers aged over 65, and 15 experienced young to middle aged drivers viewed 96 pairs of photographs. 24 scenes were low in both built and designed clutter, 24 were high in only one, and 24 were high in both. (Pilot testing showed that it was not possible to classify situational clutter based on photographs.) In each category, eight scenes had billboards; these were compared with eight matched scenes without billboards. Each pair of photographs rapidly alternated between versions with and without a changing object (a car or a sign, balanced across clutter categories and billboard presence). Drivers had to detect the change as quickly as possible.

Results: Changes in scenes with high levels of built clutter and/or designed clutter took longer to detect. Built clutter and designed clutter both significantly ($p<.001$) increased the time taken to detect changing

signs. Designed clutter (i.e. multiple signs) did not affect the time to detect vehicles ($p>.1$). Built clutter increased the time taken to detect changing vehicles by an average of half a second ($p<.001$). While probationary drivers were no slower than experienced drivers ($p>.1$), older drivers were slower to detect changes ($p<.001$), particularly for changes to road signs ($p<.001$) and changes in scenes with high levels of built and designed clutter ($p<.05$).
Billboards increased time to detect changes ($p<.001$), particularly for scenes with high levels of built ($<.01$) or designed clutter ($p<.05$). The combined effect of designed clutter and billboard presence was particularly damaging when the changing object was a road sign ($p<.01$).

Conclusion: Visual clutter impairs the selection of relevant visual information, even when that information is as salient as an appearing and disappearing car. Drivers are likely to have particular difficulty in following directions on traffic signs in road environments that have multiple traffic control devices as well as roadside advertising.

The full report of this experiment may be found in Edquist, Hosking et al (submitted).

Experiment 3: Effect of visual clutter (in the form of billboards) on driving performance

Aim: To determine the effect of high levels of visual clutter on visual behaviour, driving performance and responses to traffic signs and signals.

Method: 15 probationary drivers, 15 drivers aged over 65, and 15 experienced young to middle aged drivers drove two simulated 10-minute drives, each containing 9 intersections, 37 lane change signs and 22 billboards balanced across the intersections and signs. Time to respond to lane change signs and red traffic signals was measured, along with speed and eye movements. After the drives, participants rated the level of visual clutter in freeze-frames of the simulated environment.

Result: Subjective ratings of visual clutter confirmed the results of previous experiments: the presence of billboards, vehicles, and road signs increased rated clutter (all $p<.001$). In the presence of billboards, participants drove more slowly ($p<.001$), took longer to change lanes in response to road signs ($p<.001$), and made more errors when changing lanes ($p>.05$). Billboards also increased the proportion of time spent looking at roadsides (p.01), at the expense of the amount of time looking at the road ahead and lead vehicles when present ($p<.001$). There was no significant effect on responses to traffic signals, perhaps due to low power for this part of the experiment. Older drivers made more lane change errors overall, but particularly when billboards were present ($p<.05$).

Conclusion: Drivers were distracted by the billboards, and showed impaired visual scanning behaviour and response to traffic signs. That drivers drove more slowly past billboards perhaps indicates that they are aware of the distraction and compensating, or conversely, that they are paying less attention to speed maintenance. It should be noted that the billboards used in the simulator were much simpler than those found on roadsides today. More conspicuous, more complicated billboards are likely to hold drivers' attention for longer (Beijer *et al.*, 17), which increases the probability of adverse effects on driving performance (Horrey *et al.*, 18).

Further details of this experiment are reported in Edquist, Horberry, et al (submitted).

Overall summary

Sources of visual clutter can be divided into built clutter, designed clutter, and situational clutter. Higher numbers of objects which fall into these categories impair visual selection, including the ability to detect changes in a scene. This has flow-on effects for driving performance, including speed maintenance and the ability to follow directions on traffic signs. Older drivers are particularly affected by visual clutter in road environments.

Discussion and implications for practitioners

Ideally it would be possible to assess the effect of visual clutter on crash rates. Unfortunately, areas with high traffic, multiple road signs and markings, and much development next to the road are likely to have high crash rates for reasons that may not be related to visual clutter, so it would be difficult to isolate the effect. However, the fact that changing the visual environment has effects on tasks such as searching for road signs, detecting changes to nearby vehicles, and speed maintenance suggests that it is a source of workload that the designers and maintainers of the road network should be concerned about. The present work has identified objects and situations that contribute to this visual workload.

The principal contributors to the level of built clutter are roadside development, the complexity of the background, and the number of advertising billboards. Scenes with shops or high buildings are rated as more cluttered, and are harder to detect changes in. Complex scenes are rated more cluttered, and make visual search more difficult. Billboards increase time to detect changes and respond to road signs.

Factors that contribute to designed clutter are the number of traffic control devices, the amount of text they contain, and whether or not they require a response from drivers. More than three traffic control devices in one scene, or five in a ten-second drive, increase clutter ratings and time to detect changes. The amount of text is important because more information to read and process increases visual distraction. Traffic control devices that require drivers to respond (by braking or changing lanes etc) induce higher workload.

Situational clutter is difficult to assess from photographs of road scenes, however it may be possible to assess using the average annual daily traffic for the road. More vehicles increase clutter ratings and driver workload. Interactions such as overtaking and merging also increase driver workload.

The three types of clutter should be considered in combination with each other and with other sources of workload in the road environment. For example, a road with multiple lanes and high traffic volumes but low roadside development may be an acceptable location for roadside advertising – but not if placed just before a sharp bend concealing traffic lights or merging lanes. Similarly, the approaches to complex intersections should be as free of clutter as possible.

Prevailing speeds should also be considered, as visual clutter affects response times; this means that sources of visual clutter and/or workload will need to be more widely spaced in high-speed road environments, as drivers will travel further in the same amount of time.

The finding that billboards can impair change detection regardless of the level of other built clutter, and impair responses to traffic signs in the relatively low-clutter road environment of the driving simulator, suggests that these objects should be carefully regulated. Road authorities are justified in using information theory approaches and restriction distances around areas of high driver workload (such as intersections, merges and freeway exits) in order to ensure that the safety of road users is not compromised.

The finding that older drivers have difficulty detecting changes and following instructions on road signs in cluttered environments is particularly important, as an increasing proportion of Australia's population is moving into the over-65 age group, and an increasing fraction of this age group now hold licences. Road environments should therefore be designed so as not to disadvantage this growing group. This may require increased spacing between points which demand driver attention (e.g. complex signage, merges, billboards), removal of excess signage, and/or advance warning of hazardous situations with 'priming' road signs to spread the cognitive workload over a period of time before a response is required.

When deciding whether to place a new traffic sign or approve roadside advertising, practitioners may find the following checklist of issues to consider useful:

Table 1. Checklist for visual clutter

Specific questions regarding built clutter
B1 Is the roadside commercially zoned land?
B2 Are there currently (or likely to be in future) shops facing on to the road?
B3 Are there currently (or likely to be in future) tall buildings next to the road?
B4 Is there any other infrastructure such as overhead wires, bridges, and multiple poles that might create a visually complex background?
B5 Is there existing roadside advertising within sight?
Specific questions regarding designed clutter
D1 How many traffic control devices are visible?
D2 Are drivers asked to read a great deal of text (e.g. sorting through multiple destinations)?
D3 Are additional temporary messages (e.g. tunnel ahead closed/extended shopping hours for December/etc…) likely to be displayed nearby?
D4 Are drivers asked to make decisions (e.g. time limited regulations, choosing the correct lane for a particular destination)?
D5 Are there warning signs for hazards that are not visible from other cues, such as traffic lights or merging lanes concealed by a curve, bridge or crest?
Specific questions regarding situational clutter
S1 What is the traffic volume for the road?
S2 How often is it near capacity?
S3 Are there multiple lanes?
S4 Are there different types of vehicles (e.g. cars, buses, trucks, cyclists) which may travel at different speeds and require extra manoeuvres from drivers?
S5 Are there parking bays along the side of the road with cars reversing in and exiting frequently?

It is not intended that this checklist be used in its present form to assign a level of risk to a particular visual environment, as the research results do not yet permit the allocation of relative weights to each type of clutter or their component parts. However it would be possible, using an expert system process, to develop a set of weights that would provide an objective assessment tool for both new traffic management options and applications for approval for roadside advertising.

Conclusions

The present research identified the major sources of visual clutter and determined the effects on driving performance. The results show that a greater amount of clutter is associated with a greater likelihood of negative consequences (such as impairments in visual search, change/hazard detection, and responses to road signs). To assist the diffusion of this research into practice we have provided a checklist of objects and situations that may cause increased visual workload for the driver. The checklist requires further research and development before it is usable as a standalone assessment tool, however in its current form it may be useful for road authorities to compare with their current guidelines in such applications as roadside advertising approval.

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