

**Review of the evidence for motorcycle and motorcar
daytime lights**

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Summary

The paper reveals the defects of method, conduct or findings of *Janoff et al 1970*, *Andersson et al 1976* and the other main monitoring studies to date of the effect of motorcycle and motorcar daytime light laws. It weighs up the prima facie arguments for and against motorcycle and motorcar daytime lights, and predicts that on balance motorcar daytime lights may manifest a net safety disbenefit. It approves the method of *Olson et al 1981*'s motorcycle gap acceptance experiment, but notes the limited import of the findings. It finally canvasses how ostensible motorcycle 'conspicuity' accidents that in fact have other causes can be prevented.

Keywords

Daytime running lights lamps DRL DRLs motorcycle motorcycles motorcar motorcars accident accidents safety research conspicuity visibility odds ratio fleet study studies Perlot Prower 2003 ACEA ACEM Bijleveld Koornstra Elvik Farmer Williams NHTSA FEMA BMF

Abstract

The accepted remedy for motorcycle—and to a lesser extent also motorcar—'conspicuity' accidents with other vehicles or pedestrians in daytime is daytime lights.

So in 2002 the European motorcar manufacturers (ACEA) made an offer to the European Union to fit daytime lights to all new motorcars; and shortly after the European motorcycle manufacturers (ACEM) agreed amongst themselves also to fit them to all new motorcycles.

Against this background, the paper first, 'negatively', critically reviews the main evidence and arguments that motorcycle (or motorcar) daytime lights are effective to reduce accidents. In the course of the review the paper:

- a) Reveals the defects of method, conduct or findings of *Janoff et al 1970*, *Andersson et al 1976*, and the other main monitoring studies to date of the effect of motorcycle (or motorcar) daytime light laws;
- b) Concludes on the balance of the prima facie arguments for and against the use of motorcar (and motorcycle) daytime lights that an overall net safety benefit from daytime lights is not assured — indeed a net safety disbenefit from motorcar daytime lights cannot be discounted; and
- c) Considers the highly persuasive—but time and place specific—findings of *Olson et al 1981*'s experimental field study of the effect of motorcycle daytime lights upon the gap acceptance behaviour of ordinary motorcar drivers in Ann Arbor, Michigan.

The paper second, 'positively', describes the other possible causes of an ostensible motorcycle daytime 'conspicuity' accident besides an actual 'Lack of conspicuity of the motorcycle', such as 'Obscuration of the motorcycle' or 'Arbitrary estimation of the motorcycle's speed'.

It describes the research that remains to be conducted in order formally to establish the causes in question.

The paper finally canvasses some of the important means of prevention of motorcycle 'conspicuity' accidents that might potentially flow from successfully establishing the causes.

Review of the evidence for motorcycle and motorcar daytime lights

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Review of the evidence for motorcycle and motorcar daytime lights

1. Introduction

Daytime lights enhance the conspicuity of motorcycles.

And it is widely held by motorcyclists that in turn they prevent accidents between motorcycles and other road users.

But now daytime lights are used more and more also by motorcars.

And motorcyclists fear that their own lights will be masked, so that they will lose the advantage that they presently derive from them.

It is therefore timely:

- To review the evidence in favour of both motorcycle and motorcar daytime lights
- To consider in the light of the evidence how far the use of daytime lights by motorcars as well as motorcycles is likely to enhance overall road safety
- To review some of the other remedies for motorcycle accidents that compete for attention with the use of daytime lights.

2. Evidence of monitoring studies of effect of motorcycle and motorcar daytime lights

2.1 Motorcar daytime lights: 1960–1995

Origins: Per *Kendall 1979*, the history of motorcar daytime lights may be dated back to a 'Light up and Live' campaign that the Governor of Texas initiated in the early 1960s.

In the late 1960s various traffic and road safety organisations in Finland campaigned in favour of the use of daytime lights. In 1970 the Finnish Government issued an official recommendation to the drivers of all motor vehicles that they use daytime lights in winter outside built-up

areas. And in 1972 Finland enacted a law that made it compulsory for all vehicles to use daytime lights in the same circumstances.

In 1976 Andersson et al published a monitoring study—*Andersson et al 1976*—of the effect of the Finnish official recommendation and law. The study found that both recommendation and law been followed by a reduction of accidents.

Accordingly in 1977, on the basis of *Andersson et al 1976*'s findings, Sweden also made the use of daytime lights compulsory for all vehicles. The Swedish law was not confined to winter or built-up areas, but applied all the year round to all areas.

In 1981 Andersson & Nilsson in turn published a monitoring study—*Andersson & Nilsson 1981*—of the effect of the Swedish law. The study found that the law had been followed by a reduction of accidents, but the reduction was not statistically significant.

Since then a number of other countries, including:

- Norway (Motorcar fitting law 1985; use law 1988)
- Denmark (Motorcar use law 1990)
- Canada (Motorcar fitting law 1989)
- Hungary (All-vehicle use law [Main roads outside built-up areas] 1993; [All roads outside built-up areas] 1994),

have in turn also enacted motorcar or all-vehicle daytime light use laws, or laws—'fitting' or 'hard-wiring' laws—that require the installation of daytime lights on new motorcars.

Odds-ratio method of *Andersson et al 1976*: Nevertheless, right from the outset, the evidence in favour of motorcar daytime lights was fatally flawed.

Andersson et al 1976 used the 'odds-ratio' test to analyse the Finnish data for the predicted fall in daytime multi-vehicle accidents (or as they chose to analyse the data, daytime multi-party accidents: namely multi-vehicle, pedestrian, and other accidents).

The formulation of the odds-ratio is:

$$\frac{dmva}{dsva} \div \frac{nmva}{nsva} \quad \text{or} \quad \frac{dmva \times nsva}{nmva \times dsva} ,$$

where:

dmva = daytime multi-vehicle accidents
dsva = daytime single-vehicle accidents
nmva = nighttime multi-vehicle accidents
nsva = nighttime single-vehicle accidents.

By the formulation it is intended that the odds-ratio shall respond only to a fall in daytime multi-vehicle accidents from daytime lights, not to any coincidental falls in daytime or multi-vehicle accidents taken separately that may take place contemporaneously from unrelated other causes.

Findings of Andersson et al 1976: In their English language summary of findings, Andersson et al reported, without qualification, that the value of the odds-ratio for multi-party accidents in Finland fell from 1.88 to 1.76 following the enactment of the Finnish law in 1972; in conclusion the fall and their other findings strongly indicated that the use of daytime lights had done a great deal to reduce accidents.

However the Swedish language main text reveals:

- 1) That Andersson et al's category of 'other' accidents comprised for a large part animal accidents:

'Övriga flerpartsolyckor innehåller till en stor del djurolyckor ...',

and it was essentially only the odds-ratio value for other accidents that fell (1.35 to 0.79); the values for multi-vehicle and pedestrian accidents showed either a negligible fall (2.27 to 2.25) or rise (0.90 to 0.91)

[To comment, animal accidents in Finland are thought—vide *Lehtimäki 1984*—to comprise mainly accidents with elk or white-tailed deer.

As part of his study, Lehtimäki did in fact investigate the effect of automobile lights upon the behaviour of elk and white-tailed deer. However he reported:

'No reliable data sufficient for taking measures were found in automobile lights or in associated factors'.

Accordingly the most likely explanation of Andersson et al's findings is that they are an artifact of the changing pattern of the winter migration of elk and deer]

- 2) That over the before and after period of Andersson et al's study the monthly value of the odds-ratio in Finland varied from a low of 1.29 to a high of 6.22: so that although the odds-ratio may not respond to a fall in daytime or multi-vehicle accidents taken separately, it does respond wildly to some unrelated other factor.

[To comment, by calculation from *Andersson & Nilsson 1981*'s data for the before and after period of their study of the 1977 Swedish law, in Sweden excluding animal accidents the comparative variation was 0.86 to 5.18.

Accordingly (1) the effect is consistent between Sweden and Finland, and also (2) it is a real effect, and not again an artifact of the winter migration of elk and deer].

Or in short not only were *Andersson et al 1976*'s true findings mixed, but the findings revealed that the odds-ratio test that Andersson et al used was not specific for the effect of daytime lights.

Method of subsequent studies: Unfortunately it would appear that there is no more specific test for the effect of daytime lights than the odds-ratio test.

Certainly the subsequent monitoring studies of the Swedish (*Andersson & Nilsson 1981*), Norwegian (*Elvik 1993*), Canadian (*Arora et al 1994*) and Hungarian (*Holló 1995 & 1998*) daytime light laws continued in whole or part use the odds-ratio test — *Elvik 1993* and *Holló 1998* even though, as is clear from what they say in the discussion section of their studies,

each of them was by now fully aware both of the lack of specificity of the test, and the reason for the lack of specificity.

On the other hand *Koornstra et al 1997* states that monitoring studies of the Norwegian law by *Vaaje 1986* and the Danish law by *Hansen 1993 & 1994* deliberately did not use the odds-ratio test. They had before them the raw data that is required to apply the odds-ratio test, but preferred to use their own less rigidly 'formulaic', and more 'interpretative' methods of analysis.

Findings of subsequent studies: Likewise the studies continued, either upon the face of them, or upon scrutiny, to make a medley of mixed, neutral or adverse findings:

Sweden (*Andersson & Nilsson 1981*)

- Fall of multi-party accidents after law — But fall not statistically significant
- Fall of multi-party accidents only in first year after law; Recovery of multi-party accidents in second year after law to higher figure than in last year before law

Norway (*Vaaje 1986*)

- Fall of casualties from multi-party accidents and pedestrian accidents after 1985 law — But, per *Koornstra et al 1997*, *Vaaje* considered amount of falls implausibly high when set against estimated increase in use of daytime lights

Norway (*Elvik 1993*)

- No fall of multi-party accidents after 1985 and 1988 laws

Denmark (*Hansen 1993 & 1994*)

- Per *Koornstra et al 1997*, fall of multi-vehicle accidents after law — But statistically insignificant rise of pedestrian accidents

Canada (*Arora et al 1994*)

- Fall of multi-vehicle accidents for one-year-old motorcars built in first year after law — But unexplained lower fall for brand-new motorcars built in second year after law

Hungary (*Holló 1995 & 1998*)

- Confusing background of other road safety measures, and unexplained trends in the data caused by other factors
- Pedestrian accidents excluded from the analyses
- Small sample of accident data, and so failure to achieve statistical significance
- Initial findings made for before and after periods of just a year, so à la motorcycle study *Janoff et al 1970* post, *Holló* failed to establish normal year-to-year variation in the values of his study measures; When period extended, mixed findings from disaggregated year-to-year data.

Refinement of odds-ratio method by *Arora et al 1994*: *Arora et al 1994* did however, by the way in which they used the odds-ratio test, introduce an innovation.

Perforce, because the Canadian law was a 'fitting', not use, law, they did not conduct a 'before and after' analysis of their data, but a 'side by side' analysis that compared the odds-ratio values of motorcars for each study-year, as grouped by model year of motorcar according to whether:

- The model was introduced before the law came into effect ('Control' group)
- The model was introduced after the law came into effect ('Comparison' group).

So *Arora et al*'s findings were not subject to the influence upon the odds-ratio of any year to year factor besides daytime lights to which it might be sensitive, but instead only of any factor that might distinguish between drivers of motorcars by model year.

The same side by side method—omitting the use of the odds-ratio test—had in fact been employed in earlier studies, such as *Stein 1985*, to compare the accident experience of a fleet of vehicles that used daytime lights with the experience of a fleet that did not use daytime lights.

'Fleet study' method: But the method—which can be called for short the 'fleet study' method—suffers from its own fatal flaw, namely that in order to achieve validity, a fleet study should compare:

- The accident experience of a fleet of vehicles that do not use daytime lights against a background of other vehicles that all do not use daytime lights
- The accident experience of a fleet of vehicles that use daytime lights against a background of other vehicles that all use daytime lights

Otherwise, the study finding will confuse the enduring effect of daytime lights with their initial 'novelty' effect.

Thus, as can be seen, not only will any 'convergence' of the two background conditions cause the finding for each fleet to be biased by the novelty effect, but also the bias for each fleet will have the same 'direction' — namely the two bias effects will 'reinforce' each other, not 'cancel' themselves out, in the findings of the overall comparison.

But it is inherent in the fleet studies—or monitoring studies like *Arora et al 1994* that also compare accidents on a contemporaneous basis—that the accidents of both fleets (or groups of vehicles) are compared against the same convergent, not divergent, background of other vehicles.

'Novelty' effect: To recite a finding that is suggestive of the importance of the novelty effect, in June 1978 *Fulton et al 1980* conducted a 'pedestrian recall' experiment that was intended to compare the effect of a number of different types of daytime light to enhance the conspicuity of a test motorcycle. The test motorcycle was parked down a side street, and pedestrians who crossed over the street on their way along the major road were stopped and asked if they had seen it.

Per *Donne & Fulton 1985* (Fig 2), the results of the experiment were:

<u>Condition</u>	<u>Percentage of pedestrians who recalled seeing motorcycle</u>
Twin 15W day running lamps	48.6%
Single 10W day running lamp	27.9
40W low-beam headlamp	24.4
Control (no lights)	15.7 .

The difference between the percentage figure for each lighting condition and the 15.7% figure for the no-light control condition was statistically significant.

In March 1982 *Donne & Fulton 1985* repeated the experiment at the same site.

The results were:

<u>Condition</u>	<u>Percentage of pedestrians who recalled seeing motorcycle</u>
Twin 15W day running lamps	32.4%
Single 10W day running lamp	21.0
40W low-beam headlamp	21.5
Control (no lights)	16.7 .

Only the difference between the 32.4% figure for the twin 15W day running lamps condition and the 16.7% figure for the no-light control condition was statistically significant.

So in just under four years the 'advantage' of twin 15W day running lamps over control had fallen by a half from 32.9% to 15.7%. And the other two conditions no longer achieved any statistically significant advantage at all.

Criticisms of method and findings of studies: The defects of method and mixed findings of the monitoring studies (or fleet studies) of motorcar daytime lights did not pass without critical notice.

From the mid-1980s, in inter alia the critical study *Prower 1990 (No 2)*, lay critics Baudoin Alofs and the second author drew the attention of a political, official and academic audience to:

- The flaw in the method of the fleet studies
- The implication therefore for the fleet studies of the findings of *Fulton et al 1980* and *Donne & Fulton 1985*
- The mixed Finnish and Swedish findings of *Andersson et al 1976* and *Andersson & Nilsson 1981*
- The lack of specificity of the odds-ratio test to daytime lights.

The qualified or adverse Norwegian and Danish findings of *Vaaje 1986*, *Elvik 1993*, and *Hansen 1993 & 1994* were open on the face of the studies.

Finally academic critics *Theeuwes & Riemersma 1995* reanalysed the data of *Andersson & Nilsson 1981*, and disputed Andersson & Nilsson's conclusion that accidents had fallen following the enactment in 1977 of the Swedish all-vehicle daytime light law.

Or in short, by 1995 the evidence of all major monitoring studies (and fleet studies) in favour of motorcar daytime lights was under severe lay and academic critical attack.

2.2 Motorcar daytime lights: 1995–Date

Response to criticisms of method and findings of studies:

Following the publication of *Theeuwes & Riemersma 1995*, in an attempt to answer the cumulative criticisms of the method and findings of the motorcar daytime light studies, two separate studies—*Elvik 1996* and *Koornstra et al 1997*—each employed their own scheme of re-analysis in order to reanalyse the data of the entire literature of monitoring and fleet studies to date.

Re-analysis of study data by Elvik 1996: The scheme of *Elvik 1996* was to admit the criticisms of the odds-ratio method by *Theeuwes & Riemersma 1995*:

'Theeuwes & Riemersma (1995) have shown how sensitive the odds ratio measure of effect is to changes in the number of accidents that are supposed to be unaffected by DRL, for example, single vehicle daytime accidents',

but nevertheless to aggregate the data of all the studies together, and conduct a single 'meta-analysis' of the data by three methods — the most specific of the three methods to the effect of daytime lights being the selfsame odds-ratio method.

Elvik found from the analysis of the aggregated data by all three methods that taken overall motorcar daytime lights had been effective to reduce accidents.

But it will be observed that Elvik's single analysis does not disturb the mixed, neutral or adverse findings.

It merely 'aggregates out' the findings, and so conceals and avoids explaining them.

Similarly the use of three non-specific methods to 'corroborate' each other merely complicates: it does not by some metaphysical means achieve a new specificity.

Rather the correct means of achieving specificity is:

- To select the most specific of the methods (ie in Elvik's case the odds-ratio method)
- To identify the other factors that the method responds to
- To collect data of the size and trend of the other factors during the period of the original study data
- To adjust the method so that it reflects also the data that has been collected, and so allows for the effect of the other factors.

Re-analysis of study data by Koornstra et al 1997: The scheme of *Koornstra et al 1997*, by contrast with *Elvik 1996*, was to re-analyse the data of each study separately by a single 'new' consistent methodology.

In practice however Koornstra et al only succeeded at the same time in achieving the objects of:

- Lending statistical significance to *Andersson & Nilsson 1981*'s non-significant Swedish findings
- Reversing the adverse Norwegian findings of *Vaaje 1986* and *Elvik 1993*

by abandoning their professed scheme of analysis, and unacceptably re-analysing the original Swedish and Norwegian study data by different and inconsistent methods.

Thus by disaggregating summer and winter data for separate analysis in Sweden they achieved the first object.

But then after ten pages of struggle with the disaggregated summer and winter data also for Norway, they found themselves only able also to achieve the second object by aggregating the data back together again:

'Because of the significant differences between the summer and winter DRL-effects and their variances, one must not estimate a DRL-effect by an analysis of annual totals, but by the average of summer and winter DRL-effects.' [*Koornstra et al 1997* p112].

Recent studies: Since 1995 the two most important studies of motorcar daytime lights—apart from *Elvik 1996* and *Koornstra et al 1997*—that have come to the authors' attention are the substantive studies *NHTSA 2000* and *Farmer & Williams 2002*.

In 2000 General Motors issued a press release in the USA in which they digested briefly the findings of a study that had been conducted by Exponent Failure Analysis Associates, but the authors have not so far succeeded in locating a copy of the study in question.

NHTSA 2000 and Farmer & Williams 2002: Both *NHTSA 2000* and *Farmer & Williams 2002* are 'side by side' US fleet studies that—like *Arora et al 1994*—compare the accident experience over the same period of two 'groups' of motorcars, one made up of motorcars of model years that pre-date the installation by the motorcar manufacturer of daytime

lights on the model in question, and the other of motorcars of model years that post-date the installation of daytime lights.

The actual method of comparing accidents that was employed by the two studies differed:

- 1) *NHTSA 2000* employed the odds-ratio method.
- 2) *Farmer & Williams 2002* compared the daytime and nighttime incidence of multi-vehicle accidents.

They also added a 'control' for any difference in the volume of nighttime driving by drivers of newer, daytime lights equipped, models of motorcar, and older, non-daytime lights equipped, models.

Both studies suffer from the inherent defects of the fleet study method, as described under *Arora et al 1994*.

Both studies also made mixed findings.

General Motors study: The 2000 General Motors press release states that Exponent Failure Analysis Associates 'compared the collision rates of specific GM, Volvo, Saab and Volkswagen vehicles before and immediately after the introduction of daytime running lamps', and found a reduction in the figure of 'relevant crashes'.

The press release gives no further information.

2.3 Motorcar daytime lights: Summary and Discussion

Problems of devising specific method of the studies: The experience of the monitoring studies of motorcar daytime lights shows how deceptively difficult it is to devise a specific methodology for measuring the effect of daytime lights.

Defects of odds-ratio method: To repeat, the formulation of the odds-ratio is:

$$\frac{\text{dmva} \times \text{nsva}}{\text{nmva} \times \text{dsva}}$$

If the number of daytime multi-vehicle accidents falls in response to daytime lights, but the proportion of 'dmva x nsva' to 'nmva x dsva' in other respects remains the same, the value of the odds-ratio will fall, and the amount of the fall will afford a true measure of the effect of daytime lights.

However, as can be seen on working through a few sample calculations, the constancy of the proportion of accidents to each other in other respects is critical.

The wild variability of *Andersson et al 1976*'s table of Finnish monthly values—or the table of Swedish monthly values that can be calculated from the data of *Andersson & Nilsson 1981*—was mentioned earlier.

In fact a monthly variability of the sort will be present in all non-tropical countries, not just Finland and Sweden, because over the ordinary course of the year the proportion is disturbed by the combined effect upon it of the variation of traffic density through the twenty-four hours of the day, and the hour of onset of darkness through the twelve months of the year.

But just as the regular variability of the above 'ordinary' factors produces a marked—or indeed extreme—response from the monthly odds-ratio, so too will any 'non-ordinary' factor that operates variably from year to year contemporaneously with daytime lights to alter the proportion of 'dmva x nsva' to 'nmva x dsva' produce a similar response from the yearly ratio.

In particular, apart from daytime lights the yearly odds-ratio will be sensitive to changes in any of the factors, such as:

- The annual weather pattern
- The disposable income of the general population

- The distribution of the leisure spending of the general population as between driving, and home entertainment or foreign holidays
- The age structure of the driving population
- The incidence of nighttime drinking and driving, that selectively go to determine the volume of driving, or incidence of accidents that take place in the late nighttime hours of low traffic density — and so in turn the figure of nighttime single-vehicle accidents.

Or in short the odds-ratio is inherently unspecific to the effect of daytime lights.

Further it is notorious that, in all of the countries whose laws have been studied by the monitoring studies, the other factors besides daytime lights that, as listed above, the odds-ratio responds to have been subject during the period of the studies to important variation.

Defects of fleet study method: In like fashion to the odds-ratio, the method of the fleet studies (or the monitoring studies that share the same method) suffers from its own inherent flaw, namely an incapacity to distinguish between the 'novelty' effect, and the enduring effect of daytime lights.

The flaw, as noted, lies in the fact that, in order to discount the novelty effect, the fleet studies should compare:

- The accident experience of a fleet of vehicles that do not use daytime lights against a background of other vehicles that all do not use daytime lights
- The accident experience of a fleet of vehicles that use daytime lights against a background of other vehicles that all use daytime lights.

But in practice the studies are unable to achieve the background conditions; rather they maximise the confusion of the novelty effect and the enduring effect of daytime lights by comparing the accident

experience of the two fleets of vehicles against an identical background of other vehicles.

Treatment of problems of method by study authors: Many of the study authors who have employed the odds-ratio or fleet study methods have not recognised their inherent flaws, and so not discussed them.

The rest may, like *Elvik 1993*, *Elvik 1996* and *Holló 1998*, have recognised and discussed the flaws — but found themselves, by default, still compelled to use one or other of the methods.

However even had all of the study authors recognised the flaws, and exercised their combined powers to devise a means of eliminating them, given the discussion of the flaws by the present authors, it is almost certain that they would have found the task of overcoming them to be insuperable.

Mixed findings of the studies: The mixed findings of the studies will not be described again.

The findings have emerged either immediately upon the face of the studies, eg:

- The adverse Norwegian findings of *Elvik 1993*,
or gradually, whether upon disaggregation of the study data by lay critics, eg:
 - The mixed Finnish findings of *Andersson et al 1976*,
or upon re-analysis of the study data by academic critics, eg:
 - The neutral Swedish findings of *Andersson & Nilsson 1981*
as asserted by *Theeuwes & Riemersma 1995*.

It need merely be said that it is now likely that, truly viewed, every monitoring study of the effect of motorcar daytime lights that has been conducted to date has made either mixed, neutral or adverse findings.

Treatment of mixed findings by study authors: The attempt of *Elvik 1996* and *Koornstra et al 1997* to 'rescue' the mixed findings of the studies t

their 'global' reanalyses of the data of all existing studies to date has been described.

But as noted the attempt failed.

Koornstra et al 1997 employed an inconsistent methodology to reverse the statistically insignificant Swedish, and adverse Norwegian findings, and so in the event reversed neither of them.

Elvik 1996 could only 'aggregate out' the mixed findings by the scheme of his re-analysis, not reverse them.

Summary: Or in short, forty years on from the Texas 'Light up and Live' campaign, to date there is still no satisfactory scientific evidence from the monitoring studies of motorcar daytime lights that have been conducted since then that daytime lights have reduced accidents.

2.4 Motorcycle daytime lights

Origins: Per *Winn 1978*, between 1963 and 1976 the number of motorcyclists killed each year in the USA rose from 675 to 3300.

In response, amongst other measures, per *Muller 1984* between 1967 and 1973 a total of 14 states implemented laws making it compulsory for motorcycles to use daytime lights.

Also in 1972 California enacted a law that required all new motorcycles sold in the state to be 'hard-wired' with the headlight permanently on; but in the event California did not implement the law until 1978.

In 1970 Janoff et al published a monitoring study—*Janoff et al 1970*—of the effect upon accidents of the laws implemented in Indiana (1967), Montana (1967), Oregon (1967) and Wisconsin (1968). The study is also known as the 'Franklin Institute Report'.

In 1977 Waller & Griffin published a study—*Waller & Griffin 1977*—of the effect of the law implemented in North Carolina (1973).

In 1978 as noted—it is thought on the formal basis of the findings of *Janoff et al 1970* as now corroborated also by *Waller & Griffin 1977*—, California eventually implemented its 1972 motorcycle 'hard-wiring' law.

In response to the implementation of the California law—per *Winn 1980* at the time California represented the largest market in the USA for new motorcycles—the motorcycle manufacturers then hard-wired their entire production for the US and Canadian markets, so de facto extending the application of the California law to the whole of North America.

Subsequent implementation: Since *Janoff et al 1970* other countries besides the USA have also enacted motorcycle daytime light laws — some at their own instance, others following the ratification by them of provisions under the 1968 Vienna Convention on Road Traffic that stipulate that contracting parties shall introduce motorcycle daytime light laws.

However, by way of exception, in response in greater or lesser part to criticisms by motorcyclists organisations, or individual motorcyclists, of the findings of the motorcycle daytime light studies, as to Great Britain, Australia, and Ireland:

- *Great Britain* In 1983 the British Government withdrew a proposal for a law requiring motorcycles to be fitted with twin daytime running lamps.
Parliamentary Under Secretary of State for Transport, Lynda Chalker said, in answer to a Parliamentary Question, inter alia:
'TRRL [Transport & Road Research Laboratory] will continue to study the problem, but I do not consider on the evidence at present available that the benefits of running lamps are sufficient to justify making their fitting compulsory ...'
- *Australia* In 1997 the Australian Federal Government withdrew a rule that it had introduced in 1992 requiring all new motorcycles sold to be hard-wired with the headlight on.
Federal Minister for Transport and Regional Development, John Sharp said, in Media Statement TR139/96, inter alia:

'When I became Minister for Transport, I asked for an evaluation of the safety effects of ADR 19/01 [*The above rule*]. Two separate studies of statistics on motorcycle crashes were commissioned. Neither of these studies found evidence of a statistically significant safety benefit from this design rule.'

- *Ireland* Ireland has never enacted a motorcycle daytime light law.

Most recently in 1998 Japan enacted a motorcycle hard-wiring law.

The Japanese Government did so, at the initiative of the Japan Automobile Manufacturers Association (which also represents the interest of the Japanese motorcycle manufacturers), on the basis of a study that was conducted by the International Association of Traffic and Safety Sciences.

Or as '*News from JAMA motorcycle*' 2000 states more fully:

'In 1986 JAMA launched pointed appeals to the Japanese government, leading to the establishment of the "Council to Promote Measures to Prevent Motorcycle Accidents" inside the Management and Coordination Agency that year. As one phase of its programs, the Council consigned the "Survey Concerning Daytime Lighting on Motorcycle Headlights" to the International Association of Traffic and Safety Sciences, with JAMA acting as a major participant in this three-year survey. The study effectively answered questions about the possible negative effects associated with the practice of daytime lighting.'

The authors have not seen the IATSS study that '*News from JAMA motorcycle*' 2000 refers to.

Method and findings of Janoff et al 1970: As described also by *Janoff & Cassel 1971*, *Janoff et al 1970* is an even less satisfactory study than *Andersson et al 1976*:

- 1) The method of the study was merely to compare changes in the figure of daytime accidents with changes in the figure of nighttime

accidents following the laws that were implemented by Indiana, Montana, Oregon and Wisconsin —

Unlike therefore the more specific odds-ratio test, in addition to daytime lights Janoff et al's method will have responded to any unrelated factor that caused daytime accidents compared with nighttime accidents to fall

- 2) The length of the before and after periods of the study was only between 6–12 months —

So Janoff et al failed to establish, and as necessary allow for, the normal year-to-year variation in the figure of daytime accidents compared with nighttime accidents in the study states

- 3) As *Smith 1975* and *Williams & Hoffman 1977* amongst other critics pointed out, the findings of the study were potentially confused by the fact that only the law in Montana was enacted on its own; the other laws were enacted as part of a wider package of legislation containing other measures intended to reduce motorcycle accidents —

Janoff et al did attempt to 'control' for the potential confusion of their findings by also conducting 'side by side' comparisons of the accident experience of the four states with the experience of four 'matched' control states that had not enacted daytime light laws.

But *Williams & Hoffman 1977* criticise inter alia that they did not extend the comparison fully to a comparison of changes in daytime accidents and nighttime accidents; instead the comparison treated simply changes in the figure of total accidents

- 4) By way of mixed findings, daytime accidents only fell compared with nighttime accidents in Indiana, Oregon and Wisconsin —
In Montana, by contrast, daytime accidents rose.

Refinement of method of *Janoff et al 1970* by *Waller & Griffin*

1977: As stated previously, *Waller & Griffin 1977*—followed by *Waller 1981* extending the data series by two years—conducted a monitoring study of the 1973 North Carolina law.

In passing they acknowledged *Smith 1975*'s criticism that *Janoff et al 1970*'s Indiana, Oregon and Wisconsin findings were

potentially confused by the passage at the same time of non-daytime light legislation.

By way of increased sophistication, unlike *Janoff et al 1970*, the method of *Waller & Griffin 1977* was to compare changes in the figure of daytime multi-vehicle accidents with changes in the figure of other accidents — not simply changes in daytime accidents with changes in nighttime accidents).

By way of 'side by side' comparison, they recorded also contemporaneous changes in the same figures for motorcars.

Waller & Griffin 1977 found that motorcycle daytime multi-vehicle accidents fell markedly in North Carolina in 1974 following the law.

But on disaggregation of Waller & Griffin's data, the fall turns out to represent only a fall of multi-vehicle accidents; by contrast daytime accidents maintain the same trend as in the three years before the law.

Also confusingly in North Carolina, not only was the law enacted in September 1973, but also in the same year:

- In January 1973 the police changed the police accident report form
- In November 1973—as marked by President Nixon's speech to Congress—the Energy Crisis broke out.

Waller & Griffin did discuss the impact upon their data of the Energy Crisis. But they did not supply—or as necessary discuss—such relevant information as whether, at the same time as the police changed the accident report form, the police also changed the property damage threshold figure in North Carolina for reporting an accident.

Nevertheless as noted, in 1978 California enacted its motorcycle hard-wiring law.

Use of odds -ratio method by *Lund 1979* and *Muller 1984*: On the basis of the findings of *Janoff et al 1970*, the Nordisk Trafiksikkerhedsråd (NT) recommended in the report *NTR Rapport 12: Varselljus för motorcyklar (1977)* that the Northern countries bring in daytime light laws for motorcycles.

In 1977 Denmark accordingly enacted a motorcycle daytime light law.

About the same time the NTR's working group on daytime running lights was also contemplating extending the recommendation of *NTR Rapport 12* to motorcars and other vehicles.

So on behalf of Rådet for Trafiksikkerhedsforskning (RfT) in Denmark, Lund commenced a monitoring study of the impending Danish law.

For the purpose in *Lund 1979* he employed the method of the motorcar study *Andersson et al 1976*— not the method of *Janoff et al 1970* or *Waller & Griffin 1977*.

So Lund employed the odds-ratio test for the first time in a motorcycle daytime light study.

By contrast with *Janoff et al 1970* and *Waller & Griffin 1977*, *Lund 1979* found that the odds-ratio value rose slightly, not fell, following the Danish law.

He stated that his analysis of motorcycle accidents showed no effect of using daytime lights:

'En analyse af færdselsuheld med personskade, hvor motorcykler har været impliceret som primære uheldsparter viser ikke nogen effekt af brugen af varsellys.'

In the meantime the NTR had not waited for Lund to conclude his study.

Instead as soon as *Andersson et al 1976* published the findings of their monitoring study of the 1972 Finnish all-vehicle winter daytime light law, the NTR also—in the report *NTR Rapport 17: Varselljus – bilbelysning under dagtid (1976)*—recommended daytime light laws for motorcars.

Sweden then followed the motorcar recommendation in 1977; Norway followed it in 1985; and finally Denmark ignored its 'own' motorcycle study finding, and also followed the recommendation in 1990.

[*NTR = Nordic Road Safety Council*
'Varselljus för motorcyklar' = 'Warning lights for motorcycles' (Tr.)
RfT = Danish Council of Road Safety Research
'Varselljus - bilbelysning under dagtid' = 'Warning lights - motorcar lighting in daytime' (Tr.)]

Muller 1984 (Part 1) also employed the odds-ratio test for a monitoring study of the 1978 California law.

But like *Lund 1979*, *Muller 1984* (Part 1) found no change in odds-ratio values following the California law.

Muller 1984 (Part 2) went on to employ the odds-ratio in addition to compare the accident experience of US states with and without motorcycle daytime light laws.

Muller 1984 (Part 2) found a slight, non-statistically significant, decrease in the values of the odds-ratio for the US states with daytime light laws.

Reverter to method of *Janoff et al 1970* by *Zador 1985*: The findings of *Lund 1979* in Denmark have been passed over in silence by subsequent authors.

By contrast however in the USA, *Zador 1985* disputed the correctness of *Muller 1984* (Part 2)'s choice of the odds-ratio to compare the accident experience of US states with and without motorcycle daytime light laws.

He argued that motorcycle daytime lights prevent motorcycle single-vehicle accidents as well as multi-vehicle accidents.

Accordingly *Zador* repeated *Muller*'s comparison instead using the method of *Janoff et al 1970*: ie he compared the ratio of total daytime to nighttime accidents for the two groups of states.

Unlike *Muller*, *Zador* found a substantial, statistically significant, decrease in the ratio of daytime accidents to nighttime accidents for the US states with daytime light laws.

To comment upon the dispute between *Zador 1985* and *Muller 1984* (Part 2), on the one hand:

- *Muller 1984* (Part 2) did indeed, by dividing daytime multi-vehicle accidents by daytime single-vehicle accidents instead of adding them together, 'doubly discount' any motorcycle daytime single-vehicle accidents that daytime lights may have prevented;

but on the other hand:

- *Zador 1985*'s method was sensitive not only to the effect of daytime lights to reduce daytime accidents in the states with daytime light laws, but also—to repeat previous comments upon the design of the odds-ratio—to the effect of any unrelated geographic or traffic factors that might influence the ratio of daytime to nighttime accidents, or single to multi-vehicle accidents, differently as between the states with and without daytime light laws.

Without a detailed knowledge of US geography or police practice in recording accidents, it is not possible for the authors to take the matter further.

Recent studies: Finally two recent monitoring studies—*Radin et al 1996* and *Bijleveld 1997*—have taken opposite approaches to the problem of devising a method of analysing the motorcycle (or motorcar) study data that is specific to the effect of daytime lights.

Reverter to method of *Waller & Griffin 1977* by *Radin et al 1996*:

On the one hand, in their monitoring study of the 1992 Malaysian daytime light use law, *Radin et al 1996* abandoned any attempt to improve upon the specificity of the odds-ratio test.

Instead, like *Zador 1985*, they 'reverted' to the lesser specificity of a simple comparison of the figure of accidents of a type that might have been caused by a failure to notice the motorcycle with the figure of other motorcycle accidents.

But unlike *Zador 1985*, as can be seen the method that they reverted to was not the method of *Janoff et al 1970*, but rather a method similar to the method of *Waller & Griffin 1977*.

From the descriptions of the 'configuration' of motorcycle accidents in police reports, *Radin et al* extracted data of 'conspicuity related accidents', namely accidents where a failure by the other party to notice the motorcycle might have been a contributory cause of the accident.

Then, seemingly without being able to call upon the assistance of any other numerical data apart from the figure also of non-conspicuity related accidents, they conducted a statistical modelling exercise in which one of the theoretical postulates that they used in an attempt to 'model the observed trend' of the data of conspicuity related accidents was a reduction in conspicuity related accidents from motorcycle daytime lights.

A model whose postulates included a substantial reduction in accidents from daytime lights successfully 'predicted' the observed trend of the data; the model passed statistical tests of its 'validity'; and the figure of the reduction was presented as Radin et al's finding.

Refinement of odds-ratio method by *Bijleveld 1997*: On the other hand, in his monitoring study of the 1982 Austrian hard-wiring law, *Bijleveld 1997* employed what was ostensibly the most specific method that has been employed by any motorcycle (or motorcar) study.

Bijleveld employed the odds-ratio test to compare motorcycle odds-ratio values for years 'before and after' the law, whilst at the same time, by way of 'control' for the other factors besides daytime lights that are capable of influencing the odds-ratio, comparing the motorcycle odds-ratio value for each year 'side by side' with the motorcar odds-ratio value.

Or more shortly, Bijleveld's measure of the effect of motorcycle daytime lights was the motorcycle odds-ratio, divided for control purposes by the motorcar odds-ratio.

Nevertheless, as can be seen Bijleveld's method assumes that the other factors besides daytime lights that go to determine the value of the odds-ratio exerted a similar influence upon the incidence of motorcycle and motorcar accidents in Austria during Bijleveld's study period.

But when one considers the list of examples of the other factors that was given under 2.3 'Motorcar daytime lights: Summary and Discussion', namely to repeat the list:

- The annual weather pattern

- The disposable income of the general population
- The distribution of the leisure spending of the general population
- The age structure of the driving population
- The incidence of nighttime drinking and driving, the assumption is not obvious and requires justification.

In the event the objection in question to Bijleveld's method is irrelevant.

Bijleveld did not publish the 'motorcar-controlled' odds-ratio values that he found.

Instead he subjected the values to extensive statistical modelling, and published a 'prediction' from the exercise that the 1982 Austrian hard-wiring law had 'reduced the number of victimised motorcyclists in daytime multiple accidents by about 16%'.

However the values can be back-calculated from a graph that appears in the study of the separate motorcycle and motorcar odds-ratio values (*Bijleveld 1997* Figure 5).

The back-calculation shows that:

- The actual odds-ratio values that Bijleveld found failed to respond at all to the 1982 Austrian motorcycle hard-wiring law.

Likewise although Bijleveld did not also study the effect of a 1977 Austrian motorcycle daytime light use law that preceded the 1982 hard wiring law,

- The odds-ratio values failed equally to respond at all to the 1977 Austrian motorcycle daytime light use law.

2.5 Motorcycle daytime lights: Summary and Discussion

Problems of devising correct method of the studies: The method of the monitoring studies of motorcycle daytime lights ranges, in order of increasing specificity to the effect of daytime lights, from recording changes in:

- The simple ratio of daytime accidents to nighttime accidents: *Janoff et al 1970; Zador 1985*
- The simple ratio of daytime multi-vehicle accidents to other accidents: *Waller & Griffin 1977; Radin et al 1996*
- The odds-ratio: *Lund 1979; Muller 1984 (Part 1 & 2); Bijleveld 1997.*

Studies employing one or other of the methods have also conducted 'side by side' comparisons intended to 'control' and eliminate the lack of specificity that, as discussed under motorcar daytime light studies, still characterises even the most sophisticated method, the odds-ratio.

But the selection of control 'measures' has been controversial.

As noted *Williams & Hoffman 1977* criticised that *Janoff et 1970* merely compared changes in the figure of total motorcycle accidents as between their study states and matched control states.

Or *Bijleveld 1997* and *Waller & Griffin 1977* used contemporaneous changes in the odds-ratio value (or figure of daytime multi-vehicle accidents) for motorcar accidents as their control measure on the assumption that motorcar accidents are subject to the same 'extraneous' influences upon them as motorcycle accidents; but as previously stated, the assumption is not obvious.

To treat first the odds-ratio method, the motorcycle monitoring studies that have employed the odds-ratio method have been little more successful at overcoming the inherent flaws of the method than the motorcar monitoring studies .

Whilst to treat second the methods of the other studies, since the methods are not even formulated to exclude a response to extraneous factors that independently influence affects the respective incidence of daytime and nighttime, or single-vehicle and multi-vehicle accidents, they are—pace *Zador 1985's* arguments to the contrary—yet more flawed than the odds-ratio method.

Mixed findings of the studies: Unlike the mixed findings that were made without exception by the motorcar monitoring studies, two of the motorcycle monitoring studies, *Zador 1985* and *Radin et al 1996*, did make unmixed findings in favour of motorcar daytime lights.

But as above the method of the two studies was even less specific than the odds-ratio method.

Otherwise the remaining motorcycle studies—*Janoff et al 1970*, *Waller & Griffin 1977*, *Lund 1979*, *Muller 1984* (Part 1 & 2), and *Bijleveld 1997*— have made the same medley of mixed, neutral or adverse findings as the motorcar monitoring studies.

Summary: Or in short, thirty-five years on from the implementation in the United States of the first motorcycle daytime lights laws, in like fashion to the motorcar studies there is still no satisfactory scientific evidence from the monitoring studies of motorcycle daytime lights that have been conducted to date that daytime lights have reduced accidents.

3. Prima facie arguments for and against use of motorcycle and motorcar daytime lights

It is not in issue in the present paper whether motorcar or motorcycle daytime lights enhance the conspicuity of the vehicle that uses them.

Experimental studies, such as *Hörberg & Rumar 1975* and *Dahlstedt 1986*, have found by a satisfactory method that they do so under test conditions. And it will be taken that it is correct to project from the findings that daytime lights will also enhance the conspicuity of vehicles under real conditions.

What is in issue in the paper is, rather, how far other road users may be expected to alter their behaviour beneficially on balance upon noticing a motorcycle or motorcar.

As treated under the previous section, the monitoring studies of daytime lights, because of their defective methodology and mixed findings, afford no assistance.

The paper therefore turns from the monitoring studies to the prima facie arguments for and against the use of motorcycle or motorcar daytime lights.

3.1 Prima facie arguments for use of motorcycle and motorcar daytime lights

The prima facie arguments for motorcycle and motorcar daytime lights are no less powerful for the fact that they are essentially one argument, which can therefore be stated briefly.

If noticing the daytime lights of a vehicle causes a road user to wait where he or she is instead of overlooking it and intruding into its path, then this must prevent accidents.

It can be objected that road users can perfectly well see a motorcycle, or more forcefully, a motorcar at the sort of ranges that statistically characterise most accidents.

It can be objected that many accidents are caused by failure to estimate the speed and distance of the other vehicle, so that a driver may notice another vehicle, yet still intrude into its path.

But a substantial residue of accidents successfully prevented will remain.

3.2 Prima facie arguments against use of motorcycle and motorcar daytime lights

The prima facie arguments against motorcycle and motorcar daytime lights are more numerous, and so are most conveniently treated under separate headings.

3.2.1 Size of effect

In order to reduce accidents daytime lights must enhance the 'natural' conspicuity of a motorcycle (or motorcar) at the sort of ranges where failure to notice an oncoming motorcycle may be 'critical', ie potentially result in an accident.

'Natural' conspicuity: To consider, first, the natural conspicuity of motorcars and motorcycles, it may be observed that, in head-on view, on the one hand, the silhouette of the four-wheeled motorcar:

- Is typically 6ft (1.8m) wide
- Has a clear-cut, sharp, 'contrasty', regular outline
- Features a simple, regular pattern of extensive, shiny or glazed surfaces.

By contrast, on the other hand, the silhouette of the two-wheeled motorcycle (and rider):

- Is typically 1½ (0.46m) wide
- Has a 'confused', irregular, outline
- Features an irregular, often complex pattern of either predominantly dull, or mixed dull, shiny, and glazed, frequently non-extensive surfaces.

Thus whereas the motorcar possesses all of the features that naturally enhance conspicuity (and also assist the correct estimation of speed and distance), the motorcycle in stark contrast lacks all of them.

Apropos, *Hörberg & Rumar 1975* reported incidentally in passing (p7) that their experimental subjects were able to detect a yellow Volvo on the taxi runway of a military airfield against a background of the sky and the runway at distances of more than 3000m from them even when the Volvo had no lights on.

But unfortunately *Hörberg & Rumar* did not at the same time report the comparable distance for a motorcycle.

'Critical' ranges: To consider, second, the ranges at which failure to notice an oncoming motorcar or motorcycle may be 'critical', on the other hand, in an earlier paper—*Prower 1996*—the second author drew support from:

- The finding of *Whitaker 1980* that in 75% of the sample of 425 motorcycle accidents in Newbury and Slough UK that he analysed, the motorcycle was travelling at less than 30mph (48kph), and in 93% less than 40mph (64kph)

- The experience of *Olson et al 1979a* (as reported by *Olson et al 1981*) that although 6% of drivers at intersections infringed the right-of-way of the test motorcycle riders in their experiment when the motorcycle was 3 sec or less distant from them, none of the test riders suffered an accident
- The calculations by *Ouellet 1990* of the ranges at which an accident was inevitable if a driver at an intersection intruded into the path of an oncoming motorcycle,

to which can also in the present paper be added:

- The finding of *Hurt et al 1981* that the median pre-crash speed in their sample of 900 accidents in Los Angeles was 29.8mph (48.0kph); the median crash speed 21.5mph (34.6kph); and the 'one in a thousand' crash speed approximately 86mph (138kph),

for the proposition that it is likely that most motorcycle accidents at intersections arise either from the failure of the driver to observe, or the failure of the driver to respond to, a motorcycle that is less than 100yd (91.5m) distant from him.

Given their better braking performance in an emergency, for motorcars the distance is likely to be even less.

The second author's proposition should be qualified by the fact that either:

- A hesitation by the intruding driver in the collision zone
- An 'After you, Claude'—or 'Après vous, M. Dupont'—misunderstanding between the parties,

may considerably extend the distance.

On the other hand, drivers must detect an oncoming motorcycle or motorcar—and equally important accurately estimate its speed and distance—at a much greater range when they are overtaking in the face of oncoming traffic.

Hills 1980 states that at overtaken and oncoming vehicle speeds of 50mph (80kph), the total overtaking distance required is of the order of 1500ft (457m).

Hörberg & Rumar 1975 recite at one point in their paper the finding of *Rumar & Berggrund 1973* to similar effect that 500m is the normal distance from the oncoming motorcar in overtaking manoeuvres.

Size of effect of motorcar daytime lights: It may be concluded from what has been said, first as to motorcars, that in most ordinary driving situations where the motorcar driver is at hazard of an accident—except for overtaking in the face of oncoming traffic—their ordinary conspicuity will be perfectly adequate.

Any additional benefit that they derive from the further enhancement of their conspicuity by daytime lights will be trivial.

Further by way of offsetting 'disbenefit', it may be speculated that daytime lights might even in ordinary daylight confuse another driver's view of a motorcar's outline, so depriving him of the best aid for estimating its speed and distance.

Size of effect of motorcycle daytime lights: Second as to motorcycles, it is relatively easier to envisage situations where the motorcyclist is at hazard of an accident in which the lack of 'natural' conspicuity of the motorcycle may be critical.

But given the ranges that have been noted for motorcycle accidents at intersections, and the advantage that the narrow width of the motorcycle affords the rider in avoiding an overtaking accident, the number of such situations will still be small.

Conclusion: In conclusion, when computing the net safety benefit of daytime lights for motorcars, on the 'beneficial' side of the balance there is at most probably only a trivial benefit to be entered.

However for motorcycles the benefit may be more substantial.

3.2.2 Acclimatisation

'Novelty' effect: It is a commonplace that human beings respond with great alacrity to the novelty of the observation of some new phenomenon, such as in the present instance daytime lights.

Or as lay authors *Moir & Jessel 1995*, digesting the findings of academic authors on the working of the human brain, suggest in more formal terms how the brain stem may more readily pass through sensory information of 'novel' phenomena to the cognitive or limbic areas of the brain:

'There is a crucial area [*of the brain stem*] called the reticular activating system which sieves incoming sensory information. Only the messages that are deemed important or novel are routed onwards for treatment by the rest of the brain [*ie the cognitive and limbic areas*]. It is our alarm and arousal system; unless it rings a bell to wake up the rest of the brain, the brain will take no notice of what is going on.' [*Moir & Jessel 1995 p58*].

So given the intense competition between phenomena out on the road for the driver's attention, one might expect daytime lights to manifest a pronounced 'novelty effect' whereby they attract great attention from other drivers upon their first introduction, followed by a level of attention that gradually diminishes with the passage of time thereafter.

Initial confusion with police: The expectation is reinforced, on the suggestion of the findings of studies by US lay authors *Leonard 1974* and *Booth 1978*, should the first vehicles that take up the use of daytime lights be the vehicles of the police and emergency services.

First *Leonard 1974* compared the number of drivers who violated his right-of-way on a regular daily journey in which—save for the police motorcycle—he alternated the use of a 'control' motorcycle and 'test' motorcycle as follows:

- 'Regular'—ie standard—motorcycle with the headlight turned off (Control)
- 'Regular' motorcycle with the headlight turned on
- 'Spectacular' motorcycle: extensive use of reflective materials, bright colours, etc
- Police motorcycle.

Over 15 test days riding the police motorcycle, Leonard experienced just one right-of-way violation; by contrast over 30 test days each riding the control motorcycle and the motorcycle with the headlight on he experienced respectively 1.9 and 1.8 violations per day, or riding the control motorcycle and the spectacular motorcycle 1.8 and 2.0 violations per day — ie a total for each motorcycle over 30 test days of 54–60 right-of-way violations.

Second *Booth 1978* monitored and compared the response of motorists to a stationary police motorcycle, marked police car, and unmarked police car that were parked in clear view at the corner of an intersection under the following heads of description:

- Average distance of the motorist from the police vehicle when the brake lights of his vehicle were observed to come on
- Number of moving violations (excluding speeding) committed by motorists at the intersection
- Number of warning reports of the presence of the police vehicle that motorists broadcast by CB radio.

Booth reported his findings as follows:

	<u>Motorcycle</u>	<u>Marked car</u>	<u>Unmarked ca</u>
Average braking point	160.6 (146.8)	157.0 (143.6)	151.3yd (138.4m)
Number of violations	0	9	14
Number of CB radio broadcasts	65	20	18 .

Experimental findings: Otherwise the comparative findings of the 'pedestrian recall' experiment that *Fulton et al 1980* conducted in 1978, and the findings of the same experiment as repeated by *Donne & Fulton 1985* just under four years later in 1982, have already been recited under 2.1 'Motorcar daytime lights: 1960–1995' in support of the authors' criticisms of the method of the fleet studies.

The findings suggest the real existence of a novelty effect for motorcycle daytime lights, and by implication also a similar effect for motorcar daytime lights.

They suggest also that potentially the effect may be a substantial one.

Some qualification of the findings of *Fulton et al 1980* and *Donne & Fulton 1985* is necessary.

Thus as a matter of the timing of their experiments, the findings could well confuse the gradual diminution of an original novelty effect with a contemporaneous diminution also of an original association of daytime lights with the police and emergency services.

In more detail, it was only in 1978 in Britain that the Highway Code first advised motorcyclists to 'wear light-coloured or reflective and fluorescent clothing', or in 1987 added that 'dipped headlights on larger machines (over 150cc–200cc)' helped others to see them [*or in 1999—to complete the recital—said that 'dipped headlights' (without qualification) might make motorcyclists more conspicuous.*]

Fulton et al 1980 report that only 1.1% of a sample of motorcycles surveyed on the road in 1975/76 had their headlight on in daylight.

But *Hobbs et al 1986* report that 57% of motorcyclists who responded to a questionnaire survey in 1982 agreed with the statement: 'Motorcyclists should use their headlights in daylight'.

Nevertheless it remains that, to recall, at the end of four years *Fulton et al 1980* and *Donne & Fulton 1985* found that their 40W low-beam headlamp condition in particular retained no more than a 4.8% non-statistically significant advantage over control.

Conclusion: In conclusion, when computing the net safety benefit of daytime lights for motorcars or motorcycles, on the 'beneficial' side one must progressively 'write down' the beneficial effect of daytime lights to allow for the combined effect of a diminishing 'novelty' effect, and a diminishing 'confusion' of vehicles using daytime lights with the police.

3.2.3 Distraction

It is another commonplace that: 'What attracts also distracts'.

Daytime lights are not a 'passive', but an 'active' road safety measure.

Thus—vide the 'performance specifications' that *Hörberg & Rumar 1977* arrived at from their experiments in Sweden—daytime lights are intended to stimulate the peripheral reflex attraction towards bright light, and so 'forcefully' attract the attention of the other driver, even though the driver may be looking at an angle up to 30° away from them.

The corollary is an equally 'forceful' distraction.

The distraction in question falls to be treated separately according to its 'general' effect upon all drivers, or its 'specific' effect upon individual drivers.

'General' distraction: By way first of 'general' distraction, in most European countries, the motorcar is by far the most prevalent vehicle on the road.

So motorcar daytime lights will:

- Add substantially to the already numerous distracting elements of the normal road scene
- Promiscuously grab attention to motorcars from other road users willy-nilly.
- Create two classes of road user, one displaying daytime lights, and the other not displaying them.

Indeed in the absence of strict regulation and enforcement, on the precedent of the United States, within the class of road users who display lights motorcar daytime lights will create two further sub-classes of road user, one of drivers who display powerful lights, and the other of drivers who display less powerful lights.

'Specific' distraction: By way second of 'specific' distraction, one may expect both motorcar and motorcycle daytime lights to contribute towards the cause of a significant number of accidents.

A particular instance will be when they distract the other driver by their 'presence' in his rear-view mirror.

Conclusion: In a 'net safety benefit' evaluation of daytime lights, accidents that are caused by either the general or specific distraction of other road users by motorcar or motorcycle daytime lights fall to be weighed in the negative side of the balance.

3.2.4 Glare

The same intensity of light that is required to stimulate the peripheral reflex attraction towards bright light at an angle of 30° at daytime levels of ambient illumination will, as recognised by *Hörberg & Rumar 1975*, cause glare at lower levels of ambient illumination.

Recommendations of study authors: *Hörberg & Rumar 1975's* original recommendation for the intensity of purpose-designed motorcar daytime running lamps was therefore arrived at by compromising:

- The intensity of light that was required to attract the attention of their test subjects at a peripheral angle of 30°
- The lower intensity of light that caused the subjects to experience glare on lit roads at night.

The recommendation was 200 candlepower.

However drawing upon subsequent studies by other authors, *Schieber 1998* predicted that under US conditions an intensity of 1500cd would cause no 'disability' glare, and an acceptably low degree of 'discomfort' glare.

Further on the premise that motorcar daytime lights are effective to reduce accidents, an intensity of 3000cd would produce only a 'modest increase' in discomfort glare, and so remain an acceptable compromise.

Glare in practice: It is admitted that *Schieber 1998's* prediction of a 'net safety benefit' from 3000cd daytime lights is reasonable on its terms.

So in theory, legislators may in succession, with a progressively decreasing association of adverse glare, prescribe:

- The use of existing headlights on dipped beam in daylight
- The hard-wiring of headlights on new motorcars or motorcycles
- The fitting of purpose-designed daytime running lamps on new motorcars or motorcycles.

Nevertheless in practice—as anecdotally related to the second author by policemen, motorcar drivers, and motorcyclists—in Britain, the police only rarely enforce vehicle lighting regulations.

And it is thought that the same situation applies in many other European countries.

So even were legislators to stipulate a limiting ‘in use’ intensity of ordinary headlights used as daytime lights, or hard-wired headlights, the law itself once the motorcar or motorcycle left the showroom would be a ‘dead letter’.

Rather only legislation that requires all new vehicles as sold to be fitted with purpose-designed daytime running lamps of a suitably low maximum intensity will eventually achieve the postulated benefits of daytime lights without the adverse association of an important proportion of vehicles on the road that subject other road users to discomfort, or sometimes even disabling glare.

But legislation of the sort remains to be enacted in most European countries — let alone ‘percolate’ through the vehicle population to the point where essentially all vehicles are fitted with daytime running lamps.

‘General’ glare: The authors must treat the European situation as they find

Like distraction, daytime lights may cause ‘general’ glare or ‘specific’ glare.

To take ‘general’ glare first, the effect of the glare from daytime lights will be importantly to the visual ‘hostility’ of an already hostile normal road scene.

The parallel is not exact, but the notorious practice of ‘black cab’ taxi drivers in London of driving with only minuscule sidelights lit at night—namely at a time when, in central London, they may represent over half of the vehicles

on the road—is sometimes justified by them by the desire to avoid subjecting their fellow taxi drivers to glare.

'Specific' glare: To take 'specific' glare second, it will contribute to the cause of individual accidents in the same way as specific distraction.

Conclusion: General or specific glare may not, like distraction, be the inevitable corollary of motorcar or motorcycle daytime lights.

But in practice they must fall similarly to be weighed in the negative side of the balance.

3.2.5 Masking

Masking may take two forms:

- The masking of the headlight of a motorcycle by confusion with one the headlights of a following motorcar
- The masking of a motorcycle by the glare from the headlights of a following motorcar (or other motorcycle).

Since the subject of 'masking by glare' follows on naturally from ordinary glare, it is more convenient to treat it first.

'Masking by glare': Per *Hills 1980*, *Hartmann & Moser 1968* found that when an object is directly or nearly directly backlit by a glare source—namel viewed at a visual angle within 1.5° of the source—, the effects of glare increase rapidly.

As instanced by Hills, the situation described by Hartmann & Moser may arise when a pedestrian is waiting in the middle of the road at night to complete his crossing.

But equally in daytime, given the appropriate 'configuration' of the three vehicles, one may expect the headlights of a motorcar (or other motorcycle) that are used as daytime lights, if they are emitting glare, to mask a narrow object like a motorcycle as viewed from head-on by the driver of an oncoming vehicle.

'Masking by confusion': To repeat, masking by confusion may arise when one of the headlights of a following motorcar masks the single headlight of a motorcycle from another driver.

By contrast with masking by glare, masking by confusion can arise:

- In many frequently occurring configurations of the three vehicles
- Whether or not the headlight of the following motorcar is emitting glare.

Masking by confusion can therefore be predicted to be an important contributory cause of motorcycle accidents.

Conclusion: On the one hand the masking of motorcycles by the glare of the daytime lights of a following motorcar may not arise often, and so only be a minor cause of motorcycle accidents.

But on the other hand the masking of motorcycles by confusion with the daytime lights of a following motorcar may be expected to arise frequently, and so by contrast be a major cause.

Accordingly the masking of motorcycles by confusion must be weighed in the negative side of the balance against the positive benefits of motorcar daytime lights.

3.2.6 Frustration

Findings of Attwood 1976: *Attwood 1976* conducted an experiment in which motorcar driver subjects were required to estimate the distance that they required to overtake a 'lead' motorcar in the face of an oncoming motorcar. He compared the distance according to whether the oncoming motorcar was showing lights of different sorts, or not.

Attwood 1981's recital of *Attwood 1976's* findings reads:

'... The SG [*Safety gap*] data also suggest that the drivers consistently underestimated the distance to a more conspicuous vehicle. That is, they reported the more conspicuous vehicle

closer than it actually was. On the other hand, performance around the individual threshold luminance levels suggests that when the approaching vehicle was unlit, drivers overestimated the distance to it. In practical terms, the SG data indicate that many more risky passes would occur at low daylight levels when the approaching vehicle is unlit than when it is equipped with either full- or reduced-intensity, low-beam headlights.'

Frustration: From the wording of the recital, it is clear that *Attwood 1981* thought that *Attwood 1976* had made a 'safe' finding.

However drivers who become frustrated through missing opportunities to overtake safely may become impatient, and so overtake unsafely.

Thus to give two relevant study findings, first per *Hills 1980*, *Ebbesen & Haney 1973* studied the gap-acceptance behaviour of drivers waiting to emerge at a T-junction.

They found that being forced to wait in a line of cars before being allowed to turn did 'substantially increase the risks' that drivers took.

Second, *McDowell et al 1983* conducted a similar study.

They found that drivers accepted shorter gaps when entering a road in front of a goods vehicle than when entering a road in front of a motorcar, and speculated that part of the reason why they did so might be that they were reluctant to be held up behind a slower vehicle:

'The class of the approaching vehicle affects the merging driver's behaviour; shorter gaps tend to be accepted in front of goods vehicles than in front of cars (Table 13). This may be due to misperception of the speed of the approaching goods vehicle or a reluctance to merge behind such a vehicle, or both.'

So *Attwood 1981* was imprudent to give an unqualified welcome to a finding that daytime lights had reversed the errors of estimation of the distance of an oncoming vehicle that driver subjects made at low daylight levels.

Misestimation of speed and distance: Apart from *Attwood 1976*, the authors are not familiar with any satisfactory study that has attempted to evaluate the effect of daytime lights upon the estimation of speed and distance of vehicle by other road users.

For instance the motorcycle studies *Shew et al 1979?* and *Stroud 1982* required test subjects to estimate the speed of an oncoming motorcycle in miles per hour.

However it is unlikely that drivers on the road estimate the speed of vehicles as a quantified speed; instead they do qualitatively as 'slow', 'normal' or 'fast' by reference to what they view as a safe speed for the road in question.

If so, the findings of the two studies bear, not upon the accuracy with which the test subjects estimated the speed of the motorcycle, but merely the accuracy with which they translated their qualitative impression of the speed into miles per hour.

Conclusion: *Attwood 1976* only studied the effect of daytime lights upon the judgment of speed and distance by other drivers at the long ranges that characterise the situation of overtaking in the face of oncoming traffic.

And to repeat the authors do not know of any study that has satisfactorily studied the effect of daytime lights upon the judgment of speed and distance in other situations.

But if any other study has made findings, similar to *Attwood 1976*, that daytime lights in other situations cause drivers to underestimate the distance of an oncoming vehicle, because of the possible indirect consequence of accidents caused by resultant 'frustration', the findings can only with great caution be counted upon the positive side of the balance in favour of daytime lights.

Whilst if any study has made opposite findings, namely that daytime lights cause drivers to overestimate distance, since the direct consequence will be accidents, then the findings must be

counted less equivocally under the new heading of 'misestimation of speed and distance' on the negative side of the balance.

Or in short the only truly 'safe' finding from a study of the effect of daytime lights upon the estimation of speed and distance by drivers would be a finding that daytime lights reduce the errors of estimation in both directions—overestimation and underestimation—that drivers make.

3.2.7 'Hesitation' or 'After you Claude' collision

Collisions at an intersection between a motorcycle (or motorcar) on the major road and another vehicle may be classified under one of three headings:

- 1) 'Same time and same place' collision:
Other vehicle and motorcycle directly enter collision zone at same time, and immediately collide with each other
- 2) 'Hesitation' collision:
Other vehicle hesitates in collision zone, and motorcycle immediately collides with the vehicle
- 3) 'After you, Claude' collision:
Other vehicle hesitates in collision zone, and motorcycle collides with it after 'After you Claude' misunderstanding between driver and rider of what course of action the other party will adopt, ie:
 - Rider goes to pass behind other vehicle, but driver remains where he is
 - Rider goes to pass in front of other vehicle, but driver carries on in an attempt to clear the collision zone.

Collisions between a motorcycle (or motorcar) and a pedestrian who is crossing the road may be similarly classified.

Implications: As can be seen from the above classification, once a motorcar driver or pedestrian who has failed to notice the motorcycle intrudes into the motorcycle's path, the most favourable 'outcome'

for the motorcycle rider will often be that the driver continues unaware of his presence, and so clears the collision zone as rapidly as possible.

And correspondingly the most unfavourable outcome will often be that the driver belatedly notices the motorcycle, and hesitates in the collision zone.

Incidence: There are potentially a number of circumstances in which a driver may initially fail to observe or notice a motorcycle, but then belatedly notice it.

However in the interest of brevity, the authors will treat only the possible incidence of the circumstances in which there was a temporary obstruction of the line of sight between the other driver and the motorcycle.

Olson 1989 conveniently summarises as follows the findings of *Williams & Hoffman 1977* and *Hurt et al 1981* from their analyses as to the frequency with which the other party's view of the motorcycle was obscured:

'Both investigations considered the possibility that there may have been obstructions that prevented or limited the other driver's seeing the motorcycle. Williams and Hoffman found that in 56% of the 763 collisions in which there was a claimed failure to detect [ie 427 (or 28%) out of a total of 1508 accidents in Williams & Hoffman 1977's Victoria sample], there was an obstruction within the offending driver's vehicle, or there was another vehicle or a natural object such as a tree or shrub that interfered with the driver's seeing the motorcycle. Hurt et al. noted 221 cases of significant obscuration of the driver's view of the motorcycle. The fact that there were 457 collisions in which the right of way of the motorcycle was violated implies that in at least 48% of those cases the driver's view of the motorcycle was blocked to some degree [ie 221 (or 25%) out of a total of 900 accidents in Hurt et al 1981's Los

It is not possible to distinguish in turn from the reports of *Williams & Hoffman 1977* or *Hurt et al 1981* how far the obstruction to vision

in question persisted right up until the moment of collision, or because of the movement of the obscuring object, or the parties, was temporary.

But out of the large number of motorcycle accidents that Williams & Hoffman and Hurt et al identified in which the driver's vision of the motorcycle was obstructed, it is reasonable to suppose that an important proportion of the total number—and so also an important number absolutely—were accidents where the obstruction to vision was indeed temporary.

Conclusion: To conclude, in appraising the effect of motorcycle (or motorcar) daytime lights, against the positive effect of:

- Preventing the motorcar driver or pedestrian from intruding into the path of the motorcycle (or other motorcar) in the first place

there must be weighed in the balance the potential negative effect also of:

- Causing the motorcar driver or pedestrian belatedly to notice the motorcycle (or other motorcar), and so hesitate in the collision zone, in turn causing a 'Hesitation' or 'After you, Claude' collision between them.

3.2.8 False confidence

It is not only the effect of motorcar or motorcycle daytime lights upon the behaviour of the other road user that falls to be considered, but also the effect upon the behaviour of driver of the motorcar or rider of the motorcycle.

In the first place they may give the driver or rider false confidence that, 'because they have seen him', waiting drivers will give way to him.

Or in the second place they may cause the driver or rider, for the same reason, to assert his right-of-way over waiting drivers aggressively.

False confidence will be treated in the present section, and aggression in the next.

False confidence of motorcycle rider: To take first the effect of false confidence upon the behaviour of the motorcycle rider,

given the spectacular character of motorcycle daytime lights compared with the natural lack of conspicuity of motorcycles, he is especially liable, as above, to think that daytime lights will alter the behaviour of waiting drivers towards him.

However there are a number of other important causes why a motorcar driver (or pedestrian) may intrude in front of an approaching motorcycle besides the motorcycle's lack of conspicuity.

The second author has set out and justified the causes in the previous papers: *Prower 1990 (No 2)*, *Prower 1996*, and *Prower 1998*. A longer treatment is also in draft.

In brief résumé the causes are:

- 1) The ease and frequency with which a small vehicle, such as a motorcycle, is obscured from view by other vehicles, roadside objects, or in-vehicle obstructions to a driver's vision
(The analyses of motorcycle accidents in Victoria by *Williams & Hoffman 1977* and in Los Angeles by *Hurt et al 1981* whose findings have just been recited)
- 2) The probable perceptual impossibility, under all but perfect viewing conditions, of estimating the speed of a small vehicle, such as a motorcycle, in head-on view — so that motorcar drivers and pedestrian will usually only be able to make an arbitrary estimate of the motorcycle speed, eg as the normal speed of other traffic on the road
(The laboratory estimate by *Hills 1975b* [as recited in *Hills 1980*] of the size of the threshold angle of longitudinal movement that is detectable by the human eye)
- 3) A probable compulsive tendency of motorcycle riders to monitor the road surface — so that the rider does not see the intruding motorcar or pedestrian, or does not see it until too late
(The analysis of motorcycle accidents in Osaka Prefecture by *Nagayama 1978* [as recited by *Nagayama 1984*, and it is thought also by *Nagayama et al 1979*]; the eye-marker camera study of *Nagayama et al 1979*; the in-depth analysis of motorcycle accidents at intersections by *Nagayama 1984*)

- 4) The inadvertent failure of the motorcar driver or pedestrian to look completely to see that the road is clear
- 5) The failure of the motorcar driver or pedestrian to look completely to see that the road is clear because he or she has limited head movement
- 6) A tendency of motorcar drivers only to give way at intersections to police motorcycles

(The experimental studies by *Leonard 1974* and *Booth 1978* that were recited under 'Acclimatisation').

The authors also take the opportunity of adding to the list:

- 7) The processing load upon the motorcar driver
(One of the possible causes *that* were canvassed by *Olson 1989*).

It is principally the new motorcycle rider who is at risk of an accident from one of these other causes through false confidence that, because he is using daytime lights, the other driver or pedestrian will give way to him.

The false confidence may be dispelled by drivers or pedestrians who nevertheless intrude into his path without an accident.

But it may also be dispelled by an actual accident.

False confidence of motorcar driver: To take second the effect of false confidence upon the behaviour of the motorcar driver, as can be seen from the list of other possible causes of a motorcycle accident besides a lack of conspicuity, not all of the causes will apply to a motorcar accident.

And the new motorcar driver will not feel his conspicuity to be enhanced to the same degree as a new motorcycle rider by daytime lights.

So false confidence from daytime lights is less likely to cause the new motorcar driver to have an accident than a new motorcycle rider.

Conclusion: False confidence therefore falls to be weighed as a potential important negative factor against the positive effect of motorcycle daytime lights.

However it is less likely to be an important factor as regards motorcar daytime lights.

3.2.9 Aggression

To repeat, motorcar or motorcycle daytime lights may cause the driver or rider to assert his right-of-way over waiting drivers aggressively 'because they will have seen him'.

But there are other causes besides their lack of conspicuity why another driver may intrude into the path of an oncoming motorcar or motorcycle, so the result of such aggression may be an accident.

Unlike false confidence daytime lights may cause experienced as well as new drivers or riders to behave aggressively towards waiting drivers.

Also because of the relative 'invulnerability' of the motorcar driver, the situation of false confidence is reversed, and it is the motorcar driver, not the motorcycle rider, who is more likely to behave aggressively.

The treatment can be short because the authors know of no relevant study findings.

And anecdote can equally support the position that it is the aggressive driver who by 'self-selection', favours an intimidatory display of lights, or less confidently that 'behaviourally', in line with the present argument, a display of lights can render the ordinary driver more aggressive.

Conclusion: In conclusion therefore, it is suggested that the more aggressive assertion by ordinary motorcar drivers of their right-of-way may be a negative effect of motorcar daytime lights.

To a lesser extent the same suggestion may apply to motorcycle daytime lights.

3.3 Summary

It is a subjective exercise to balance the prima facie arguments that have been presented.

But the judgment of the authors is that no net safety benefit can be predicted from the arguments for either motorcar or motorcycle daytime lights.

Indeed for motorcar daytime lights a possible excess of negative over positive effects—and so an actual increase of accidents from daytime lights—cannot be discounted.

The judgment conflicts with the anecdotal experience of many motorcycle riders who use daytime lights.

But most riders who use daytime lights also 'believe' in them, so that they always use them.

They therefore do not supply the 'controlled' anecdotal experience of the rider who 'uncommittedly' sometimes uses daytime lights, and sometimes does not do so.

Only such a rider can carry matters forward by saying, as the case may be, that indeed when he is using daytime lights: 'Fewer motorcar drivers pulled out in front of me'.

Fortunately though for motorcycle riders who believe in daytime lights, the motorcycle issue is not concluded entirely by the findings of the monitoring studies and the prima facie arguments.

One important controlled experimental 'field' study has been conducted. The findings of the study will be described next.

4. Evidence of experimental field studies of effect of motorcycle daytime lights

Apart from the monitoring studies, at least two other important types of study have been conducted of the effect of motorcycle daytime

lights upon accidents or driver behaviour: 'accident involvement' studies, and 'experimental field' studies.

The accident involvement studies will be treated formally at short length. The experimental field studies—to wit the main study of the sort, the 'gap acceptance' study *Olson et al 1979a*—will be afforded a more lengthy treatment.

4.1 Accident involvement studies

The accident involvement studies compare the frequency of use of daytime lights by a group of motorcycle riders who have been involved in an accident with the frequency of use of daytime lights by a 'control' group who have not been involved in an accident.

The two principal studies of the sort that have been conducted are the New South Wales study *Vaughan et al 1977*, and one of the analyses that formed part of the Los Angeles study *Hurt et al 1981*.

Problems of method of accident involvement studies: The problem of method of the accident involvement studies is that the riders in the 'accident' group may suffer from 'self-selection'.

Perforce accident involvement studies are performed under conditions of voluntary daytime light use: and it may be that, under the conditions, it is the more cautious, less accident-prone, sort of rider who 'preferentially' chooses to use daytime lights.

Or in other words the accident group may 'select itself' according to some other 'relevant' condition besides the 'test' condition.

Further the findings of the accident involvement studies may also be confounded by the 'novelty' effect.

Thus to take the Los Angeles findings of *Hurt et al 1981* as example, *Hurt et al* collected their accident group data during 1976 and 1977, and their control group data during 1978 and 1979.

But between the two periods on 1 January 1978 California implemented its motorcycle hard-wiring law.

So riders in Hurt et al's accident group who used daytime lights may have 'benefited' to a substantially greater degree more from the 'novelty' effect than riders in the control group who used daytime lights.

Neutral findings of accident involvement studies: Both *Vaughan et al 1977* and *Hurt et al 1981* found a much lower frequency of daytime light use by the riders in their accident group than the riders in their control group

However lay study *Motor Cycle Council of New South Wales 1984* and *Muller 1984* reanalysed the data of the two studies and found that *Vaughan et al 1977* and *Hurt et al 1981* had in fact made mixed findings.

In particular *Muller 1984* discounted the effect of self-selection by analysing only the accident group data of the studies.

He was able to make comparisons of the percentage figures of daytime light use and non-daytime light use for:

- Head-on collisions versus Other collisions (Both studies)
- Head-on & peripheral collisions versus Other collisions (Both studies)
- Multi-vehicle accidents versus Single-vehicle accidents (*Vaughan et al 1977*).

Out of the five comparisons only the last comparison manifested a lower percentage figure of daytime light use — ie proportionately fewer of riders involved in multi-vehicle accidents than single-vehicle accidents were using daytime lights. For the rest the comparisons actually manifested higher percentage figures of daytime light use.

4.2 Experimental field studies

Gap acceptance studies: The most sophisticated type of experimental field studies are the 'gap acceptance' studies.

The principal gap acceptance study of motorcycle daytime lights was conducted at Ann Arbor, Michigan in the late 1970s by *Olson et al 1979a*.

Kirkby & Stroud 1978 did conduct another gap acceptance study at Derby, England.

The study is one of a number of studies—including the pedestrian recall study that was recited earlier—that later *Fulton et al 1980* also reported upon together.

However the scope of *Kirkby & Stroud 1978* was much more limited than *Olson et al 1979a*, so only *Olson et al 1997a* will be further treated post.

Gap acceptance method: To describe the gap acceptance method, as it was adopted by *Olson et al 1979a* for their study, volunteer test riders on a motorcycle (or motorcar) along a thoroughfare in Ann Arbor, Michigan offering a set time gap in front of them to ordinary drivers waiting at a junction. The test rider indicated the intended manoeuvre of the waiting driver, and whether or not he 'accepted' the gap, ie proceeded to carry out the manoeuvre.

By repeating the procedure for the test rider and motorcycle in 'experimental condition' using one of a variety of 'conspicuity treatments'—including daytime lights—, or in 'control condition' not using an conspicuity treatment (or driving the motorcar), Olson et al accumulated comparative 'gap acceptance' data for the conditions under the heads:

- Condition of test rider and motorcycle
- Time gap offered to waiting driver
- Intended manoeuvre of waiting driver
- Whether or not time gap accepted by driver.

Olson et al then analysed the data and presented the results as the findings of their study.

As can be seen, by contrast with every other type of study that has been treated in the paper, the gap acceptance studies are perfectly 'controlled' studies.

Thus the test rider rides the motorcycle in the control conditions along the same road, over the time span of the same study period, as the motorcycle in the experimental conditions.

Because of the perfect control—and as will be seen a number of important implications for the prevention of motorcycle accidents that flow from Olson et al's findings—the authors will treat *Olson et al 1979a* at length.

Nevertheless, as follows, the gap acceptance studies are not spared their own important problems of method.

Problems of method of gap acceptance studies: The first problem of the method of gap acceptance studies is that it is not known from the general literature on the subject how far the frequency with which drivers accept a short gap in front of an oncoming vehicle may be expected to translate into a frequency of actual accidents — or as it is put, the 'predictive power' of the findings of gap acceptance studies is not known.

Olson et al 1981, summarising the findings of *Olson et al 1979a*, themselves utter a caution to this effect.

For instance, it may be canvassed that infringements of a motorcycle rider's right-of-way are more likely to 'catch out' the rider, and so result in an accident, not in proportion, but in inverse proportion, to their frequency of occurrence.

Thus although the point can only be supported by anecdote, certainly the second author feels far safer riding a motorcycle in Central London where he may expect a 'serious' infringement say every mile, than in the country where he may expect an infringement every 200 miles.

The second problem of method is that the findings of the gap acceptance studies are subject to the 'novelty' effect.

So the findings of *Olson et al 1979a* are specific to Ann Arbor in the late 1970s.

The specificity is especially limiting in Olson et al's case because although, per *Muller 1984*, in the late 1970s Michigan did not have

a motorcycle daytime light law, as previously noted, following the implementation of the California hard-wiring law on 1 January 1978, the motorcycle manufacturers hard-wired their entire production for the North American market.

So it is even more difficult to 'project' the effect of daytime lights, as found by *Olson et al 1979a* for Ann Arbor in the late 1970s, to other times or places.

Findings of *Olson et al 1979a*: Per *Olson et al 1979b*, *Olson et al 1979*, settled upon a time gap of 3 sec or less for their study: so few motorcar drivers accepted a gap of less than 2 sec that no reliable statistical analysis for such gaps could be conducted.

In turn *Olson et al 1981* summarise the findings of *Olson et al 1979a* for the motorcycle rider in control condition, and inter alia the experimental conditions:

- Motorcycle displaying daytime lights
- Motorcycle rider wearing fluorescent clothing
- Motorcycle fitted with fluorescent fairing

and motorcar drivers inter alia:

- Waiting on the minor road with the intention of crossing over the intersection, or turning left into the major road
- Waiting in the centre of the major road with the intention of turning left into the minor road [*Traffic travels on the left of the road in the USA*].

First for the motorcycle and rider in control condition:

- A figure of 6% of drivers who were waiting on the minor road to turn left or cross the major road accepted a gap of 3 sec or less ahead of the motorcycle
- A figure of 5% of drivers who were waiting on the major road to turn left into the minor road accepted a gap of 3 sec or less ahead of the motorcycle.

Second for the motorcycle and rider in the experimental conditions:

- All three conditions—ie daytime lights, fluorescent clothing and the fluorescent fairing—achieved a substantial reduction in the figure of gaps of 3 sec or less that were accepted by drivers who were waiting on the minor road to turn left or cross the major road
- Daytime lights and fluorescent clothing, but not the fluorescent fairing, achieved a substantial reduction in the figure of gaps of 3 sec or less that were accepted by drivers who were waiting on the major road to turn left into the minor road.

[However as between daytime lights and fluorescent clothing, only the improvement from fluorescent clothing was statistically significant].

In short to rank conspicuity treatments, fluorescent clothing achieved the best 'improvement' in driver behaviour: it was the only treatment to achieve statistically significant improvements for both of the two driver manoeuvres under consideration.

Daytime lights came next: they failed to achieve a statistically significant improvement for the second manoeuvre.

And the fluorescent fairing came last: it failed to achieve any improvement for the second manoeuvre.

Cautions of *Olson et al 1981* and Olson (interview with *Despain 1981*): At the same time as reporting the above findings, *Olson et al 1981* went on to caution and comment:

- Whilst daytime lights and fluorescent clothing reduced the percentage figure of gaps of 3 sec or less that drivers accepted for the two manoeuvres, sometimes substantially, neither eliminated them
- The finding for the fluorescent fairing was surprising. In the opinion of Olson et al it was a more effective treatment than the fluorescent clothing. They speculated why this might be so.

And in an interview reported by *Despain 1981*, drawing also upon additional findings—presumably from preliminary trials—that *Olson et al 1981* did not report, Olson developed the cautions and comments.

First, not only were the 'rankings' of the three conspicuity treatments, as taken together with other treatments that have been omitted for simplicity counter-intuitive, but when the test riders dropped back to allow time gaps of 4 sec or 5 sec in front of them, a number of the rankings changed, some markedly.

In the interview, Olson went on to discuss the implications of the facts at length.

The implications are complex, so that it is not possible within the scope of the present paper to summarise the discussion in full.

Instead the authors will merely note Olson's:

1) General comment that:

'Certain things we did clearly maximised the conspicuity of the bike, but had little effect upon the reactions of drivers';

2) General speculation that:

'That suggests we may not be dealing with a simple problem of conspicuity — the driver's ability to detect';

3) And specific speculation, inter alia, that:

'This could be a problem of judgement in speed/spacing relationships'.

Related findings of other studies: In addition to *Olson et al 1979a*

- The general tenor of the findings of the experimental non-field study *Dahlstedt 1986* is in accord with *Olson et al 1979a's* counter-intuitive findings
- The general tenor of the findings of the experimental field study by *Donne & Fulton 1985* that has been mentioned is in accordance—in their case as between different experimental sites—with the inconsistent ranking of treatments that *Olson et al 1979a* found as between gaps offered of different lengths of time.

Conclusion: The practical implication of the findings of *Olson et al 1979a* for motorcycle riders is that, if they use daytime lights—or one of the other conspicuity treatments that Olson et al tested—, they cannot consistently or predictably rely upon a consequent reduction of the frequency with which other drivers (or pedestrians) infringe their right-of-way.

Rather motorcycle riders must:

- As a matter of attitude, continue to anticipate infringements by other drivers of their right-of-way
- As a matter of practice, continue to take all of the other defensive measures that they know to prevent infringements from occurring, or if they fail, to avoid that the infringement turns into an accident.

The theoretical implication of the findings for the purposes of the paper is unfortunately limited by the problems of method that were described at the outset, namely to repeat:

- The difficulty of projecting from findings of the incidence of short gaps accepted by other drivers to actual accidents
- The specificity of the findings of *Olson et al 1979a*, because of the novelty effect, to the circumstances prevailing in Ann Arbor, Michigan in the late 1970s at the time when they were made.

5. Recent initiatives to fit motorcycles and motorcars as manufactured with daytime lights

Introduction: Recently in 2001 the European Automobile Manufacturers Association (ACEA) offered to the European Commission by way of a voluntary commitment to fit daytime lights on all new vehicles from 2003 as part of a package designed to improve the safety of vulnerable road users.

In response the Federation of European Motorcyclists' Associations (FEMA), together with the European Cyclists' Federation (ECF) and the European Federation of Road Traffic Victims (FEVR), nevertheless made representations to the European Commission against the ACEA offer.

In a joint campaign the parties raised the safety concerns of motorcyclists, cyclists and pedestrians over the car manufacturers' offer. In particular FEMA raised the present lack of convincing evidence in favour of motorcar daytime lights.

Shortly after the announcement of the ACEA offer, the Association of European Motorcycle Manufacturers (ACEM)—which also includes amongst its members the European distributors of Japanese motorcycles—informed the Federation of European Motorcyclists' Associations of their decision to hard-wire the lights on their production of motorcycles too for the European market.

Given that, as recited earlier, it was at the initiative of the Japanese motorcycle manufacturers that the Japanese Government enacted the 1998 Japanese motorcycle hard-wiring law, the ACEM decision probably reflects a more extensive decision by the European and Japanese motorcycle manufacturers to hard-wire their entire production of motorcycles for the worldwide market.

First issue: Between them the two initiatives raise the 'perennial' issue of the lack of convincing scientific evidence that motorcar or motorcycle daytime lights have a beneficial effect to reduce road accidents.

Second & Third issues: But given the situation in the European Union that most motorcycle riders use daytime lights, but most motorcar drivers do not, the motorcar initiative also 'topically' raises the new issues:

- Whether altering the situation so that most motorcar drivers also use daytime lights will reduce the conspicuity of motorcycles, and so increase the number of motorcycle accidents
- If so whether the reduction of accidents from the enhanced conspicuity of motorcars will nevertheless be greater than the increase of accidents from the reduced

conspicuity of motorcyclist -- ie whether motorcar daytime lights will nevertheless achieve a 'net safety benefit'.

Treatment: The second author has written extensively on the first issue.

This paper therefore confines the discussion of the following section, which arises out of the motorcar initiative, to the second and third issues, and only treats the first issue perfunctorily insofar as the state of the scientific evidence is also material to the second and third issues.

Likewise it confines the discussion of the next following section, which it is timely to renew against the background of the motorcycle initiative, to other remedies besides daytime lights for motorcycle accidents at intersections that are potentially available subject to the completion of supporting research studies.

6. Effect of use of daytime lights by both motorcars and motorcycles upon motorcycle accidents

6.1 First issue: Are motorcycle daytime lights effective?

For purposes of the present discussion the authors will defer to the anecdotal experience or intuition of motorcyclists, and in line with the majority opinion amongst them, take it that motorcycle daytime lights are effective to prevent accidents.

Thus whatever view the authors may take on the soundness of the evidence of the monitoring studies, or the balance of the prima facie arguments for and against motorcycle daytime lights, the majority opinion has the important residual if qualified support of the findings of *Olson et al 1979a*.

And as will be seen, in regard to a number of points that are made in the discussion it is in fact immaterial whether or not motorcycle daytime lights are effective.

6.2 Second issue: Will motorcycle accidents increase?

The best prediction is: Yes.

To take up from what was said under 3.2.6 'Masking by confusion', it is likely that the masking of the single daytime light of a motorcycle by the twin daytime lights of a following motorcar will significantly increase the number of motorcycle accidents. The particular configuration of vehicles that was mentioned under 3.2.5 'Masking by glare' may also in some circumstances occur.

As discussed under 3.2.1 'Size of effect', unlike motorcars, motorcycles lack many features that make for ready conspicuity. So anything that subtracts from their conspicuity will increase motorcycle accidents.

To take up from what was said under 3.2.2 'Acclimatisation', the use of daytime lights by all vehicles will accelerate the rate of acclimatisation of road users to motorcycle daytime lights.

To take up from 3.2.3 'Distraction', motorcar daytime lights will draw the attention of road users away from motorcycle daytime lights, and from motorcycles generally. They will distract the attention of motorcyclists.

As discussed under 3.2.4 'Glare', motorcar daytime lights will importantly increase the visual 'hostility' of the present road scene. Other road users may more readily overlook motorcycle daytime lights, and motorcycles generally. Motorcyclists may overlook situations of potential hazard to them.

To take up from what was said under 3.2.10 'Aggression', motorcar daytime lights may encourage aggressive motorcar drivers to undertake manoeuvres where the lights of the motorcar are visible to the oncoming vehicle, such as overtaking, or turning right off a major road, in the face of an oncoming vehicle regardless of the vehicle's

right-of-way. They may do so more readily in the face of a narrow vehicle such as a motorcycle on the basis that 'It can get out of their way'.

As discussed under 3.2.7 'Frustration', in low daylight motorcyclists as well as other drivers may be the perpetrator or victim of reckless overtaking a driver who is frustrated by repeatedly underestimating the distance away from him of oncoming motorcars that are using daytime lights, and so thinking that they are 'unsafely' closer to him than they are.

6.3 Third Issue: If so, will other accidents decrease more?

The question can be answered shortly: No. The study evidence is worthless and the prima facie arguments fail to rescue it.

As stated under 2. 'Evidence of monitoring studies of effect of motorcycle and motorcar daytime lights', the motorcar studies have employed a defective methodology that is not specific to the effect of daytime lights. To boot the motorcar studies have made mixed findings.

As concluded under 3. 'Prima facie arguments for and against use of motorcycle and motorcar daytime lights', on the balance of the arguments a net reduction of accidents can be predicted from motorcar daytime lights. Indeed there may be a net increase of accidents.

7. Potential of other measures besides daytime lights to reduce motorcycle accidents

Daytime lights for motorcycles are intended principally to treat accidents between:

- A motorcycle rider who has right-of-way at an intersection and a motorcar
- A motorcycle rider and a pedestrian who crosses the road in front of the motorcycle.

For the sake of brevity, such accidents will usually be called simply 'motorcycle accidents at intersections', or 'pedestrian accidents'.

Daytime lights are intended to treat motorcycle accidents at intersections or pedestrian accidents by supplying a remedy for a 'lack of conspicuity' of the motorcycle as the cause of the accident.

The following section concludes the main body of the paper by taking up the other potential causes of a motorcycle accidents at an intersection or a pedestrian accidents besides a lack of conspicuity of the motorcycle that were listed under 3.2.8 'False confidence', and canvassing remedies for them also.

The arrangement of the section is:

- To give, by way of establishing their importance, the incidence of motorcycle accidents at intersections (or pedestrian accidents)
- To repeat, by way of reminder, the full set of potential causes of a motorcycle accidents at an intersection
- To describe the current remedies for the causes
- To describe the current status of research findings into the causes
- To list the research needs that the description of the current status of research findings reveals
- To describe prospective remedies for the other causes of motorcycle accidents at intersections besides a lack of conspicuity of the motorcycle.

7.1 Incidence of motorcycle accidents at intersections (or pedestrian accidents)

To give the incidence of motorcycle accidents at intersections and pedestrian accidents, the incidence of each type of accident is, in line with the relevant studies or statistics, most conveniently given separately.

Incidence of motorcycle accidents at intersections: First, as follows, the figure of accidents between a motorcycle rider who has right-of-way at an intersection and a motorcar could be as high as one third or more of all motorcycle accidents.

Older studies: *Faulkner 1975* analysed inter alia accidents involving 192 drivers and 261 motorcycle riders at a sample of junctions not controlled by traffic lights in Great Britain. He found that, consistently between junctions categorised as:

- 'Outer London (50–70mph roads)'
- 'Other Southern towns (30–40mph roads)'
- 'Rural junctions',

a figure of 91% of motorcycle riders were travelling on the major road. [*Speed limits in Britain range from 30–70mph (48–113kph)*].

Faulkner's analysis did not however distinguish between daytime and darktime accidents at the sample of junctions.

Whitaker 1980, as previously noted, analysed 425 motorcycle accidents that took place in 1974 in the Slough and Newbury Divisions of the Thames Valley Police Force area in Great Britain. He found that 'the motorcycle was going ahead, and the other vehicle manoeuvring in 72% of multi-vehicle junction accidents'.

Whitaker's analysis did not again distinguish between daytime and darktime multi-vehicle junction accidents: but overall 72% of all multi-vehicle accidents in his sample took place in daylight.

A total of 51% of all motorcycle accidents in *Whitaker 1980's* sample were multi-vehicle accidents at junctions, roundabouts or private entrances.

So—assuming that the motorcycle was going ahead in 72% of accidents at roundabouts or private entrances as well as junctions—accidents between a motorcycle rider with right-of-way at an intersection, private entrance or roundabout and a motorcar represented 37% of all motorcycle accidents in Whitaker's sample.

Or—assuming in turn that 72% of the accidents in question, like motorcycle multi-vehicle accidents overall, took place in

daylight—accidents in daylight between a motorcycle rider with right-of-way at an intersection, private entrance or roundabout and a motorcar represented 27% of all motorcycle accidents.

More recent studies: *Olson 1989* analysed inter alia data of the daytime motorcar-motorcycle collisions that took place in Texas in 1986. He found that in 90% of collisions in which one vehicle was turning left, and the other going straight, it was the motorcycle that was going straight.

Per *Motor accidents in New Zealand, 2000*, excluding fatal accidents the 'movement classification' of a figure of 39% out of the total number of 645 injury accidents involving motorcyclists that took place in New Zealand in 2000 was:

- 'Intersections or driveways
 - Turning versus same direction
 - Crossing no turns
 - Crossing vehicle turning
 - Vehicles merging
 - Right turn against',

as opposed to:

- 'Vehicle manoeuvring'.

Separated into accidents of the sort that took place in daytime and darkness, the figure of accidents in darkness at 'Intersections or driveways' was 9% out of the total number of accidents, and the residual figure for accidents in daytime 30%.

It may be reasonably speculated that the New Zealand figures in question do in fact represent accidents at intersections or driveways between a motorcycle travelling straight ahead and another vehicle — thus in police jargon, when presented all together such accidents will often be classified, by reference to the motorcycle, as: 'Vehicle going ahead at intersection or driveway; other vehicle manoeuvring'.

Summary: Thus to sum up there is good concordance between the analyses of studies undertaken before, and after, the use of daytime lights by motorcyclists became widespread that:

- In up to 90% of motorcycle accidents between a motorcycle and another vehicle at an intersection, the motorcycle may be travelling straight ahead
- Motorcycle accidents at an intersection between a motorcycle that is travelling ahead and another vehicle that take place in daytime may represent some 30% of all motorcycle accidents (or in darkness a further 10%).

Incidence of motorcycle accidents with pedestrians: Second assuming that most accidents between motorcycles and pedestrians represent an accident between a motorcycle rider and a pedestrian who crosses the road in front of the motorcycle, the figure of such accidents may in some countries, according to official statistics, be substantial.

In Great Britain for instance, by calculation from the official statistics the proportion of pedestrians to motorcycle riders killed in motorcycle accidents for the period 1994–2000 was as high as the proportion of motorcycle passengers to motorcycle riders:

	<u>TWMV</u> riders	<u>TWMV</u> passengers	<u>Pedestrians</u> hit by TWMV
1994	(100.0%)	11.3%	10.3%
1995	(100.0%)	7.0%	10.8%
1996	(100.0%)	6.3%	9.9%
1997	(100.0%)	6.7%	6.7%
1998	(100.0%)	6.9%	5.8%
1999	(100.0%)	4.2%	4.8%
2000	(100.0%)	5.6%	7.7%

TWMV = Two-wheel motor vehicle

Source: Calculation from *Road Accidents Great Britain 1994–2000*.

7.2 Full set of causes of motorcycle accidents at intersections (or pedestrian accidents)

To repeat the list of potential causes of motorcycle accidents at intersections (or pedestrian accidents) from 3.2 'False confidence', it should be noted that, for present purposes, the list has been altered and re-numbered so that:

- The cause 'Lack of conspicuity of the motorcycle' now also appears in the list
 - The cause 'Processing load upon the motorcar driver' no longer appears at the end as an addition to the list, but is included in its appropriate place:
- 1) The lack of conspicuity in head-on view of the silhouette of a motorcycle and rider
 - 2) The ease and frequency with which a small vehicle, such as a motorcycle, is obscured from view by other vehicles, roadside objects or in-vehicle obstructions to a driver's vision
 - 3) The probable perceptual impossibility, under all but perfect viewing conditions, of estimating the speed of a small vehicle, such as a motorcycle, in head-on view — so that motorcar drivers and pedestrians will usually only be able to make an arbitrary estimate of the motorcycle speed, eg as the normal speed of other traffic on the road
 - 4) The processing load upon the motorcar driver
 - 5) A probable compulsive tendency of motorcycle riders to monitor the road surface — so that the rider does not see the intruding motorcar or pedestrian, or does not see it until too late
 - 6) The inadvertent failure of the motorcar driver or pedestrian to look completely to see that the road is clear
 - 7) The failure of the motorcar driver or pedestrian to look completely to see that the road is clear because he or she has limited head movement
 - 8) A tendency of motorcar drivers only to give way at intersections to police motorcycles.

7.3 Current remedies

The principal remedy for motorcycle accidents at intersections (or pedestrian accidents) that has been proposed and implemented to date is, to repeat, motorcycle daytime lights.

As noted under 3.2.4 'Distraction', daytime lights are not intended simply to make a motorcycle noticeable when it is viewed by another road user directly in central vision; rather daytime lights are intended also to make a motorcycle noticeable in peripheral vision when they are viewed by another road user who is looking in a direction up to 30° away from the motorcycle.

But motorcycle daytime lights have extensive limitations as a remedy, and an important potential adverse side-effect.

Limitations of daytime lights: First as can be seen from the full list of potential causes of motorcycle accidents at intersections or pedestrian accidents, out of the list daytime lights will only treat:

- Cause (1) 'Inconspicuity of motorcycle'
- Cause (6) 'Failure to look'
- Cause (7) 'Limited head movement' above.

Further Cause (1) 'Inconspicuity of motorcycle' will only operate to cause accidents in limited circumstances.

To refer back to 3.2.1 'Size of effect', in the case of most accidents, the motorcycle will be less than 100yd away from the motorcar driver (or pedestrian)—and so perfectly noticeable to the driver—when the driver ignores its presence.

The critical range may be extended by:

- The operation of Cause (5) 'Preoccupation of rider with road surface'
- A hesitation by the other driver or pedestrian in the collision zone
- An 'After you, Claude' misunderstanding between the parties.

But a Hesitation or After you, Claude collision is initiated by the driver's noticing, rather than failing to notice, the motorcycle.

So Cause (1) 'Inconspicuity of motorcycle' will only operate as the cause of an accident in the case of an extension of the range by Cause (5) 'Preoccupation of rider with road surface'.

As to the remaining causes, daytime lights will not treat:

- Cause (2) 'Obscuration of motorcycle'.

And even though by virtue of daytime lights the motorcar driver or pedestrian may notice the motorcycle:

- Cause (3) 'Arbitrary estimation of speed & distance'
- Cause (4) 'Processing load upon driver'
- Cause (5) 'Preoccupation of rider with road surface'
- Cause (8) 'Response to police motorcycles only'

will continue to operate.

Potential adverse side-effect of daytime lights: Second, to refer back to 3.2.8 'Hesitation' or 'After you Claude' collision', there are circumstances when daytime lights, by causing a motorcar driver or pedestrian belatedly to notice a motorcycle, may cause him to hesitate in the collision zone, and thereby precipitate, not prevent, an accident.

Thus either:

- Cause (2) 'Obscuration of motorcycle',
- Cause (6) 'Failure to look'
- Cause (7) 'Limited head movement',

may operate initially to cause the driver to fail to notice the motorcycle, and so enter the collision zone.

Should the driver then, because of daytime lights, notice the motorcycle instead of proceeding safely on his way, and so clearing the collision zone, he may hesitate in the collision zone, so causing a Hesitation or After you, Claude collision to occur between the parties.

7.4 Current status of research findings

To summarise the current status of research findings into the full set of potential causes of a motorcycle accident at an intersection (or a pedestrian accident):

Cause (1) 'Inconspicuity of motorcycle': Since the enactment of the first motorcycle daytime light laws in the USA in the 1960s, Cause (1) 'Inconspicuity of motorcycle' has preoccupied the attention of the road safety lobby, road safety research scientists, and government largely to the exclusion of any investigation also of the other potential causes of motorcycle accidents at intersections.

Including the studies that have been digested in the present paper, to date Cause (1) has been investigated by well over 100 original and digest studies. Indeed a total number of over 300 studies is not implausible.

The main findings of the investigation—namely the findings of the monitoring studies and *Olson et al 1979a*—have already been described by the paper.

Cause (1) 'Inconspicuity of motorcycle' is now treated widely by daytime lights.

Either motorcycle riders have taken up the use of daytime lights voluntarily; motorcycle manufacturers de facto 'compelled' their use by fitting them to new motorcycles; or governments formally enacted legislation that compels either riders to use them, or manufacturers to fit them to new motorcycles.

Cause (2) 'Obscuration of motorcycle': As already previously described, by their analyses of motorcycle accidents in Victoria and Los Angeles, *Williams & Hoffman 1977* and *Hurt et al 1981* have fully investigated Cause (2) 'Obscuration of motorcycle', and estimated its incidence.

Cause (3) 'Arbitrary estimation of speed & distance': The operation of Cause (3) 'Arbitrary estimation of speed & distance' remains conjectural.

As previously mentioned, in a laboratory study *Hills 1975b* estimated the size of the threshold angle of longitudinal movement that is detectable by the human eye.

But *Hills 1975b* was only a pilot study, and Hills changed his area of work before he was able to take the study further (Personal communication to second author).

The speculations of *Olson et al 1981*; Olson as interviewed by *Despain 1981*; and *Olson 1989* have been recited.

But so far as is known, the speculations have not been taken up and investigated by other authors.

As to Olson et al—namely Olson, Halstead-Nussloch & Sivak—themselves, it is believed that Sivak remains active, but has not returned to the subject; Halstead-Nussloch now works in a different area; and Olson has retired.

Nagayama et al 1980 report the findings of two experiments in which they attempted to measure the errors of misestimation of speed and distance to which an oncoming motorcycle is subject.

But as critically reviewed by the second author in *Prower 1990 (No 2)*, the study suffers from defects of method and presentation, and is unsatisfactory.

Nagayama continued to work on the causation of motorcycle accidents up until the publication of *Nagayama 1984*. But he is not thought to have published any studies in the area since.

So far as is known, no subsequent authors have attempted a similar study to *Nagayama et al 1980*.

Cause (4) 'Processing load upon driver': Cause (4) 'Processing load upon driver' is, as the authors understand, a subject that is currently the subject of extensive investigation in the motorcar field.

Cause (5) 'Preoccupation of rider with road surface': Cause (5) 'Preoccupation of rider with road surface' is the subject of findings by two eye-marker camera studies, a study by *Mortimer & Jorgeson 1975*, and the study by *Nagayama et al 1979* that has already been mentioned.

Both *Mortimer & Jorgeson 1975* and *Nagayama et al 1979* were experimental field studies that compared the duration and direction of the eye fixations of test subjects according to whether they were driving a motorcycle or motorcar. Both were conducted in daytime.

However the studies differed respectively in:

- The purpose of the study
 - Mortimer & Jorgeson 1975*: To predict the best beam pattern of motorcycle headlamps at night;
 - Nagayama et al 1979*: To investigate the cause of certain motorcycle accidents from an analysis that was conducted in Osaka, Japan by *Nagayama 1978* — namely accidents at intersections in which a motorcycle rider travelling straight ahead crashed almost without braking into a motorcar turning right [*Traffic travels on the left of the road in Japan*]
- The road conditions of their experiment
 - Mortimer & Jorgeson 1975*: Rural roads in the USA;
 - Nagayama et al 1979*: Urban roads in Osaka
- The presentation of their findings.

In particular, in one striking diagram—as presented unreadably in *Nagayama et al 1979*, but later re-presented readably in *Nagayama 1984*—*Nagayama et al 1979* compared the time-weighted distribution of the fixations of their test subjects when driving the motorcycle and motorcar at approximately 50kph.

Whereas for the motorcar, as time-weighted, a figure of 11% of fixations were below the road horizon, for the motorcycle the figure was 82%; and whereas for the motorcar a figure of 0% of fixations were directly at the road surface, for the motorcycle the figure was 29%.

By contrast *Mortimer & Jorgeson 1975* did not combine their findings as to the direction and duration of the fixations of their test subjects in a single presentation in the same way.

In *Nagayama 1984* Nagayama followed up the findings of *Nagayama et al 1979* by conducting an in-depth analysis of 118 motorcycle accidents at intersections in Osaka.

But since *Mortimer & Jorgeson 1975* and *Nagayama et al 1979*, so far as the authors know only one further eye-marker camera study of motorcycles has been undertaken — a recent experimental laboratory study that was conducted as a pilot study by Langham, Hole & Land of the University of Sussex.

It is not known if Langham et al's pilot study will be followed up by a full study. Likewise it is not known if the findings of the pilot study will be published.

Cause (6) 'Failure to look': Cause (6) 'Failure to look' has been taken for granted as a cause of accidents at intersections, certainly by the motorcar daytime light studies.

Thus as noted under 3.2.3 'Distraction', as ideally specified by *Hörberg & Rumar 1975*, purpose-designed daytime running lamps are intended to stimulate the peripheral reflex attraction towards bright light even though the other driver may be looking in a direction up to 30° away from them.

However recently Land and colleagues at the University of Sussex also conducted an eye-marker camera study of motorcar driver subjects in which one of the vehicles that the subjects observed at an intersection was an oncoming motorcycle.

It is not known if Land et al's study was a laboratory study or field study; or a full study or pilot study. Likewise again it is not known whether the findings of the study will be published.

Cause (7) 'Limited head movement': Cause (7) 'Limited head movement' has not, so far as the authors know, yet to date been investigated, whether as to its incidence amongst drivers, or its importance as a cause of accidents.

Åberg & Rumar 1975 have however conducted a preliminary perceptual study of the part played by head movements in driving a motorcar.

And as noted above, ideally daytime lights should at least attract the attention of a driver with limited head movement even though he may be unable to turn his head closer than 30° in their direction.

Cause (8) 'Response to police motorcycles only': Cause (8) 'Response to police motorcycles only' still remains unconfirmed.

To date so far as is known no academic authors have repeated the experimental studies of *Leonard 1974* and *Booth 1978*.

7.5 Research needs

To list the research needs that are revealed by the summary of the current status of research findings, they divide into a need for:

- Substantive studies to supply gaps in present knowledge of the causes of motorcycle accidents at intersections (and pedestrian accidents)
- Accident analysis studies to supply gaps in present knowledge of the incidence of the causes in question.

Substantive studies: To give first the research needs as to substantive studies, they are:

- 1) A full study that repeats the measurements by *Hills 1975b* of the size of the threshold angle of longitudinal movement that is detectable by the human eye
- 2) A study that measures and establishes—in a manner that avoids the defects *Nagayama et al 1980*—the errors of estimation of the speed and distance of a motorcycle that test subjects make in head-on view
- 3) An eye-marker camera study that repeats the experiments of *Mortimer & Jorgeson 1975* and *Nagayama et al 1979*— and so establishes with greater confidence how far the attention of motorcycle riders may be preoccupied by monitoring the road surface

- 4) A survey of the prevalence of limited head movement amongst motorcar drivers and pedestrians
- 5) A study that repeats *Leonard 1974's* experiment — and so establishes how far, by way of a behavioural as opposed to perceptual response to motorcycles, motorcar drivers may infringe the right-of-way of a police motorcycle with lesser frequency than the right-of-way of an ordinary motorcycle
- 6) A study that repeats *Booth 1978's* experiment — and so establishes how far, by way of a purely perceptual response to motorcycles, motorcar drivers may respond later (or as Booth found, one must suppose due to the intrusion also of a behavioural response, earlier) to the observation of a police motorcycle than they do to the observation of a police motorcar.

Accident analysis studies: And to give second the research needs as to accident analysis studies, they are:

- 7) The conduct of a 'qualitative' in-depth survey of motorcycle accidents at intersections that is designed to identify the operation of the full eight causes, and evaluate their contribution to the accident — thus the survey will analyse accidents for instance according to such criteria as:
 - Whether they represent a 'Same time & same place', 'Hesitation', or 'After you, Claude' collisions
 - Whether the motorcycle was viewed by the other driver from head-on, or obliquely at an angle
 - What speed the motorcycle was travelling at relative to the normal speed of other traffic on the road
 - When the parties responded to each others presence.
- 8) The conduct of a 'quantitative' middle-sized survey of motorcycle accidents at intersections, as 'piloted' by the in-depth survey, that is designed to enumerate the operation of the full eight causes, and rank them by importance for remedy.

7.6 Prospective remedies

It is not possible in a short paper to canvass all of the new remedies for motorcycle accidents between:

- A motorcycle rider who has right-of-way at an intersection and a motorcar
- A motorcycle rider and a pedestrian who crosses the road in front of the motorcycle,

that prospectively might be established by the conduct of the studies that are listed under 'Research needs' above, and so the formal 'establishment' of the full set of potential causes of such accidents.

To make therefore a selection of the some of the most important, or most readily practicable, new remedies, they include:

- 1) To inform motorcycle riders, motorcar drivers, and pedestrians by means of appropriate publicity of the limits of human perception of the speed of an approaching motorcycle, so that all three groups of road users conduct themselves on the road accordingly.

Thus presently:

- Motorcycle riders often take the view that the failure of motorcar drivers or pedestrians to give way to motorcycles is culpable, and so fail dispassionately as a matter of routine nevertheless always to expect it
- When an approaching vehicle is a motorcycle, motorcar drivers and pedestrians often fail to observe with especial rigour the rule of the road: 'Only proceed if you are positively sure that it is safe to do so'

- 2) To inform motorcycle riders under instruction of the two particular 'non-intuitive' consequences for them that flow from the limits of human perception of the speed of an approaching motorcycle:

Since motorcar drivers will therefore usually only be able to make an arbitrary estimate of the speed of a motorcycle in head-on view:

'The closer that the rider rides past a waiting driver at an intersection, not only the less opportunity that he will have to avoid a collision should the driver pull out in front of him, but also—to compound matters—the greater the likelihood that the driver will pull out in front of him'.

Since motorcar drivers will therefore in turn probably adopt as their estimate of the speed of the motorcycle the 'normal speed of other traffic on the road'.

'The faster that the rider rides past a waiting driver at an intersection, not only the less chance that he will have of stopping in time should the driver pull out in front of him, but also—to compound matters—the greater the likelihood that the driver will pull out in front of him'

- 3) To advise motorcycle riders under instruction whenever possible to ride an oblique—as opposed to head-on—line of approach to waiting motorcar drivers at intersections or pedestrians, so as to maximise the perceptual information that the driver receives of their true speed of approach

[*Ouellet 1990* also calculates that riders can minimise the length of the zone in which a collision is inevitable if a waiting motorcar driver fails to give way to them by positioning themselves as far as possible in the road away from the motorcar.

Although the reasons for the two precepts differ, fortunately in practice the 'Ouellet line', and the 'oblique line' will usually coincide]

- 4) To advise motorcycle riders under instruction that they must deliberately raise their eyes from the road surface in the presence of hazard
- 5) To accelerate the development of anti-lock brakes for the mass motorcycle market — The preoccupation of motorcycle riders with the road surface must flow to a large extent from their fear of locking up the wheels under emergency braking.

8. Summary and conclusions

The purpose of this paper has been:

- To review the evidence in favour of both motorcycle and motorcar daytime lights
- To consider in the light of the evidence how far the use of daytime lights by motorcars as well as motorcycles is likely to enhance overall road safety
- To review some of the other remedies for motorcycle accidents that compete for attention with the use of daytime lights.

In conclusion the formal evidence of the monitoring studies of the effect of both motorcycle and motorcar daytime lights fails to establish satisfactorily that daytime lights have had any overall effect to reduce accidents.

The methods that the studies have employed are inherently flawed: the odds-ratio method is not specific to the effect of daytime lights, and the fleet study method is incapable of distinguishing between the immediate 'novelty' effect of daytime lights, and their enduring true effect.

The prima facie arguments in favour of motorcar daytime lights in turn fail to 'rescue' the studies. On the positive side of the balance, the effect of daytime lights to reduce accidents is likely to be trivial. On the negative side there are important potential adverse side-effects.

The situation of motorcycle daytime lights is similar, save that there is more to be weighed in their favour on the positive side of the balance.

Experimental field studies might assist to carry matters forward.

The authors know of only one important study: the motorcycle study *Olson et al 1979a*.

Encouragingly, Olson et al made findings that—although they were specific to the prevailing situation in Michigan in the

late 1970s—suggested that motorcycle daytime lights might have a positive beneficial effect.

On the other hand Olson speaking informally to *Despain 1981*, and later also *Olson 1989* cautioned that 'conspicuity treatments' might not treat all of the causes of motorcycle accidents at intersections.

Against this background in 2001 the European motorcar manufacturers and importers offered to the institutions of the European Union to hard-wire all of their production of motorcars for the European market from 2002 with the headlights permanently on.

At the same time the European motorcycle manufacturers and importers decided also to 'hard-wire' all of their production of motorcycles for the European market.

Given that, on the evidence of the study findings and arguments, it is unlikely that motorcar daytime lights confer any positive 'net safety benefit'—indeed it is possible that they may even manifest a negative safety disbenefit—, the offer of the motorcar manufacturers is misguided.

Further it is likely that motorcar daytime lights will diminish the positive safety benefit that, it is less controversially asserted, motorcycle daytime lights confer upon motorcycles.

The offer of the European motorcar manufacturers should therefore be unequivocally rejected.

The authors pass over the unfortunate revival, by the decision of the motorcycle manufacturers, of the bitter controversy that has divided motorcyclists and motorcyclist's organisations in different countries over the past thirty years whether governments should override the objections of the section of motorcyclists who oppose daytime lights by legislating to make motorcycle daytime lights compulsory.

Instead the authors take up from the cautions against a blind belief in the efficacy of motorcycle daytime lights that were uttered by *Olson 1989* — they list, drawing inter alia upon

the suggestions of Olson's paper, a number of causes, or possible causes, of motorcycle accidents at intersections (or motorcycle accidents with a pedestrian) that motorcycle daytime lights do not, or will not prevent — and in the spirit of moving forward they canvass research needs and the potential that also exists for devising new means of prevention.

The authors conclude by recommending the prompt conduct, in the interest of the safety of motorcyclists, of the research in question.

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Stephen Prower

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