

Are roadside Electronic Static Displays a threat to safety?

Rena Friswell ^{a*}, Elia Vecellio ^{ab}, Raphael Grzebieta ^a, Julie Hatfield ^a, Lori Mooren ^a,
Murray Cleaver ^c, Michael De Roos ^c

^a Transport and Road Safety (TARS) Research, UNSW

^b Now at Centre for Health Systems and Safety Research, UNSW

^c NSW Centre for Road Safety, NSW Department of Transport Roads and
Traffic Authority

* Corresponding author. Email: r.friswell@unsw.edu.au

Abstract

With increasing research interest in the effect that in-vehicle technologies have on driver performance and safety, driver distraction has emerged as a major issue confronting the road safety community. Despite this interest, relatively little attention has been paid to the impact of roadside advertising as a source of distraction outside the vehicle. Advances in electronic technology have made it possible for advertisers to present very large, high quality, static or moving images to passing motorists and, not surprisingly, the advertising industry is keen to exploit the benefits of the new technology. Regulators, both in Australasia and around the world, have been looking to research evidence on the safety impact of these fixtures to inform policy, but have been confronted with diverse findings and sometimes contradictory conclusions. This paper reviews the research evidence on the effects of Electronic Static Displays (ESDs) on driver distraction, driving performance and safety and discusses the implications of the findings for research and policy. Because the body of research directly assessing the safety effects of ESDs remains limited in both scope and design, policy makers should err on the side of public safety when considering their regulatory options.

Introduction

This paper is based on work originally done to inform guidelines around electronic roadside signs in NSW. Like at least 11 other reviews of the research literature conducted around the world in the last decade (Coetzee, 2003; Farbry, Wochinger, Shafer, Owens, & Nedzesky, 2001; Finnish Road Administration, 2004; Hatfield, 2005, 2008; Molino, Wachtel, Farbry, Hermosillo, & Granda, 2009; Spiers, Winmill, & Kazi, 2008; SRF Consulting Group Inc, 2007; SWOV Institute for Road Safety Research, 2009; Wachtel, 2009; Wallace, 2003a, 2003b), this work was commissioned by a government body seeking regulatory guidance from the empirical literature in the face of industry lobbying to use large electronic advertising signs along roadways.

Current technology permits outdoor electronic advertising signs to be large. For example, a sign installed near Red Square in Moscow in 2010 to show moving video advertisements measured 220m by 15m. As well as allowing high quality static or

moving video images to be screened, electronic sign technology can display those images brightly enough to be seen clearly during the day or night. In addition, the development, installation and scheduling of electronic sign content can be done remotely, giving these signs cost and flexibility advantages over traditional sign types. Not surprisingly, the advertising industry is keen to exploit the potential commercial benefits of electronic signs.

This paper focuses on one type of electronic roadside sign; Electronic Static Displays (ESDs) - also referred to in the literature as electronic or digital billboards (EBBs or DBBs) and commercial electronic variable message signs (CEVMS). Like traditional roadside billboards, ESDs present a single, unchanging or static image for a period of time. Unlike traditional billboards, the display period for an image on an ESD can be very short (seconds). This means that many different static images can be presented in the period of time it takes a single motorist to pass.

The success of any roadside advertisement depends on it attracting the attention of passing motorists sufficiently for them to understand the product message being presented. However, this entails distracting or reducing the attention drivers can pay to the driving task and so poses a potential risk to road safety. The extent of the risk and the circumstances under which it varies are critical pieces of information for the development of evidence-based policy and regulation around ESDs. Consequently, the aim of this paper is to present an up-to-date review of the scientific research on the safety impact of ESDs

Method

A review of the peer-reviewed and grey empirical literature published during the last 10 years (2001-2010) was conducted. Earlier papers identified by previous reviews and directly relevant to ESDs were also examined. The review also included a series of field studies commissioned by the Outdoor Advertising Association of America (OAAA) through its Foundation for Outdoor Advertising Research and Education (FOARE). A number of these studies were reviewed by Wachtel (2007, 2009) but they have not been made widely available to the research community.

The literature search was conducted using a range of literature databases to ensure broad coverage of the published scientific research, including: PsycInfo; Ergonomics Abstracts; Proquest Social Science Journals; CSA/ASCE Civil Engineering Abstracts; SAE database; Medline; Scopus; ScienceDirect; Web of Science; Business Source Premier; Journals@Ovid Fulltext. In view of the recency of ESD technology and the availability of earlier reviews, the database searches were restricted to the period 2005 to August 2010 inclusive. The searches were also restricted to English language documents. The following search terms were sought in all search fields: "driv* and distract* and sign*"; "driv* and distract* and advertis*"; and "driv* and distract* and external". The term "safe*" was trialled in place of "distract*" in the PsycInfo search but it did not increase the capture of relevant references.

To access the grey literature, including guidelines and reports by government and industry bodies and unpublished reports by research bodies, a Google search was conducted using the same search terms. In addition, the reference lists of relevant publications were scanned for documents that had not been uncovered through the

formal searches. Documents with restricted access were sought from the Outdoor Media Association (OMA) of Australia or from the authors of the documents, as appropriate.

Results

Although there is a growing evidence base on the impact of in-vehicle distractions such as mobile phones, in-vehicle GPS and entertainment technologies, the current literature search revealed very little research on the external distraction posed by ESDs. Only eleven studies were identified that bore directly on ESDs. Table 1 summarises their design features and Table 2 outlines the main measures, results and methodological problems with these studies.

Over half of the studies were conducted by Tantala and Tantala (2007, 2009a, 2009b, 2010a, 2010b; 2005) and were commissioned by the US outdoor advertising industry group (OAAA/FOARE). Including these studies, 73% of the publications used police-recorded crashes before and after ESD installation along public roads as the main outcome measure. One naturalistic observation study, one laboratory driving simulator study and one laboratory experimental study were also relevant and these studies examined aspects of driver behaviour such as reaction speed, lane keeping, vehicle speed and gaze behaviour.

None of the studies parametrically investigated the impact of different ESD or site characteristics on outcome measures although Tantala and Tantala (2010b) summarised the crash data for ESDs with 6-8s and with 10s image dwell times separately. They reported an apparently smaller reduction in crash rates at 6-8s over the study period. Although this suggests that the shorter dwell time contributed to higher crash rates, no statistical testing was undertaken and the 6-8s and 10s sites were not matched on extraneous factors in any way so it would be difficult to attribute any difference to dwell time.

Most of the crash studies combined multiple ESD sign sites with varied characteristics so that potential differences in the impact of individual signs may have been averaged out. This strategy also introduces noise into the data. Many of the crash studies also examined ESDs at sites that were previously occupied by traditional billboards or other types of roadside signs. For this reason, the period before the ESD installation was not a true no-intervention baseline period – crash rates may have already been elevated due to the presence of the previous signs.

Five of the eight crash data studies reported no adverse effect of ESD installation on crashes. However both of the studies (Massachusetts Outdoor Advertising Board, 1976; Tantala & Tantala, 2010b) that compared post-installation crashes with the rates predicted by the trend in pre-installation crashes found statistically significant evidence of increased crashes following installation. This type of analysis takes account of changes in crashes that would occur regardless of the presence of the ESD and ensures that the effects of installation are not hidden by a pre-existing declining trend in crashes.

The studies using measures other than crashes reported mixed findings. Gaze was directed towards the sign stimuli in the simulator and on-road studies, dual task

reaction time was slowed in the presence of the sign stimuli in the laboratory experiment, and lane keeping was impaired in the simulator study but reductions in lane keeping only approached significance on-road and there was no evidence of speed disruption on-road.

Discussion

This review of the literature found very few empirical studies dealing directly with ESDs. The majority of the studies were analyses of crash data collated across multiple sites where ESDs had been installed, often replacing existing traditional signs. Typically, these studies did not have adequate 'no-sign' controls and did not attempt to control or systematically examine the effects of physical sign characteristics or location characteristics on crashes. In most of the studies, trends in crashes before the ESD installation or at comparable control sites were not accounted for. Given these methodological problems (it is unsurprising that most of these studies (specifically Tantala & Tantala, 2007, 2009a, 2009b, 2010a; Tantala & Tantala, 2005) found no statistically significant change in crashes associated with the installation of ESDs. Indeed, the authors highlight the fact that the raw crash numbers are generally lower after ESD installation (albeit not statistically significantly lower). In contrast to these studies, however, the two crash studies that compared post-installation crashes with the levels expected from the pre-installation or control site trends (Massachusetts Outdoor Advertising Board, 1976; Tantala & Tantala, 2010b) found significantly elevated crashes after ESD installation. This result is consistent with the findings of the Wisconsin Department of Transport study and with the simulator and laboratory studies which reported deteriorations in basic responses such as reaction time and lane keeping. It would appear that the better controlled studies of ESD effects show some adverse effects. Further investigation is required to determine whether the different findings reflect true variations in the impact of ESDs or are merely artefacts of differences in methodology.

Research using other types of signs (Crundall, Van Loon, & Underwood, 2006; Smiley, et al., 2005) has suggested that the elevation of the sign may be an important physical characteristic contributing to driver distraction, with higher elevations (i.e., those above the driver's horizontal Hazard Inspection Window) being less likely to distract a driver's gaze. Unfortunately, ESD characteristics like this have not been systematically studied for their effect on distraction and safety. Similarly, although one study of ESDs presented data from signs using different image dwell times, the data were not compared statistically and the design of the study would have made it difficult to interpret the result. Understanding the effects of dwell time is particularly important because it is a distinguishing perceptual feature of ESDs, and a likely feature for regulatory control. Research that systematically examines ESD features like dwell time is needed. Of note, no research has examined whether ESDs might have positive effects on performance and safety under certain circumstances, for example, by reducing monotony and any associated performance deterioration on long, rural drives at night.

Table 1: Research studies of ESDs and road safety – study design and sign characteristics

Reference Country/state	Design	Sign type	Size	Position	Change parameters	Road conditions
Tantala & Tantala (2010b) US/PA	Crash Data; Pre-post; between 1-4 years each; Non-ad control: ?	ESDs	26 signs at 20 locations; 3.3x6.7m to 4.7x16m	Spacing: ? Sight distance: ? Lateral offset: ? Elevation: ?	Dwell time: 6, 8, or 10s Transition: ?	Type: Usually arterial large roads Speed limit: ? Other:
Tantala & Tantala (2010a) US/NM	Crash Data; Pre-post; 2 or 3.5 years each Non-ad control: No	ESDs	13x (3.7mx7.3m) and 1x (4.7mx9.3m)	Spacing: Shortest gap is ~160m, but facing opposite directions (opposite face of each sign holds a conventional advert – checked in Google streetview). Next gap size is 780m (different roads), then gap sizes larger again.? Sight distance: ? Lateral offset: ? Usually adjacent to road Elevation: ?	Dwell time: 8s Transition: ?	Type: Usually arterial large roads Speed limit: ? Other:
Tantala & Tantala (2009b) US/MN	Crash Data; Pre-post; 11-25 months each Non-ad control: No	ESDs	5x (3.5mx12m)	Spacing: ? appears to be more than 2-3km between each ESD (spread is fairly even) Sight distance: ? Lateral offset: ? Elevation: ?	Dwell time: 8s Transition: ?	Type: Usually arterial large roads Speed limit: ? Other: High traffic; ESD3 appears to be at an intersection, ESD5 is on an exit ramp of highway
Tantala & Tantala (2009a) US/OH	Crash Data; Pre-post; 4 years each Non-ad control: No	ESDs	7x (4.7mx16m)	Spacing: ? but ESDs appear quite well spread (min 3km separation) and on separate roads Sight distance: ? Lateral offset: 18-58m from nearest lane Elevation: ?	Dwell time: 8s Transition: ?	Type: Usually arterial large roads Speed limit: Mostly 100- 110km/h Other: High traffic
Tantala & Tantala (2007) US/OH	Crash Data; Pre-post; 12 -18 months each Non-ad control: No	ESDs	7x (4.7mx16m)	Spacing: ? but ESDs appear quite well spread (min 3km separation) and on separate roads Sight distance: ? Lateral offset: 18-58m from nearest lane Elevation: ?	Dwell time: 8s Transition: ?	Type: Large roads (3-5 lanes each direction) Speed limit: Mostly 100- 110km/h Other: High traffic
Tantala & Tantala (2005) Study 2 US	Crash Data; Pre-post; 1 year each Non-ad control: No	Electronic Dynamic Display (EDD; inc animation effects)	2 faces, each 1.8mx5m	Spacing: Single EDD, near intersection with traffic lights Sight distance: ? located at NE corner of intersection, visible to both roads at intersection Lateral offset: ? Elevation: top 7.6m	Dwell time: ? Transition: ?	Type: 2 lanes same direction for both roads Speed limit: ? Other: 18,500 – 20,000 vehicles daily; at intersection with traffic lights

Table 1 continued

Reference Country/state	Design	Sign type	Size	Position	Change parameters	Road conditions
Wisconsin Dept Trans 1994 (see Wachtel, 2009) US/WI	Crash Data; Pre-Post; 3 yrs each Non-ad control: No	ESD	?	Spacing: Single ESD sign; No information on other signage Sight distance: ? but easier to see from eastbound lanes Lateral offset: ? Adj to westbound lanes Elevation: ?	Dwell time: mean 5s Transition: ?	Type: Highway (I-94) Speed limit: ? Other: merge
Massachusetts Outdoor Advertising Board (1976) US/MA	Crash data; Pre-Post; 3 - 2.25yrs Non-ad control: Yes	Flip-Disc based ESD	9.9x4.3m	Spacing: Single ESD sign; No information on other signage Sight distance: ? Lateral offset: ? Adj Elevation: ?	Dwell time: ? Transition time: 2.67s	Type: Highway (I-93) Speed limit: ? Other:
Lee et al (2007) US	On-road driving, Naturalistic observation Non-ad control: Yes	ESDs vs conventional billboard vs non-controlled comparison sites vs no-sign baseline sites	4.7mx16m	Spacing: ? but 5 ESD, 15 conventional billboard, 12 non-controlled comparison sites, 12 no-sign baseline sites in 80km route Sight distance: ? but at least one ESD had number legible from > 1.1km (longer visibility distance) Lateral offset: ? Elevation: ?	Dwell time: 8s Transition: Instant	Type: Highways (I480, I90, I77) and urban streets Speed limit: ? 90-110km/h on highways, 40km/h urban Other: Non rush-hour (9am-4pm) + night session
Edquist (2008a)(p114) and Edquist et al (2011) AUS	Simulator driving; Non-ad control: Yes	Static and Dynamic	8mx 5m	Spacing: No adverts ever simultaneously visible Sight distance: 140m Lateral offset: Adjacent to road Elevation: ?	Dwell time: ~3s between sign appearance and sign change Transition: Instant	Type: 3 lane divided road Speed limit: 70km/h Other: no traffic vs 3 leading cars condition (very low traffic), includes traffic lights and intersections
Johnston & Cole (1976) AUS	Laboratory driving analog task (5x experiments) Non-ad control: Yes	ESD-analog adverts projected onto surface near primary task area (Exp1: moving, Exps2-5: stationary)	Approx 8° x 8°	Spacing: ? but never simultaneously visible Sight distance: Approx 90cm viewing distance Lateral offset: Exp1: motion 5° left through to 45° right; Exps2-5 (directly above primary task display) Elevation: ?	Dwell time: Exp1: 8 sec; Exps2-5: 6.5s Transition: Exp1: ? instant; Exp2-5: 1.5s	n/a

AUS = Australia US = United States of America MA = Massachusetts MN = Minnesota NM = New Mexico OH = Ohio PA = Pennsylvania WI = Wisconsin
n/a = not applicable ? = information not provided or unclear Adj = adjacent to roadway

Table 2: Research studies of ESDs and road safety – measures and results

Reference	Outcome measures	Results	Main Criticisms
Tantala & Tantala (2010b)	Police recorded crashes (within 0.16, 0.32, 0.48, 0.64, and 0.80 km of sign – NB: this is less than previous studies); Empirical Bayes Method (EBM) analysis using 57 undefined comparison sites	11.1% decrease (non-sig diff) in crashes within 0.8 km of digital advert before-and-after (1063 v 925 crashes); no change for young/old drivers, or day/night driving; dwell time had no effect on crash rates; BUT the EBM showed a 0.87% increase in crashes compared to projected trend without digital adverts (925 v 917 crashes); reportedly $p < .0001$, but this appears to be interpreted incorrectly by the authors to mean they are not statistically different)	No comparison sites to understand ongoing changes in crash rates; only using police reported crashes (issue of under-reporting); only used up to 800m (less than previous studies) on either side of ESD site (visibility of signs is further); significant conclusions from EBM analysis ignored; formal analysis of dwell time effect not completed (there appears to be a dwell time effect, where longer dwell time resulted in greater reduction of crashes)
Tantala & Tantala (2010a)	Police recorded crashes (within 0.32, 0.64, 0.96, 1.28, and 1.6 km of sign)	A 0.3% decrease (non-sig diff) in crashes within 1km of digital advert before-and-after (1646 v 1641 crashes); no change for young/old drivers, or day/night driving	No comparison sites to understand ongoing changes in crash rates; only using police reported crashes (issue of under-reporting); only used up to 1.6km on either side of ESD site (visibility of signs is further)
Tantala & Tantala (2009b)	Police recorded crashes (within 0.32, 0.64, 0.96, 1.28, and 1.6 km of sign)	An average of 5% reduction in monthly crash rates within 1km of ESD before-and-after (although some ESD sites showed an increase in crashes); total 1883 v 1784 crashes before and after; no change for young/old drivers, or day/night driving	No comparison sites to understand ongoing changes in crash rates; only using police reported crashes (issue of under-reporting); only used up to 1.6km on either side of ESD site (visibility of signs is further); Inferential statistics not reported so cannot know statistical significance; Findings claim to have compared to no-billboard sites, but no comparison actually reported
Tantala & Tantala (2009a)	Police recorded crashes (within 0.32, 0.64, 0.96, 1.28, and 1.6 km of sign)	A 14.9% (2.2% normalized for year-to-year and county-wide traffic) decrease (non-sig diff) in crashes within 1km of digital advert before-and-after; within 1 km, total 1835 v 1562 crashes before and after; no change for young/old drivers, or day/night driving	No comparison sites to understand ongoing changes in crash rates; only using police reported crashes (issue of under-reporting); only used up to 1.6km on either side of ESD site (visibility of signs is further)
Tantala & Tantala (2007)	Police recorded crashes within VRD (320m) approach to sign	A 21% decrease (non-sig diff) in crashes within Viewer Reaction Distance (VRD = 320m) of digital advert before-and-after (although some ESD sites showed an increase of as much as 21%); total 345 v 271 crashes in 18 months before and 18 months after; > 0.2 correlation between billboard density (conventional and ESD) and crash density	No comparison sites to understand ongoing changes in crash rates; only using police reported crashes (issue of under-reporting); VRD incorrectly defined as 320m on approach to ESD site (visibility of signs is further); some analyses deliberately exclude crashes occurring in high-demand contexts (intersections, hazard avoidance); correlation sizes incorrectly explained (anything less than 0.7 is weak – not true)
Tantala & Tantala (2005) Study 2	Police recorded crashes (seems to be at the actual intersection itself, only)	Reduction of 11.8% over the study period (from 68 to 60 crashes), while traffic volume increased 5.3%	No comparison sites to understand ongoing changes in crash rates; only using police reported crashes (issue of under-reporting); only used crashes at intersection

Table 2 continued

Reference	Outcome measures	Results	Main Criticisms
Wisconsin Dept Trans 1994 (see Wachtel 2009)	Police recorded crash rates per million vehicle miles	36% increase Eastbound 21% increase Westbound Also reported figures for each direction for sideswipe and rearend separately and for the first year after installation	No comparison sites to understand ongoing changes in crash rates; Relied on crashes reported to police (under-reporting issue)
Massachusetts Outdoor Advertising Board (1976)	Police recorded crash rates	Crashes were reduced in visibility range of Tele-Spot sign; crashes were also reduced along the whole on the entire Southeast Expressway; the reduction in crashes was 10% less near the Tele-Spot sign than for the remainder of the expressway; therefore, the sign was associated with a relative increase in crashes	Relied on crashes reported to police (under-reporting issue)
Lee et al (2007)	Eye-gaze number and duration directed away from road, speed management, lane position control; post-task subjective questionnaire	Eye-gazes were drawn towards ESDs and non-controlled comparison sites more than conventional billboards and no-sign baseline sites, this was especially true at night and when using tails distribution. 42% of Ss reported that billboards were top attention getter in daytime; 7.5% found billboards to be most memorable event of drive (equal level with the test car); Speed maintenance did not differ for various sites; non-significant trend suggests that lane positioning was poorer near billboards (ESD and conventional); ESDs reported as more noticeable/attention-getting than conventional; ESDs were even more attention-getting during night-drive (25% of drivers indicated ESD as single most memorable event); despite automatic luminance regulation, at nighttime the ESDs were 10x more luminous than baseline, and 3x more luminous than conventional billboards	Badly chosen comparison sites (no-sign baseline sites more appropriate; eye-gaze data analysed using mean gaze durations rather than tails distribution; data only recorded/analysed for 8 sec period that driver approached each site (not sufficient to cover the visibility distance of some ESDs and potential for events to occur after car passes a sign); many sites were not 'pure' (eg an ESD and other sign could be simultaneously visible)
Edquist (2008a) (p.114) and Edquist et al (2011)	Errors/Reaction Time (RT) to traffic signal, Errors/RT to lane change signs, vehicle control, eye-gaze fixations	No effect of adverts on Errors/RT to traffic signal. Lane changes slower, and more errors, when passing advert than control, esp. when instructed to verbalise, esp. for older drivers. In no traffic, adverts associated with slower driving and more roadside eye-fixations. While silent, dynamic adverts delayed first fixation on lane change sign; while verbalising, first fixation was faster when static advert present. Adverts generally associated with fewer fixations on road ahead, and more fixations to roadsides esp. for probationary and older drivers having to verbalise. More time fixating dynamic advert > static > control. Greater vertical gaze variability when approaching dynamic adverts > static > control.	Simulator ESDs did not act naturally, they spontaneously appeared at 140m and changed at 85m distance; simulated ESD advertisements much simpler (possibly also less relatively 'vibrant') than real ESDs
Johnston & Cole (1976)	Single tracking task: Correct responses and RTs for a tracking task (using a joystick to respond left/right based on arrows projected onto a screen). Dual-task include the tracking task overlaid with detection task for infrequent (10-35 sec delays) stimulus (analog of emergency braking)	Exp1 was single tracking task using regular schedule, moving advert distracters but found no distraction effect. Exp2 was single tracking task using random schedule, had stationary distracters that flashed at 1.24Hz, found a performance decrement with adverts but small magnitude. Exps3-5 were all dual-task, presence of adverts slowed down RTs to detection (emergency braking) task, but had little impact on tracking task.	Only a driving-analog task with ESD-analog distracters with hazard-detection-analog task, reduced ecological validity. Flashing ads in Exp2-5 reduces ecological validity further

Clearly, the current empirical evidence on ESDs and safety does not provide an unambiguous platform upon which policy-makers and regulators can base regulation. Although the small body of studies suggest that the installation of ESDs can reduce road safety, and although this conclusion is consistent with the wider literature on human attention and driver distraction, there is little guidance in the research about the particular ESD and traffic circumstances under which risk is heightened. In the absence of such data, regulators might be wise to opt for prohibition rather than trying to devise specific operational regulations to manage poorly understood risks.

Conclusion

Like the other literature reviews conducted in this area, the current review acknowledges the fairly weak research designs adopted and the limited scope of the studies on ESDs. Control over extraneous conditions has often been poor and there has been almost no attempt to examine the impact of sign- and site-related variables that might underpin operational regulation. Nonetheless, there does seem to be evidence that ESDs can have a negative impact on attention, driving performance and safety. For this reason, it might be most prudent for regulatory bodies to consider prohibition in the first instance. Well-controlled research is clearly needed to identify the effects that ESD installation and ESD sign characteristics, such as image dwell time, have on driver performance and safety.

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