THE URBAN WILDLANDS GROUP, INC.
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March 20, 2013

Councilmember Ed Reyes, Chair
Planning and Land Use Management Committee
Los Angeles City Council
200 North Spring Street
Los Angeles, CA 90012

Re: Council File 08-2020

Dear Chair Reyes and Commissioners:

The Urban Wildlands Group is a Los Angeles-based nonprofit dedicated to the protection of species, habitats, and ecological processes in urban and urbanizing areas. We have a particular interest and expertise in the effects of artificial night lighting on the natural world and on human health. We encourage you in the strongest possible terms to adopt the sign ordinance that was before your committee in 2012 without any changes that would legalize or grandfather the now-illegal digital billboards that have been installed in the city. Current research on the effects of artificial light on human health and of digital billboards on traffic safety should provide sufficient basis to support such a decision as being in the best interest of the residents of the City of Los Angeles.

Digital billboards are extraordinarily bright, and can disrupt sleep by residents when they shine into windows. This is not a trivial impact, and one cannot expect residents near such billboards to have to purchase and install blackout shades. Sleep is necessary for restoring physiological and biological processes (Bennington and Heller 1995), in consolidating memory (Drosopoulos et al. 2007), and for maintaining a healthy metabolism (Taheri et al. 2004). Darkness in the sleeping environment is tied strongly to sleep duration and quality, including the production of key hormones such as the pineal neurohormone melatonin, which is produced at night under dark conditions (Arendt 2005). For the elderly and others in institutional care, lights (and noise) have been shown to be particularly disruptive (Schnelle et al. 1999). The evidence that outdoor lighting results in indoor exposure is found in epidemiological studies (Kloog et al. 2008; Kloog et al. 2009a; Kloog et al. 2009b; Kloog et al. 2011), and such exposure is implicated in an increased risk of breast cancer (Stevens 1987; Hansen 2001b; Hansen 2001a; Stevens and Rea 2001; Schernhammer et al. 2006; Kloog et al. 2009a; Kloog et al. 2011) and prostate cancer (Pukkala et al. 2006; Kloog et al. 2009b). Light at night from digital billboards can also harm other groups of animals, such as birds (Kempenaers et al. 2010; Longcore 2010).

The most recent research on driver behavior and performance shows that drivers are more distracted by digital billboards than by other signs on the same stretch of road (Dukic et al.

2013). This research was conducted on a heavily trafficked stretch of highway in Stockholm, Sweden, where the digital billboards were installed for the experiment. Drivers looked at the digital billboards longer and more often than they did at non-digital signs (Dukic et al. 2013); this has also been shown by other studies (Beijer et al. 2004; Smiley et al. 2005). The Swedish results confirmed previous simulator research showing that drivers took more time to react to road conditions when exposed to electronic billboards, especially among novice and elderly drivers (Edquist et al. 2011). Previous researchers have also found an increase in side-swipe and rear-end crashes attributable to electronic billboards (Wisconsin Department of Transportation 1994).

Based on the results of the Swedish study described above, which demonstrated driver distraction from electronic billboards, the Swedish government discontinued the tests and removed the billboards (Dukic et al. 2013). The City of Los Angeles should do the same to protect the health and safety of its residents, and to make the environment friendlier for other species as well, by removing all existing digital billboards and banning them permanently.

Sincerely,

Travis Longcore, Ph.D.
Science Director

Dan Silver, M.D.
Board of Directors

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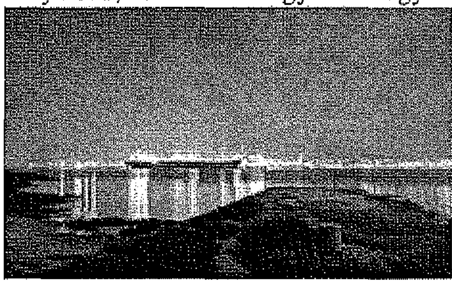
SCIENCE : PHYSICS : TECH : NANO : NEWS

Light pollution transforming insect communities

May 23rd, 2012 in Biology / Ecology



Falmouth. Photo by Kevin Murphy.

(Phys.org) -- Street lighting is transforming communities of insects and other invertebrates, according to research by the University of Exeter. Published today in the journal *Biology Letters*, the study shows for the first time that the balance of different species living together is being radically altered as a result of light pollution in our towns and cities.

Believed to be increasing by six per cent a year globally, artificial lighting is already known to affect individual organisms, but this is the first time that its impact on whole communities has been investigated.

This study shows that groups of invertebrates living near to artificial lights include more predators and scavengers. This could be impacting on the survival rates of different species, having a knock-on effect on birds and mammals that rely on these species for food. The effects could be affecting entire ecosystems and even humans.

The research team based their study in the market town of Helston in West Cornwall. They placed pitfall traps directly under and between street lamps that were 35 metres apart for a number of days and nights. This allowed them to compare, not only results for day and night, but also differences between areas under and away from street lights.

They collected 1,194 individuals covering 60 species. They discovered that total numbers were more abundant under street lights, where they also found more predatory and scavenging species, such as ground beetles and harvestmen. This was the case during the day, as well as at night, suggesting that the effect on communities is ongoing.

Lead author Dr Tom Davies of the Environment and Sustainability Institute at the University of Exeter's Cornwall Campus said: "Our study shows that light pollution could be having a dramatic effect on wildlife in our towns and cities. We need to be aware of how the increase in artificial lighting is impacting on the delicate ecosystems on which we all rely. Our research shows, for the first time, the changes that light pollution is making to entire communities of invertebrates. We now need to examine what impact this is having on other communities and how this may be affecting important ecosystem services and whether we should change the way we light urban spaces."

Provided by University of Exeter

"Light pollution transforming insect communities." May 23rd, 2012. http://phys.org/news/2012-05-pollution-insect.html

The Basics of Digital Signage and Energy Consumption

by Gregory Young

In the world of outdoor advertising, successive technological and stylistic advancements have prompted cities and states to rethink their signage regulation and policy. There has been much controversy regarding the potential safety hazard posed by digital signage. Many studies show that such signage can lead to driver distraction and traffic delays (Wachtel, 2009). This research, and the resultant outcry from activists and concerned citizens, has led some policymakers to regulate distracting, electronic signage displays. There has been relatively little research, however, regarding the environmental and energy-consumption issues raised by this new technology.

First, *what exactly is digital signage*? Digital signage packages consist of three key pieces: player, extender(s), and display. The player is essentially a computer, equipped with software to generate the displayed content. Players are typically mounted behind the screen, and must be kept cool (via internal or accessory fan) and must be easily accessible for repairs or rebooting. These player/fan arrangements typically consume between 200 and 300 Watts[1] while running, slightly more than a home dishwasher. Depending on the relative location of the player to the screen, there may be a need for a video extender, essentially a cable which connects the player to the screen. This brings us to the most important component of any digital sign: the screen, or, in industry parlance, "the display." There are three main categories of digital display: LCD, plasma, and LED.

LED is the name used for Light Emitting Diode (aka LED) boards, commonly used in small to medium sized on-premise electronic advertising[2]. They are the overwhelming preference for large off-premise[3] digital billboards; designed for long-distance impact, they are often up to 1200 sq. ft. in size (20'x60'). According to the U.S. Department of Energy, LEDs produce more light (in lumens per watt) than incandescent bulbs, and their efficiency is not affected by shape and size, unlike traditional fluorescent light bulbs or tubes.

3051 Front St., Philadelphia
Off-premise LED sign

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[1] **Watt**—a unit of power which measures the rate of energy conversion. It is defined as one joule per second. The kilowatt (kW) is equal to one thousand watts. For a sense of perspective, one kilowatt of power is approximately equal to 1.34 horsepower. A small electric heater with one heating element can use 1.0 kilowatt. If that heater is used for one hour, it will have used one kilowatt hour.

[2] **On-premise** or **accessory** signage is defined as a business establishment's on-site advertisements.

[3] **Off-premise** or **non-accessory** billboards/signs are those which advertise a business or product not sold at the signs' location. Roadside billboards are a popular form of off-premise advertising.

Proponents of digital signage tout the "greenness" of LEDs; lower wattage and greater luminance[4] than the more traditional fluorescent, incandescent, or halogen bulbs.

These claims overlook one key bit of common sense: whereas traditional, static signage is illuminated by two or three "inefficient" lamps at nighttime, digital signs are comprised of hundreds, if not thousands, of "green" LED bulbs, each using between 2-10 watts, lit twenty-four hours a day. For instance, a 14'x48' LED billboard can have between 900 and 10,000 diodes.

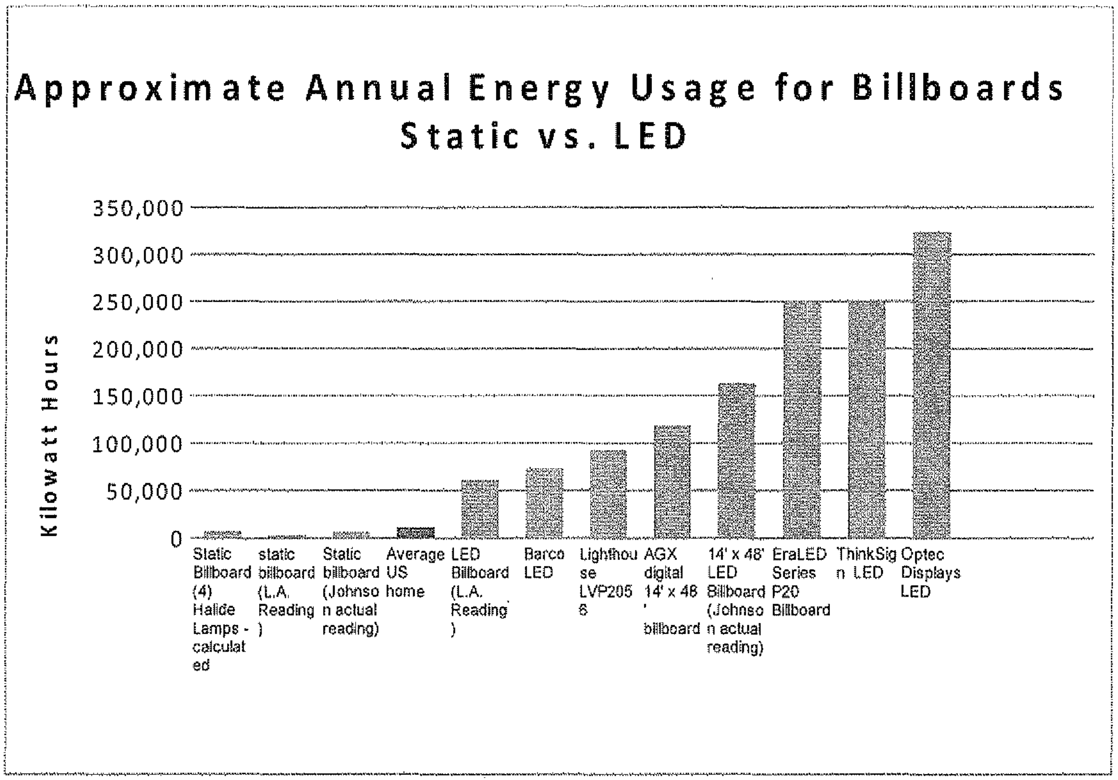
Considering this simple fact, intrinsic to digital billboard design, it is no surprise that overall energy consumption of digital signage exceeds that of static signage, and makes bulb-to-bulb comparisons irrelevant in this context.

Additionally, with all digital display types, the players which control the changeable images and the fans required to cool them must be taken into account, as they too increase energy consumption. Adding auxiliary equipment, such as extenders, further increases the power demand.

Determining the exact power consumption for a digital billboard is difficult; usage is dependent upon many variables, including size, resolution (how close pixels are spaced, aka diode density), how many LEDs are in each pixel, the color capabilities of the board (tri-color or full color), the image being displayed and time of day (daytime operation requires more power than nighttime operation, as the lit image must compete with the brightness of the sun).

Despite these difficulties, we have compiled an objective chart of consumption rates. Our information was provided by a variety of sources, ranging from manufacturers, fellow researchers, advocacy groups, and independent meter readings.

[4] **Luminance** is a measure of the perceived brightness of a light-emitting surface, such as a digital sign. Its unit of measure is candela per square meter (c/m^2), informally referred to as "nits."



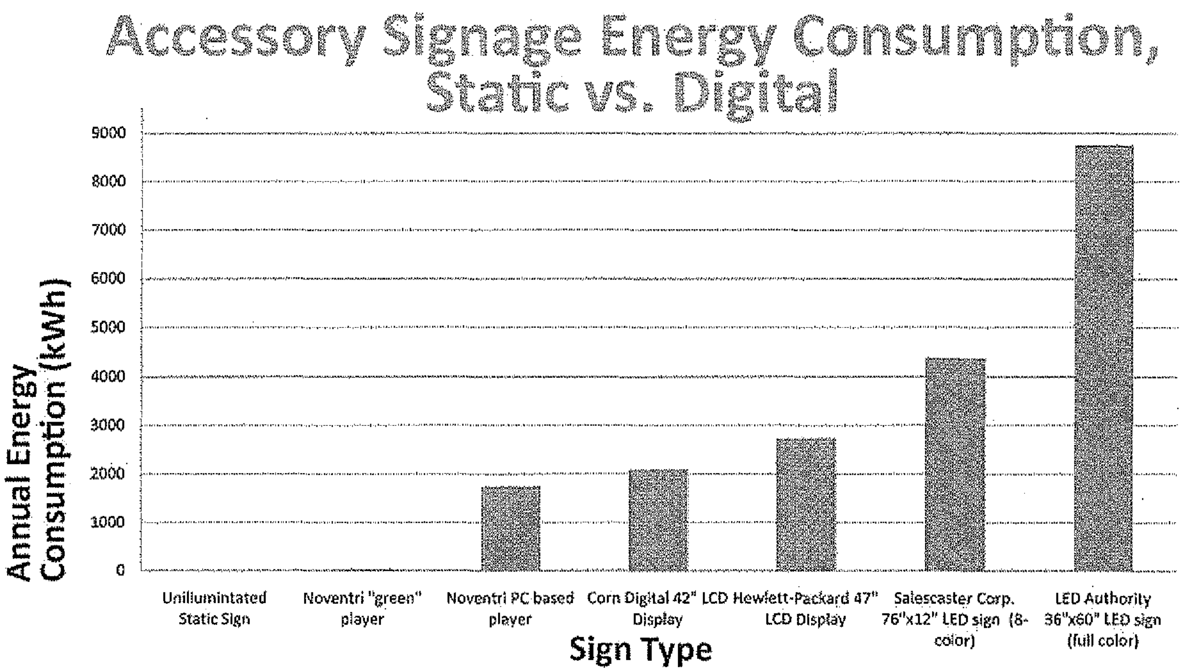
LED units generate heat, and cannot function well in heat, which reduces the unit's life expectancy. As a result of the tremendous amount of heat generated in LEDs , and the additional impact of hot weather on the signs, an air conditioning unit is incorporated to cool the components. The energy drawn from the grid is highest during the summer months when the heat from the sun coupled with the heat generated by the higher brightness of the LED unit requires increased demand on the air conditioning system installed for cooling the LED unit.

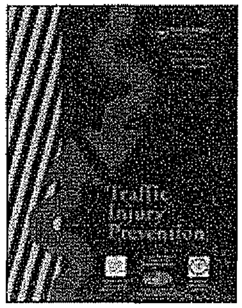
This energy use corresponds directly with maximum peak demands from businesses and residences. Utility companies now provide a discount for homeowners if they can disconnect their air conditioners from the grid during the peak load demands. There is no discussion or plan that we are aware of to disconnect

LED air conditioners or darken signs during periods of high demand. If traditional billboards continue to be replaced by LED signs, the growing draw of energy during peak hours could negate the efforts of Utility companies to reduce demand during peak times.

Rates of Energy Consumption		
Product type	**Annual Usage, kWh***	**Annual cost****
Unillumintated Static Sign	0	$0
Noventri "green" player	35	$4.80
Noventri PC based player	1,752	$240
Corn Digital 42" LCD Display	2,103	$288
Hewlett-Packard 47" LCD Display	2,737	$375
Salescaster Corp. 76"x12" LED sign (8-color)	4,380	$600
Static Billboard (4) Halide Lamps - calculated	**7,008**	**$960**
LED Authority 36"x60" LED sign (full color)	8,760	$1,200
Average US home	**11,040**	**$1,512**
LED Billboard (L.A. Reading)	61,032	$8,361
Barco LED	73,584	$10,081
Lighthouse LVP2056	92,715	$12,792
AGX digital 14' x 48 ' billboard	117,866	$16,148
14' x 48' LED Billboard (Florida actual reading)	**162,902**	**$22,318**
EraLED Series P20 Billboard	249,690	$34,208
ThinkSign LED	248,993	$34,112
Optec Displays LED	323,773	$44,357
* Energy Usage (((24))((365))/1000		
** Average costs per kWh=$.137 (Metro Area)		

In many applications---such as television/computer display, general lighting, and small electronics---LCD, plasma screen, and LED technological advancements have proven more energy efficient than their predecessors, but research indicates that out-of-home advertising is simply not an appropriate or responsible application for digital technology.





Effects of electronic billboards on driver distraction

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Keywords:	Visual distraction, electronic billboard, traffic safety, field study, eye tracking

Effects of electronic billboards on driver distraction

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ABSTRACT

Objective: There is an increase in electronic advertising billboards along major roads which may cause driver distraction due to the highly conspicuous design of the billboards. Yet, only limited research on the impact of billboards on driving performance and driver behaviour is available. The Swedish Transport Administration recently approved the installation of twelve electronic billboards for a trial period along a four-lane motorway with heavy traffic running through central Stockholm, Sweden. The aim of this study was to evaluate the effect of these electronic billboards on visual behaviour and on driving performance.

Method: A total of 41 drivers were recruited to drive an instrumented vehicle passing four of the electronic billboards during day and night conditions. A driver was considered visually distracted when looking at a billboard continuously for more than two seconds, or if the driver looked away from the road for a high percentage of time. Dependent variables were eye-tracking measures and driving performance measures.

Results: The visual behaviour data showed that drivers had a significantly longer dwell time, a greater number of fixations and longer maximum fixation duration when driving past an electronic billboard compared to other signs on the same road stretches. No differences were found for the factors day/night, and no effect was found for the driving behaviour data.

Conclusion: Billboards have an effect on gaze behaviour by attracting more and longer glances than regular traffic signs. Whether the billboards attract attention too much, that is, whether they are a traffic safety hazard, cannot be answered conclusively based on the present data.

KEYWORDS

Visual distraction, electronic billboard, traffic safety, field study, eye tracking.

INTRODUCTION

Electronic billboards are designed to attract attention using static, dynamic or full-motion pictures. The more conspicuous and eye-catching the images are, the more likely they are to attract attention. In Sweden and unlike many other countries, the Swedish Transport Administration has been very restrictive in that roadside billboards and electronic billboards have not been permitted. In 2009, however, the administration gave temporary permission to the installation of twelve roadside electronic billboards, eight of which were installed at the time of the study. The trial period was subject to road traffic safety evaluation where driver distraction was of particular interest.

For 50 years electronic billboards have been allowed in many countries such as USA, Australia, Canada and New Zealand. In order to control and limit the potential negative effect on driver behaviour, different rules and guidelines have been established. The guidelines differ between countries and states, but typically they restrict the placement of the signs (i.e. avoid intersections), the luminance of the signs (i.e. avoid dazzling), the size of the board and the length and font size of the message (Cairney & Gunatillake, 2000; Farbry et al., 2001; Transit, 2008).

Driver distraction in general is believed to be a contributory factor to many accidents (Klauer et al., 2006; NHTSA, 2009; Olson et al., 2009). Modern electronic billboards are able to display dynamic messages either as slideshows or as animations or videos. The intent of these dynamic messages is to trigger bottom-up processes from the visual-sensory channels in order to capture the driver's attention. Most previous works have not been able to attribute increased crash rates to electronic billboards per se (McMonagle, 1952; Tantala & Tantala, 2007; Wallace, 2003), however, Farbry et al. (2001) found an increase in especially sideswipe crashes and rear-end crashes. Results from simulator studies show that the dynamic content as well as the placement of the billboard with respect to its surroundings have an influence on driving performance, i.e. greater variability on lateral lane position or slower speed while passing the billboards (Chattington et al., 2009; Crundall et al., 2006; Hughes & Cole, 1986). Eye-tracking studies confirm the attention grabbing nature of electronic billboards (Beijer et al., 2004; Crundall et al., 2006; Smiley et al., 2005; Young & Mahfoud, 2007; Young et al., 2009). A recent simulator study by Edquist et al. (2011) showed that billboards affected visual scanning, caused increased reaction times to road signs and increased the number of driver errors. Moreover, novice and older drivers were more affected. In another simulator study, Bendak and Al-Saleh (2010) found that road stretches with billboards caused more lane deviations and more occasions of recklessly crossing dangerous intersections.

A two-dimensional framework for attention selection in driving has been proposed by Trick and Enns (2009) where the first dimension accounts for top-down (goal-driven) processing versus bottom-up (stimulus-driven) processing, while the second dimension accounts for automatic processing versus controlled processing. Automatic processes can be *reflex* (bottom-up) or *habit* (top-down). These automatic processes are innate and are triggered by certain stimuli in the driving environment. Controlled processes can be *exploratory* (bottom-up) or *deliberate* (top-down). In the context of electronic billboards, the mechanism that has the greatest influence on the driver is reflexive attention selection (automatic/bottom-up). Reflexive responses cannot be disengaged and at best the negative effects can be minimised by intentional inhibition (Trick & Enns, 2009). Also, if the driver is interested in the advertisement, deliberate attention selection may occur (controlled/top-down).

Driver inattention has been defined as "insufficient, or no attention, to activities critical for safe driving" (Regan et al., 2011). This implies that whether a driver has been distracted or not can only be determined in retrospect, at least if "safe driving" is defined as the absence of crashes or critical situations. Based on Trick and Enns framework, a glance towards a billboard can have different reasons. The driver may employ a routine scanning behaviour to assess the traffic situation continuously. Noticing the billboard, the driver may choose to have a closer look, while having a mental picture of how the traffic situation is likely to develop. Thus, the glance is planned and unlikely to result in a dangerous situation. According to the definition above, such behaviour would not be considered distracted. Only if the driver's attention is absorbed by the billboard more than originally intended, the driver may become distracted. Additionally, the billboard may also attract the driver's attention in a reflexive manner, such that the glance can be described as involuntary. This may occur in all kinds of situations, including those in which averting the glance from the traffic scene is likely to lead to insufficient uptake of information. As it is difficult to separate intended from reflexive glances based on eye movement measurements, a more pragmatic definition was employed in the present study, which builds on the duration and frequency of glances directed towards the billboard.

The objective of this study is to evaluate the effect of electronic billboards on drivers' visual behaviour and driving performance in a realistic field setting.

METHODOLOGY

The data were collected during a field study performed on a motorway in Stockholm, Sweden, in the fall of 2010. The study was approved by the local ethics committee in Linköping (2010-309-31).

Participants

In total, 41 drivers participated in the study. Their mean ± sd age was 42 ± 8 years and they had held their driving licence for 22 ± 9 years. Twenty participants drove between 9 a.m. to 3 p.m. (daylight conditions) and 21 participants drove between 6.30 p.m. to 9.30 p.m. (night-time conditions).These hours were chosen to avoid rush hours. All participants gave their informed consent and the local ethics committee approved the study.

Criteria for the recruitment of participants were that drivers should be between 35 to 55 years old, drive at least 5,000 km/year and drive several times a week. The recruitment process was done in two steps. First, a randomised sample of 200 drivers was acquired from the Swedish vehicle register. Based on this selection twelve drivers agreed to participate in the study. In a second step, the remaining drivers were recruited via an advertisement on the Swedish National Road and Transport Research Institute's website.

Stimuli and Apparatus

Visual behaviour was measured with a head-mounted eye tracker (IView, SMI, Teltow, Germany). An instrumented vehicle, a Volvo V70, was equipped with a data acquisition unit (VBox, RaceLogic, Buckingham, U.K.) to measure vehicle dynamics, and with a camera (MobilEye, Amstelveen, the Netherlands) to record the lateral position and longitudinal headway. All signals were sampled at 50 Hz.

Four electronic advertisement billboards were investigated in the study. The Swedish Transport Administration had constrained how the advertisements were to be displayed, for example, no video messages were allowed. In practice, the billboards changed the message every seven seconds which results in three to four different advertisements while passing the billboard. One of the billboards is illustrated in Figure 1. In addition to the four electronic advertisement billboards, another seven traffic signs were included in the study for comparison. These include three overhead gantries showing navigation information, two guide signs and one bus lane sign. Furthermore, one large static paper billboard sign was included. These signs were all located in the vicinity of the electronic billboards to ensure that the traffic conditions were comparable.

Insert figure 1 about here

There are some distinct differences between the electronic billboards and the other signs in the study: The billboards are lit, while the other signs are retroreflective, which most likely makes the billboards brighter. The message on the billboards is changed every 7th second, which makes them somewhat dynamic, as each driver will see a number of changes on approach. In addition, the billboards are bigger than most regular traffic signs, which also increase their bottom-up attractiveness.

Design and Procedure

Light condition (daylight / night time) was treated as a between-subjects factor whereas type of sign (electronic billboard / conventional sign) and road stretch (stretch 1 – billboard, stretch 2 – before billboard, stretch 3 – after billboard) were treated as within-subjects factors.

The participants were welcomed at the office and started out by filling in an informed consent form. Then, the calibration of the eye tracking system was performed in the vehicle before the drive. The participants got accustomed to the car and to the eye tracker while driving from the office to the motorway where the actual experiment took place. The experimental route was 40 km long and took approximately 40 minutes to complete, depending on the traffic density. The participants received navigational instructions from an experimenter present in the car.

The participants were not informed about the purpose of the experiment until after the drive. Instead, they were told that the aim of the experiment was to investigate whether the eye tracking equipment could be used in real traffic and under different weather conditions.

Analyses

Driving behaviour was analysed in terms of mean speed, standard deviation of lateral position and minimum time headway. Since the traffic environment and the surrounding traffic changed continuously over time, it is important that baseline values were sampled in close proximity of the billboards. Therefore, the performance indicators were calculated based on data from three different road stretches in the proximity of each billboard. The stretch corresponding to the electronic billboard started where the sign became visible (at 750 m, 450 m, 650 m and 700 m for the four signs) and ended at the location of the sign. The other two stretches had the same length as the billboard stretch and were located just before and just after the billboard stretch. The distances indicating when the advert became visible were determined based on the helmet mounted camera on the eye tracker, and may underestimate the true distance since the camera has limited resolution and does not show everything in the visual field. Road stretches with a mean velocity below 50 km/h were excluded from the analysis.

Gaze analyses were carried out in BeGaze 3.0 (SensoMotoric Instruments, Teltow, Germany). In this software the areas of interest, that is the four electronic billboards and the seven other signs, were marked in the recorded video stream of each driver. Gazes and glances towards these highlighted areas were then automatically quantified. In this study, visual behaviour was analysed in terms of four different performance indicators: (i) dwell time, defined as the accumulated total time that the participants looked at a sign; (ii) visual time sharing, the percentage of time that the driver looked at a sign, defined as the dwell time divided by the exposure time; (iii) number of fixations, the total amount of fixations directed towards a sign and (iv) maximum fixation duration, the duration of the longest fixation directed towards a sign. Exposure time is defined as the duration from when the sign became visible until the vehicle passed the sign, excluding the time when the line of sight was obstructed by, for example, surrounding traffic. Fixations were detected based on a dispersion algorithm built into the analysis software, with a minimum fixation length of 80 ms and a maximum dispersion of 100 pixels.

The statistical analyses involved two-factor ANOVAs with interaction terms, using the factors time-of-day (daytime vs. night-time) and sign (billboard vs. control sign). Visual behaviour was analysed in two steps. It has to be noted that not all drivers looked at all signs. In the first analysis step the percentage of drivers who looked at billboards and the percentage of drivers who looked at control signs was determined. Gaze-based performance indicators (PI) could only be computed for those instances in which a driver had looked at a sign. It was decided to calculate one PI value per sign, which equals the mean of all instances in which a participant had looked at this particular sign. The analysis of variance was then conducted based on each sign, which could either be an electronic billboard or a control sign, and which could have been looked at during daytime or during night-time. The factors were treated as "between-subjects", as the glances which each sign attracted stemmed from different participants for the time-of-day factor, and could stem from either the same or different participants for the sign-type factor.

ANOVAs were also conducted for driving behaviour, but with the factors time-of-day and road stretch (stretch 1 – billboard, stretch 2 – before billboard, stretch 3 – after billboard). Separate analyses were performed for the four billboards since the preconditions, for example the speed limit, differed between the billboards. Missing values were present in the driving behaviour data as well, partly due to data acquisition issues but also since a lead vehicle was not always present.

All analyses were carried out in Matlab 7.11 (Mathworks Inc., Natick, MA, USA) and all tests used a significance level of $\alpha = 0.05$.

In the present study, a driver is considered to be visually distracted when looking at a billboard for more than two seconds with a single long glance or if the driver looks away from the road for a high percentage of time. The first criterion is based on the observation that long glances away from the road are detrimental for traffic safety (H.T. Zwahlen, Adams, Jr., et al., 1988). In the second criterion, the threshold for "high percentage" is set as when the dwell time is equal to or exceeds (exposure time +12)/9. This threshold stems from naturalistic driving studies where it has been found that the odds ratio for a crash is larger when the driver looks away for more than two seconds during the past six seconds or, alternatively, for more than three seconds during the past fifteen seconds (Klauer et al., 2010). The threshold, dwell time ≥ (exposure time +12)/9, is simply the linear function that connects the two coordinates <dwell time=2, exposure time=6> and <dwell time=3, exposure time=15>, where dwell time is used as a surrogate for eyes off road and exposure time is used as a surrogate to past 6/15 seconds. The range of the linear equation was limited to the interval of exposure times between 6 – 15 seconds (figure 5). The lower limit is motivated by earlier research which states that eye glances away from the road rarely exceed a duration of two seconds (Tania Dukic et al., 2005; Wikman et al., 1998) and that glances with durations longer than two seconds are considered dangerous (Klauer et al., 2006; Helmut T Zwahlen, Adams, & DeBald, 1988). The upper limit is based on Klauer's (2010) work which only considers time durations up to fifteen seconds.

RESULTS

The percentage of drivers who looked at the various signs is shown in figure 2. When aggregating the different signs into the two groups electronic billboards (S1 – S4) and other signs, it becomes clear that significantly more participants looked at the billboards ($F(1,18) = 13.3$, $p < 0.05$) than to the other signs. However, there is no significant difference between daytime and night-time ($F(1,18) = 0.5$, $p = 0.47$). "No tracking" indicates data loss which may be due to makeup, strong sunshine, reflections in the participants'eyeglasses or any other factor that interferes with the eye tracker.

Insert figure 2 about here

The differences in visual behaviour between the factors time-of-day and sign are presented in table 1. When drivers passed an electronic billboard, as compared to other signs, the dwell times were longer ($F(1,18)=16.4$, $p<0.05$), the number of fixations were greater ($F(1,18)=18.6$, $p<0.05$) and the maximum fixation duration was longer ($F(1,18)=5.7$, $p<0.05$). However, no significant effect on visual time sharing behaviour was found ($F(1,18)=1.8$, $p=0.19$). No significant differences were found in the visual behaviour variables between daytime and night-time, nor were there any significant interactions between the two factors. Boxplots for the different gaze behaviour variables and for all signs are presented in Figure 3 and estimated marginal means, divided by the factors time-of-day and sign, are presented in Figure 4.

Insert table 1 about here

Insert figure 3 about here

Insert figure 4 about here

In total there were 75 fixations to the billboards during daytime and 61 fixations during night-time. Corresponding numbers for the other signs were 23 fixations during daytime and 42 fixations during night-time. There were six fixations on the four electronic billboards that lasted for more than two seconds (range 2.1–3.5 s). These fixations originated from different drivers and were distributed amongst all four billboards except S1. In comparison, such long fixations only occurred once in total for the seven other signs. Figure 5 shows that there were five cases that were classified as visually distracted according to the visual time sharing criteria. Since two of the eleven distraction cases coincided, this adds up to nine distracted drivers. Outside the distraction boundaries, i.e. exposure times below 6 s or above 15 s, there were another ten occurrences of intensive visual time-sharing behaviour. Note that all cases where the visual time sharing intensity exceeds the threshold belong to the electronic advertising billboard group.

Insert figure 5 about here

Driving behaviour based performance indicators for the factors day/night and road stretch are presented in table 2. No consistent effects were found for any of the factors. A significantly lower speed was found during the night, but only for billboard S1, $F(116,1)=11.55$, $p<0.001$, and S2, $F(117,1)=62.75$, $p<0.001$. There was also a significantly longer time headway during the night, but only for billboard S3, $F(56,1)=4.71$, $p=0.03$. For the factor road stretch, significantly different speeds were found for billboard S1, $F(116,2)=12.55$, $p<0.001$, and S4, $F(100,2)=6.08$, $p=0.003$. Significantly different variability in lateral position was also found for billboard S1, $F(85,2)=7.50$, $p=0.001$, and S3, $F(95,2)=8.17$, $p=0.0005$, with . Post hoc analyses with t-tests showed that these differences mainly occurred on road stretches before and after the billboards, with lower speed on stretch 2 for S1 and higher speed on stretch 2 for S4, and with larger variability in lateral position on stretch 1 for S1 and larger variability on stretch 2 for S3.

Insert table 2 about here

Discussion

Overall, the electronic billboards attract more visual attention than the other traffic signs included in the study. Dwell times are longer, the visual time sharing intensity is higher, very long single glances are more frequent, and the number of fixations is greater for the electronic billboards. As the information on the billboards changes with regular intervals, the signs have the potential ability to keep up the drivers' curiosity over an extended period of time.

In short, the billboards are designed to attract attention in a bottom-up fashion, while traffic signs are built to inform when and where necessary, and drivers usually know approximately where to look for them. Earlier research has shown that drivers usually do not recall road signs that were not of direct relevance to the driver (Johansson & Backlund, 1970; Johansson & Rumar, 1966; Sprenger et al., 1997). This is an indication that drivers either ignore the signs already when passing them, as their top-down script tells them that those signs are not relevant at the moment, or that they process their content on a shallow level, without lasting memory traces. This is completely meaningful for traffic signs, both from the drivers' perspective and from the perspective of the road administration who set up the signs. For billboards this is different. Here the obvious wish of the producer is to attract attention and to create lasting memory traces. This means that signs must be visually conspicuous and attract attention long enough and intensively enough for passers-by to store them to memory.

Our data show that the billboards, in fact, attract more glances than the other signs. This comes as no surprise since there is something new to look at every seventh second. This particular cycle length is a compromise between traffic safety demands and requests from the billboard owners and was specified by the Swedish Road Administration based on trial and error followed by further refinements after complaints from the public. A different cycle length would probably have resulted in a slightly different outcome. A longer cycle length makes the billboards more similar to traditional signs whereas a higher message rate will eventually allow full motion video. A further refinement that resulted from official complaints was how the transition between to messages occurred. In the beginning two messages were separated by blanking out the display. This was found to cause distraction since some drivers said that they couldn't help waiting for the next message to appear. The transition was therefore altered so that two commercial messages followed directly after each other.

Our data also show that the billboards attract the glances of more drivers than the other signs do, which speaks for a reflexive component in the glance behaviour, according to the framework by Trick and Enns (2009). The next question is whether this reflexive component is strong enough that it endangers safe driving or not. Is the drivers' gaze inadvertently drawn to the billboards, or can drivers ignore the signs if necessary? As can be deducted from Figure 2 a substantial number of drivers did not look at the billboards at all, which is a strong indication that they actually can be ignored. We cannot know whether drivers actively ignored the signs, willing themselves not to look at them (Hallett, 1978), or whether drivers did not notice the signs at all. If they actively ignored the signs, this could be due to a top-down component of traffic requiring attention, or to the drivers' having learnt the position of the signs during earlier trips, which led to the drivers' making an active decision not to look at the presented advertisements.

For the investigated performance indicators, no differences were found between daytime and night-time driving. Theoretically it should be assumed that the billboards would be more conspicuous at night, as they appear brighter, but still, drivers did not look at the billboards more or for longer periods of time than during daytime. One reason might be an increased top-down pressure to fixate on the road in low visibility conditions. Another reason could be that the drivers chose to ignore the billboards in order to resist glare.

As the drivers' glances do not appear to be drawn to the billboards invariably, it can be assumed that drivers have a choice, at least to a certain extent, whether to look at the billboards or not. If drivers consider it safe to do so, is it still dangerous? Especially during night-time there could be other issues that are not caught by the performance indicators investigated here. As the billboards are rather bright in comparison to standard signs, there can be a concern about glare, due to the high contrast to the surrounding environment. Unfortunately we did not have the opportunity to measure the luminance of the electronic billboards. However, drivers did not avoid looking at the billboards at night-time more than during daytime, indicating that the brightness was not so high as to cause considerable glare.

Figure 4 shows that more glances are directed at the billboards than at the other signs. This could be due to the fact that a driver who looks at the billboard becomes interested in the message. Several glances might follow to decode the message completely, which may lead to insufficient attention to traffic due to a shift of goals. As shown in Figure 5, six out of seven glances exceeding two seconds were actually directed at the electronic billboards, and in four of these six cases high levels of glance diversion were reached with respect to the 2-in-6 to 3-in-15-seconds rule.

No consistent significant changes in driving behaviour with respect to speed, lateral placement of the vehicle or headway could be found between the phases before the billboard was visible, while it was visible and after it was passed. This finding is not completely unexpected, as this type of behaviour is rather automated. While no driving related impairments could be measured, it is still possible that latent decrements were present. It is theoretically possible that performance was reduced somewhat when drivers looked at the billboards intensively, but not enough to lead to conflicts. It is also possible that drivers would have had delayed reaction times and an impaired capability to detect divergent behaviour of other road users, making the long glances a catalyst for traffic conflicts. On the other hand, it might also be the case that performance was not reduced, as the drivers still might have kept enough resources directed at the traffic to perform unaffectedly. How driving behaviour and gaze behaviour would change in more or less complex situations than the one under examination here needs to be investigated in future studies.

The data can be interpreted in the way that those drivers who are understimulated by the traffic situation look around for entertainment, which is provided by the billboards. If this notion can be corroborated, the phenomenon might be used to steer drivers' attention in the desired direction in situations where it can be expected that drivers are likely to get bored, as situational stimulation is low. This could be the case in long tunnels, on motorways or long country roads with low traffic volumes.

The data were collected during real driving, thereby ensuring high external validity. The head mounted system used for eye tracking allowed gaze target detection, which made the glance evaluation reliable. However, the percentage of tracking loss was quite substantial, with losses of around 30% of the participants for some of the signs. Due to time and budget restrictions it could not be investigated whether those losses varied systematically with other variables that might have influenced the drivers' propensity to look at the billboards.

Furthermore, the drivers were not required to stay in a certain lane, as their driving behaviour should be as natural as possible. This means that trucks in adjacent lanes could obstruct the view of the billboards for some drivers, but not for others. This issue is in part taken care of by using the actual exposure time, that is, the time that the driver was physically able to see the sign, as a dimensioning factor for the relevant PI.

The participants in this study received their navigational instructions from the experimenter present in the car, which implies that there was only a limited need for the participants to look at signs with navigation information. Consequentially there should be no or only very little top-down activation to search for navigation signs, while other traffic signs like speed limits or lane restrictions still provide useful information. All drivers were familiar with the road including the billboards, which might have influenced how they reacted to the billboards, but also to the other signs. Top-down processing is likely to have a higher impact on a familiar route, as drivers do not need to look for signs and information the way they would have to on an unfamiliar route. This increases the likelihood that drivers who looked at the billboards extensively actually wanted to do so.

External validity, i.e. how generalizable the results are, was considered through the following measures. A homogeneous group of participants who were very familiar with the road was selected to make shore that the billboards were not novel to the driver. Middle-aged experienced drivers were selected to reduce the spread in the data further. The subject sample selected for this study should be seen as a best case scenario as both novice and older drivers have been found to be more affected by electronic billboards (Edquist et al., 2011). In general, both novice and older drivers have difficulties to manage larger amounts of information (de Waard et al., 1999; Ponds et al., 1988), and elderly drivers have deteriorated physiological abilities and are more prone to suffer from glare (Puell et al., 2004). Limited resources allowed us to include at most 40 participants, and to maintain a critical mass in each subgroup, we were left with the choice of either investigating daytime versus night-time effects or different age groups. In this case we selected to study the effects of different light conditions while leaving the equally important question about age to future studies.

As the billboards had already been in place when the study was commissioned, it was not possible to run a baseline-treatment comparison in the exact location of the billboards. This was only considered a minor problem in the analyses of driving behaviour; road stretches in immediate vicinity to the billboards were very similar to those where the billboards were placed, both in terms of geographical factors, traffic density, weather and lighting conditions. Therefore, these stretches could be used as viable baselines.

Conclusions

To conclude, billboards appear to have an effect on gaze behaviour as that they attract more and longer glances than regular traffic signs. This clearly indicates that they do what they are built for. Whether they attract attention too much, that is, whether they are a traffic safety hazard, cannot be answered conclusively based on the present data. This has to be investigated on the one hand in more controlled studies, where traffic situations of varying complexity can be staged and the environment can be controlled in a better way, and on the other hand in on-road studies that do not only consider gaze behaviour, speed and lateral position data, but also tactical manoeuvring and conflicts.

The present study constitutes one part of a larger investigation (T. Dukic et al., 2011), where analyses of speed at a macro level and accident statistics from 2003 to March 15, 2011, were included (no significant differences were found that could be attributed to the billboards when comparing before and after their installation). The Swedish Road Administration also administered a larger questionnaire study (unpublished) which showed that glare and visual clutter was seen as a problem. Based on the results reported here, along with results from the other studies, the Swedish authorities decided not to extend the test period and to remove the billboards under investigation.

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Table 1: Mean and standard deviation of the different gaze behaviour variables grouped by the factors day/night and electronic billboard versus other types of signs.

	Day		Night	
	Billboard	Other signs	Billboard	Other signs
Dwell time (s)	2.23 ± 2.26	0.87 ± 0.73	2.09 ± 2.21	1.16 ± 0.74
Visual Time Sharing (%)	15.29 ± 13.21	9.20 ± 5.84	11.33 ± 11.84	10.80 ± 5.87
Number of fixations (#)	2.68 ± 1.93	1.26 ± 0.45	2.10 ± 1.37	1.50 ± 0.88
Maximum fixation duration (s)	0.95 ± 0.78	0.62 ± 0.55	1.00 ± 0.73	0.70 ± 0.43

Table 2: Mean and standard deviation of the different driving performance variables in groups of the factors day/night and road stretch (at the billboard, before the billboard and after the billboard).

		Day			Night		
		Billboard	Before	After	Billboard	Before	After
Mean velocity (km/h)	S1	86.41 ± 5.53	81.94 ± 5.19	88.03 ± 5.88	83.30 ± 6.93	78.09 ± 5.93	84.28 ± 5.14
	S2	105.43 ± 4.32	105.26 ± 5.33	106.32 ± 4.16	99.04 ± 4.82	98.94 ± 4.86	98.05 ± 5.66
	S3	88.48 ± 8.04	90.85 ± 5.41	90.53 ± 4.30	89.97 ± 5.95	90.31 ± 6.06	89.79 ± 6.63
	S4	82.82 ± 6.17	85.65 ± 4.38	80.42 ± 5.98	82.45 ± 6.66	86.67 ± 5.37	82.64 ± 6.03
Standard deviation of lateral position (cm)	S1	16.76 ± 3.84	16.02 ± 5.70	14.53 ± 5.85	24.20 ± 12.95	14.16 ± 6.60	12.67 ± 3.95
	S2	12.85 ± 3.11	15.62 ± 4.49	14.15 ± 9.83	18.15 ± 11.52	17.16 ± 5.83	14.02 ± 7.41
	S3	14.18 ± 5.07	26.45 ± 20.41	16.65 ± 5.23	12.66 ± 3.88	18.50 ± 7.85	15.94 ± 7.73
	S4	16.31 ± 5.36	17.74 ± 4.60	14.48 ± 5.13	15.66 ± 5.15	19.72 ± 7.36	16.01 ± 7.34
Minimum time headway (s)	S1	1.70 ± 0.73	2.02 ± 1.02	1.90 ± 0.90	1.79 ± 0.82	1.64 ± 0.91	2.32 ± 1.14
	S2	1.86 ± 0.85	1.81 ± 0.84	1.91 ± 0.88	2.14 ± 0.81	2.32 ± 0.87	2.03 ± 0.82
	S3	1.85 ± 0.48	2.25 ± 1.33	1.63 ± 0.34	2.89 ± 1.29	2.56 ± 1.54	2.22 ± 0.98
	S4	1.53 ± 0.60	1.63 ± 0.63	1.65 ± 0.46	1.91 ± 0.84	1.67 ± 0.88	1.60 ± 0.86

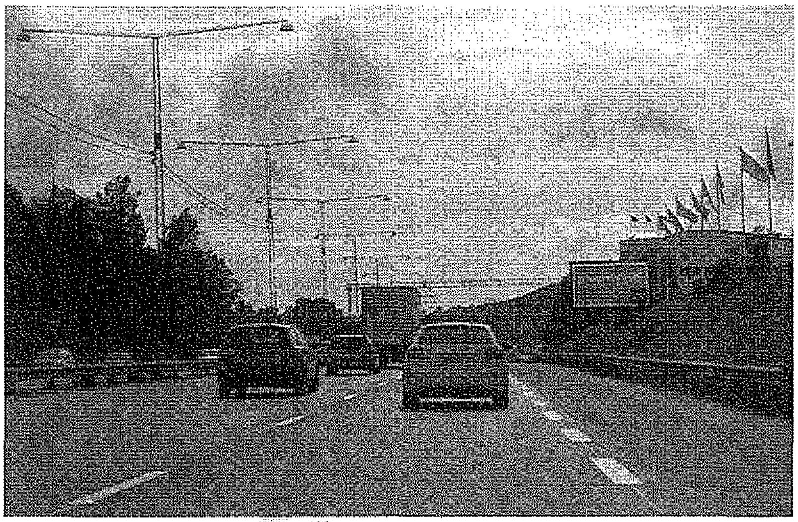

Figure 1: Example showing one of the electronic advertising billboards.

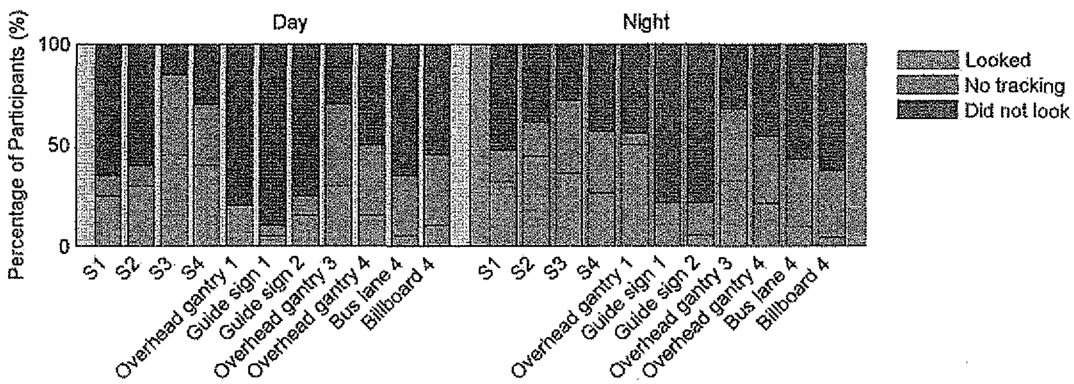

Figure 2: The percentage of participants that looked (green) or did not look (red) at the different signs. Light grey background indicates daytime driving and dark grey background illustrates night-time driving. The number after the signs indicates the location from where the data originates. For example, overhead gantry 1 and guide sign 1 were located in the vicinity of the electronic billboard S1.

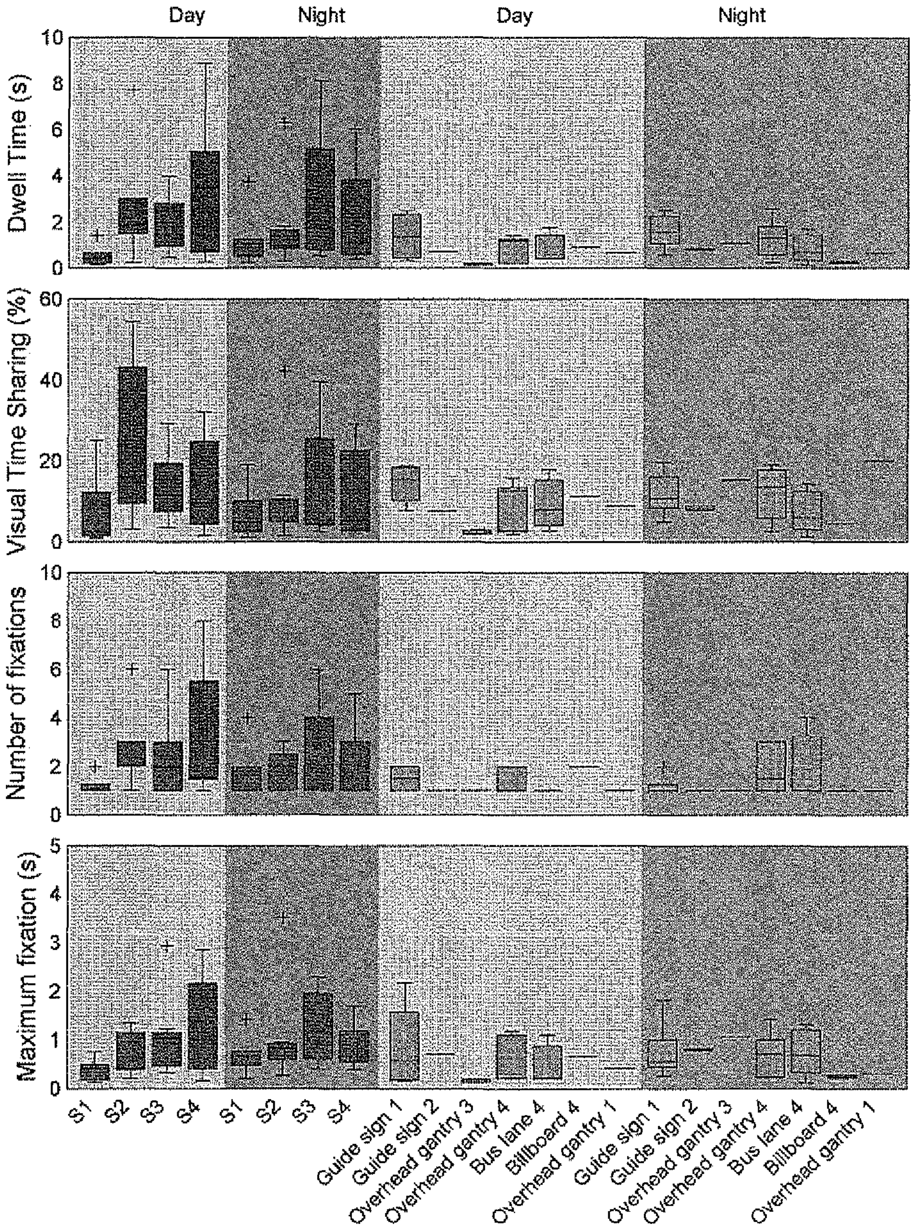

Figure 3: Boxplots of dwell time, visual time sharing, number of fixations and the longest fixations for each sign. Red boxes are electronic billboards, green boxes are other signs. Light grey background indicates daytime driving and dark grey background illustrates night-time driving. On each box, the central mark is the median, the edges of the box are the first and third quartiles, the whiskers extend to the most extreme data points within 1.5 times the interquartile range and outliers are plotted individually.

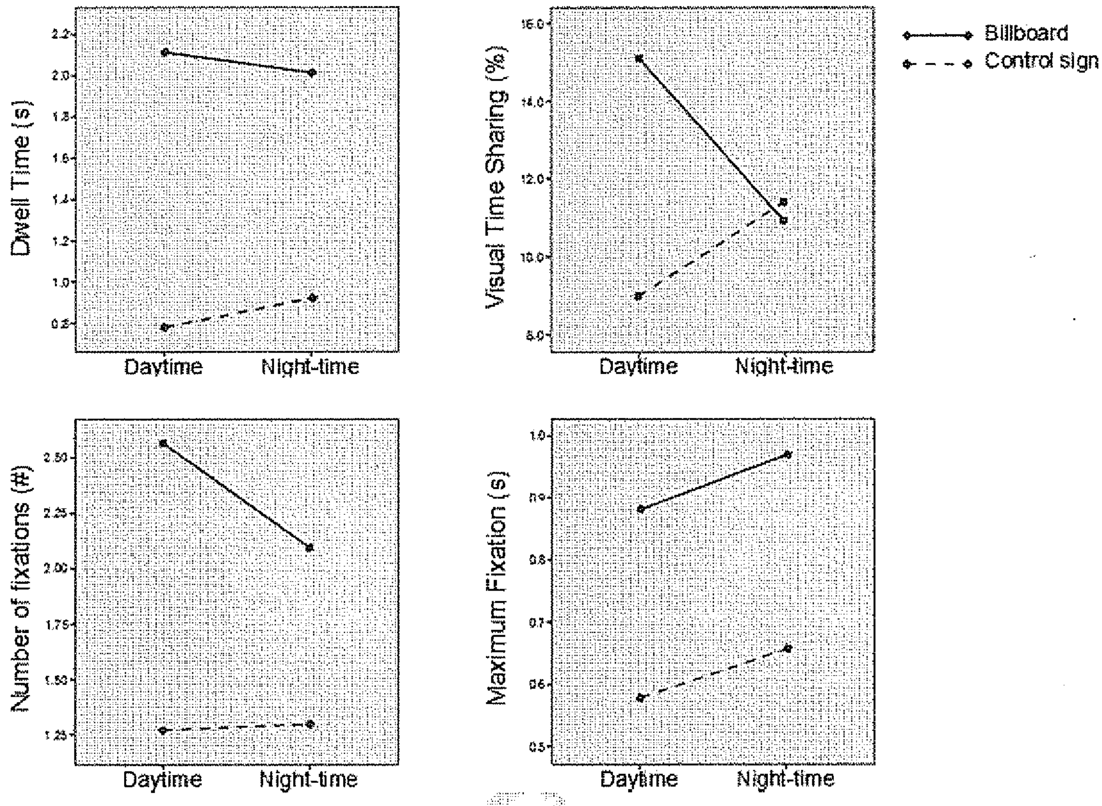

Figure 4: Mean values across participants and signs for dwell time, visual time sharing, number of fixations and the longest fixations for the factors time-of-day and sign-type.

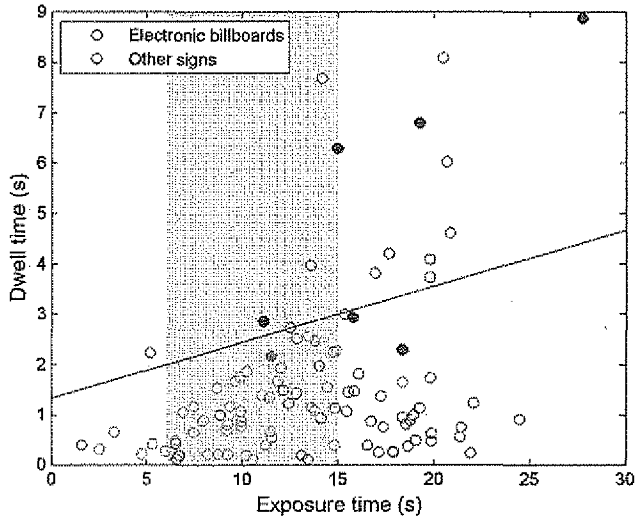

Figure 5: Scatter plot of dwell time as a function of exposure time. Red circles indicate glances at electronic advertising billboards and green circles represent glances at other types of signs. Filled circles represent cases with a single glance longer than two seconds. The line represents a threshold based on the 2-in-6 and the 3-in-15 rules, where all cases above the line are considered as occurrences of visual distraction. The shaded area determines where these rules are considered as valid.