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‘Visual clutter’ and external-to-vehicle driver distraction

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New highway developments, roadside advertisements and street-side vendors, and increased traffic flow combine to increase the amount of visual information presented to drivers from outside the vehicle. The objective of this paper is to investigate the possibilities for driver distraction from these external-to-vehicle sources of information. The first section will review previous research applicable to the external distraction problem, including studies of crash data, on-road investigations and laboratory experiments. The second section will describe research recently conducted at the Monash University Accident Research Centre into ‘visual clutter’ and its effect on drivers. A series of focus groups was conducted with drivers aged 18 to 60. A total of 54 drivers participated in one of six groups. Each group was asked to describe what visual clutter is, what are its most common forms in the road environment, and how (if at all) it affects their driving. They also discussed two different road scenes in detail. Results revealed a strong connection between the perceived levels of visual clutter in a scene and the level of attention drivers felt would be required to drive safely along the road in that scene. Drivers felt that they would be more stressed and more likely to be distracted from the driving task when driving down roads with high levels of visual clutter. The implications of these findings for the study of visual clutter and driver distraction are discussed.

External-to-vehicle distraction and crash risk

Driver distraction is a topic of increasing concern to road safety. However, it is difficult to accurately estimate the involvement of distraction in crashes. At the low end is Lam’s (2002) estimate of 3.6%; this figure was arrived at from the analysis of four years of mass data from NSW Traffic Accident Database System (collected from police forms). At the higher end, Wang, Knipling & Goodman (1996) found that distraction was implicated in 13.3% of crashes, and another 9.7% of crashes are described as ‘looked but did not see’. Wang and colleagues used data from the NHTSA Crashworthiness Data System, which investigates a representative sample of crashes in detail.

This discrepancy between studies based on mass data and in-depth crash studies may be explained by the fact that police investigations tend to focus on attributing culpability. Drivers may therefore be reluctant to admit to police that they were distracted at the time of the accident. With no way of determining whether distraction was a contributing factor to a crash, most mass data systems provide catch-all codes such as ‘driver inattentive’ or ‘failed to see’. There is also the possibility that drivers were unaware that they were distracted at a crucial moment before the crash, so even the in-depth data may provide an underestimate of the size of the problem.

Of crashes where distraction was involved, it has been estimated that the source of distraction is outside the vehicle in 30-35% of cases (Stutts et al 2001; Glaze & Ellis 2003). One potential source of external-to-vehicle distraction is advertising billboards. These

objects tend to be large, brightly coloured, and placed near the road, which makes them highly conspicuous- indeed they are designed to grab the attention of drivers.

Two recent reviews of the literature on billboards and crash rates concluded that these two factors correlate, with the usual caveat that correlation does not establish causation. Cairney and Gunatillake (2000) reviewed studies correlating crash data with advertisement location and found greater density of advertisements correlated with a higher crash rate, especially for changeable-message signs. Farbry and colleagues (2001) concentrated on the effect of electronic billboards on crash rates. They concluded that crash rates are higher where electronic billboards are installed.

Wallace (2003) also reviewed the literature on billboards and noted that the presence of billboards correlated with high crash rates in some circumstances, but not others. Higher crash rates were associated with billboards in two situations: at intersections, where billboards can function as visual clutter and interfere with the driver's ability to perceive important traffic signs; and on long monotonous stretches of road, when drivers may be surprised by the sudden appearance of a billboard, or fixate upon it as the brightest object in their visual field. Wallace concluded that more research should be done to identify the conditions under which billboards interfere to a dangerous extent with the driving task.

Laboratory studies give further insights into the potential distracting effects of outdoor advertising on driving performance. For example, Johnston and Cole (1976) performed a series of five laboratory experiments in which participants moved a joystick to track arrows that appeared on a screen, while distracting advertisements were occasionally presented just above the arrows. They concluded that distractions from advertising billboards probably do not affect vehicle control (simulated by a tracking task) but probably do affect hazard detection (simulated by peripheral target detection, which was an additional task in three of the experiments).

The present research, being undertaken by the first author at the Monash University Accident Research Centre, focuses on the effects of visual clutter on driving performance. Although potential driver distraction is one of these effects, there are other effects of visual clutter that can also have a negative effect on driver performance. Drivers may have difficulty with visual search (for example, searching for street signs) in environments that are highly cluttered. This will not only interfere with the immediate task of finding a particular street; the necessity of devoting more attention to the search task will increase driver workload. This cognitive distraction may also have effects on the driver's ability to drive safely, over and above the effects of purely visual distraction.

Visual search

Visual search, in the psychological literature, refers to searching for a target one expects to be there (such as a stop or give way sign at an intersection). So defined, visual search is necessary for two driving tasks: responding to traffic signs and signals, and navigating to the driver's destination. It is also necessary for many other tasks that humans perform every day; unsurprisingly, there is a large amount of literature on the subject. In short, visual search for a particular target is hindered by the presence of similar-looking 'distractors' (e.g. Treisman 1980; Duncan & Humphreys 1989; Wolfe et al, 1989). In the driving domain, this implies that visual search for traffic signs will be more difficult when there are advertisements of similar appearance in the vicinity.

A number of studies have investigated this possibility. Holahan and colleagues (1978), for example, made slides consisting of a stop sign and varying numbers and colours of distractor signs on a white background. Reaction time to locate the sign increased with the number of distractors, similarity of colours, and proximity to the target sign. Boersema and Zwaga (1985) showed students slides of railway stations and asked them to find routing signs (which were always white on blue) in various backgrounds. More advertisements and/or larger advertisements decreased the probability of subjects correctly locating the routing sign.

Jenkins (1982) used photographs of real-world scenes and asked participants to detect discs of various contrasts that had been placed in the scene. This was the first study to attempt to find the effects of 'visual clutter'. Jenkins asked participants to rate the scenes from most to least cluttered, and found that there was a relationship between the clutter ranking and how well participants were able to detect the disc targets. The next study to specifically investigate visual clutter was not for another two decades, when Ho and colleagues (2001) asked participants to classify a set of real-world photographs into 'high clutter' or 'low clutter' groups. A different set of participants then searched for a target sign; they made more errors in the 'high clutter' scenes. (Interestingly, this pattern only held for daytime scenes; there was no consistent pattern for 'night' scenes, which had been created from the day scenes to minimise differences.) It is fairly clear that visual clutter caused by advertisements and other objects can interfere with drivers' ability to search for traffic signs.

Workload

A number of on-road and simulator studies have found that increasing the driver's workload lowers the driver's ability to detect potential hazards, particularly in peripheral vision. Lee and Triggs (1976) found that drivers missed more lights in a peripheral detection task while driving through busier and more complex environments (this study was performed on-road, whereas more recent studies tend to be in simulators). Martens and van Winsum (2000) found negative effects on both reaction time and hit rate for a peripheral detection task when driving task difficulty was increased by external causes such as narrow curves or the appearance of an unexpected obstacle. Baldwin and Coyne (2003) found similar effects on secondary task performance when they increased workload by increasing the traffic density. Wood et al (2003) found that drivers took longer to brake for critical events when they were given the task of counting the number of a certain type of pedestrian.

There has been little research on the interaction between external to vehicle and internal to vehicle sources of workload (Regan, 2004). Obviously when drivers have to look at something inside the vehicle, they cannot simultaneously look outside the vehicle, so their ability to respond to external events suffers (Olsson & Burns 2000, Horberry et al 2003). However Olsson and Burns (2000) found that counting backwards interfered with the detection of peripheral lights, and Horberry and colleagues (2003) found that a simulated hands-free mobile phone conversation impaired drivers' responses to a pedestrian crossing the road (both of these were simulator studies).

Non-visual distractions can thus increase driver workload, with resulting negative effects on the driver's ability to detect hazards. In addition, non-visual distractions can impair the driver's ability to make appropriate decisions. Cooper and Zheng (2002) found that participants in their study of turning gap acceptance were less able to take into account relevant information when making the decision while distracted by a complex verbal message. If the external environment is more cluttered, this will add to drivers' difficulty in selecting relevant information.

The effects of cognitive distraction may therefore be worse when combined with demanding driving environments external to the vehicle. McPhee and colleagues (2004) investigated the interaction between these two factors by asking participants to search for a particular sign in high or low cluttered scenes. In the 'single task' condition participants subsequently performed a verbal memory test designed to simulate a mobile phone conversation, while in the 'dual task' condition they performed the verbal task and the search task simultaneously. Although McPhee and colleagues did not find an interaction between clutter and task condition, they admit that their results in the absence of demands from the driving task itself are likely to be optimistic, and that replication of the study in a simulator or on-road environment might well find greater effects.

Visual clutter: A focus group study

There are suggestions in the literature that visually cluttered road environments can have negative effects on driver workload, visual search and ability to maintain attention on the driving task. However, so far there has been little research into what actually constitutes 'visual clutter'. In preparation for later experimental work, we felt that an appropriate place to start our research would be an exploratory investigation into drivers' perception of what visual clutter is, and what effects it can have.

Participants

Fifty-four drivers were recruited by advertising in Monash University's staff notices bulletin and on the student job website. All participants received a small cash payment as compensation for their time and travel costs. Drivers ranged in age from 18 to 58, with driving experience of less than one to forty years. Nineteen participants were male, and thirty-five were female.

Procedure

Participants undertook the experiment in groups of approximately ten. Drivers filled out a brief questionnaire on their age, sex, licence type, and driving experience. Participants viewed a series of photographs of various road scenes for another experiment being conducted concurrently, and then took part in the focus group discussion. The facilitator began the discussion with general questions about what participants thought visual clutter was, and what effects it had on them while driving. Participants were then shown a photograph of a crowded city scene and asked a series of questions about what grabbed their attention first; which objects contributed to the amount of clutter in the scene; what could distract them from the driving task; and how easy they thought it would be to find a street sign and detect a potential hazard while driving down the road in that scene. These questions were repeated for a second photograph, which showed a low-traffic road in a rural environment. The discussion was recorded on audiotape for later transcription by the experimenter.

Results

What is clutter?

The first question '*What do you think visual clutter is?*' elicited four points of view. Simplest was the idea that 'cluttering' objects are those that occlude other objects. Perhaps surprisingly, this idea was not what most drivers thought of first – all the other points of view were more closely related to attention.

One of the most common ideas was that visual clutter is everything you can see. Proponents of this viewpoint agreed that visual clutter took up attention, but they thought that everything in the visual field has to be attended briefly in order to assess whether it needs to be attended to in more detail. The other common viewpoint was that clutter is made up of objects that distract the driver from the driving task. Of course, this is subjective and changes depending on the situation; what is an unnecessary sign to one driver might be a useful navigation landmark to another. A corollary to this idea was the view that cluttered scenes are those with many objects that are necessary for the driving task, for example many signs or intersecting roads, all of which demand attention.

The consistent theme that comes through is that drivers feel the amount of visual clutter in a scene is related to the amount of attention they must give to objects in that scene.

When asked '*What are the most common forms of visual clutter in the driving environment?*', participants gave responses that fell into the same categories: 'objects that require attention as part of the driving task' (signs, other cars, trams, pedestrians etc), 'objects that distract attention from the driving task' (billboards and other advertising signs), and 'objects that occlude vision' (tall buildings, trees, trams and other cars to a certain extent).

<u>What effect do you think visual clutter in the road environment has on your driving?</u>
Two consistent themes appeared in responses to this question: distraction, and attention overload. Both caused drivers to miss traffic signs and potential hazards. Drivers reported that familiarity could ameliorate the effects of a highly cluttered environment, as could a passenger giving navigation instructions. Both of these result in a lessening of the driver's cognitive load, allowing the driver to concentrate more on the current traffic situations (rather than having to, for example look for a particular street sign – a navigating passenger can do that for them, and familiarity with the area means they can use other cues to know when to turn). Familiarity also allows a driver to 'tune out' the objects that they know are not relevant, for example advertising billboards, which again increases the amount of attention they can give to the driving task.

The facilitator then showed this urban scene and asked a series of questions about it.

Most participants regarded this scene as cluttered. Those who disagreed tended to have more experience in driving in the city, confirming that familiarity with a particular environment allows drivers to ignore irrelevant objects.

Would you be able to easily find a street sign in this scene?
This question received mixed responses; some drivers felt it would be quite difficult to distinguish a street sign from all the other signs, while others felt that the unique size, shape, and positioning of street signs should enable them to find it easily.

What about potential hazards like pedestrians?
This question also received mixed responses, mostly due to the presence of parked cars occluding the driver's view of potential pedestrians down the road. The general feeling was that drivers should expect pedestrians in this sort of road environment and be on the lookout.

Particularly cluttering objects
Certain objects came up repeatedly in different questions. The large billboard on the right-hand side of the scene, on the side of a building, and the brightly coloured 'shop for lease' sign on the building on the left-hand side of the road were both mentioned as objects that were noticed first, that would distract drivers on the road, and that participants would take out of the scene to make it less cluttered. Other objects that were noticed first were conspicuous because of their size (the buildings to the side of the road), color and/or location (the green trees near the center of the photograph).

As with the responses to common forms of visual clutter, the objects that people would remove to reduce clutter fell into a few categories: those which must be watched to drive safely (parked cars, trams); those which distract attention from the driving task (advertising signs, billboards – because of size, colour, and presence of writing, which takes extra time to read); and those which occlude other objects (parked cars again, and trees).

The facilitator subsequently showed this rural scene and asked a similar set of questions.

All participants in all groups described this scene as not cluttered. They felt that street signs, pedestrians and other hazards would be very easy to detect in this environment.

What is it about this scene that makes it not cluttered? What are the important differences between this scene and the previous scene?
Drivers felt the rural scene was less cluttered than the urban scene for two reasons: there are fewer objects to look at and fewer things to think about. Drivers felt that the scene was more predictable (i.e. fewer objects in the scene were likely to move), and that if an unexpected hazard appeared they would have more time to deal with it than it the urban scene. Some drivers also noted that the single sign was the only object that required extra attention; there was nothing else to distract from steering and maintaining speed.

The sign was mentioned most commonly as the first thing seen. Other answers included the mountains/horizon/view, the car in front, the sky, the embankment on the right of the road, and nothing in particular.

Drivers felt that the only distraction in the rural scene is the view of the mountains. Some participants noted that because there is no clutter and the scene is so relaxing, they would be concentrating on their driving less than they would in the city scene.

Discussion

The purposes of this paper were to review the literature on the effects of visual clutter on driving performance, particularly with respect to driver distraction, and to describe a recent exploratory study of drivers' perceptions of visual clutter. In short, the main themes that came out of the focus groups were all related to the idea that objects that demand attention increase visual clutter.

These themes can be summarised as four points of view:

1) 'Everything is clutter' – some drivers feel that scenes that are cluttered simply have too many individual objects to pay attention to.
2) 'Occluding objects are clutter' – objects that get in the way of seeing other objects that the drivers need to pay attention to cause clutter.
3) 'Distracting objects are clutter' – many drivers felt that objects that are conspicuous, but not necessary for the driving task, are a source of clutter in the road environment and should be removed or restricted.
4) 'Too many driving-related objects make clutter' – another cause of clutter is when there are too many objects to which the driver must attend in order to drive safely. When the demands of the driving task exceed the driver's attentional resources, the driver may lose control of the vehicle (Fuller & Santos, 2002). If the driver must continually pay attention to a large number of objects (near the maximum number that the driver can attend to), this may lead to fatigue, with consequent negative affects on driver safety.

There is opportunity for traffic engineers to reduce clutter in all four categories. For example, traffic signs must be placed so that drivers can adequately absorb the messages in each sign while also reacting to traffic (theme 4). Other objects should not be placed too close to traffic signs, so that they do not crowd, occlude, or distract from the signs. In particular,

advertising billboards may need regulation, as these objects fall into three of the four categories of clutter producing objects.

The major limitation of this study is the usual problem with focus group research, in that the results are merely subjective opinions. However, the opinions expressed by focus group participants seem to relate easily to previous objective research, which suggests that distraction, impairment of search for traffic signs and increased workload can all be caused by visual clutter.

This research has suggested certain attributes of clutter that should be investigated further. The next stage is to perform more quantitative research into how much visual clutter is contributed by each element in a scene, first in a static environment with maximum experimental control, and secondly in a dynamic environment to maximise environmental validity. Once we know which attributes are most cluttering, we will be able to manipulate levels of each attribute within MUARC's advanced driving simulator and determine the effects on drivers' ability to drive safely.

Visual clutter is a complex problem, and many results of interest lie in the interaction of variables. For example, research has already established that in some situations advertising billboards are dangerous, while in others they are not. Determining what characterises the dangerous situations (is the driver's attentional capacity already stretched? Are there too many other distracting objects?) will help road authorities deal with the problem of driver distraction and other effects of visual clutter.

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Appendix A - Focus group questions

1. What do you think visual clutter is?

1.a) What are the most common forms of clutter in the driving environment?

2. What effects do you think visual clutter in the road environment has on your driving?

3.a) I'm going to show you a photograph of a road scene, and I would like you to tell me what grabs your attention first.

b) Would you describe this scene as cluttered?

- Why is it cluttered?

- If you took some objects out of the scene, would it still be cluttered?

- Which objects? (*prompt if necessary: cars, buildings, signs, trees, shop displays…)*

c) Would you be able to easily find a street sign in this scene?

- What about potential hazards like pedestrians?

d) Imagine you are driving down this road. Would you be distracted by anything in this scene?

4.a) Now I'm going to show another photograph. Again, please tell me what grabs your attention first.

b) Would you describe this scene as cluttered?

- What is it about this scene that makes it not cluttered?

- What are the important differences between this scene and the previous scene?

c) Would you be able to easily find a street sign in this scene?

- What about potential hazards like pedestrians?

d) Imagine you are driving down this road. Would you be distracted by anything in this scene?

PRESENTATION SLIDES

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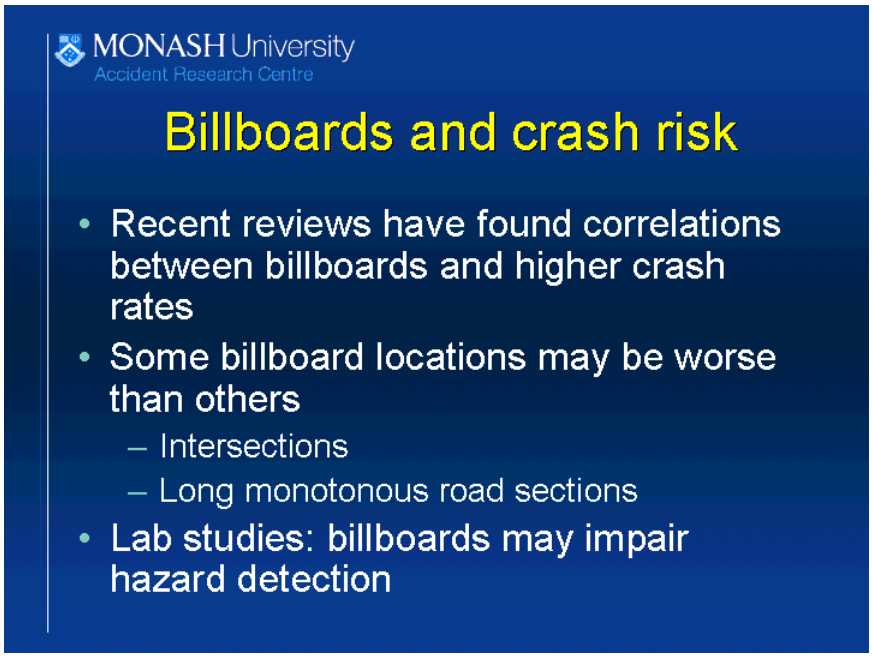
Driver distraction

- Involved in 3.6% - 25% of crashes
- Of these crashes, source of distraction is outside the vehicle in 30% - 35% of cases
- Advertising billboards are a potential source of external distraction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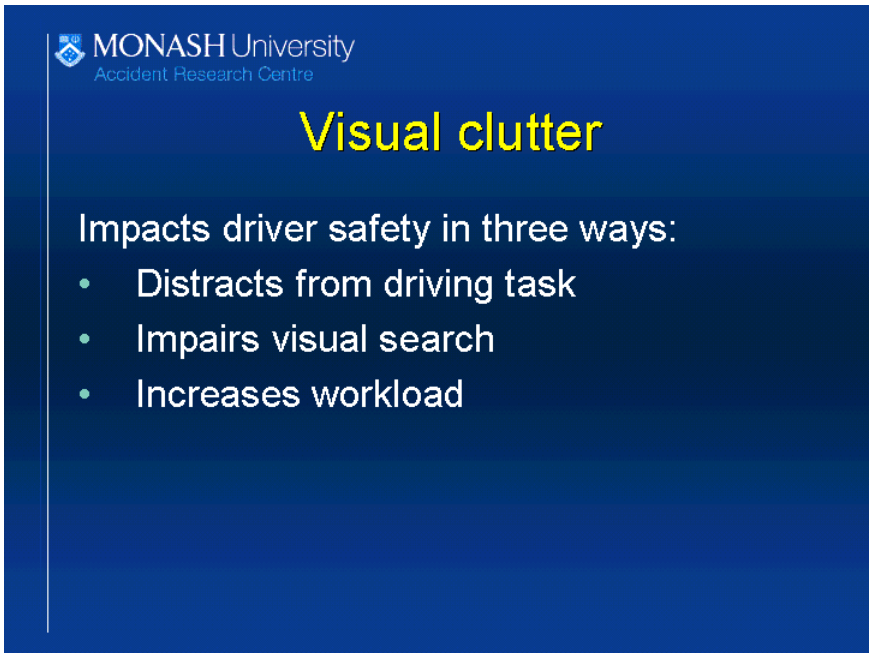
Billboards and crash risk
• Recent reviews have found correlations between billboards and higher crash rates
• Some billboard locations may be worse than others
– Intersections
– Long monotonous road sections
• Lab studies: billboards may impair hazard detection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Visual clutter
Impacts driver safety in three ways:
• Distracts from driving task
• Impairs visual search
• Increases workload


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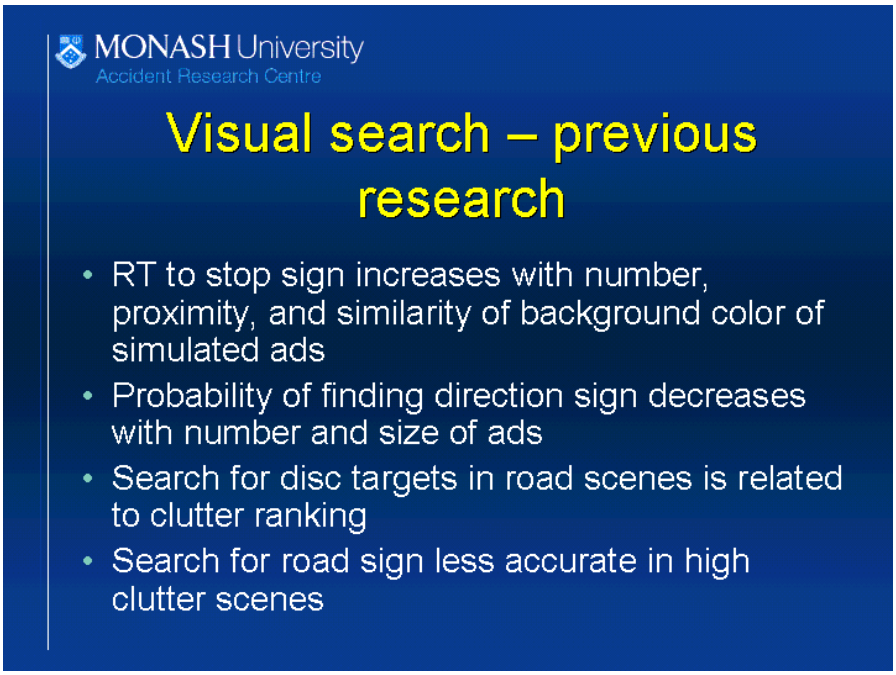
Visual search
• Searching for a target you expect to be there (eg stop sign at intersection)
• Hindered by distractors that look similar to the target
• Search for traffic signs: impaired by presence of advertising signs with similar size, shape, colour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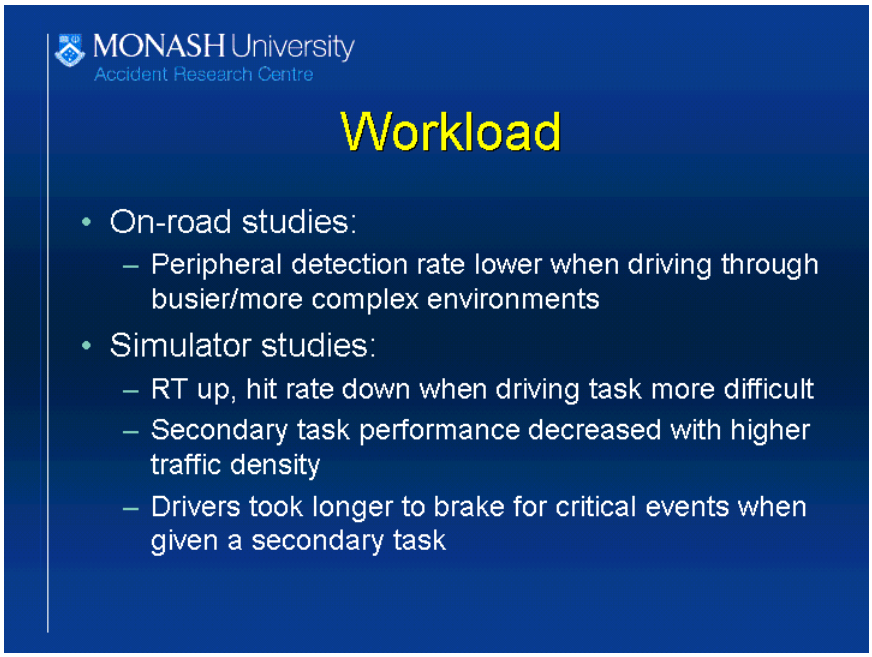
Visual search – previous research
• RT to stop sign increases with number, proximity, and similarity of background color of simulated ads
• Probability of finding direction sign decreases with number and size of ads
• Search for disc targets in road scenes is related to clutter ranking
• Search for road sign less accurate in high clutter scenes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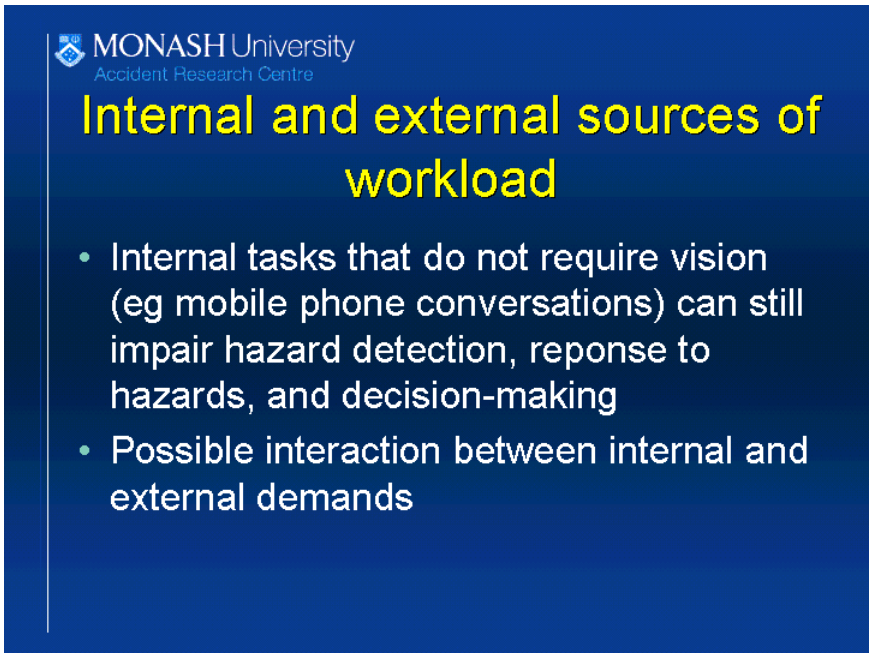
Workload
• On-road studies:
– Peripheral detection rate lower when driving through busier/more complex environments
• Simulator studies:
– RT up, hit rate down when driving task more difficult
– Secondary task performance decreased with higher traffic density
– Drivers took longer to brake for critical events when given a secondary task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Internal and external sources of workload
• Internal tasks that do not require vision (eg mobile phone conversations) can still impair hazard detection, reponse to hazards, and decision-making
• Possible interaction between internal and external demands


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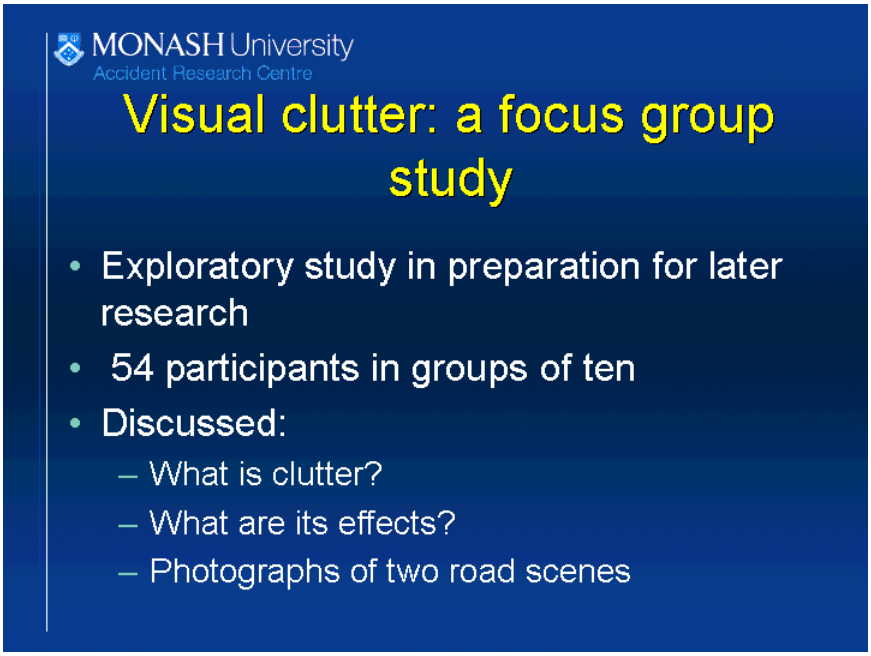
Summary of previous research
• Visual cluttered road environments can have negative effects on:
– driver workload
– visual search
– ability to maintain attention on the driving task (distraction)
• But there is little research into what constitutes visual clutter…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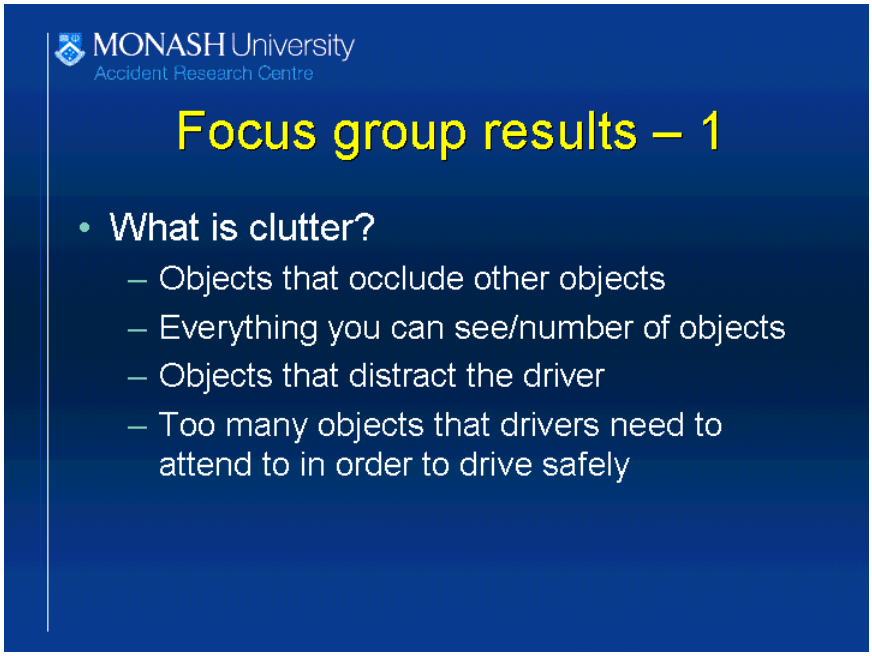
Visual clutter: a focus group study
• Exploratory study in preparation for later research
• 54 participants in groups of ten
• Discussed:
– What is clutter?
– What are its effects?
– Photographs of two road scenes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Focus group results – 1
• What is clutter?
– Objects that occlude other objects
– Everything you can see/number of objects
– Objects that distract the driver
– Too many objects that drivers need to attend to in order to drive safely


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Focus group results – 2
• Most common forms:
– Traffic signs
– Other vehicles
– Billboards & other advertising signs
– Tall buildings
– Trees
– Trams

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Focus group results – 3

- Effects of visual clutter:
  - Distraction
  - Overload: temporary (impairs visual search)
  - Overload: continuous (causes fatigue)
- All cause drivers to miss traffic signs & potential hazards
- Familiarity with road can help drivers cope

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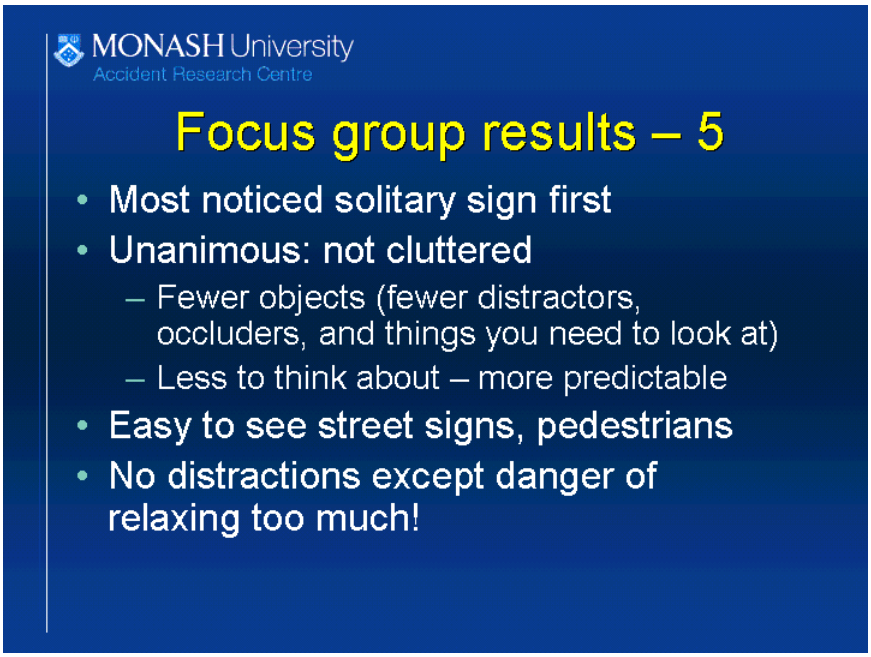
Focus group results – 4

- Is it cluttered?
  - Depends on familiarity with city driving
- Easy to see street signs, pedestrians?
  - If they are where drivers expect
- Billboard, shop for lease sign were
  - Noticed first
  - Sources of distraction
  - Mentioned as things to take out to reduce clutter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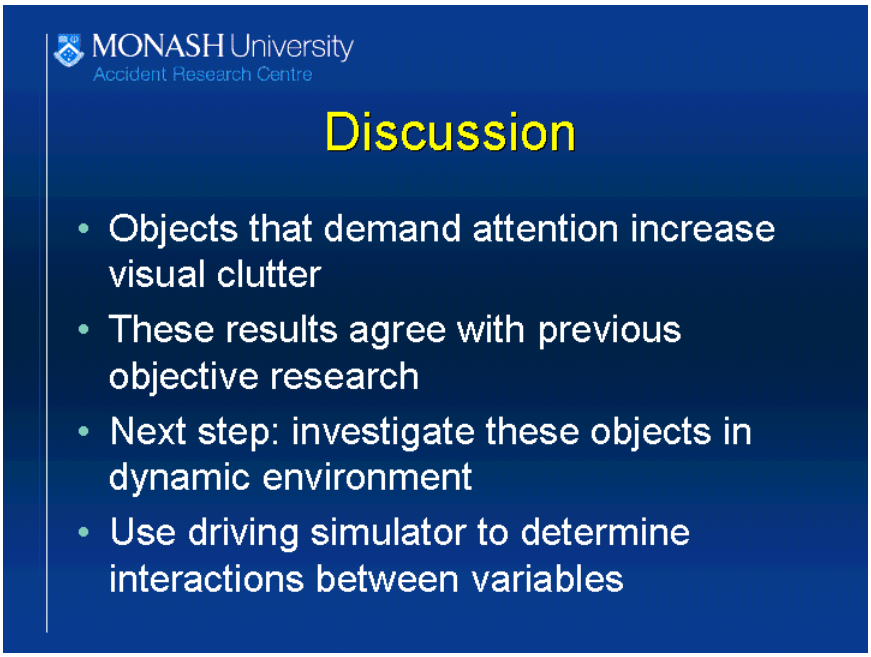
Focus group results – 5
• Most noticed solitary sign first
• Unanimous: not cluttered
– Fewer objects (fewer distractors, occluders, and things you need to look at)
– Less to think about – more predictable
• Easy to see street signs, pedestrians
• No distractions except danger of relaxing too much!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Discussion
• Objects that demand attention increase visual clutter
• These results agree with previous objective research
• Next step: investigate these objects in dynamic environment
• Use driving simulator to determine interactions between variables