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RUNNING LIGHTS—CONSPICUITY, GLARE AND ACCIDENT REDUCTION

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Abstract—The utility of daytime running lights for motor vehicles came under consideration in the United States during the 1960s. In the 1970s, the idea was again taken up, this time in the Nordic countries. At the present time, Finland and Sweden have compulsory daytime running lights (normally low beam) for cars and motorcycles. Norway is expected to follow suit and Denmark, as well as many other countries, has a similar requirement for motorcycles. This report presents the research arguments behind these actions. The report provides the reader with a general background in the area of visual functioning, ambient illumination conditions, detection studies of cars in traffic, experimental studies of vehicle detection as a function of general illumination and running light characteristics and, finally, studies of accident reduction.

BACKGROUND

It is more or less a truism to state that most of the information collected by road users in traffic is visual in nature. It is likewise generally accepted that a considerable number of traffic accidents are caused by the fact that the road users do not detect each other in time (or at all).

The visual system is constructed to react to contrasts and contrast changes in the visual field. Blackwell [1964] made thorough studies of contrast sensitivity, and showed that if the brightness contrast between a target and its background is lowered, the probability for detection of the target also is diminished.

When ambient illumination levels are lowered (e.g. dawn, dusk, twilight) contrast ratios are reduced, and vision is consequently impaired. In addition to this, situations often occur in which the illumination in the visual field is very unevenly distributed. This may lead to misadaptation (bright sky, dark road situations) or to glare (low sun). Such situations further reduce visual contrast. Ambient illumination primarily depends on the sun's altitude and the weather. The sun's altitude is a function of latitude and season, while weather has a more complex background. The closer to the poles, the longer are the twilight periods, as are the periods with low sun and generally low ambient illumination. The twilight period in June, for example, is 215 min in Stockholm (60°N) and 65 min in Rome (40°N). In December, the ambient illumination at noon is five times higher in Rome than it is in Stockholm.

With this as a background, it is natural that the use of daylight running lights to increase visual contrast between the vehicle and the background has met with special interest in the Nordic countries and in Canada. A special working group within the Nordic Road Safety Council is studying the problem and has produced two reports concerning running lights on motorcycles [1975] and on cars [1976].

In the following sections, a series of studies of daylight running lights is reported. In the first section, detection factors in real rural traffic are considered. In the second section, vehicle detection in the peripheral and central visual field is discussed as a function of running light characteristics and level of ambient illumination. In the third section, the effect of daylight running lights on accident statistics is analyzed, based on Finnish data. Finally, the present status of daytime running lights in the Nordic countries is described, and suggestions for needed research are given.

DETECTION OF CARS IN RURAL TRAFFIC

In a preliminary study Dahlstedt and Rumar [1973] studied the factors determining detection of oncoming vehicles in rural daylight driving in Sweden. The study used five subjects driving

along normal two-lane roads in central Sweden in a specially equipped vehicle. As soon as a subject detected an oncoming vehicle, he pressed a button which caused a picture to be taken of the road scene and also started a tape recorder into which the driver described what he experienced to be the main cause of this detection. The experiments were done in the 1960s, when very few cars had low beams on during daylight hours. On the basis of the photos and the driver comments, the principal causes for driver detection of oncoming vehicles during summer and winter conditions were tabulated (see Table 1).

These results suggest the importance of brightness contrast generally and especially of low beams when used as running lights.

Based on the above findings, Dahlstedt and Rumar [1973] carried out a systematic study of car conspicuity as a function of colour of car, background and low beams usage. The primary conspicuity criterion used was time to detect a mockup vehicle (with various colours) photographed on roads against various backgrounds. Ten subjects took part. Besides these detection time measurements, some subjective conspicuity ratings also were obtained. The same ten subjects made magnitude estimations using the least and best conspicuous vehicles as anchoring points with the values 10 and 100 respectively.

The results showed very strong interactions between colour of vehicle and colour of background. The best conspicuity (shortest detection time) was obtained with different car colours, depending on the colour of the background. But—and this was maybe the most interesting result—a conspicuity equal to the one obtained with the best colour contrast in each situation could be obtained for all colours if the vehicle had its low beam lights on (see Table 2). However, since this was a laboratory experiment, the real world validity is not known and further more realistic studies were carried out.

EXPERIMENTAL STUDIES OF VEHICLE DETECTION

Allen and Clark [1964], King and Finch [1969] and Hörberg and Rumar [1975] have studied central conspicuity as a function of ambient illumination level and running light intensity. The conclusion reached from these studies is that when fixated, even vehicles equipped with low intensity running lights (~ 100 cd) have higher conspicuity than vehicles without running lights—especially under levels of low ambient illumination.

From both behavioural and safety view points it can be argued, however, that the most interesting detection situation is the one involving peripheral, rather than central vision. This is

Table 1. Primary cause for detection of oncoming vehicles as reported by five subjects in real traffic

<u>Summer</u> (no low beam cars)		
Brightness contrast	52%	(70% positive, 30% negative)
Colour contrast	16%	
Reflections	21%	(in paint, chrome or glass surface)
Silhouette	3%	(normally towards sky)
Motion	8%	
	100%	
<u>Winter</u> (with snow on the ground)		
Brightness contrast	40%	(40% positive, 60% negative)
Low beam	25%	(= all cars with low beam)
Reflections	17%	
Silhouette	14%	(sky plus snow fields and haze)
Motion	4%	
	100%	

Table 2. Mean exposure time for detection (ms) of a vehicle mock up with various colours with and without low beam. Several backgrounds were tested, this is the result when using a dark forest background. Ten subjects

Vehicle colour	No lights	Low beam
Black	918	407
Dark grey	543	
Light grey	419	
White	395	384
Light yellow	406	
Clear yellow	419	407
Dark yellow	654	
Light red	415	
Clear red	417	
Dark red	471	413
Light blue	435	
Clear blue	457	
Dark blue	544	
Light green	457	
Clear green	468	
Dark green	556	

because when fixated, even very low contrasts are detected (also vehicles without running lights). In other words—the hypothesis is that when vehicles appear where they are expected, where road users focus their attention, the effect of running lights is probably very limited, since vehicles are easily detected anyway and accidents are not likely to occur. However, when vehicles appear where they are not expected, they are not likely to have been fixated but appear, rather in the peripheral field of vision, where contrast sensitivity is considerably lower. In such situations, the accident risk is high, and the favourable effect of daylight running lights should be significant.

Hörberg and Rumar [1975] have systematically studied the peripheral (30° and 60°) detection distance of various running lights (intensity, colour, area) at various levels of ambient illumination (vertical sky illumination of 6000 lx and lower). Figure 1 shows the experimental set-up and Fig. 2 summarizes the results. The 30° and 60° angles chosen can be taken as representative for the position of rear view mirrors or for the attention angles normal in urban traffic (street crossings). Two of the running lights which were produced especially for this test had intensities of 50 and 150 cd each. The test also employed normal halogen Continental European low beam of 400 cd each and high beam of 60,000 cd each. The luminous areas used for the special running lights were 70 and 200 cm².

The results show that in 30° and 60° peripheral vision, running lights with lower intensities (50 and 150 cd) do not seem to improve detection distance over the unlighted car. At those levels luminous areas do not seem to influence conspicuity. At 30°, the low beam has a

Fig. 1. Experimental set up in the daylight test of peripheral vehicle detection distance. The visual task consisted of successively projected letters and digits that the subject should read.

Fig. 2. Mean vehicle detection distance (m) in daylight for two peripheral angles as a function of running light intensity (cd) and surface area (cm²).

considerable effect on detection distance and the high beam is very effective. At 60°, however, low beam has no effect.

In another part of the same study it was shown that although yellow was subjectively rated as having better conspicuity than white light no real difference could be experimentally measured. It was further observed that some glare problems occurred with the high beams also under the general ambient daylight (sky) levels prevalent during the experiments (3000–6000 lx).

In still another part of the same study car and motorcycle conspicuity was compared at 6000 lx vertical sky illumination and at 30° peripheral vision. The running light of the motorcycle was low beam (250 cd). Without running lights the detection distance for the motorcycle was 83 m and for the car 175 m. When the motorcycle used low beam the detection distance increased to 183 m—roughly equal to that of the car without running lights. Janoff *et al.* [1970] report that the number of car drivers reporting having detected an oncoming motorcycle increased two to three times when the motorcycle had its low beam on.

Hörberg [1977] in a special study of peripheral (20°) detection under twilight conditions (100–2000 lx) reports that under no snow conditions even such a low intensity running light as 100 cd has considerable effect at ambient illumination levels lower than about 800 lx. In snow conditions on the other hand even a 300 cd running light has no marked effect above about 600 lx ambient illumination and a 100 cd running light has no clear effect until the ambient illumination is lower than about 350 lx.

Attwood and Angus [1975] and Attwood [1976] in Canada have shown that the possibilities to determine the lateral position on the road of an oncoming car are improved by turned on low beams. They also report that according to perceptual laws a vehicle with lights is estimated to be somewhat closer to the observer than a vehicle without lights. The “lights on” condition on oncoming cars resulted in somewhat safer marginals (longer) in the overtaking situation. Also, running lights should improve the driver’s ability to judge the direction of motion of distant vehicles.

It is generally accepted that when driving at night on well lit roads oncoming low beams deteriorate the visual conditions. But, on the other hand, parking lights are often not conspicuous enough. In the above situation a running light could be a solution. This is the so called city beam. But, could the daylight running light also be used as a night driving city beam? In order to study this problem Hörberg and Rumar [1975] carried out a series of experiments. The results show that the glare effect (reduced detection distance of a dark obstacle) of a 150 cd city beam is only about half that of a low beam. On the other hand peripheral (80°) detection

distance of a car with low beam is about 50% longer than that of a car with 150 cd city beam. In conclusion, it could be said that if it were not for the visibility of retroreflective materials on road markings, road signs, vehicles and unprotected road users the city beam should have an intensity which is considerably lower than that of a daylight running light. This has also been suggested by several authors [e.g. Balder, 1957; Dahlstedt, 1973; Fisher, 1974; Hisdal, 1973; Jehu, 1963; Nielsen, 1974; Schreuder, 1974].

RUNNING LIGHT EFFECT ON ACCIDENTS

In the 1960s several more or less controlled studies of the effect of running lights on accidents were carried out in U.S.A. The best known is probably the Greyhound bus study from 1962. The company reported a 10% decrease of accidents. Allen [1965] described a questionnaire study of about 50 companies that installed running lights on their vehicles. Results suggested accident reduction for vehicles with running lights was close to 40%. Cantilli [1968] studied the effects of running lights on accident among vehicles belonging to Port of New York Authority and reports a reduction of 18%. Allen [1970] states that a Chicago taxi company obtained an accident reduction of 12%. Janoff *et al.* [1970] in probably the best controlled accident study of running lights so far, reports about experience from four U.S.A.-states with compulsory running lights for motorcycles and concludes that the use of running lights led to a 4% accident reduction. Attwood [1975] describes a large Canadian study in progress with 350 matched cars. In this study the accident effect as well as the practical, technological and economical effects will be studied.

The most recent, largest and best-controlled accident study is the one carried out by Andersson, Nilsson and Salusjärvi [1976] on Finnish data for the years 1968–74. As a result of successive degrees of legislation (publicity campaigns during 1968–70, recommendation for use of running lights during 1970–72, and mandatory use after 1972), the frequency of cars using low beams during daylight hours in rural areas during the winter half-year progressively increased until during the compulsory period, it was 93–99%. The basic hypothesis in the study was that during the winter half-year running lights should affect *multiple accidents in daylight*, while other accident types should not be affected and could, consequently, be used as controls. The control groups used were multiple accidents in darkness, single accidents in daylight and single accidents in darkness.

For these four accident categories a regression analysis was made for the period 1968–74. The results show:

1. Multiple accidents in daylight decreased by 32%.
2. Multiple accidents in darkness decreased by 4%.
3. Single accidents in daylight decreased by 4%.
4. Single accidents in darkness increased by 6%.

The overall accident reduction was approx. 10%.

By forming the ratio

$$\delta = \frac{\frac{\text{number of daylight multiple accidents}}{\text{number of darkness multiple accidents}}}{\frac{\text{number of daylight single accidents}}{\text{number of darkness single accidents}}}$$

the effect of measures having general influence, multiple/single influence and daylight/darkness influence on accidents may be minimized. With this method of analysis, a reduction of daylight multiple accidents of 21% during the period 1968–74 was demonstrated. A more detailed analysis of accident types shows that head-on accidents decreased by 28%, accidents involving crossing paths decreased by 17% and rear-end accidents increased by 9%. Also, daylight pedestrian accidents decreased by 24% during the time period studied.

This study, which was initiated by the above-mentioned Working Group within the Nordic Road Safety Council, concludes that although accident analyses such as this one always are difficult due to other variables and variation in external conditions, the results strongly indicate

the favourable effect of running lights predicted by the above mentioned behavioural experiments. In a way the results can be taken as a validation of the behavioural studies.

PRESENT STATUS

In Sweden the use of running lights during daylight hours has been considerable, especially in lowered daylight conditions (e.g. twilight, bad weather). In the winter of 1975–76, the usage of running lights in rural areas in Sweden was studied by Sävenhed [1977], who reported that on the average, 3 cars out of 4 used low beams or special running lights. In poor illumination conditions the usage was above 90%, while in good illumination conditions, 50% of the cars have their lights on.

With these data as a background, it is not surprising that since 1 October 1977, the use of low beam or special running lights has been compulsory in Sweden during daylight hours. As mentioned above, Finland already has such a law, Denmark has it for motorcycles (as do several other countries, e.g. France), and Norway is expected to follow suit in 1979.

NEEDED RESEARCH

Two problems concerning running lights still remain to be solved. The first one is determination of the optimal characteristics of a running light. A special Swedish committee is presently preparing a draft standard in this area. The main question is the range of acceptable intensity. The present proposal is 300–800 cd. In this context, integration of the running light with a city beam has also been discussed, but no conclusion has yet been drawn.

The other problem concerns what to do about those vehicles for which running lights are presently not compulsory (e.g. tractors, mopeds). It is a reasonable hypothesis that the relative conspicuity for those vehicle categories will be reduced when a majority of the other vehicles in traffic use running lights. A recent study of Attwood [1979] reports the glare (masking) effects. But the expectation effect may be larger.

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