SB 953

Compendium of Recent Research Studies on Distraction from Commercial Electronic Variable Message Signs (CEVMS)

Prepared by
Jerry Wachtel, CPE
President, The Veridian Group, Inc.
Berkeley, California

VERIDIAN GROUP

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Background

This is the second in a series of brief updates based upon this author's 2009 report for AASHTO through NCHRP Project 20-7/256,[1] which was a comprehensive and critical review of research that had been undertaken, and guidelines that had been developed up to that time that addressed the potential consequences for driver distraction from Commercial Electronic Variable Message Signs (CEVMS) along the roadside.

We critically reviewed all of the research papers (more than 40) that had been published or presented within the prior 30 years. These papers represented the work of academic, industry, and government researchers in many countries (including, but not limited to: Sweden, Denmark, Israel, Canada, US, England, and Australia), and which followed many different research protocols. Whereas earlier studies (primarily those from the 1990s and prior) often suffered from limitations in equipment, methodology, or statistical rigor, leaving their conclusions open to question and controversy, those performed in the more recent past were generally more robust, and tended to reach similar conclusions to each other.

The previous update was done in June, 2013 and presented at a joint meeting of AASHTO's traffic engineering and highway safety subcommittees. The new material in this update includes nine studies in five countries.

Broadly summarized, the more recent studies have tended to find that outdoor advertising signs, particularly CEVMS, attract drivers' attention, and that more dramatic and salient signs attract longer and more frequent glances. This attention is often captured through a "bottom up" physiological process, in which the driver attends to the sign unintentionally and unconsciously, with the eyes captured involuntarily by the sign's changing imagery, brightness, conspicuity, and/or movement.

Several of the reported studies suggested that the distraction caused by outdoor advertising signs could be tolerated by experienced drivers and when attentional or cognitive demands of the driving task were low, but that the risk increased when such signs competed for the driver's visual attention with more demanding road, traffic, and weather conditions, when travel speeds were higher, or when an unanticipated event or action (such as a sudden lane change or hard braking by a lead vehicle) occurred to which the driver had to respond quickly and correctly.

In addition, the more recent research continues to show that the drivers most susceptible to unsafe levels of distraction from roadside billboards are the young (who are more prone to distraction and less adept at emergency vehicle response) and the elderly (who have more difficulty with rapidly shifting attention, poorer night vision and glare susceptibility, and slower mental processing time). As will be seen in this Compendium, these concerns are heightened today, with our elderly driver population growing quickly, traffic

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[1] Wachtel, J. (2009). "Safety Impacts of the Emerging Digital Display Technology for Outdoor Advertising Signs: Final Report. NCHRP Report 20-7/256. Available at: http://rightofway.transportation.org/Documents/NCHRP%20Reports/20-7(256)%20digital%20outdoor%20advertising_aashto.pdf

increasingly dense, more roads under maintenance or repair (construction and work zones create added risks), and larger, brighter digital and video roadside advertising signs competing for the driver's attention.

Finally, the most recent epidemiological studies (dating from 2014 and 2015) have begun to demonstrate what has long been suspected but not proven – that roadside billboards are associated with increases in crash rates where such billboards are located.

The research and guidelines reviewed in our 2009 report set the stage for the 21 research articles and guidelines that are reviewed and summarized in this compendium.

While employing a broad array of approaches and methodologies, the common theme clearly indicates that the more that commercial digital signs succeed in attracting the attention of motorists that render them a worthwhile investment for owners and advertisers, the more they represent a threat to safety along our busiest streets and highways, where these signs tend to be located.

The long awaited study by the Federal Highway Administration (FHWA), announced on the agency's website on December 30, 2014, is an outlier in this group of recent studies (except for those sponsored by the outdoor advertising industry[2]), in that it found no relationship

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[2] In 2007, two studies sponsored by the outdoor advertising industry (the Outdoor Advertising Association of America [OAAA] and its research arm, the Foundation for Outdoor Advertising Research and Education [FOARE]) were submitted through the peer review process to the Transportation Research Board of The National Academies. Both reports, one a human factors study by the Virginia Tech Transportation Institute (VTTI), and the other an epidemiological study by Tantala and Tantala, received overall negative reviews from peer reviewers, and were therefore rejected by TRB both for presentation and publication. Although Virginia Tech has not performed subsequent work in this field, Tantala and Tantala have continued to perform research under the sponsorship of OAAA/FOARE. However, for whatever reasons, FOARE and OAAA have not made the subsequent studies available to the public, so they could not be addressed in this Compendium of research.

The Tantala and Tantala 2007 study was an epidemiological analyses of crash rates, but the authors established data collection parameters that led them to exclude from examination the very driver cohorts (older drivers) and road locations (interchange areas) known to be at greatest risk for distraction. Subsequent comments from the senior author of these studies, to the effect that their subsequent studies follow the same basic methodology as the one performed in 2007 (with the exception of a more robust statistical technique to analyze the data), remains a cause for concern because of these methodological biases. The other industry study released by FOARE in 2007, the human factors analysis performed by VTTI, actually found that digital signs were associated with more long-duration glances away from the forward roadway than other types of signs, and further found that the problem was considerably worse at night. However, the authors edited their final report to make it seem as if these adverse consequences did not exist, and their industry sponsors terminated the nighttime research after the pilot data had been collected and reviewed. At that time, many experts considered an "eyes-off-road" duration of two seconds or longer to be the threshold for a substantially higher level of crash risk, and the Virginia Tech team actually found a number of instances in which digital signs caused participating drivers to take their eyes off the road for two and three seconds or longer, whereas the other test conditions (areas with traditional billboards and roadway sections devoid of billboards) did not produce this result to the same extent.

between digital billboards and adverse driver scanning behavior. The FHWA study, however, has been severely criticized for faulty methods and analyses in a peer-reviewed critique by the present author[3]. The FHWA study remains available on the agency's website, but has never been formally published.

It has been shown that road environments cluttered with driving-irrelevant material (often called visual complexity) make it difficult to extract critical information necessary for safe driving in a timely manner, a particular problem for older drivers. In addition, with the growing proliferation of CEVMS, ever-newer technology that renders them more compelling, the expansion of on-premise signs using this technology, and several States considering the use of such signs within the right-of-way, it was deemed appropriate to provide an up-to-date review of the most recent research and guidelines.

The next section of this report provides a brief summary of each of the studies. The following section, the Compendium itself, provides further details about each study, including its sponsorship, research protocol, strengths and weaknesses, and source identification. This document concludes with a complete list of references as cited.

[3] Wachtel, Jerry (2015). "A Peer-Reviewed Critique of the Federal Highway Administration (FHWA) Report Titled: "Driver Visual Behavior in the Presence of Commercial Electronic Variable Message Signs (CEVMS)." Available at:
http://nebula.wsimg.com/722c5bb9d76d4b10b6d7add54d962329?AccessKeyId=388DC3CA49BF0BEF098B&disposition=0&alloworigin=1

Summary of Findings

This section summarizes the major findings of each of the 22 studies discussed in the Compendium. Key conclusions are highlighted in **bold.** The subsequent section of this report, the Compendium itself, provides additional detail about each study, and information about how to access the study, where available.

The studies are cited here, and in the Compendium, in generally chronological order.

Chan, et al., 2008 – USA, Amherst, MA

The researchers compared susceptibility to distraction from sources inside the vehicle (e.g. phone dialing, map reading) to those outside the vehicle (e.g. billboards) for both young novice drivers and experienced drivers. As predicted, for the in-vehicle distractors, the young drivers looked away from the roadway for extended periods (2 seconds or longer) more than twice as often as the experienced drivers. Surprisingly, however, results showed that: (a) external distractors were even more distracting, and (b) the experienced drivers were just as distracted as the newly-licensed drivers on this critical measure of distraction when they performed the outside-the-vehicle tasks. The authors had assumed that experienced drivers would exercise the same degree of caution with the external distractors as they did with the internal ones. Instead, "the experienced drivers showed little concern for the effect that diverting their attention to the side of the roadway might have had on their ability to perceive potential risks immediately in front." In some 81% of the external tasks, older drivers glanced for longer than 2s away from the forward roadway. The authors concluded by saying: **"...we think that our drivers engaged in the external search task were truly distracted with potentially serious consequences."**

Young, et al., 2009 - England

In this driving simulator study, participants drove rural, urban, and highway routes in the presence and absence of roadside billboards, while their driving performance was measured. Billboards had a detrimental effect on lateral control, and appeared to increase crash risk. Longitudinal control was not affected. The most striking effects were found for driver attention. Driver mental workload (using the NASA developed TLX scale) significantly increased in the presence of billboards. On rural roads and motorways, results showed that billboards were consciously attended to at the cost of more relevant road signs. The authors reached a **"persuasive overall conclusion that advertising has adverse effects on driving performance and driver attention.** Whilst there are sometimes conflicts of interest at Local Authority level when authorizing billboards (since Councils often take a share of the profit from roadside advertising), these data could and should be used to redress the balance in favour of road safety."

Backer-Grøndahl, & Sagberg, 2009 - Norway

The authors asked drivers who had actually been involved in a crash to identify, from a list, what they believed were the causes of distraction for that crash. (Cell phone use was excluded). The most frequently reported sources of distraction were: (1)

conversations with passengers, and (2) attending to children in the back seat. However, **when the researchers applied the statistical method known as quasi-induced exposure, they found that distractions with the "highest relative risk" were: (1) billboards outside the vehicle, and, (2) searching for addresses. The authors note that both of the highest risk distractors were *visual* distractions, rather than physical, auditory, or cognitive ones.**

Chattington, et al., 2009 - England

The researchers found "significant effects on both drivers' visual behavior and driving performance" in the presence of both static and video billboards. As expected, the video signs were seen as more potent distractors than similarly placed static signs. The authors state that their results "support and extend (the findings of) other studies of driver distraction by advertising," citing studies by Crundall, et al, and of Young and Mahfoud (both of which were extensively reviewed in the Wachtel 2009 report for AASHTO). The study showed that **several aspects of driving performance were adversely affected by both video and static billboards, with the video signs generally more harmful to such performance than the static signs. The authors list these effects as: speed control, braking, and lane position maintenance.**

Horberry, et al., 2009 - Australia

Road authorities may be justified in using the best research information available, even if incomplete, coupled with engineering judgment, for the development of billboard guidelines. **The authors recommend that their client (Queensland, Australia) adopt advertising restrictions at known areas of high driver workload, including "locations with high accident rates, lane merges, curves/bends, hills and road/works/abnormal traffic flows."** (They state that) "this is broadly in line with Wachtel who recommended a restriction of advertisements at times when driver decision, action points and cognitive demand are greatest – such as at freeway exits/entrances, lane reductions, merges and curves. Although useful for all road users, such restrictions would be of specific benefit to older drivers."

Gitelman, et al., 2010 - Israel

The authors studied crashes at two highway locations along the same heavily traveled freeway – a "treatment" section in which previously visible billboards were covered as part of a trial period, and a "control" section in which the billboards remained visible. At the control sites, crashes remained essentially the same throughout the 3-year study period; at the treatment sites, crashes declined dramatically after the billboards were covered. The results were similar for injury and fatal crashes. After adjusting for traffic volume, **crashes were reduced at the treatment sites (where billboards had been covered) by the following percentages: all crashes by 60%; injury/fatal crashes by 39%; property damage crashes by 72%.**

Bendak & Al-Saleh, 2010 - Saudi Arabia

The authors used a driving simulator in which test subjects drove on two similar roads, one with advertising signs and one without. Twelve male volunteers, ages 23-28,

participated in the study. Driver opinions about billboards were also sought using a simple questionnaire distributed to male drivers at random in the city of Riyadh, Saudi Arabia. 160 questionnaires were returned. Results of the simulator study showed that **the driving speed of participants was not affected by the presence of advertising signs. However, two of the five indicators were statistically significant. Both "drifting unnecessarily from (the) lane" and "recklessly crossing dangerous intersections" were significantly more prevalent in the presence of billboards.** Although not reaching statistical significance, each of the other three measures, tailgating, speeding, and failure to signal, were all worse in the presence of billboards. Half of the respondents to the questionnaire indicated that they had been distracted by a billboard, and 22% indicated that they had been put in a dangerous situation due to distraction from billboards.

Milloy & Caird, 2011 - Canada

This was a driving simulator study that looked at distraction effects of a video billboard and a wind turbine. **The results demonstrated a *causal* (italics original) relationship between the presence of a video billboard and collisions with, and delays in responding to, the lead vehicle.**

Edquist, et al., 2011 - Australia

"The finding that the presence of billboards increases time to detect changes is an important one." Billboards can automatically attract attention when drivers are engaged in other tasks, delaying their responses to other aspects in the environment. The effect of billboards was particularly strong in scenes where response times are already lengthened by high levels of visual clutter. This is of particular concern because roads with high levels of clutter are the very kind of busy, commercial, high traffic environments where billboards are most often erected."

The results are consistent with growing evidence suggesting that billboards impair aspects of driving performance such as visual search and the detection of hazards, and therefore should be more precisely regulated.

Dukic, et al., 2012 - Sweden

In this on-road, instrumented vehicle study, **drivers had a significantly longer dwell time (time looking at the billboards), a greater number of fixations, and a longer maximum fixation duration when driving past digital billboards compared to other signs along the same road sections.**

Perez, et al., 2012 – USA, Washington, DC

The authors of this Federal Highway Administration (FHWA) sponsored study used an instrumented vehicle that recorded volunteer drivers' eye glances as they drove along pre-determined routes in Reading, Pennsylvania and Richmond, Virginia. The routes included digital as well as static billboards, undefined on-premise signs, and areas free of commercial signage. The routes were driven during daylight and at night, and the report found that **digital billboards "were not associated with 'unacceptably long glances away from the road'." As noted above, however, the draft report of this**

study was strongly criticized by the agency's selected peer reviewers, particularly with regard to the efficacy of the obtained eye glance data. Indeed, the participants in the study did gaze more often to digital billboards than to other signs, in some cases more than twice as much. (For example 71% vs. 29% at night in Richmond). As a result of the critical peer reviews, the authors took 33 months to revise the study, which, although dated September 2012, was released on the agency's website on December 30, 2013. This revised report, in turn, was reviewed by the present author, whose critical report was reviewed and agreed-to by 14 independent expert peer reviewers. To our knowledge, the revised FHWA report was not subjected to peer review by the agency prior to its issuance on the agency website, and it has never been given an official agency report number, putting it in a state of uncertainty with regard to its publication.

Divekar, et al., 2013 – USA, Amherst, MA

Experienced drivers are far less likely to be distracted by inside-the-vehicle tasks (e.g. cell phone, map display, entertainment system) than novice drivers. However, the researchers were surprised to find that **experienced and novice drivers are at an equal and elevated risk of getting into a crash when they are performing a secondary task outside the vehicle such as looking at billboards**

Roberts, et al., 2013 - Australia

The appearance of movement or changes in luminance can involuntarily capture attention, and engaging information can capture attention to the detriment of driving performance, particularly in inexperienced drivers. Where this happens in a driving situation that is also cognitively demanding, the consequences for driving performance are likely to be significant. Further, if this results in a situation where a driver's eyes are off the forward roadway for 2 seconds or longer, this will further reduce safety. Additionally, road environments cluttered with driving-irrelevant material may make it difficult to extract information that is necessary for safe driving, particularly for older drivers. The studies that have been conducted show convincingly that roadside advertising is distracting and that it may lead to poorer vehicle control.

Herrstedt, et al., 2013 - Denmark

The authors studied drivers using an instrumented car equipped with an eye-tracking system, a GPS system for registering the vehicle's speed, and a laser scanner for measurement of following distances to other road users. The overall findings of the studies demonstrate that **"advertising signs do affect driver attention to the extent that road safety is compromised."** In 69% of all drives past advertising signs, the driver glanced at least once at the sign; in almost half of all drives, the driver glanced twice or more at the same sign. For 22% of all drives, the total glance duration of successive glances was two (2) seconds or longer. In 18% of all drives, glance durations of one (1) second or longer was recorded. In approximately 25% of all glances, the safety buffer to the vehicle ahead was less than two (2) seconds, and in 20% of the glances, the safety buffer was less than 1.5 seconds. This study has been praised in independent peer review by Dr. Richard Pain, Transportation Research Board Senior Program Officer, retired. Dr. Pain considered this study to be the best designed and

conducted on-road study in this field, the conclusions of which, he believes, were far more valid and robust than those of the FHWA study (discussed above).

Hawkins, et al., 2014 – USA, College Station, TX

This study, sponsored by the on-premise signage industry, was a statistical (epidemiological) analysis of crash rates in the vicinity of on-premise digital signs that had been first installed in 2006-07. On premise signs differ from billboards in several ways. Per the common meaning of the term, on-premise signs must advertise only a business or service that is available on the property on which the sign is located. Because of that, on-premise signs typically function to identify the business and, as such, they may have little text or imagery other than that required for such identification. On the other hand, they are often closer to the road than billboards are permitted to be, and it is often possible for them to be larger than billboards and to feature motion or the appearance of motion. This study employed an analysis methodology known as *empirical Bayes* (or EB) to look at before-and-after crash data in four states. A total of 135 sign locations and 1,301 control sites were used, and the researchers found **"no evidence the installation of on-premise signs at these locations led to an automatic increase in the number of crashes."**

Schieber, et al., 2014 – USA, Vermillion, SD

In this simulator study the authors varied message length (4, 8, or 12 words) on digital billboards that participants drove past at either 25 or 50 MPH. Although there was no decrement in lane keeping or billboard reading performance at the lower speed on straight roads, **"clear evidence of impaired performance became apparent at the higher (50 MPH) driving speed." The analysis revealed that, rather than weaving in and out of lane while reading the billboards with longer messages, participants tended to slowly drift away from the lane center and then execute a large amplitude corrective steering input about eight (8) seconds *after* passing the billboard.** Eye gaze analysis showed that information processing overload began to emerge with a message length of eight (8) words, and was clearly present with twelve (12) word messages under the 50 MPH condition.

Gitelman, et al., 2014 - Israel

In 2014, these authors had the opportunity to add an additional data set to that in their 2010 study (discussed above), and to reanalyze the data from the original study. This was because the road authorities issued a decision to reauthorize the display of billboards that they had previously had ordered covered. In other words, the authors had the opportunity to study traffic crashes on a single roadway when billboards were: (a) visible, then (b) covered, then (c) visible again. The 2010 study examined conditions (a) and (b), and the 2014 supplement added condition (c) and a reanalysis of (a) and (b). They found that: **"The results support and strengthen the previous findings." Removal/covering of the billboards from the highway (condition [b]) was associated with a 30-40% reduction in injury crashes from condition (a) according to two different databases, whereas the reintroduction/uncovering of the billboards (condition [c]) was associated with a 40-50% or 18-45% increase in such crashes, depending on the database cited. The trends were similar and**

consistent across damage-only, injury, and total accidents as well as nighttime vs. daytime injury accidents.

Sisiopiku, et al., 2015 – USA, AL, FL

The authors analyzed crashes from eight (8) digital billboard locations in Alabama and ten (10) in Florida. All sites were on high speed, limited access highways. A total of 377 crashes in Florida and 77 in Alabama were used in the analysis. Actual traffic collision reports were used since the authors discovered numerous errors in coding in the summary crash databases that they initially examined. Although the data set was too small to employ statistical analyses, the authors found that **"the presence of digital billboards increased the overall crash rates in areas of billboard influence compared to control areas downstream of the digital billboard locations. The increase was 25% in Florida and 29% in Alabama."** The predominant crash types that were overrepresented at billboard locations were rear-end and sideswipe collisions, both typical of driver distraction.

Rempel, et al., 2015 - Canada

These authors, working on behalf of the Transport Association of Canada, developed a set of guidelines for the control of digital and projected advertising signs. The resultant guidelines are based on a comprehensive literature review, a survey of Canadian governmental jurisdictions, a review of existing sign regulations, interviews with international Governmental agencies, discussions with sign industry representatives, and the application of human factors and traffic engineering principles. **The key principle documented in the Guidelines is that they "provide recommendations designed to control (digital billboards) *such that they emulate static advertising signs* (italics added), and therefore result in a similar distracting and road safety effect as static advertisements."**

Samsa & Phillips, 2015 - Australia

These authors, working on behalf of the Outdoor Media Association of Australia, studied 29 participants, ages 25-54 in an instrumented vehicle. The participants were fitted with "eye tracking glasses" and their eye fixations and driving performance was assessed as they drove a 14.6 km route in Brisbane, Queensland. **The route took them past a "number" of advertising signs, including static, digital, and on-premise signs. The results showed that fixation durations "were well below" 0.75 seconds, and that there were no significant differences in vehicle headways between the three types of signage. One statistically significant finding was that lateral deviation was poorer when billboards were present.** (Note that, at present, only an Abstract of this industry-sponsored study is available).

Belyusar, et al., 2016 – USA, Cambridge, MA

In this on-road study, data was collected from 123 subjects, nearly equally divided between males (63) and females (60) and between young (age 20-29, N = 63) and older (age 60-69, N = 60). These volunteers drove an instrumented vehicle under normal driving conditions (with no specific tasks to perform) past a digital billboard on a

posted 65 MPH roadway with four travel lanes in each direction. Data was collected during late morning and early afternoon to avoid commuter traffic. The authors state: **"In contrast to the recent FHWA report (Perez, et al., 2012), the findings revealed statistically significant changes in total number of glances and, depending upon the direction of travel, moderate-to-long duration glances in the direction of the billboard." Older drivers were thought to be particularly affected. The authors also found that: "Drivers glanced more at the time of a switch to a new advertisement display than during a comparable section of roadway when the billboard was simply visible and stable."** Given typical billboard dwell (cycle) times of six (6) or eight (8) seconds, these findings add to the argument the dwell times for such signs should be considerably longer.

Compendium of Recent Research Studies on Commercial Electronic Variable Message Signs (CEVMS)

Key to Codes Used in Tables:

*Type of Study:

N = on-road, naturalistic
Q = on-road, quasi-naturalistic
C = on-road, controlled
S = lab, simulator
L = lab, other
E = epidemiological, crash data
R = review of other work
CR = critical review of other work
D = discussion /consultation with experts
G = guidelines or regulations development
QI = questionnaires, interviews, surveys, focus groups, etc.

**Type of Signs Studied:

O = On-premise
C = Conventional billboard
D = Digital billboard
V = Sign contains video or animation
H = Official highway sign
U = Unknown

Date 1st published/presented	2008
Location	U.S. (Massachusetts)
Author(s) Title Affiliation	Chan, E., Pradhan, AK, Knodler, MA, Jr., Pollatsek, A. & Fisher, DL Empirical Evaluation on a Driving Simulator of the Effect of Distractions Inside and Outside the Vehicle on Drivers' Eye Behaviors
Forum	TRB – presentation and CD ROM
Peer Reviewed?	Yes
Sponsor/funding source	National Science Foundation; National Highway Traffic Safety Administration (NHTSA)
Type of Study*	S
Type of Signs Studied**	C (simulated)
Brief Description of Method	Young, novice drivers (age 16-17) are at greatly elevated risk of crashing, and it is believed that distraction plays a large role in such crashes. More experienced, older teen drivers (age 18-19) have also been shown to look away from the forward roadway for extended periods of time. This simulator study compared such extended, off-roadway glance durations of newly licensed drivers to those of older, experienced drivers, using eye movement recordings as participants drove along a simulated roadway and engaged in distracting tasks both inside and outside the vehicle.
Summary of Findings	The researchers compared the average maximum duration of an *episode*, (the maximum time that drivers spent continuously looking away from the forward roadway). For the in-vehicle distractors, the average was 1.63s for the experienced drivers, and 2.76s for the younger drivers. Another measure, the percentage of scenarios in which the maximum duration of an episode was greater than 2s, yielded similar findings. The results were statistically significant between the two groups. As predicted for in-vehicle distractors, the young drivers looked away from the roadway for extended periods (2s o longer) more than twice as often as the experienced drivers while engaged in inside-the-vehicle distractors (such as phone dialing, map reading, and CD searching). Surprisingly, however, results showed that: (a) external distractors were even more distracting, and (b) there was no difference between newly-licensed and experienced drivers on this critical measure of distraction when the drivers performed outside-the-vehicle tasks, specifically, searching for a target letter in a 5x5 grid representative of a billboard. The authors had assumed that experienced drivers would exercise the same degree of caution with the external distractors as they did with the internal ones. Instead, "the experienced drivers showed little concern for the effect that diverting their attention to the side of the roadway might have had on their ability to perceive potential risks immediately in front. In fact, in 81% of the external tasks, older drivers glanced for longer than 2s away from the forward roadway. The authors conclude: "...we think that our drivers engaged in the external search task were truly distracted with potential serous consequences."
Strengths	The study is the first to directly compare the susceptibility to distraction from internal and external tasks between newly licensed and experienced drivers.
Weaknesses/Limitations	Older drivers were not included in this study. The representativeness of the outside-the vehicle task is questionable.
Availability/Accessibility	TRB 2008 Annual Meeting CD-ROM

Date 1st published/presented	2009
Location	UK (England, London)
Author(s) Title Affiliation	Young, MS, Mahfoud, JM, Stanton, N. Salmon, PM, Jenkins, DP & Walker, GH. "Conflicts of Interest: The implications of roadside advertising for driver attention." Brunel University, West London, England
Forum	Transportation Research Part F: Traffic Psychology and Behaviour, Vol. 12(5), Septembe 2009, 381-388.
Peer Reviewed?	Yes
Sponsor/funding source	Insurance company – The Rees Jeffreys Road Fund
Type of Study*	S
Type of Signs Studied**	C, H
Brief Description of Method	The study was conducted in the University's driving simulator. 48 drivers drove urban, rural, and motorway routes in the presence and absence of billboards. Dependent variables included measures of speed and lateral control, and driver attention (mental workload, eye movements, and recall of signs and billboards).
Summary of Findings	The presence of billboards had a detrimental effect on lateral control, and appeared to increase crash risk. Longitudinal control was not affected. More striking effects were found for driver attention. Driver mental workload significantly increased in the presence of billboards. On rural roads and motorways, results showed that billboards were consciously attended to at the cost of more relevant road signs. "We must once again emphasize the persuasive overall conclusion that advertising has adverse effects on driving performance and driver attention. Whilst there are sometimes conflicts of interest at Local Authority level when authorizing billboards (since Councils often take a share of the profit from roadside advertising), these data could and should be used to redress the balance in favour of road safety."
Strengths	A fully interactive high fidelity simulator was used. The use of the NASA-TLX instrument for measuring subjective mental workload was a useful tool that is used too infrequently in studies of driver performance. All participants experienced identical road and sign condition the only manipulation being the presence or absence of billboards.
Weaknesses/Limitations	The sample of participants did not include either older or younger drivers – the age groups thought to be at greatest risk for adverse consequences of billboard distraction. Measures of lateral and longitudinal variability were constrained by the study design an were not fully representative of the measures of these variables used most commonly in the US.
Availability/Accessibility	Journal is available online.

Date 1st published/presented	2009
Location	Norway
Author(s) Title; Affiliation	Backer-Grøndahl, A., & Sagberg, F. "Relative crash involvement risk associated with different sources of driver distraction." Institute of Transport Economics, Norway
Forum	First International Conference on Driver Distraction and Inattention
Peer Reviewed?	Yes
Sponsor/funding source	Unknown
Type of Study*	E, QI
Type of Signs Studied**	C
Brief description of method	Used web- and paper-based questionnaire to ask 4300+ drivers who had been in a crash to identify from a list of possible choices the cause of their crash. Separated those at faul from those not at fault. Relative crash risk of each factor was estimated using the quasi-induced exposure method.
Summary of Findings	The most *frequent* sources of distraction were: (1) conversations with passengers, and (2) attending to children in the back seat. When the statistical method was applied to the data, it was found that distractions with the "*highest relative risk*" were: (1) billboards outside the vehicle, and, (2) searching for addresses. The authors note that both of the highest risk distractors were *visual* distractions, vs. physical, auditory, or cognitive.
Strengths	Authors controlled for possible confounding variables (such as age, gender, driving experience [years] and annual mileage driven) using logistical regression with culpabilit as the dependent variable.
Weaknesses/Limitations	Some researchers question the viability of the quasi-induced exposure method; cell phone use was (intentionally) excluded from the questionnaire. (It likely would have proven to be the highest risk factor). Confidence intervals were quite large.
Availability/Accessibility	Presented at large international conference; published in conference proceedings.

Date 1st published/presented	2009
Location	UK - England
Author(s) Title Affiliation	Chattington, M., Reed, N., Basacik, D., Flint, A., & Parkes, A. "Investigating Driver Distraction: The Effects of Video and Static Advertising: Transport Research Laboratory
Forum	Report
Peer Reviewed?	Yes
Sponsor/funding source	Transport for London
Type of Study*	S
Type of Signs Studied**	C, V
Brief Description of Method	Used the high fidelity TRL driving simulator, with a specifically designed urban/suburban database typical of the area around London. 48 participants drove 4 different routes, each of which required about 15 minutes. Participants did not know the purpose of the study. Their eye movements were unobtrusively recorded. Roadside advertising was designed to vary by: location (placement within the scene); type (static or video); and exposure duration (at 30 MPH, drivers could see at least 50% of the advertisement for either 2, 4, or 6+ seconds. Video ads ran in a 6-second loop.
Summary of Findings	"The report has found significant effects on both drivers' visual behavior and driving performance when static and video adverts are present and that the video adverts seem more potent distractors than similarly placed static adverts. The results support and extend (the findings of) other studies of driver distraction by advertising." (Here, the authors cite the work of Crundall, et al, and of Young and Mahfoud, both of which were extensively reviewed in the Wachtel 2009 report for AASHTO). The study showed that several different aspects of driving performance were adversely affected both video and static billboards, with the video signs generally more harmful to such performance than the static signs. The authors describe these effects as being "fundamental to the safe control of the vehicle." The effects include: speed control, braking, and the variability of each of these measures, as well as drivers showing that they are "less able to maintain a consistent lane position"
Strengths	A very comprehensive and sophisticated simulation study. The researchers went so far to pre-screen the content of the simulated advertisements to ensure that they were of equivalent interest to the different age groups in their participant population.
Weaknesses/Limitations	It is important to note that this study compared digital video billboards to traditional static billboards (i.e. it did not examine digital billboards with intermittent displays (i.e. those that change their message every 6-8 seconds) that are typical in the U.S. Although the authors state that their participants represented a "wide range of ages," it is not known how well young and old drivers were represented in the study. This is of concern because these two age groups at the ends of the driving population distribution are known to have the greatest degree of difficulty with attention and distraction.
Availability/Accessibility	TRL Report Number RPN256.

Date 1st published/presented	2009
Location	Australia, Queensland
Author(s) Title Affiliation	Horberry, T., Regan, MA, & Edquist, J. Driver Distraction from Roadside Advertising: The clash of road safety evidence, highwa authority guidelines, and commercial advertising pressure. University of Queensland (Australia), INRETS (France), Monash University (Australia).
Forum	Unknown
Peer Reviewed?	Yes
Sponsor/funding source	Swedish National Road and Transport Institute, VTI
Type of Study*	CR, D, G
Type of Signs Studied**	C, D
Brief Description of Method	Critical review of the research, worldwide, as well as existing guidelines and regulations
Summary of Findings	"Road authorities around the world may ... be justified in using the best research information available (albeit incomplete) coupled with engineering judgment for the development of 3rd party advertising guidelines." The authors recommend that Main Roads Queensland adopt advertising restrictions at known areas of high driver workloa including "locations with high accident rates, non-junction related lane merges, curves/bends, hills and road/works/abnormal traffic flows. This is broadly in line with Wachtel who recommended a restriction of advertisements at times when driver decision, action points and cognitive demand are greatest – such as at freeway exits/entrances, lane reductions, merges and curves. Although useful for all road users, such restrictions would be of specific benefit to older drivers." The authors correctly point out the flaw in arguments that suggest that guidance or regulatory controls are premature because there is a lack of data showing a causal relationship between billboards and accidents
Strengths	The study examined in detail the existing (2002) guidelines that seek to "minimize the possibility for 3rd party roadside advertisements to distract drivers..." with an intent toward developing upgraded guidelines.
Weaknesses/Limitations	The review of current guidelines, worldwide, is somewhat superficial.
Availability/Accessibility	https://document.chalmers.se/download?docid=653291678

Date 1st published/presented	2010
Location	Israel (Tel Aviv)
Author(s) Title Affiliation	Gitelman, V., Zaidel, D., & Doveh, E. "Influence of Billboards on Driving Behavior and Road Safety,"
Forum	Presented at: Fifth International Conference on Traffic and Transportation Psychology (2012); and at Annual Meeting of Transportation Research Board of the National Academies (2013)
Peer Reviewed?	Yes
Sponsor/funding source	Israel National Roads Authority
Type of Study*	E
Study Design	Quasi-experimental: Before and after crash date with controls – Crash data with DBBs present (2006-7) and absent (2008), with and without signs that were covered. Dependent measure – crashes and injuries. Control variable – traffic volume. Study sites – 8 treatment and 6 control.
Type of Signs Studied**	C
Brief Description of Method	Because of complaints, Israel's Supreme Court ruled that a series of billboards on an urban freeway near Tel Aviv had to be removed for 1 year while an evaluation took place. At control sites, the billboards remained visible throughout the study period. At treatment sites, billboards were visible in the "before" period (2006-7), and were covered during the "after" period (2008). Crashes were recorded and categorized (property damage only, injury or fatality) under four conditions: (a) at treatment sites while signs were visible; (b) at treatment sites after signs were covered; (c) at control sites where signs were visible; and (d) at the same control sites while signs were still visible but signs were covered at the treatment sites.
Summary of Findings	At control sites, crashes remained essentially the same throughout the 3-year study period; at the treatment sites, crashes declined dramatically after the billboards were covered. The results were the same for injury and fatal crashes. After adjusting for traffic volume, crashes were reduced at the treatment sites (where billboards were visible in the "before" period but covered during the "after" period) by the following percentages: all crashes by 60%; injury/fatal crashes by 39%; property damage crashes by 72%.
Strengths	For a field study, this used a well-controlled research design. Before-and-after measures were obtained both for sites where the billboards were covered during the study, and for the sites where the billboards remained visible during this same time period. Road sections were in close proximity, on the same highway, ensuring that traffic speeds and volumes, as well as weather conditions, law enforcement activity, etc. were comparable
Weaknesses/Limitations	There might have been differences in certain roadway characteristics between the treatment and control sites (e.g. curves, merges, etc.) that were not identified.
Availability/Accessibility	Findings available as PowerPoint from either conference; original study is in Hebrew only; English translation not yet available.

Date 1st published/presented	2010
Location	Saudi Arabia
Author(s) Title Affiliation	Bendak, S., & Al-Saleh, K. "The Role of Roadside Advertising Signs in Distracting Drivers." King Saud University
Forum	*International Journal of Industrial Ergonomics, 40,* 233-236.
Peer Reviewed?	Yes
Sponsor/funding source	Research Centre of the College of Engineering, King Saud University
Type of Study*	S, QI
Study Design	
Type of Signs Studied**	O, C, D, V
Brief Description of Method	Twelve male drivers, age 23-28, drove a simulator consisting of two urban roadways, each 9.3-km long, and matched for physical, environmental and traffic characteristics. One road contained advertising signs; the other was devoid of advertisements.
Summary of Findings	The average driving duration was 12.83 minutes for each route showing that the presence of advertising signs did not materially affect driving speed. There were no accidents. Lane placement and position maintenance suffered significantly in the presence of advertising signs. According to the authors: "swinging and drifting from lan in the presence of advertising signs is a strong indication of how such signs distract drivers and affect their performance." A second finding was that "recklessly crossing dangerous intersections" was also significantly and adversely affected by the presence of advertising signs. This finding, according to the authors "indicates the loss of this fine coordination between paying attention and driving. ... This can reasonably attributed... to the longer reaction time needed in the presence of hazards due to being distracted." All three of the other measures: tailgating, "overspeeding," and failure to signal, were poorer in the presence of advertising signs, but these were not statistically significant. I response to the questionnaire, 50% of the 160 respondents said they had been distracted by advertising signs, and 22% reported having been in a dangerous situation at least once due to being distracted by advertising signs.
Strengths	The two simulated routes driven were matched for key characteristics; the differences between them were essentially only in the presence or absence of advertising signs.
Weaknesses/Limitations	No females and no drivers older than 28 were included. "Advertising" signs of many different types were comingled, so it was impossible to identify the effects of any one category of signs, such as billboards. No definition is provided of the behavior identifiec as "recklessly crossing dangerous intersections." The authors attribute poorer performance in this measure to longer reaction time in the presence of the advertising signs, but there is no indication that they measured this response. The questionnaire completed by 160 respondents was not included in the paper.
Availability/Accessibility	www.elsevier.com/locate.ergon

Date 1st published/presented	2011
Location	Canada (Calgary, Alberta)
Author(s) Title Affiliation	Milloy, SL; and Caird, JK. "External Driver Distractions: The Effects of Video Billboards and Wind Farms on Driver Performance." University of Calgary
Forum	Book chapter
Peer Reviewed?	Yes
Sponsor/funding source	Unspecified
Type of Study*	S
Type of Signs Studied**	V (simulated)
Brief Description of Method	The contribution to driver distraction from in-vehicle technologies such as cell phones, I Pods, and navigation systems have been studied extensively. But it is external distractions that compose the single largest category of distraction-related crashes. The least is known about such crashes, possibly because the variety of people, objects and events that make up external distractions are very difficult to study in a controlled empirical fashion. In theory, drivers often have spare cognitive capacity that they can allocate toward distractors such as billboards. The question asked here was: what happens when an unlikely but totally plausible emergency event takes place – can the driver "reallocate" his or her attention so as to respond to the event in a timely manner. In this "event-based" scenario, either the driver responds adequately or not. In this simulator study, drivers on a freeway moving at 80 km/h (50 mph) in an industrial environment passed a video billboard at the same time that a lead vehicle suddenly braked hard.
Summary of Findings	The results found a *causal* (italics original) relationship between the presence of the video billboard and collisions with, and delays in responding to, the lead vehicle. The authors note that the billboards in this study were less able to capture the drivers' attention than video billboards in the real world because the simulated billboards were not as bright as actual billboards, and because the study was not conducted at night, where the distracting effects were believed to be greater. The implication is that real world safety problems may be more significant than those indicated by the study.
Strengths	A high fidelity, interactive driving simulator with a 150-degree forward field of view wa: used. All 21 subjects made three drives, and viewed two static and two video billboards in each. The images on the billboards were different in each presentation. A lead vehicle appeared intermittently, and, twice during each presentation, braked suddenly so that the subject had to respond quickly to avoid a collision
Weaknesses/Limitations	Younger and older drivers, those believed to be most susceptible to such distractions, were not included in the study. Learning may have occurred from earlier drives, and subjects may have come to use the appearance of billboards as a visual cue to prepare tc brake for the lead vehicle.
Availability/Accessibility	Published in: "Handbook of Driving Simulation for Engineering, Medicine and Psychology." Edited by: D.L. Fisher, M. Rizzo, J.K. Caird, & J.D. Lee. Boca Raton: CRC Press

Date 1st published/presented	2011
Location	Australia, Perth
Author(s) Title Affiliation	Edquist, J., Horberry, T., Hosking, S. & Johnston, I "Advertising billboards impair change detection in road scenes" Monash University Accident Research Centre
Forum	2011 Australasian Road Safety Research, Education & Policing Conference
Peer Reviewed?	Yes
Sponsor/funding source	Unknown
Type of Study*	L
Type of Signs Studied**	C, H
Brief Description of Method	The authors used a "change detection" paradigm to study how billboards affect visual search and situation awareness in road scenes. Change detection time has been shown to correlate with at-fault errors in a simulated driving task. In a controlled experiment, inexperienced (mean age 19.3), older (73.0), and comparison (34.8) drivers searched for changes to road signs and vehicle locations in static photographs of road scenes. The road scenes ranged from suburban main streets to multilane highways to provide varying levels of background clutter. The actual experimental protocol is too complex to include in this summary, but may be found in the original article.
Summary of Findings	"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 in 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." 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 an official road sign, and for older drivers. The results are consistent with the small but growing body of evidence suggesting that roadside 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.
Strengths	The change detection task has been shown to be relevant to safe driving performance, but has been underutilized in research. The inclusion of three diverse age cohorts addresses limitations in many other studies.
Weaknesses/Limitations	The study did not include an actual, or simulated driving task; rather a surrogate measure for visual subtasks required during driving. (However, the results are consistent with mounting evidence showing that roadside billboards impair key aspects of driving performance). Horberry, et al., (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 minimize the probability of interference with driving."
Availability/Accessibility	http://casr.adelaide.edu.au/rsr/RSR2011/4CPaper%20166%20Edquist.pdf

Date 1st published/presented	2012
Location	Sweden (Stockholm)
Author(s) Title Affiliation	Dukic, T., Ahlstrom, C., Patten, C., Kettwich, C., & Kircher, K. "Effects of Electronic Billboards on Driver Distraction." Swedish National Road and Transport Research Institute, and Karlsruhe Institute of Technology
Forum	Journal of Traffic Injury Prevention
Peer Reviewed?	Y
Sponsor/funding source	Swedish Transport Administration
Type of Study*	Q
Type of Signs Studied**	D
Brief Description of Method	The Swedish government allowed 12 digital billboards to be erected along highways nea Stockholm for a trial period during which this, and related research was conducted. 41 volunteers drove an instrumented vehicle past 4 of the billboards in both day (N = 20) and night (N = 21) conditions. Eye movements (and other measures) were recorded. "A driver (was) considered to be visually distracted when looking at a billboard continuously for more than two seconds with a single long glance, or if the driver looked away from the road for a 'high percentage of time'." (This is defined in the study based o prior research, but is too complex for inclusion in this brief summary). Dependent measures were eye tracking and driving performance measures.
Summary of Findings	Drivers had a significantly longer dwell time (time looking at the billboards), a greater number of fixations, and a longer maximum fixation duration when driving past a DBB compared to other signs along the same road sections. No differences were found for day-night, or for specific driver performance variables.
Strengths	Excellent review of the relevant literature and explanation of the psycho-physiological processes involved
Weaknesses/Limitations	It is known from other research that younger drivers (e.g. those under age 25) and older drivers (e.g. those over age 65) are more likely to be distracted by roadside stimuli that are irrelevant to the driving task; this study was limited to drivers between the ages of 3 and 55.
Availability/Accessibility	http://www.tandfonline.com/doi/abs/10.1080/15389588.2012.731546

Date 1st published/presented	2012
Location	USA
Author(s) Title Affiliation	Perez, WA, Bertola, MA, Kennedy, JF, & Molino, JA "Driver Visual Behavior in the Presence of Commercial Electronic Variable Message Sign (CEVMS)." SAIC (now Leidos)
Forum	Unnumbered FHWA Report
Peer Reviewed?	N[4]
Sponsor/funding source	Federal Highway Administration
Type of Study*	C
Type of Signs Studied**	O, C, D, H
Brief Description of Method	FHWA contractor used instrumented vehicle with on-board eye glance data recording as participant drivers drove along predetermined routes in Reading, PA and Richmond, VA. Each route took the participants past a series of on-premise and off-premise (billboard) signs, apparently both conventional and digital, during daytime and at night.
Summary of Findings	Gazes to the road ahead were high across all test conditions; however, in three of the fou test conditions digital and conventional billboards resulted in a lower probability of gazes to the road ahead as compared to the control conditions in which billboards were not present (although on-premise signs, including, potentially, electronic signs, might have been present). In Richmond, drivers gazed more at the digital than standard billboards at night, but this difference was not found in Reading.
Strengths	The study used state-of-the-art eye glance recording equipment. The study route had drivers pass signs on rural and urban routes, and surroundings that differed in visual complexity.
Weaknesses/Limitations	Numerous critical discrepancies between draft and final reports; errors in identifying billboard locations including size, distance from road edge, side of road; both far and near distances at which eye glances to billboards were recorded were artificially truncated; two experimenters sat in the vehicle with the participant driver; data overloa required experimental vehicle to pull off road for resets; inappropriate recordation of billboard luminance levels; confounding of billboards with on-premise signs.
Availability/Accessibility	Report is available on the FHWA website at http://www.fhwa.dot.gov/real_estate/oac/visual_behavior_report/final/cevmsfinal.pdf

[4]In March 2011, FHWA released a draft version of the report to three pre-selected peer reviewers. The reviewers were not identified and the draft report was not made available to the public. The comments of two of the three reviewers (the third did not provide meaningful or comprehensive comments) were so critical of the draft report (stating, in essence, that the report's findings about eye glance durations to billboards were not credible) that FHWA spent the next 33 months revising and rewriting the report. A final report, which was *not* peer reviewed, was released on the agency's website on December 30, 2013, although the report was dated September 2012. Although the unreleased draft report was given the official agency report number FHWA-HEP-11-014, the final report remains unnumbered and unpublished.

Date 1st published/presented	2013
Location	U.S. (Massachusetts, Amherst)
Author(s) Title Affiliation	Divekar, G., Pradhan, AK, Pollatsek, A., & Fisher, DL; "Effects of External Distractions" University of Massachusetts, Amherst
Forum	Journal
Peer Reviewed?	Yes
Sponsor/funding source	National Institutes of Health, National Science Foundation, Arbella Insurance Group Charitable Foundation
Type of Study*	S
Type of Signs Studied**	D (simulated)
Brief Description of Method	Following previous research in the same lab, the authors sought to understand: (a) why experienced drivers were taking such long glances at external distractions (simulated billboards) when they were unwilling to do so for distractors inside the vehicle, and (b) if these experienced drivers were sacrificing some of their ability to monitor visible hazards in the roadway ahead of their vehicle, are they sacrificing even more of their ability to anticipate unseen hazards. Novice and experienced drivers performed an external search task (reading a simulated billboard) while driving in a simulator. Eye movements were recorded, as were vehicle performance.
Summary of Findings	Distractions are a major contributor to crashes, and almost one-third of such distractions are caused by sources external to the vehicle. Of these, digital billboards stand out because of their brightness and changing imagery. Recent research indicates that such billboards may attract attention away from the forward roadway for extended periods of time, and converging evidence shows that looking away from the forward roadway for such extended periods is associated with elevated crash risk. The external tasks in this study were designed to be similar to scanning a sign dense with informatior in the real world, such as a digital billboard that changed message every few seconds. "This study provides clear evidence that external tasks are distracting not only for novice drivers, but also for more experienced drivers." For both groups, external distractions significantly affect the drivers' anticipation of hazards. Overall the study showed that experienced as well as novice drivers are at an elevated risk of getting into a crash when they are performing a secondary task such as looking at a billboard.
Strengths	Sophisticated driving simulator with realistic hazard scenarios.
Weaknesses/Limitations	The simulated billboards, although requiring an external, visual distraction task, were not very representative of roadside billboards. There was no effort to study the effects of such external distractions on older drivers, a group known to be at high risk for such distraction
Availability/Accessibility	Transportation Research Record, Journal of the Transportation Research Board No. 2321.

Date 1st published/presented	2013
Location	Australia
Author(s) Title Affiliation	Roberts, P., Boddington, K., & Rodwell, L. "Impact of Roadside Advertising on Road Safety" ARRB Group (formerly Australian Road Research Board)
Forum	Austroads Road Research Report: Publication No. AP-R420-13
Peer Reviewed?	Unknown
Sponsor/funding source	Austroads (The Association of Australian and New Zealand Road Transport and Traffic Authorities)
Type of Study*	CR, G
Type of Signs Studied**	O, C, D, V
Brief Description of Method	(a) A critical review of existing literature to study the risk of distraction from roadside advertising, and to communicate these findings; (b) document and review existing guidelines across different highway agencies to identify gaps and inconsistencies; (c) develop guiding principles and make guidance recommendations that could be used to create guidelines and to harmonize guidelines across diverse agencies.
Summary of Findings	Most drivers, under most conditions, most of the time, probably possess sufficient spare cognitive capacity that they can tolerate driving-irrelevant information. The problem comes in some driving situations where it becomes likely that (the appearance of) movement or changes in luminance will involuntarily capture attention and that particularly salient emotional or engaging information will capture attention to the detriment of driving performance, particularly in inexperienced drivers. Where this happens in a driving situation that is also cognitively demanding, the consequences for driving performance are likely to be significant. Further, if this attentional capture also results in a situation where a driver's eyes are off the forward roadway for a significant amount of time (i.e. 2 seconds or longer) this will further reduce safety. Additionally, road environments cluttered with driving-irrelevant material may make it difficult to extract information that is necessary for safe driving, particularly for older drivers. The studies that have been conducted show convincingly that roadside advertising is distracting and that it may lead to poorer vehicle control. Results from the Klauer, et al (2006) studies show that looking at an external object increased the crash risk by nearly four times, nonetheless the number of crashes resulting from such distraction is probably quite small. This suggests that the contribution of roadside advertising to crashes is likely to be relatively minor. Nonetheless, from the Safe System perspective it would be difficult to justify adding any infrastructure to the road environment that could result in increased distraction for drivers. The exception to this may be in the case long drives on monotonous roads where drivers are likely to suffer the effects of passive fatigue.
Strengths	A comprehensive review, not only of existing research, but also of relevant human factors principles, advertising sign technology, and best practices.
Weaknesses/Limitations	Although the authors extensively review and comment on existing regulations and guidelines, only brief mention is made of guidelines in the U.S.
Availability/Accessibility	Available on the Austroads website

Date 1st published/presented	2013
Location	Denmark
Author(s) Title Affiliation	Herrstedt, L., Greibe, P., & Andersson, P. "Roadside Advertising Affects Driver Attention and Road Safety." Trafitec, Denmark
Forum	International Conference
Peer Reviewed?	Yes
Sponsor/funding source	Unknown
Type of Study*	Q
Type of Signs Studied**	C, D
Brief Description of Method	32 drivers, both men and women between the ages of 23 and 70, drove an instrumented vehicle on one of several comparable routes. Drivers had to have a current license and not require eyeglasses while driving. Drivers were not informed in advance of the purpose of the drive. The car's instruments recorded eye movements, vehicle speed and position, and proximity to vehicles ahead of the test vehicle. A "safety buffer" was calculated which reflected the time available for the driver to respond to a sudden critical situation requiring immediate action to avoid an accident.
Summary of Findings	A total of 109 drives past advertising signs were completed, and a total of 233 glances to the 16 roadside advertising signs were recorded. Results showed that, in 69% of all drives, the driver glanced at the advertisement at least once. In nearly half of all drives, the driver glanced two or more times to the same billboard. 18% of all glances lasted for 1 second or longer, and the total duration of successive glances on a single drive was 1.5 seconds or longer in 29% of trials, 2.0 seconds or longer in 22% of trials, and 3.0 seconds or longer in 10% of trials. In 65 of the 233 glances (28%), a vehicle ahead was present within a time gap of less than 3.0 seconds. In 59 cases (25%) the safety buffer was less than 2.0 seconds, and in 20% of all cases, the safety buffer was as low as 1.5 seconds. The authors conclude that, in 25% of all cases, driving safety was reduced because the safety buffer was less than 2 seconds to the lead vehicle. Further, in 16% of all drives (17 out of 109), the sum of cumulative glances to the same billboard resulted in visual distraction using the method developed by VTTI (2.0 seconds or more within a 6.0 second window). In other words, the authors state: "In more than every sixth drive past, visual distraction occurs as a result of the advertising sign." Their overall conclusion was that "the investigated advertising signs do capture drivers' attention to the extent that it impacts road safety."
Strengths	This is one of only two known on-road studies to combine measures of driver glance behavior (number and duration of glances to billboards) with the simultaneous measure of following distance to a vehicle ahead, and the only one to (apparently) calculate such following distances via laser scanner for accuracy. Older drivers were included in the participant group.
Weaknesses/Limitations	More details about the specific billboards studied would have been helpful.
Availability/Accessibility	*Proceedings of the 3rd International Conference on Driver Distraction and Inattention.*

Date 1st published/presented	2014
Location	US
Author(s) Title Affiliation	Hawkins, HG, Jr., Kuo, P-F, & Lord, D. "Statistical Analysis of the Traffic Safety Impacts of On-Premise Digital Signs" Texas A&M University
Forum	93rd Annual Meeting of the Transportation Research Board
Peer Reviewed?	Yes
Sponsor/funding source	On-premise sign industry (Signage Foundation, Inc.)
Type of Study*	E
Type of Signs Studied**	O
Brief Description of Method	135 sites in four states, where on premise signs had been installed in 2006-07, were compared to 1,301 control sites using the Empirical Bayes (EB) statistical methodology.
Summary of Findings	There were no statistically significant changes in crash frequency associated with the installation of the on-premise digital signs studied. A calculated safety effectiveness index was equal to 1.00, with the 95 percent confidence interval between 0.93 and 1.07. The findings were similar for each of the four investigated States. The researchers concluded that "there is no evidence (that) the installation of on-premise signs at the locations (studied) led to an automatic increase in the number of crashes." The authors point out in their conclusions that it might be of interest to examine whether or not the index varies as a function of sign design and operation or characteristics of the crashes themselves.
Strengths	The study employed a large database and a robust statistical analysis procedure.
Weaknesses/Limitations	The on-premise signs to be studied were chosen by the sponsor and individual sign companies rather than by the authors or at random. It is possible that the selection criteria included a bias toward the least potentially distracting signs (in terms of size, color, contrast, animation, video, etc.).
Availability/Accessibility	Paper No.: 14-2772 of the 93rd Annual Meeting of the Transportation Research Board.

Date 1st published/presented	2014
Location	USA
Author(s) Title Affiliation	Schieber, F., Limrick, K., McCall, R., & Beck, A. "Evaluation of the Visual Demands of Digital Billboards Using a Hybrid Driving Simulator" University of South Dakota
Forum	Journal
Peer Reviewed?	Yes
Sponsor/funding source	Unknown
Type of Study*	S
Type of Signs Studied**	D (Simulated)
Brief Description of Method	The authors used a purpose-built hybrid driving simulator designed "for investigating the limits of sign reading performance while driving." The driving task and the view of the road ahead used a validated, commercial simulator; but the digital billboard stimulus was implemented on a separate 20:1 scaled LCD display mounted on a linear actuator rail that could move the simulated sign toward the observer at angular velocities simulating speeds up to 55 mph. 18 university undergraduates participated. Gaze direction (road ahead vs. billboard) was captured by a video recording of each participant's face as they drove– this technique was previously demonstrated by the senior author. Participants drove once at 25 and again at 50 mph. Digital billboard stimuli were presented at predetermined random intervals, and contained either 4, 8, or 12 frequently used English words, also displayed at random.
Summary of Findings	The authors state: "Although little or no decrement in lane keeping or reading performance was observed at slow speed (25 MPH) on straight roads, clear evidence of impaired performance became apparent at the higher driving speed (50 MPH). Lane keeping performance was significantly degraded when participants were required to read digital billboards with 8 or more words at the higher speed. This decrement became greater when the sign contained 12 words. Surprisingly, the decrements in lane keeping performance emerged *after* the participants had finished reading the sign. The participants tended to slowly drift away from the center of the lane, and then executed a large amplitude corrective steering input during the 8-second interval after encountering the digital billboard. Eye gaze statistics and reading performance showed that information processing overload began to emerge at a message length of 8 words and was clearly present when 12 words were displayed.
Strengths	Sophisticated, hybrid driving simulator with a custom built zoomed image sign projecto designed to overcome traditional simulator constraints on sign legibility at realistic distances. Simulated digital billboards contained different, common words of 4-5 letters each, and each was presented in the same size and location on the billboard.
Weaknesses/Limitations	No older drivers were studied. There is no discussion of the validity of the hybrid driving simulator for this specific application. The simulated billboards were only 10 ft. in width, only about one-fifth the width of typical highway billboards.
Availability/Accessibility	*Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting,* 2214-2218.

Date 1st published/presented	2014
Location	Israel (Tel Aviv)
Author(s) Title Affiliation	Gitelman, V., Zaidel, D., Doveh, E., & Silberstein, R. "Accidents on Ayalon Highway - Three Periods Comparison: Billboards Present, Removed, and Returned"
Forum	
Peer Reviewed?	Yes
Sponsor/funding source	Israel National Roads Authority
Type of Study*	E
Study Design	Quasi-experimental: Billboards present (2006-07), absent (2008), present again (2009-12) with controls. Dependent measure – property damage and injury crashes. Control variable – traffic volume. Study sites – 8 treatment and 6 control.
Type of Signs Studied**	C
Brief Description of Method	Because of complaints, Israel's Supreme Court ruled that a series of billboards on an urban freeway near Tel Aviv had to be removed, i.e. covered, for one year while an evaluation took place. At the end of the experimental period, the billboards were uncovered such that they were again visible to motorists. At control sites, the billboards remained visible throughout the study period. At treatment sites, billboards were visible in the "present" period (2006-7), covered during the "removed" period (2008), and visible again in the "returned" period (2009-12). Crashes were recorded and categorized (property damage only, injury or fatality) under six conditions: (a) at treatment sites while signs were visible; (b) at treatment sites after signs were covered (c) at treatment sites where signs were visible again after having been uncovered; (d) a control sites where signs were visible; and (e) at the same control sites while signs were still visible but signs were covered at the treatment sites; and (f) at control sites while signs were again visible at the treatment sites.
Summary of Findings	At control sites, crashes remained essentially the same throughout the 6-year study period; at the treatment sites, crashes declined dramatically after the billboards were covered, and returned just as dramatically once the billboards were uncovered and therefore again visible. The results were the same for injury and fatal crashes. After adjusting for traffic volume, crashes were reduced at the treatment sites (where billboards were visible in the "before" period but covered during the "after" period) by the following percentages: all crashes by 60%; injury/fatal crashes by 39%; property damage crashes by 72%.
Strengths	For a field study, this used a well-controlled research design. Before-and-after measure were obtained both for sites where the billboards were covered during the study, and for the sites where the billboards remained visible during this same time period. Road sections were in close proximity, on the same highway, ensuring that traffic speeds and volumes, as well as weather conditions, law enforcement activity, etc. were comparable
Weaknesses/Limitations	There might have been differences in certain roadway characteristics between the treatment and control sites (e.g. curves, merges, etc.) that were not identified.
Availability/Accessibility	Complete study is in Hebrew only; English translation is available for the Executive Summary only.

Date 1st published/presented	2015
Location	USA
Author(s) Title Affiliation	Sisiopiku, VP, Islam, M., Haleem, K., Alluri, P. & Gan, A. "Investigation of the Potential Relationship between Crash Occurrences and the Presence of Digital Billboards in Alabama and Florida"
Forum	Conference Paper
Peer Reviewed?	Yes
Sponsor/funding source	U.S. Department of Transportation/RITA, Alabama Department of Transportation, Florida Department of Transportation
Type of Study*	E
Type of Signs Studied**	D
Brief Description of Method	The authors analyzed historical crash records from the states of Alabama and Florida. They identified locations of digital billboards along major limited-access roadways and chose 18 suitable sites for analysis, each with its own control site. Crash records were obtained for a five-year period from a centralized database in Alabama, and crash rates were determined per million vehicle miles travelled at each site. The procedure was similar in Florida, although only three years were studied. Because many crashes in the vicinity of the billboards were found to be located incorrectly, the authors retrieved the actual police traffic collision reports for 783 crashes. Of these, 406 had to be eliminated due to coding errors in the original summary reports, leaving a total of 377 crashes for the safety assessment.
Summary of Findings	The authors state: "The overall results were consistent between the two states. The presence of digital billboards increased the overall crash rates at "digital advertising billboard influence zones" by 25% in Florida and 29% in Alabama, compared to control sites. In addition, sideswipe and rear-end crashes were overrepresented at digital billboard influence zones compared to control sites.
Strengths	Included in their influence zone was a short distance (minimum 0.05 mile) downstream of each billboard. This is in keeping with the findings of Schieber, et al., discussed elsewhere in the present document. The influence zone and associated control zone for each billboard were matched for traffic and roadway conditions.
Weaknesses/Limitations	The authors provide no explanation for how the specific billboard locations were chosen out of all possibilities that they identified. Apparently, they identified "influence zones" by calculating the distances upstream of each digital billboard from which the sign could be seen, using Google Street View. There seems to have been no effort to relate sight distance in the real world to that shown in the Google Street View images. It is unclear whether their 5 years of data (AL) and 3 years (FL) correspond to periods when the billboards studied were actually in place, given that the authors seem to have selected sites from Google Street View.
Availability/Accessibility	*Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting,* 2214-2218.

Date 1st published/presented	2015
Location	Canada
Author(s) Title Affiliation	Rempel, G., Montufar, J., Forbes, G., & Dewar, R. "Digital and projected advertising Displays: Regulatory and Road Safety Assessment Guidelines." MORR Transportation Consulting, Ltd., Intus Road Safety Engineering, Inc.., Western Ergonomics, Inc.
Forum	Transportation Association of Canada Report
Peer Reviewed?	Yes
Sponsor/funding source	Transportation Association of Canada
Type of Study*	CR
Type of Signs Studied**	O, D
Brief Description of Method	The authors performed a critical literature review, met with representatives of Canadian government agencies and outdoor advertising companies, investigated practices and regulations/guidelines in other countries, and applied human factors principles toward the development of guidelines for Canada.
Summary of Findings	The resultant guidelines are specific to traffic safety issues – they do not address the aesthetic, "nuisance," or economic factors of such signs. Guidance is developed for sign density, spacing, dwell time (which they call "frame duration"), illuminance (which they authors call "brightness"), proximity to traffic control devices and driver decision points message sequencing and text scrolling, animation, and transition time between messages. The overriding principle proposed in this report is that digital advertising signs should "emulate" traditional signs.
Strengths	A comprehensive review, not only of existing research, but also of relevant human factors principles, advertising sign technology, and best practices.
Weaknesses/Limitations	Accepted industry practices regarding DBB lighting rather than getting the views of lighting experts or undertaking their own independent evaluation.
Availability/Accessibility	Available for purchase from Transportation Association of Canada at http://tac-atc.ca/en/digital-and-projected-advertising-displays-publication-now-available

Date 1st published/presented	2015[2]
Location	Australia
Author(s) Title Affiliation	Samsa, C., & Phillips, T. "Digital Billboards 'Down Under': Are they Distracting to Drivers and can Industry and Regulators Work Together for a Successful Road Safety Outcome?" Samsa Consulting, Outdoor Media Association of Australia
Forum	*4th International Conference on Driver Distraction and Inattention*
Peer Reviewed?	Yes
Sponsor/funding source	Outdoor Media Association of Australia
Type of Study*	C
Type of Signs Studied**	C, D, O
Brief Description of Method	29 participants, ages 25-54, drove an instrumented vehicle along a 14.6 km route in Brisbane, Queensland. Drivers were fitted with "eye tracking glasses."
Summary of Findings	Average fixation durations were "well below 0.75 s". There were no significant differences in average vehicle headway between the three signage types. There was a statistically significant difference in lateral deviation when billboards were present.
Strengths	The data showing significant differences in lateral deviation in the presence of billboards is in accord with findings from other recent studies.
Weaknesses/Limitations	No older drivers were studied. There is little description of the eye tracking glasses used, but this apparatus is not known to provide the precision necessary to determine exactly where the wearer is looking. No information is provided to enable the reader to determine how vehicle headways were measured; as such it is not possible to compare this study to the one conducted in Denmark, where headway measurement was clearly described.
Availability/Accessibility	https://www.ivvy.com/event/DD2015

[2]At the present time, this paper is available only as an Abstract. Our comments might change once we are able to review the complete paper.

Date 1st published/presented	2016
Location	USA
Author(s) Title Affiliation	Belyusar, D., Reimer, B. Mehler B., & Coughlin, JF. "A Field Study on the Effects of Digital Billboards on Glance Behavior During Highway Driving." New England University Transportation Center & MIT Age Lab
Forum	Accident Analysis and Prevention, 88, 88-96
Peer Reviewed?	Yes
Sponsor/funding source	US Department of Transportation, Region 1 New England, University Transportation Center at MIT, and the Toyota Class Action Settlement Safety Research and Education Program.
Type of Study*	Q
Type of Signs Studied**	D
Brief Description of Method	This on-road study had 123 subjects, nearly equally divided between males and females and between young and old. Participants drove an instrumented vehicle under normal driving conditions, with no specific tasks to perform, past a digital billboard on a highway with a speed limit of 65 MPH.
Summary of Findings	The authors found statistically significant changes in total number of glances and, depending upon the direction of travel, moderate-to-long duration glances in the direction of the billboard as compared to sections of the roadway in which the billboard was not visible. Older drivers were particularly affected. The authors also found that: "Drivers glanced more at the time of a switch to a new advertisement display than during a comparable section of roadway when the billboard was simply visible and stable." They concluded: "Given typical billboard dwell (cycle) times of six (6) or eight (8) seconds, these findings add to the argument the dwell times for such signs should be considerably longer."
Strengths	The driving task was quasi naturalistic; both young and old drivers, and both males and females, were equally represented.
Weaknesses/Limitations	Only one billboard, with two faces, was used in the analysis. There could be characteristics of that sign, or its location, which make the results not generalizable to other billboards.
Availability/Accessibility	http://www.sciencedirect.com/science/article/pii/S0001457515301664

Citations:

Backer-Grøndahl, A., & Sagberg, F. (2009). "Relative crash involvement risk associated with different sources of driver distraction." Presented at the First international Conference on Driver Distraction and Inattention. Gothenburg, Sweden: Chalmers University.

Belyusar, D., Reimer, B., Mehler, B., & Coughlin, JF. (2016). "A field study on the effects of digital billboards on glance behavior during highway driving." *Accident Analysis and Prevention, 88,* 88-96.

Bendak, S., & Al-Saleh, K. (2010). "The role of advertising signs in distracting drivers." *International Journal of Industrial Ergonomics, 40,* 233-236.

Chan, E., Pradhan, AK, Knodler, MA, Jr., Pollatsek, A. & Fisher, DL. (2008). "Empirical Evaluation on a Driving Simulator of the Effect of Distractions Inside and Outside the Vehicle on Drivers' Eye Behaviors," Washington, DC: 87th Annual Meeting of the Transportation Research Board of the National Academies.

Chattington, M., Reed, N., Basacik, D., Flint, A., & Parkes, A. (2009). "Investigating Driver Distraction: The Effects of Video and Static Advertising." Report No. RPN256. United Kingdom: Transport Research Laboratory

Divekar, G., Pradhan, AK, Pollatsek, A., & Fisher, DL. (2013). "External Distractions": Evaluations of their effect on younger novice and experienced drivers' behavior and vehicle control." Transportation Research Record, Journal of the Transportation Research Board No. 2321. Washington, DC: Transportation Research Board of the National Academies.

Dukic, T., Ahlstrom, C., Patten, C., Kettwich, C., & Kircher, K. (2012). "Effects of Electronic Billboards on Driver Distraction." Journal of Traffic Injury Prevention, *14,* 469-476.

Edquist, J., Horberry, T., Hosking, S. & Johnston, I. (2011). "Advertising billboards impair change detection in road scenes." Paper presented at the 2011 Australasian Road Safety Research, Education & Policing Conference.

Gitelman, V., Zaidel, D., & Doveh, E. (2012). "Influence of Billboards on Driving Behavior and Road Safety," Presented at: Fifth International Conference on Traffic and Transportation Psychology. Groningen, The Netherlands: University of Groningen.

Gitelman, V., Zaidel, D., Doveh, E., & Zilberstein, R. (2014) "The Impact of Billboards on Road Accidents on Ayalon Highway Three Periods Comparison – Billboards Present, Removed, and Returned." Report to the Israeli National Road Authority.

Hawkins, HG, Jr., Kuo, PF, & Lord, D. (2014). "Statistical Analysis of the Traffic Safety Impacts of On-Premise Digital Signs." Paper No: 14-2772. Presented at the 93rd Annual Meeting of the Transportation Research Board.

Herrstedt, L., Greibe, P. & Andersson, P. (2013). "Roadside Advertising Affects Driver Attention and Road Safety." *Proceedings of the 3rd International Conference on Driver Distraction and Inattention, Gothenburg, Sweden.*

Horberry, T., Regan, MA, & Edquist, J. (2009). Driver Distraction from Roadside Advertising: The clash of road safety evidence, highway authority guidelines, and commercial advertising pressure. Downloaded from the web at: https://document.chalmers.se/download?docid=653291678

Milloy, SL and Caird, JK. (2011). "External Driver Distractions: The Effects of Video Billboards and Wind Farms on Driver Performance." Published in: *Handbook of Driving Simulation for Engineering, Medicine and Psychology.* Edited by: D.L. Fisher, M. Rizzo, J.K. Caird, & J.D. Lee. Boca Raton: CRC Press.

Perez, WA., Bertola, MA, Kennedy, JF, & Molino, JA. (2012). "Driver Visual Behavior in the Presence of Commercial Electronic Variable Message Signs (CEVMS)." Unnumbered Report, Federal Highway Administration, Washington, DC. Downloaded from the web at: http://www.fhwa.dot.gov/real_estate/oac/visual_behavior_report/final/cevmsfinal.pdf

Rempel, G, Montufar, J., Forbes, G. & Dewar, R. (2015). "Digital and Projected Advertising Displays: Regulatory and Road Safety Assessment Guidelines." Unnumbered Transportation Association of Canada Report.

Roberts, P., Boddington, K., & Rodwell, L. (2013). Impact of Roadside Advertising on Road Safety. Austroads Road Research Report: Publication No. AP-R420-13. City: Australia, ARRB Group.

Samsa, C., & Phillips, T. (2015). Digital Billboards 'Down Under'. Are they Distracting to Drivers and can Industry and Regulators Work Together for a Successful Road Safety Outcome? *Paper Presented at the 4th International Conference on Driver Distraction and Inattention,* Sydney, Australia.

Schieber, F., Limrick, K. McCall, R, & Beck, A. (2014). Evaluation of the Visual Demands of Digital Billboards Using a Hybrid Driving Simulator. *Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting,* 2214-2218.

Sisiopiku, VP, Islam, M, Haleem, K, Alluri, P. & Gan, A. (2014). Investigation of the Potential Relationship between Crash Occurrence and the Presence of Digital Advertising Billboards in Alabama and Florida. *Proceedings of the Transportation Research Board (TRB) 94th Annual Meeting.*

Young, MS, Mahfoud, JM, Stanton, N. Salmon, PM, Jenkins, DP & Walker, GH. (2009). "Conflicts of Interest: The implications of roadside advertising for driver attention." *Transportation Research Part F: Traffic Psychology and Behaviour, Vol. 12*(5), 381-388.