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DRIVER ATTENTION IS CAPTURED BY ROADSIDE ADVERTISING SIGNS

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ABSTRACT

During the last decades roadside advertising has become a major and rapidly expanding industry. Until the last decade, the extent of roadside advertising signs along rural roads has been strongly restricted in Scandinavian countries, mostly for safety reasons and aesthetic considerations. But growing pressure on road authorities caused by significant financial interests has resulted in a rapidly increasing number of advertising signs along rural roads.

The signs are placed at roadsides with the purpose of capturing and keeping driver attention. When the driver's attention is captured, resulting in long eye glances in large horizontal angles away from the road, the time available for driver's response to avoid a crash if something unexpected occurs is reduced. In this perspective, it is relevant to ask whether roadside advertising signs influence driver attention to such an extent that it affects road safety.

With the purpose of investigating, if and how, roadside advertising signs affect road safety a literature study followed by empirical studies has been carried out. The empirical studies were made by using an instrumented car equipped with a camera system to track eye movements, GPS for registration of speed behaviour, and laser scanner for measurement of distances to other road users. Registration data verifies whether the driver is looking at the advertising signs and the number of glances, - including glance duration and glance angles. Those measurements are related to driving speed and distances to other road users and thereby critical situations are detected.

The overall results of the empirical studies show that advertising signs do affect driver attention to the extent that road safety is compromised.



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1 INTRODUCTION

During the last decades, road side advertisement has become a major and rapidly expanding industry and the growing pressure on road authorities caused by big financial interests has resulted in a rapidly increasing number of rural roadside advertising signs.

Signs are becoming larger, and luminous and video advertising signs are used deliberately to capture road user attention. In this perspective, it is relevant to ask whether roadside advertising signs influence the driver's attention to the extent that it disturbs road safety.

The roadside signs are placed with the purpose of attracting and keeping driver attention to a subject irrelevant for the driving task. Every time this objective is met, the driver's attention to traffic and other road users is disturbed. When the driver's attention is captured, resulting in long eye glances in large angles away from the road, the driver's response time to avoid a crash if something unexpected occurs is reduced.

With the purpose of investigating, if and how, roadside advertising signs affect road safety a literature study followed by empirical studies has been carried out.

2 SUMMARY OF LITERATURE STUDY

The literature study includes 41 international references summarised in Herrstedt (2004) and (2011).

Roadside advertising signs are very diverse - as are people. Size, movement and light, however, are very powerful artefacts affecting most of us. Consequently, the advertising industry utilises these artefacts to attract and keep our visual attention.

Several foreign studies, including a study from Brunel University (Young and Mahfoun 2007), have demonstrated that roadside advertising signs has a clear impact on the drivers' lane position control. The results suggest that roadside advertising may increase the mental stress and draw the road user's attention away from the traffic. The effect of roadside advertising may be more pronounced in monotonous traffic situations where the mental stress is low compared to urban area driving, where the mental stress is already relatively high (Chattington et al 2009).

Studies have shown how increased visual complexity in the traffic environment – number of road signs, advertising signs and other information – result in the driver needing more time to search for road direction information (Akagi et al 1996). This accounts particularly for elderly drivers who generally have less capacity to ignore irrelevant information in the traffic (Helmets et al 2004)

Two Danish studies

In a Danish study from 2003, *conflict studies in 4 Copenhagen urban intersections* before and after installation of advertising signs were conducted. Conflict data registration was carried out using the Swedish conflict measuring method developed at the Technical University of Lund (Hydén, 1987; Almquist et al 1999). The analysis is based on a comparison of serious conflicts among road users in those traffic flows mostly exposed to distraction through advertising signs.

The results from the study proved that the number of serious conflicts significantly increased during periods of advertising sign placement in the urban intersections (Andersson & Lund 2003).



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In another Danish study from 2004, *drivers' visual behaviour* while passing a large advertisement located very close to a highway was examined. The advertisement in itself was an airplane which was used as advertisement and showroom by an advertising agency.

Based on 40 test drives using an eye tracking system, it was recorded whether drivers were looking at the advertisement – and for how long. Concurrently, speed measurements and recording of time intervals between cars on the highway were recorded.

The results showed that the driver's attention was captured by the advertisement when passing it on the highway. In most cases (80%) only quick glances of less than 1 second. However, 20% of the glances lasted more than 1 second, and 7% lasted 1.5 seconds or more. In a few cases, glance duration at the airplane was more than 2 seconds.

In a fourth of the test drives, the driver was glancing at the advertisement for more than 1 second with a time interval of less than 2 seconds to the vehicle ahead - in some cases as low as 1 second (Herrstedt & Lund 2004).

Canadian study of video advertisements

During the period 2002-2005, a number of Canadian studies were conducted on the impact of video advertisements on drivers' behaviour in three downtown intersections and on a 6-lane urban expressway in the city of Toronto (Smiley 2005). The study consists of five sub-studies: 1) Registration of eye movement in relation to the advertisements, 2) Conflict studies in the three intersections with and without video advertising, 3) A before-and-after sign installation study of headways and speeds on the urban expressway, 4) Crashes were compared before and after advertising sign installation at the intersections, 5) Stop interviews with drivers for clarification of road user perception of the impact of advertisements on road safety.

The main results of these studies are summarised in the following:

- Video advertisements attracted drivers' attention and in several cases this possessed a danger to the road safety because the time gap to the drivers ahead was very short (1 second or less) at relatively long eye glances (glance duration more than 1.5 seconds) and with relatively wide angles away from the road ahead.
- More than a fifth of all glances towards the video advertisements lasted more than 0.75 seconds. When the driver was looking at the video advertisements, an entire 38% of the time gaps to the driver ahead were less than 1 second. A quarter of the glances at the advertisements went away from the road at an angle of 20 degrees or more from the road ahead.
- Drivers tend to look more at digital video advertisements than at conventional static advertising signs. They glance several times and the glance duration is longer.
- Although drivers looked at video advertisements, when available, in approximately half the cases, the majority of the tracked glances (76%) were directed at the road ahead. Next were traffic lights and street names (7%) and pedestrians on sidewalks (6%). Glances at static advertising signs and video boards accounted for 1.5%.
- On roads leading to the three intersections with visible video advertising a significantly higher number of conflicts in the form of sudden braking was reported
- On roads leading to the three intersections with visible video advertising, a slower start of vehicle was reported at traffic lights changing to green



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- A before & after comparison of driving patterns indicated a slight decrease in average driving speed, while the variation in speeds increased at the same time as the time gap to the drivers ahead decreased when the video advertisements were visible.
- A before & after comparison of traffic accidents in the three downtown intersections showed a 43% increase in the number of personal injury accidents and a 13% increase in the number of rear end collisions in traffic flow at intersection approaches with visible advertisements. However, the differences were not significant.
- 59% of the surveyed drivers say that their attention is attracted by video advertisements and around 6% have experienced near-crash situations caused by the presence of video advertisements.

Inattention increases the risk of conflicts and accidents

During the period 2002-2006, Researchers from Virginia Tech Transportation Institute conducted a comprehensive study, *The 100 Car Naturalistic Driving*, in which 100 drivers drove an instrumented car in their daily life (Klauer et al 2006). This provided a strong base of data e.g. with respect to the drivers' visual behaviour. Also, during the study period 12 accidents reported by the police, 70 less serious accidents of material damage and 761 near-crash situations (serious conflicts), were recorded.

The cumulative average time which the driver looked away from the road in the last 6 seconds leading up to the episode was 1.8 seconds for accidents and 1.25 seconds for near-crash situations. For baseline driving the time was measured to be 0.85 seconds. All differences are significant.

The average duration of the longest glance away from the road was measured to be 1.6 seconds for accidents and just less than 1.2 seconds for near-crash situations. For baseline driving, the duration was measured to be slightly less than 0.80 seconds.

A major finding of the study was that the risk of getting involved in a serious conflict (traffic accident or near-crash situation) was twice as large as usual when drivers were looking away from the traffic (at driving irrelevant stimuli) for periods of 2 seconds or more within a 6 second period.

Video advertisements distract more than static advertising signs

Another study conducted by Virginia Tech Transportation Institute in 2007 (Wachtel 2009) shows that the incidence of drivers' long eye glancing away from the traffic is significantly higher on roads with large billboards. In addition, digital billboards with movement were found to attract road users' attention to a far greater extent than conventional static billboards.

In a British study by the Transport Research Laboratory (Chattington et al 2009) a simulated test compared the impact on driving behaviour of video billboards and static billboards respectively. The main results showed that:

- Drivers glance longer and more frequently at video billboards compared to static billboards
- The billboards affect the drivers' control of lane positioning. The variation in lane positioning is larger at sites with video billboards.
- There are more incidents of sudden braking linked to video billboards.
- The speed is decreased when passing video billboards.



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Generally, video advertising billboards has a bigger impact on road user behaviour compared to static advertising billboards. This corresponds with the experiences of the surveyed persons based on interviews, showing that:

- Video advertisements are more distracting than static advertisements – videos are very distracting.
- Video advertisements are more dangerous to traffic safety than static advertisements
- No difference in the distraction of advertisements placed in the left or right side of the road
- Advertisements placed directly above the road in the visual field are more distracting than roadside placed signs.

Conclusion on the literature studies

Overall, the results from a large number of research projects show, that advertisements – and especially the more aggressive ones – may capture road users' attention to the extent that it affects road user behaviour and traffic safety.

3 NEW EMPIRICAL STUDIES IN DENMARK

The empirical studies have been carried out on rural main roads in Denmark during a four year period starting in 2009.

3.1 Purpose

The purpose was to study whether roadside advertising in rural areas captures and keeps drivers' attention to the extent that it affects driver behaviour and thereby traffic safety.

Initially, the following issues must be clarified:

- A) To what extent are the drivers' visual attention captured by roadside advertisement signs in rural areas?
- B) Do the roadside advertisement signs – or some of them – capture the drivers' attention to the extent that it affects road safety?

3.2 Method

Initially, systematic considerations (method of analysis) were made as to the choice of method. "On road instrumented car studies" were estimated to be most suitable for the purpose. This choice has since been supported by an American method of analysis (Molino et al 2009).

The main features of the applied method is comparable with methods known from other international studies of the distraction effect of roadside advertising signs (Smiley et al 2005 and Dukic, T. et al – VTI 2011).

Test drives have been performed using an instrumented car on 4 different routes in rural areas. The test drivers were asked to drive as usually and they were not informed in advance about the purpose of the drive. Data from these test drives are used as basis for the responses in A and B.

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The instrumented car

The instrumented car includes a SMART EYE 3-camera system for tracking of eye movements, a scene camera for video detection of the traffic situation ahead, GPS for registration of speed and a laser scanner (Ibeo Lux) placed in the car front for measurements of distances to other road users ahead.



Figure 1: The 3-camera system for tracking eye movements together with the scene camera behind the rear view mirror (photo left). The scanner is installed in front of the car (photo right).

Registration data verifies whether the driver is looking at the advertising signs and the number of glances. Glance duration and glance angles are measured as well. Those measurements are related to present driving speed and distances to other road users and thereby critical situations are detected. The three cameras in the SMART EYE system track the head and eye movements of the test driver 60 times per second (60 hz).

The laser scanner tracks all objects in a horizontal angle of approximately ± 50 degrees from the instrumented car's driving direction – and at a driving distance of up to 80-120 m depending on the object's reflection properties. The vertical scanning angle is 3.5 degrees at which four separate levels are scanned. The scanning frequency is 12.5 hz. Laser scanner results are displayed as a scan of the area in front of the car.

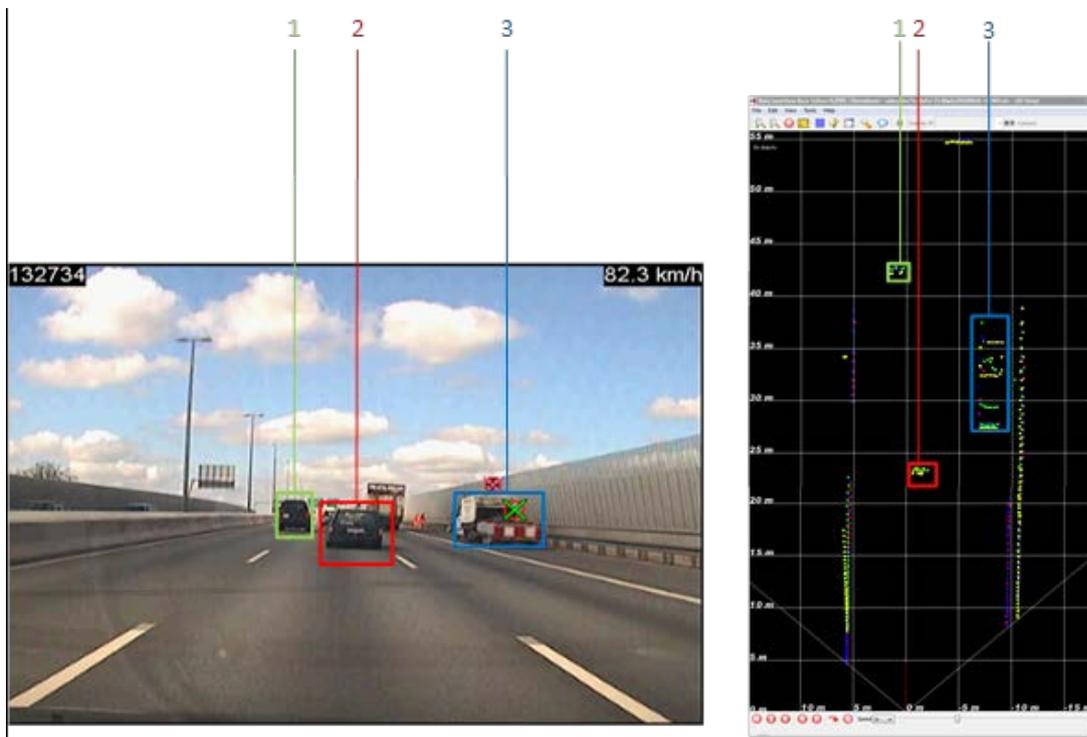


Figure 2: Example. Screen dump photo from the scene camera (left) and the laser scan result (right) from the same traffic situation. The small green cross with the red ring around it on the photo indicates the eye glance direction of the test driver.

Figure 2 shows an example from the scene camera and the laser scan results from the same traffic situation. A screen dump from the scene camera is on the left in Figure 2 and shows the current traffic situation. The driving speed of the instrumented car is shown in the upper right corner of the photo. In addition, the small green cross with a red ring around it indicates the eye glance direction of the test driver. Three vehicles appear in front of the test driver (1, 2, 3). The three vehicles can also be seen on the laser scanner result (right in Figure 2), and the driving distance between the test driver and the vehicles ahead can be read. Based on the driving speed the time gap to the vehicle ahead can be calculated.

Safety buffer

In order to answer question B), a *Safety Buffer* is calculated. The safety buffer reflects the time available for the driver to respond to a sudden critical situation requiring immediate action to avoid an accident.

The time gap to the vehicle ahead is calculated from the length of distance and the driving speed. In situations where the time gap to the vehicle ahead is larger than 3 seconds, the test driver is defined as “free running”, meaning without vehicles ahead.

In situations where the test driver is looking at an advertisement while there is a vehicle within a time gap of 3 seconds ahead, a “Safety buffer” is calculated:

$$T (sec.) = l (sec.) - t (sec.)$$

where

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T = Safety buffer (sec.)
l = Time gap to driver ahead (sec.)
t = Advertising glance duration (sec.)

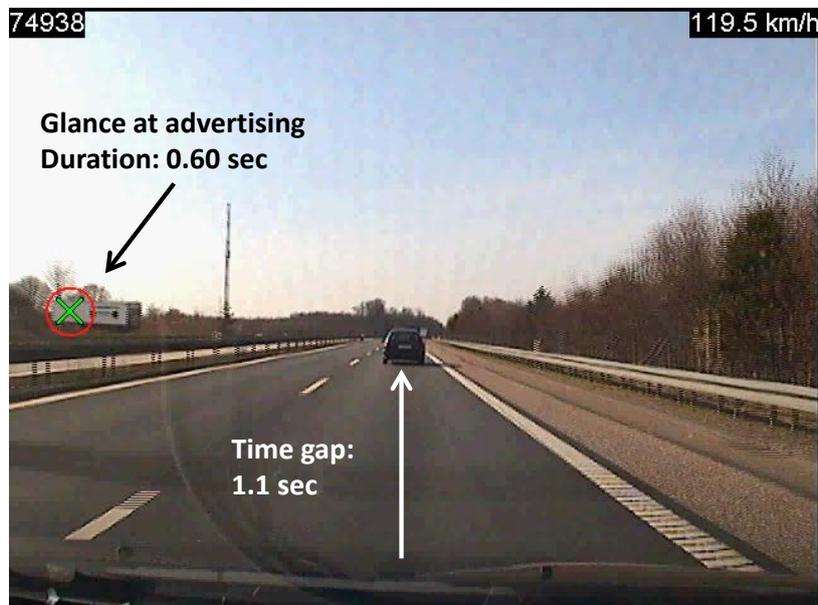


Figure 3: Safety buffer = Time gap to vehicle ahead (seconds) minus advertising glance duration (seconds).

If the distance from test driver to vehicle ahead e.g. is 1.1 second, and the advertising eye glance is 0.6 seconds, a safety buffer of $T = 1.1 \text{ sec.} - 0.6 \text{ sec.} = 0.5 \text{ sec.}$ (Figure 3). In other words, the safety buffer decreases when looking away from the road ahead, and is a measure of the maximum time the test driver has to perceive, interpret and respond to a sudden incident, which the test driver registers after re-directing the eye glance away from the advertisement and back to the road ahead.

Visual distraction

The second key parameter underlying the response to question B) is the amount of registered cases of visual distraction.

When a driver is looking away from the road ahead at driving irrelevant stimuli for a total period of at least 2 seconds within a 6 second continuous period, the risk of being involved in an accident or near-crash situation almost doubles (Klauer et al 2006). These situations are defined as *visual distraction*.

Background data for the analysis

The total data compiled for the analysis includes 109 drive pasts of 16 different static advertising signs. The roadside advertising signs were selected amongst the – by Danish standards – most striking conventional rural roadside advertising signs. Figure 4 shows a few examples.

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All test drives are conducted during the day and outside of peak hours and is divided into 4 different routes located in three different regions around Denmark (Northern Jutland, Funen, Zealand).

The test drives are carried out by 32 different drivers, both men and women, between 23 and 70 years of age. It was a requirement that all test drivers possessed a valid Danish driving license, that they all drove a car regularly, that they were at least 23 years of age, and that they did not need glasses when driving. The latter was necessary to secure data quality from the eye tracking records.



Figure 4: Examples of some of the roadside advertising signs included in the study.

3.3 Results

A total of 109 drives past advertising signs have been completed. A total of 233 glances upon the 16 roadside advertising signs have been registered.

The purpose of the study was to elucidate the two main questions A) and B), as stated in Section 3.1. The primary results of the study are summarised below.

A) To what extent are the drivers' visual attention captured by roadside advertisement signs in rural areas?

The results show that the advertising signs do attract the test drivers' attention. In 69% of all drive pasts the driver was tracked glancing at the advertisement at least once. In almost half of all drive pasts the driver glances twice or more at the same advertisement.

The vast majority of glances at the advertising signs are short. 44% of the advertising glances, however, last more than 0.5 seconds or more. The entire 18% of the tracked glances at advertising signs last 1 second or more (Figure 5).

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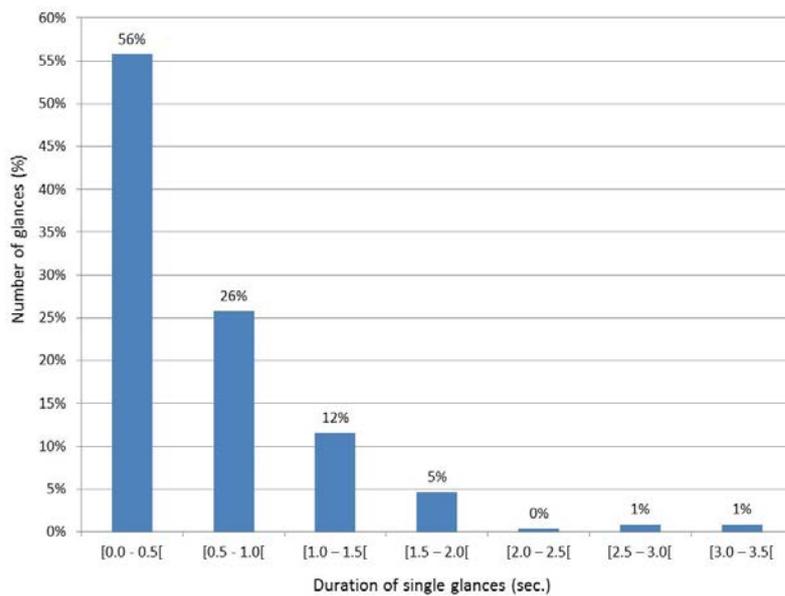


Figure 5: Number of single glances at the advertisements in % distributed on glance duration (sec.)

When looking at the total duration of successive advertising glances at the same drive past, the total advertising glance duration was tracked to 1.5 second for more than 29% of the drive pasts. For more than 22% of the drive pasts the total glance duration is 2.0 seconds or more, and for 10% of the drive pasts the total glance duration is 3.0 seconds or more.

B) Do the roadside advertisement signs – or some of them – capture the drivers’ attention to the extent that it affects road safety?

Safety buffer

In order to answer question B), a safety buffer is calculated. The safety buffer reflects the time available for the driver to respond to a sudden critical situation. The safety buffer is calculated from “time gap to vehicle ahead” and “glance duration”.

In 65 of the 233 advertising glances, a vehicle ahead was present within a time gap of below 3.0 seconds. In these situations, a safety buffer (see Table 1) has been calculated. In 59 cases, representing 25% of all tracked advertising glances, the safety buffer is less than 2 seconds. These 59 cases are divided into 15 different test drivers and 12 advertising signs. For 20% of the advertising glances, the safety buffer is as low as 1.5 second.

Safety buffer to vehicle ahead T (sec)	Glances at roadside advertising sign		
	Number	%	%-cum
<0.0	2	0.9	0.9
[0.0 - 0.5[17	7.3	8.2
[0.5 - 1.0[20	8.6	16.7
[1.0 - 1.5[9	3.9	20.6

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[1.5 - 2.0[11	4.7	25.3
[2.0 - 2.5[5	2.1	27.5
[2.5 - 3.0[1	0.4	27.9
Not estimated (no vehicles ahead)	168	72.1	100.0
Total	233	100.0	

Table 1: Estimated safety buffer to vehicle ahead (time gap to vehicle ahead minus glance duration)

In summary, the results show that approximately ¼ of the tracked advertising glances is associated with a reduction in driving safety as the safety buffer in these situations is less than 2 seconds to the vehicle ahead.

Glance duration and horizontal glance angle

Figure 6 shows the number of advertising glances within the respective measured horizontal angles. Most tracked advertising glances lie at an angle of 5-9 degrees; however, advertising angles of up to 45 degrees have also been tracked. Advertising angles in rural roads generally lie within +/- 10 degrees. The greater the angle when looking away from the road ahead, the more time the driver needs to re-direct the attention to the road ahead.

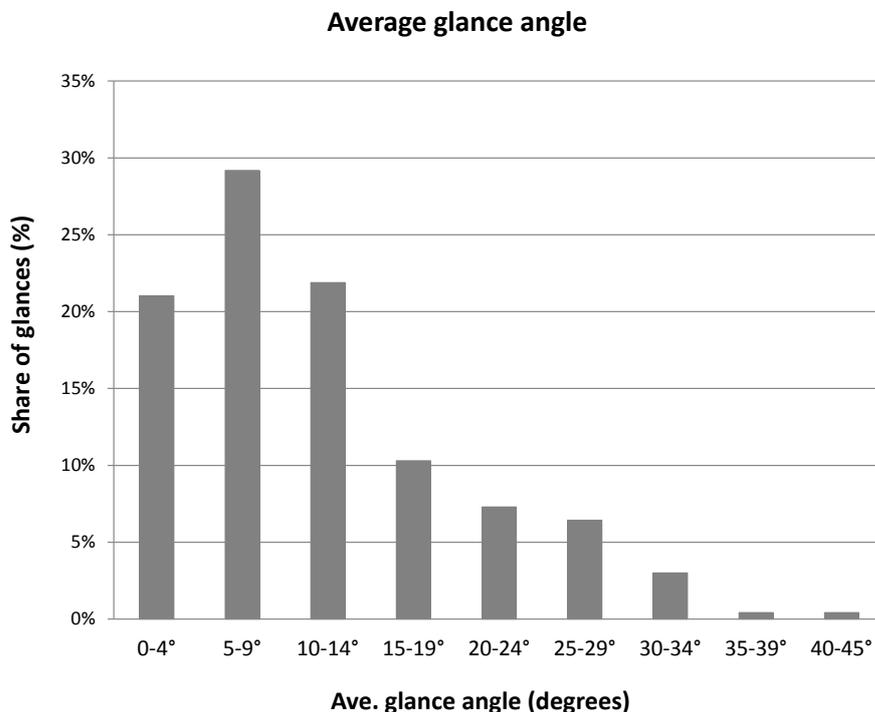


Figure 6: Distribution of horizontal glance angle for glances at advertising signs.

Figure 7 shows all 233 tracked glances at advertising signs by horizontal glance angle and glance duration in seconds. Each dot represents an advertising glance.

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Glances below the red line lie within the “normal range” for Danish rural road driving. All glances above the red line are critical to some extent; either due to large glance angles or due to large glance duration or a combination of glance angle and glance duration. The larger the horizontal glance angle – and the longer the glance duration at the advertising sign – the more critical. Among the 233 advertising glances, 48 glances (21%) lie outside the “normal range” and are therefore regarded critical.

Glance angle (degrees) and glance duration (sec)

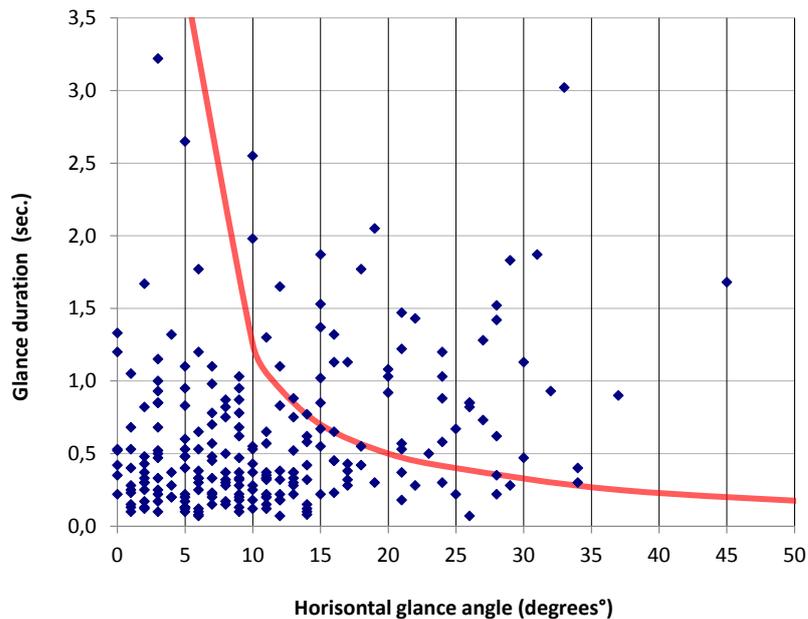


Figure 7: Horizontal glance angle (degrees) and glance duration (sec.) for all glances at advertising signs. Each dot represents a roadside advertising glance. The area below the red line is considered the “normal range”.

Visual distraction

When a driver is looking away from the traffic at driving-irrelevant stimuli for a total period of at least 2 seconds within a 6 second continuous period, the risk of being involved in an accident or near-crash situation almost doubles (Klauer et al 2006). These situations are defined as visual distraction.

The results of this study show that for 17 out of the 109 drive pasts included in the study, visual distraction is taking place. A few more than every 6 drive past is the sum of several successive advertising glances at the same advertising sign in 2 seconds or more within a period of 6 seconds. This means that, for every 6 drive past, visual distraction caused by the advertising sign is a fact.

The 17 drive pasts at which the test driver is visually distracted are divided into 11 different test drivers. Consequently, the impact of advertising signs seems to apply to a substantial part of all road users and is not concentrated on a single – or few – persons. On average, approximately every third test driver experiences a situation of visual distraction.



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The situations of visually distracted drivers are also divided into 8 out of the 16 advertising signs covered in the study.

3.4 Conclusion on empirical studies

Based on the results of the empirical studies using an instrumented car, the following can be concluded in response to the two initial questions A) and B):

A) Results document that drivers' attention is captured by the roadside advertising signs

- In 69% of all drive pasts the driver is glancing at least once at the advertising sign, and in almost half of all drive pasts the driver is glancing twice or more at the same advertising sign.
- 18% of the drivers' advertising glances have glance duration of 1 second or more.
- For 22% of the drive pasts the total glance duration of successive glances is 2 seconds or more.

B) Results show that the drivers' visual attention to the roadside advertising signs does impact road safety

- For approximately $\frac{1}{4}$ of the tracked advertising glances, the safety buffer to the vehicle ahead is less than 2 seconds, and for 20% of the advertising glances the safety buffer is lower than 1.5 seconds.
- More than 20% of the glances are a combination of horizontal angle and glance duration, which lies outside the normal range of road users' visual behaviour on rural roads.
- In more than every 6 drive past visual distraction occurs as a result of the advertising sign.

Overall, the results of the present study therefore show that the investigated advertising signs do capture drivers' attention to the extent that it impacts road safety.

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