ROAD SAFETY AND DAYTIME RUNNING LIGHTS

A concise overview of the evidence

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SUMMARY

Studies of road accidents in Japan, Canada and the Federal Republic of Germany show that human perception errors and perception related misjudgments form a main causal factor in road accidents, ranging from about 20% to about 50%. Types of conflicts for which daytime running lights (DRL) may be benificial, such as overtaking collisions and crossing collisions, are overrepresented in daylight accidents. A reduction of accidents would occur if DRL would match the selective perception of traffic in darkness. Estimations of distance to other road user are shorter if DRL is on, while visibility as such is only partially enhanced. These perceptual results points to an explanation of the effect of DRL as based on the enhancement of timely perceptual selection and judgement, instead of based on the enhancement of mere visibility only.

Studies on the effect of changes in the use of DRL in Finland, Sweden and Norway report reductions of 22% to 40% for multiple daytime accidents. Studies in the USA and Canada for large fleet-owners introducing DRL show reductions from 7% up to 32% for multiple daytime accidents.

The generality to Western Europe or The Netherlands have been questioned, because of the better daylight conditions due to the southern latitude, the relative dominance of built-up areas and the larger share of cyclists and pedestrians in traffic. The Swedish results indicate that no marked reducing effect is to be expected from better daylight conditions in the summer.

Also the fleet-owner results only show a minor influence of the degree of latitude on the reduction of daylight accidents: in Canada 24% (mean latitude about 51°), in New York 18% (latitude 40°) and the mean effect for four fleets over entire USA 18% (mean latitude 39°). From the relation between latitude and the results of the nine studies, it can be concluded that even on the level of Rome (42°) the estimated effect is still just below 20%. This expectation is in accordance with the given perceptual explanation for the effect.

A greater effect on the reduction of conflicts between cyclists or pedestrians and cars is observed in the Norwegian (-49% pedestrians) and Swedish (-43% cyclists and -35% pedestrians) studies. This greater effect can be explained by the fact that cyclist and pedestrians can nearly always avoid a collision even at short distances, once the danger is percieved. This explains the vivid psychological and political objection of cyclist

and pedestrian associations in The Netherlands that an obligation for DRL puts a greater burden on the shoulders of pedestrians and cyclists. This cannot be denied; neither their own safety benefits. Since pedestrian and cyclist accidents are mainly located in built-up areas, one might expect also a greater overall effect on urban roads. This seems, however, not to be the case since the effect for multiple car accidents on urban roads tends to be less than on rural roads. This can be explained by shorter sight distances in built-up areas.

Criticism has been cast on the validity of the studies mentioned. It must be agreed that none of the single studies in itself is completely convincing: the large effect of the Norwegian study cannot be explained; the Swedish study is based on relative small and fluctuating numbers for single and darkness accidents; the Finnish study only pertains to rural roads in the winter; results found in fleet-owner studies may be diminished by an obligation for all vehicles. To these critics comes the weakness of field studies as such: there always may be other, even unknown, simultaneous explaining factors. However, no study leads to an adverse or non-positive effect. Explanation of results in nine independent studies by many different hypotheses, is untenable from a scientific point of view as one common explanation consistent with theory and all the (sub)results is available. The sound scientific overall conclusion is that DRL has a significant effect on road safety.

Therefore, it is concluded from the studies that in Europe and particular in The Netherlands, an obligation for DRL will most likely reduce the number of daytime multiple accidents by about 25% and will surely reduce these accidents by more than 10%. Since in The Netherlands the number of these accidents is about half the total number of accidents, the expected reduction of the total number of accidents is at least 5%. The measure has surely a very good cost-benefit ratio; total costs will increase by less than Hfl 30.- per car per year.

An extensive experimental and evaluative study up to a two year after period is planned. Theoretical research and literature surveys are used to test specific hypotheses. Apart from results on specific perception processes the two main expected results are: flank and head-on car collisions in daylight will be reduced by more than 10% and collisions of cars with mopeds, cyclists and pedestrians at daylight will be reduced by more than 20%. If the obligation is introduced at the end of 1990 in The Netherlands, the final Dutch results will be reported in 1993 in English.

VISUAL PERCEPTION AND ROAD SAFETY

There is no doubt that visual perception is vital to traffic safety. Visual perception is not only determined by visibility, neither is it independent of cognition. Perception is closely related to the attention level, the selection and the activation of memory elements and also to the central information processing that leads to judgments and motor performances. Perception in driving generally takes place in dynamic conditions. Perception in traffic is active cognitive perception and may be better described by foreseeing. Seeing elicts in the experienced road user a selection of elements that are considered to be relevant for the dynamic behaviour of himself and of others. He has to foresee the next coming conditions by a routinely prediction of the behaviour of other road users, in order to adjust his own behaviour. Incorrect seeing and incorrect selection of elements for foreseeing in traffic can be fatal. Studies of accidents by analysis of situational evidence and by interviewing involved road users have revealed that human perception and judgment errors play a dominant role in the causation of accidents. A detailed study from Japan (Nagayama, 1978), for example, specifies the following percentages of factors in the main causes of 38,625 accidents.

Main cause	Percentage
Preoccupied with other things and/or did not notice	21.6
Obstructed visibility	8.1
Believed enough attention was paid	16.3
Delayed perception for other reasons	7.8
Subtotal Perception	53.7
Believed other party would avoid collision	4.9
Other misjudgments (road, signals, etc.)	32.3
Subtotal Misjudgment	37.2
Other non-human or unidentified factors	9.1

Table 1. Classification of accidents by type of human error

These findings are in accordance with Canadian observations where 43% of the accidents where contributed to perception errors and a German in-depth study (Otte et al., 1982) identifying 25% as caused by insufficient information processing.
Enhanced conspicuity of the relevant dynamic elements in traffic may enable the road user to notice them earlier and to select better the elements for the proper judgments; such as distances, speeds, and direction of correctly identified vehicles. Indeed experimentel research (Attwood, 1976 and Hörberg, 1977) proved that distances are judged better with daytime running lights. DRL, daytime running lights, may serve that purpose and probably reduce accidents of certain types. Therefore, one may expect that those types of daytime accidents which should benefit from DRL's, like overtaking and crossing collisions, will be relatively less frequent in darkness. In order to investigate this hypothesis, an analysis of the injury-accident data of 1987 in The Netherlands was carried out. The frequencies of overtaking and crossing accidents on intersections and straight road-sections in daylight and in darkness with street lighting are compared with other multiple accidents in these conditions. Accidents in twilight were omitted, as it is not known whether the vehicle lighting is on or not. Accidents in curves or roundabouts and accidents in darkness on roads without street lighting were also omitted, since it is known that these situations are more dangerous at night due to these perceptual road factors. In Table 2 we present the results.

Type of accidents	Daylight	Dark + streetlighting	Ratio
right of way overtaking street intersections	8628	1801	4.8
other multiple accidents	19709	4693	4.2

Table 2. Injury accidents 1987 in The Netherlands at crossings (T-crossings included) and straight road-sections.

The ratio of accidents in daylight and in darkness for the types of conflicts that benefit most from DRL is 14% higher than the ratio of other

multiple accidents which are believed to benefit less from these lights. If DRL would in daylight condition match the selective perception of traffic against their background in darkness with street lighting, one would expect a lower ratio for these daylight multiple accidents.
Since visibility as such during daylight is normally better than during darkness with street lighting, the eventual effect of DRL must not only be sought in better visibility but in the activation of correct attention; for example to the field of peripheral vision, and the selection of relevant cues for foreseeing, like cues for estimation of speed and distance. A typical Dutch type of accident may illustrate this. The type of accident is called "polder blindness". Two cars driving in daylight on two intersections roads in our new polders collide not infrequently at an intersection. These roads have low traffic volumes and are straight, easy or even boring to drive and comfortable, while intersections are very conveniently arranged without visual obstructions. No doubt the crossing cars are very well visible from a long distance in the wide horizon of the flat landscape. Still they collide. The nearly automatic driving mode, so it seems, brings the driver in a passenger mode. DRL may induce the attention and reaction of the night-driving mode. This example suggests that DRL may not only effect visibility, but may also activate visual information selection and processing. It may help to correct unjustified beliefs about the subsequent position of the other road user.

DIRECT EVIDENCE ON THE SAFETY EFFECT OF DAYTIME RUNNING LIGHTS

The evidence for the safety effect of DRL comes from two types of studies. Studies on a national scale with changing levels of the use of DRL and studies of the effect on the introduction of DRL by large fleet-owners. The obligation was first introduced in Finland for rural roads in winter time in the early seventies, later in Sweden in the late seventies and in Norway for new cars in 1986. In Canada the obligation holds for new cars from december 1989 on. The results of the reported national results are given in Table 3. The effects in these national studies are estimated from the reduction of developments in multiple daylight accidents with respect to developments of accidents in darkness and single accidents. Single vehicle accidents are not effected by DRL and serve as control group.

Country	Change from % to %	Observed % effect	Estimated %[x)] total effect
Finland	50% -> 97%	- 21%	- 36.5%
Sweden	55% -> 98%	- 11%	- 22.5%
Norway	35% -> 65 %	- 14%	- 40%

Table 3. Effects of daytime running lights on multiple day-light accidents in the Nordic European Countries.

The Norwegian and Finnish results are rather high. The Norwegian author (Vaaje, 1986) concludes: "that the increased use of daytime running lights constitutes the only explanation for this large difference, is however not likely", but he also states that other factors were not discovered. Statistically the Finnish and Norwegian results were significant. The Finnish results (Anderson et al., 1976) applies to winter-time rural road accidents. The Swedish study (Anderson & Nilsson, 1981) is the most detailed study. Distinction is made in multiple daylight accidents between summer and winter, between head-on, flank and rear-end car-car collisions, and collisions of cars with cyclists and of cars with pedestrians. The comparison with single accidents and darkness multiple accidents were not statistically significant in the Swedish study, mainly because of the simultaneous decrease in multiple car-accidents in the darkness. Some detailed comparisons, however, were statistically significant; especially the reduction of accidents beween cars and cyclists or pedestrians. This significance, however, is partly the result of increasing darkness accidents of that type. Despite these statistical inconsistencies Rumar (1981) concluded that "the obtained effects on accidents coincide well with the results from the Finnish study".

[x)] The relation between the observed effect (e) and total effect (t) is computed from the percentage before (b) and after (a) by

$$\frac{1 - t.a}{1 - t.b} = 1 - e \text{ or } t = [(a-b)/e + b]^{-1}$$

Source	Method	Vehicle type	Area	Effect
Cantilli (1965, 1970)	control group	cars	New York	- 18%
Allen & Clark (1964)	before/after	buses	USA	- 12%
id.	id.	buses	Canada	- 24%
Attwood (1981)	before/after	lorries	USA	- 32%
id.	control group	taxis	USA	- 7%
Stein (1984)	control group	cars	USA	- 22%

Table 4. Effects of DRL at large fleet-owners in North-America.

The oldest studies on the effect of DRL come from results of the introduction by large fleet-owners in North-America. In Table 4 these results are summarized.
The problem with studies at fleet-owners is that effects of DRL may diminish if all the vehicles have DRL, since the effects may be due to their higher conspicuity compared with other vehicles. One even may assume that, with a high level of DRL-use, accidents for vehicles without DRL will increase. The above findings of the national studies indicate that such interactive or countereffects are not manifest. We conclude therefore that the results of fleet-owner studies are in line with the national results.

THE GENERALITY OF RESULTS

The generality to Western Europe or The Netherlands of these results has been questioned for three reasons. Firstly because of the better daylight conditions due to the southern latitude compared to the Scandinavian countries. Secondly because of the relative greater shares of built-up and denser populated areas in the more southern countries. Thirdly, especially for The Netherlands, because of the larger proportion of cyclists and pedestrians in traffic.
The Swedish results indicate that no marked reducing effect is to be expected from better daylight conditions in the summer compared with the winter in Sweden. Also the fleet-owner results only show a minor influence

of the degree of latitude on the reduction of daylight accidents: in Canada 24% (mean latitude about 51°), in New York 18% (latitude 40°) and the mean effect for four fleets over entire USA 18% (mean latitude 39°).
Because no interactive or countereffects for partial DRL use were shown (see also Helmers, 1988), we may assume that fleet-owner effects are indicative for national usage effects. Under this assumption we may relate effects of fleet-owners and total national effects with latitude over a broader range of latitudes. This relation is presented in Figure 1. The effective mean latitudes for Canada, Norway, Sweden and Finland are taken to be one third of the range of latitudes above the southernmost latitude of the country, as the population and traffic is concentrated there.

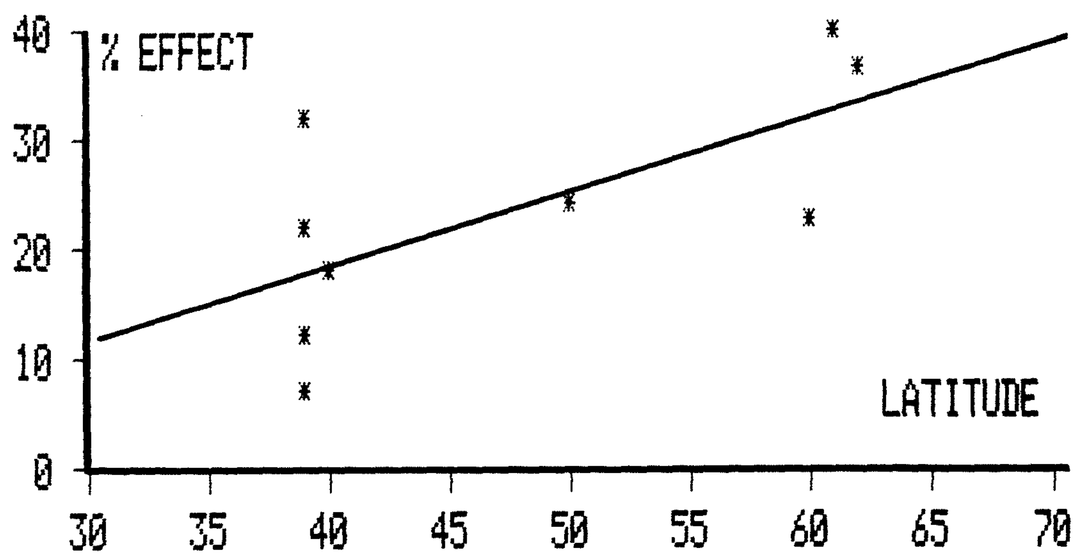

Figure 1. Relation between latitude and total DRL-effect

From the statistical non-significant correlation (r=0.45) between latitude and the results of the nine studies, it can be estimated that even on the latitude of Rome (42°) the effect is still just below 20%.
This expectation is in accordance with the given perceptual explanation for the effect of DRL, as only partially a matter of mere visibility. Since visibility as such is better in more southern countries and will partially influence the effect of DRL, the decreasing figure is also theoretically to be expected. For the location of The Netherlands one would predict an overall effect of about 25% reduction for multiple accidents.

A greater effect on the reduction of conflicts between cyclists or pedestrians and cars is observed in the Norwegian study (with a total DRL-effectivity for pedestrians of -47%) and Swedish study (with a total DRL-effectivity for cyclists of -38.5% and for pedestrians of -32.5%). This greater effect can be explained by the fact that cyclists and pedestrians can nearly always avoid a collision even at short distances, once the danger of a car is percieved. This explains to the vivid psychological and political objection of cyclist and pedestrian associations in The Netherlands that an obligation for DRL puts a greater burden on the shoulders of pedestrians and cyclists. This can not be denied; neither their own safety benefits. One may expect that a larger proportion of pedestrians and of cyclists in traffic will not reduce the effect of DRL. It even may lead to an increase of the effect of DRL if no other countereffects in areas of high concentrations of cyclists and pedestrians are to be expected.

Since collisions between pedestrians and cyclists with cars primarily take place in built-up areas, one might expect also a greater overall effect of DRL on urban roads. This seems, however, not to be the case since the effect for multiple car accidents on urban roads in the Swedish study tends to be less than on rural roads. This can be explained by the shorter sight distances in built-up areas (even DRL can not be seen around the corner).
Due to the plausible and empirically indicated opposite changes in effects for multiple car accidents and for cars in collision with pedestrians or cyclists in built-up areas, it is not expected that the total effectivity of DRL willl be different for rural and urban roads.
The conclusion seems to be that the effects of DRL can be fairly well generalized for other countries. The total expected effect of DRL in a country may be determined by the cautious use of Figure 1.

THE ANSWER TO DOUBTS AND CRITISISM

Criticism has been cast on the validity of the studies mentioned. It must be agreed that none of the single studies in itself is completely convincing.
The Norwegian study shows an effect higher than expected, for which other

additional explanations must be found. If so, why then not assume that these still unknown factors can explain the total result?
The Swedish study is based on relative small and fluctuating numbers for single and darkness accidents. Their results are statistically not significant, so why consider them?
The Finnish study only pertains to rural roads in the winter. It can easily be argued that these results may be only of importance on icy roads under the northern light. It has even been argued that the effect on fatal accidents is no longer significant if fatal accidents with elks are omitted from the Finnish data. So what can the relevance of these data be?
Effects of DRL in fleet-owner studies may be quite well explainable by the exclusive position of these vehicles in traffic or by the simultaneous change in driver behaviour induced by the positive expectations of DRL by the company. If so the effect will be less with an obligation for all vehicles. So why consider them as evidence?
To these doubts and critics comes the weakness of field studies as such: there always may be other, even unknown, simultaneous explanatory factors.
Every good scientist should have his doubts !

Good scientists, however, also consider cumulative evidence in rejecting and accepting hypotheses and theories. It is a good scientific practice and a statistically founded procedure to add information from independent sources, both statistical significant and non-significant results, to one estimation of the likelihood of a hypothesis. And it must be noted that none of the nine studies finds an adverse or non-positive effect.
Questions on validity may exist but explanation of results in nine independent studies by many different hypotheses, is untenable from a scientific point of view as one common explanation consistent with theory and all the (sub)results is available.
The sound scientific overall conclusion, therefore, must be that DRL has a significant effect on road safety.

THE NETHERLANDS AS A NORTH-WEST EUROPEAN EXPERIMENT FOR DRL

An extensive experimental and evaluative study up to a two year after period is planned in The Netherlands. The research will be carried out by two independent scientific institutes, namely at SWOV Institute for Road Safety Research and at IZF-TNO Institute for Perception of the Netherlands Organization for Applied Scientific Research.

Theoretical research and literature surveys are used to test the hypotheses. Apart from results on specific perception processes the two main expected results are: flank and head-on car collisions in daylight will be reduced by more than 10% and collisions of cars with mopeds, cyclists and pedestrians at daylight will be reduced by more than 20%. If the obligation is introduced at the end of 1990 the final Dutch results will be reported (in English) in 1993.

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