CONSPICUITY OF POWERED-TWO-WHEELERS

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ABSTRACT

The 2BeSafe project (2-Wheeler Behaviour and Safety) is a collaborative project (co financed by the European Commission) that aims to study the naturalistic behaviour of Powered-Two-Wheeler (PTW) riders in normal and critical riding situations. That includes the interaction between PTW riders and other road users and possible conflicts between them.

One of the predominant causes of accidents involving PTWs is that PTWs are often overlooked by other road users. One task of the project lead by BASt therefore deals with possible improvements in conspicuity and the development of recommendations.

Particularly using the findings of the studies on conflict situations, promising lighting arrangements to enhance conspicuity of PTWs during the day and at night are selected. An abstract recognizing pattern for PTWs is defined, enabling other road users (e.g. car drivers) to clearly identify riders. Lamps and outfit like lighting configurations of different colours, different helmet lights, reflect / luminescent clothing parts and retro-reflective markings are designed and manufactured. Then, the different solutions are tested in a laboratory setting using experimental motorcycles together with riders to which the equipment is fitted. As result a proposal for a uniform signal pattern or lamp configuration in the front of all motorcycles and riders will be outlined.

The contribution first gives a short overview of the topics of the research project that deal with conflicts and their connection with poor conspicutiy and then presents in detail the methods used in the activities concerning solutions for the improvement of conspicuity together with first results.

INTRODUCTION

The background for considering an improvement of the conspicuity of powered-two-wheelers is that the development of the number of fatal accidents involving motorcycles are completely different to the declining number of accidents in general in recent years [1]. The number of fatal PTW accidents remains constant and thus the percentage of deaths of PTW riders increase. They have a much greater risk to die in a traffic accident then passenger car occupants. One of the most important reasons why accidents happen to motorcyclists is that they were not seen or were seen too late. Until now, the use of low (or passing) beam by day, is especially a feature of motorcycles and mopeds, but from now on there is an increasing number of multi-track vehicles with daytime running lights (low beam or equipped with dedicated daytime running lights) on the road since dedicated DRL are mandatory for new passenger car types in the European Union since February 2011 [2]. Thus, it is feared that motorcyclists could be seen worse in the future, because low beam on the day is less visible than special daytime running lights. It is expected that by using daytime running lights in conjunction with an innovative arrangement powered-two-wheelers could become more visible and clear.

To examine this hypothesis different subjects rated various lighting configurations during the day and at night have been examined in the context of the 2BeSafe project.

The overall strategy of 2BeSafe consists in conducting innovative research focussing on riders' behaviour and on riders-drivers' interactions. These topics of research are derived from accidentology findings and are supported by activities in designing the required technological tools to measure naturalistic driving behaviour.

The results acquired are then compiled and transversally analysed, following a systemic approach to develop guidelines and policy recommendations for the observation of riders' behaviour and for the elaboration of measures to improve PTWs' safety through the design of relevant and adapted countermeasures.

The part of the project that deals with conspicuity is divided into the following tasks:

- Conflict studies
- Experimental studies on PTW visual conspicuity
- Development and evaluation of recommendations

A short outline of these tasks is given in the following sections. Thereafter, as consequence of the identification of possible safety measures, we describe in detail the realisation of certain solutions for better lighting and their evaluation by use of experiments involving human subjects.

CONFLICT STUDIES

The goal of the conflict studies in 2BeSafe is to understand the behaviour of PTW riders and especially their interaction with other motor vehicle drivers. There is a substantial portion of accidents in which PTWs are involved that happen in the frame of interactions, or as consequences of interaction. For that reason it is important for safety work to understand interaction processes with other road users.

Appropriate high risk sites (intersections, curves or route sections that can be overlooked by one or two observers) are selected in many European countries on the basis of accident analyses (typical safety problems) in combination with local experience. In the following two examples are described more in detail:

Figure 1: Observation site at an intersection (Dresden / Germany) /BASt/

One observation site is a big road network where two traffic streams cross and is located in an area zoned for economic activities at the boundary of Dresden (see figure 1). Carriage ways are separated and contain multiple lanes for the each direction. Both roads work as motorway feeder but are also used by road users for accessing shopping parks etc. The whole intersection is signalized through traffic lights.
Motorcycles and scooters approaching from all directions have been observed and registered by two observers, if feasible (simultaneous occurrences of PTWs at the big intersections led to non-observance of some cases). The manual observation sheets from the observers were post-hoc double-checked with video tapes recorded during the observation time.

Figure 2: Observation site at a curve (Linz / Germany) /BASt/

As other observation site a certain curve has been selected in result of interviews with traffic and motorcycle experts. The curve is at a rural road track located near to Linz / Germany (see figure 2). The road consists of 1 lane for each direction and within the course of the curve overtaking is prohibited (signalized by traffic signs and a solid line). The 180° shape is a specific feature of this curve which challenges the riding skills and might provoke also critical situations within the interaction with other road users.
Motorcycles and scooters approaching from both directions have been observed.

At those sites analyses were carried out, including traffic conflict analyses making use of comparable traffic-conflict-registration techniques.

More than 1600 PTWs were recorded. "30.6 % of the observed PTWs could be identified as *sports bikes*, 39.6 % have been categorized as *scooters,* whereby *scooters with max. 50 ccm* engine displacement was the most frequently observed category (37.2%). Furthermore, 8.5 % *mopeds*, 4.9 % e*nduros* 3.4 % *cruiser* and 3.3 % t*ourer* have been registered. Additionally, 8.2% were classified as "others" whereby that category covers, among others, naked bikes with 4.7 %

Nearly all registered riders wore a helmet, except one BMW C1 rider (it is not mandatory to wear a helmet while riding that PTW model). 60.0 % of the riders wore a rather dark helmet and in 13.1 % of the observed cases the helmet was rather bright. The remaining 26.9 % of riders wore a helmet that was neither dark nor bright. The same trend could be observed for the PTW's color: the most frequently observed PTW color was a dark color (60.9%). In 6.8 % of the cases, the observed bike was bright and 31.6 % of the color of the bike was neither particular dark nor particular bright. Concerning the riders' preferences of clothing colors, it has been observed that 77.1 % of the PTW rider wore dark clothes, 3.7 % wore bright clothes and 19.1% wore clothes which were neither dark nor bright. Furthermore, 32.2 % of the riders were fully equipped with motorcycle clothing, 34.4 % wore just partly motorcycle clothing and 31.8% rode the bike with normal street clothes.

PTWs were riding without running head light in 8.2 % of the registered cases, 89.1 % of the riders had their head lights on. Particularly, moped riders and 50 ccm-scooters more likely had their head lights off." [3].

These observations show that although conspicuity should be an issue taken into account by PTW riders, dark clothing, dark helmets and dark PTWs are very common.

EXPERIMENTAL STUDIES ON PTW VISUAL CONSPICUITY

It is the objective of this activity of the 2BeSafe project to address phenomena related to PTW visual conspicuity as a critical factor in between-vehicle interaction. Specific issues are considered:

- Failed recognition of oncoming PTWs in spite of appropriate roadway inspection by car drivers
- Effects of modifying certain PTW features on sensory and cognitive conspicuity
- Identification of effective conspicuity treatments (e.g. helmet and headlight features)
- Description and examination of the relative and absolute conspicuity of the motorcycle in different background lighting conditions and traffic situations

These tasks are carried out by the 2BeSafe partners INRETS, University of Nottingham, Technical University Dresden and Ben Gurion University.

The sensory and cognitive conspicuity of PTWs on rear-view mirrors is investigated in a simulated car-driving task and by means of video footage and picture analysis. A tool for semi automatic analysis of data coming from an eye tracker is developed.

PTW conspicuity is also assessed through detection by using real-world video sequences of intersection traffic, including various conditions of visual noise (e.g. presence of car DRL), ambient illumination and special PTW conspicuity treatments.

Gaps accepted by car drivers towards PTWs when crossing or turning at intersections are investigated in a simulator study using various conditions of visual noise and PTW conspicuity treatments. Significant visual situations in traffic and their characteristic conditions are defined; these conditions are systematically varied and tested through simulations and emulations [3].

The following two aspects of the outcome of the above mentioned experimental studies have importance with regard to the tests carried out by BASt which are described in the next chapter: Experiments lead and carried out by Technical University Dresden yielded a T-arrangement and a V-arrangement (which are explained below) for the lighting pattern as two reasonable solutions for improving PTWs conspicuity. In parallel, studies from Ben Gurion University recommended helmet lights [4]. Although helmet lights are a rather inconvenient measure which would be connected with unforeseeable hurdles if a legislative approach on UNECE level with regard to allowing such a solution in real traffic will be started it was included in the study for research reasons.

DEVELOPMENT AND EVALUATION OF RECOMMENDATIONS FOR IMPROVED CONSPICUITY

This activity of 2BeSafe dealing with the development and evaluation of possible solutions for improved conspicuity is lead by BASt and is carried out together with the partners Technical University Dresden and FACTUM. Particularly using the findings of the experimental studies on PTW visual conspicuity mentioned above contrived possible lighting arrangements to enhance conspicuity of PTWs during the day and at night were tested in a laboratory setting. For those tasks, experimental motorcycles with different lighting configurations of different colours as well as different helmet lights, reflect / luminescent clothing parts and retro-reflective markings were used.

Discussions with PTW riders concerning conspicuity aspects were conducted. Test viewers were asked to assess and to compare the different lighting patterns for typical traffic situations and ambient lighting conditions; in this way it could be found out which measures are suited best to enhance conspicuity and thus to protect the riders .

Solutions for improving the identification of PTWs in situations with interaction and simultaneous appearance of other vehicles were studied in an experimental environment; concurrently the acceptance of design solutions by PTW riders was evaluated in laboratory settings as well as in field trials [5]. Scale models were made for all designs by Technical University Dresden.

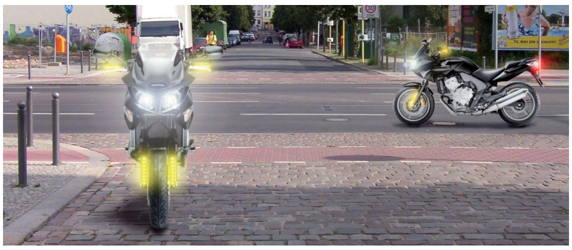

Figure 3: T-Design, Honda CBF 600 /TU-Dresden/

The T-arrangement of light sources in one horizontal line (handlebar) and in a vertical line at the bottom of the front fork is one of the proposed design solutions as result of the studies mentioned above (see figure 3). The advantages of the T-arrangement are a good reproduction of the motorcycle shape and size for the front view), large luminous surfaces and a high recognition in front view. The disadvantages are mounting problems - especially at the front end with a single arm front fork (scooter) - and no sufficient clarification of the front end in lateral view.

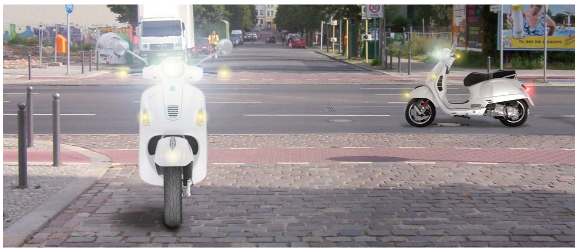

Figure 4: V-Design, Vespa GTS 300 /TU Dresden/

Another promising solution is the V-arrangement shown in figure 4 with light sources in an open top arrangement with top lamps at the handlebar and lower lamps on the front fender. The advantages are a clear form in front view, the clarification of the anterior end in lateral view; a high recognition in both views and a simple arrangement. The disadvantages are a poor visibility of the actual motorcycle size and an arrangement of the medium lamps possibly too close to low beam and high beam headlamps.

After considering the advantages and disadvantages the T-Design was selected to be used for the experiments with and without helmet lights [5].

ASSESSMENT OF NEW LIGHTING ARRANGEMENTS

Experimental Setup

In following the installation of the T-arrangement to a real motorcycle is described. For the installation of the T-arrangement five type approved DRLs were used. The choice of the applied DRLs resulted from comparisons between different light sources. The best solution turned out to be light emitting diodes. One of the most important aspects are the energy consumption as well as the freedom of designing and the small cross-section. Other available solutions would have been the use of bulb light sources H4, new H15 or gas-discharge light sources.

Daytime running lights of “Hella KGaA Hueck & Co.” fulfilled our requirements best. Two different models of DRL types were fixed to the Motorcycle. A total of 5 DRLs plus 2 lights attached to the helmet were used for the realization of the T-configuration. One of the chosen DRL products is called “LEDayFlex”. The advantage of it is that the lamps consist of different numbers of single modules, from 5 to 8 single modules are available. In the end we attached to the motorcycle: 2 x 8 series (for the wheel fork), 1 x 5 series (in center over the headlamp), 2 x 1 series (for the helmet) and 2 x 5 series (in this case called LEDayLine right and left under the handlebar).

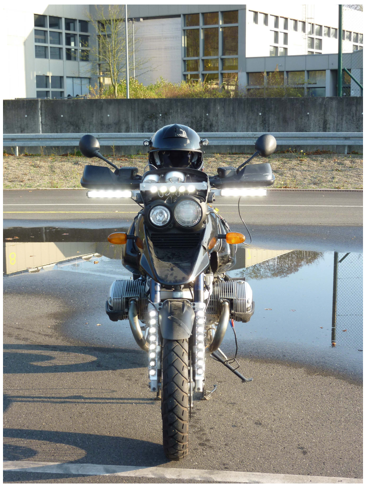

Figure 5: Test motorcycle with LED-DRL forming the T-arrangement

Before attaching the DRLs to the motorcycle they were calibrated in the laboratory. The method of testing is indicated in the corresponding ECE-Regulation. The aim of calibrating the DRLs was to compare the results from BASt with the manufacturer´s information to get an impression of the real luminous intensity of all DRLs. These tests gave also information about the duty factor. So the characteristic curve (luminous intensity vs. applied voltage) of the different DRLs was generated. The obedience between light intensity and duty factor is important since one future consideration is to adapt the luminous intensity to the ambient light intensity. First of all the positions of the attachments were defined. After that the elaboration of the design of the attachments for the DRLs took place.

Different requirements while designing the fittings for the DRLs had to be followed. For example detachable connections, lightweight, short dimension, illustration of the T-Design, helmet light, orientation of the DRLs etc. had to be considered.

The drafting of the different attachments took place with a CAD program. The mechanical drawings resulted from the stereoscopic models which were designed with the drawing program after measuring the dimensions of the motorcycle. The angle of the wheel fork is one of the important dimensions because it has impact on the arrangement of the DRLs (see figure 6). DRLs have to radiate in forward direction parallel to the road surface. One other important aspect was that the constructions should have detachable connections that are why the most of them use screws. Altogether the motorcycle got 8 components to attach the DRLs. All of them consist of Aluminum because of the light weight.

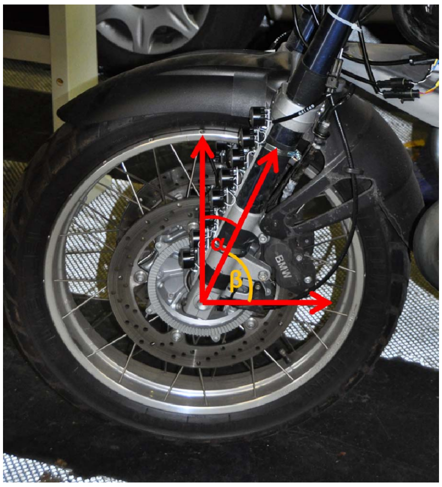

Figure 6: DRL attachment at the front fork of the motorcycle

After the mechanical workshop had produced all parts and attached them to the motorcycle, the tests could start. Tests for darkness took place in a hall, daytime tests took place on an open proving ground.

The different signal patterns that were presented to compare the new T-arrangement with other signal patterns were:

A: Low Beam
B: DRL (white); row of 5 LEDs
C: T-arrangement (day level)
D: T-arrangement (night level = DRLs were dimmed down to position lamp luminous intensity)
E: T-arrangement + helmet lights flashing (day level)
F: T-arrangement + helmet lights flashing (night level)

In the tests the subjects had to judge the different light configurations in a paired comparison of the different signal patterns. At a distance of 50 m and at a distance of 100 m the subjects had to observe the signal patterns (in the following only the results for 50 m are given). Each signal pattern was shown for 3 seconds.

Afterwards the subjects had the time to decide which one, in their opinion had a better conspicuity.

For the test at night, the signal patterns A, D and F were compared. The test for the day level contained signal patterns A, B, C and E.

Tests with night level

A number of 40 subjects participated in the test with nighttime conditions (darkness). The group of the interviewed subjects involved motorcycle riders as well as other road users; all age classes and both sexes were represented. The result was unambiguous. The diagram below (figure 7) shows the evaluation of the different signal pattern referring to a better conspicuity. Signal pattern D and F were definitively judged much better than signal pattern A. Signal pattern F got 245 votes from a total of maximum 320 votes. That means with a frequency of about 77 %, signal pattern F was chosen when it was presented in a paired comparison. Signal pattern D was following behind F with about 63 %. Signal pattern A only got about 10 %. That means the current allowed signal pattern in road traffic (just low beam) is inferior to the new designed ones. So the results clearly indicate that further improvements of the conspicuity of the signal pattern of PTWs are possible to increase safety.
With all different configurations the motorcycle was recognized as single-track vehicle. Some subjects pointed out that the T-arrangement gives a good impression of the dimension of the motorcycle. One negative aspect in reference to signal pattern A (low beam) is that these vehicles could also be a double-track vehicle which one defect head lamp. The problem of signal pattern F (T-arrangement + helmet light flashing) is that some subjects noted that the flashing is irritating or annoying.
However, the question, which signal pattern would make sense as standard equipment, was answered by a majority of 21 subjects with signal pattern D. 9 subjects would choose the current signal pattern A and just 3 subjects thought that signal pattern F would make sense as standard equipment.

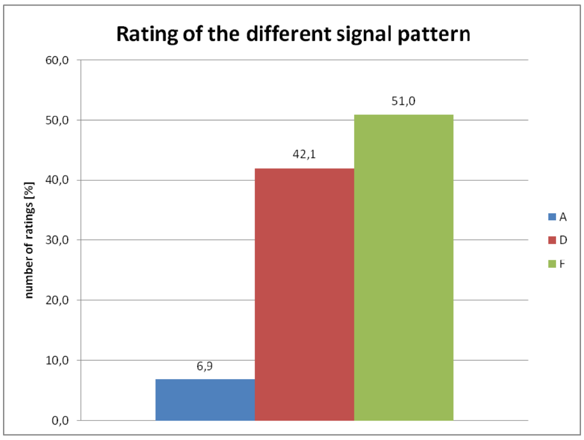

Figure 7: Result of the test with night level (distance: 50 m; 40 subjects)

Tests with day level

For the day level tests 45 subjects regarded and evaluated the different signal patterns. As well as for the test at night level subjects of different ages and sexes were involved. The result of the daytime tests was again unambiguous (see figure 8). That means signal pattern E got the most votes with a frequency of about 44 %. Second-best visible signal pattern was signal pattern C with 37 %. The difference between these two signal patterns is relatively small. But it is noticeable that the flashing helmet light in signal pattern E is chosen more often than signal pattern C. The difference of these two signal patterns in reference to the signal patterns A and B is much bigger. Signal pattern A, the current low beam, is just voted with a frequency of 3 % referring to a better conspicuity. Signal pattern B got about 15 %.

Thus, the results of the night level and the day level tests are similar. All signal patterns are judged as more efficient concerning the conspicuity than the low beam. That means for improvement of the conspicuity of PTWs the DRLs will be a sensible further development especially in the T-arrangement. The comments to the different configurations following the paired comparisons in general correspond to those given for the night level. Some subjects noticed that the low beam is not bright enough compared with the DRLs. So it is an issue that a couple of subjects are of the opinion that signal pattern B (one DRL in the centre over the headlamp) is better than the low beam. The statements to signal pattern C and E are similar to the nighttime statements: The T-arrangement gives information about the size of the motorcycle. On the one hand the helmet light attracts interest but on the other hand it is irritating and it could lead to distraction. Some subjects also said that the helmet luminous intensity was too low, that means that it was not conspicuous enough.

The question of which signal pattern would be reasonable as standard equipment is answered mostly with signal pattern C. A total of 20 subjects chose the T-arrangement. Signal pattern B followed by 17 votes. The fewest votes got signal pattern E with only 2 votes. Even the low beam got a number of 7 votes.

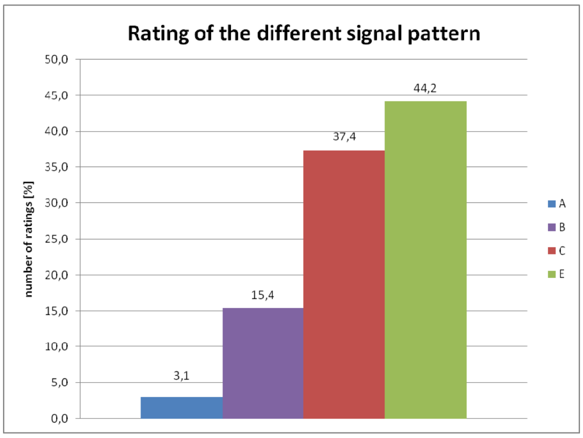

Figure 8: Result of the test with daylevel (distance: 50 m, 45 subjects)

CONCLUSIONS

The motivation for this study considering an improvement of the conspicuity of powered-two-wheelers comes from the fact that the development of the number of fatal accidents involving motorcycles are completely different to the declining number of accidents in general in recent years. The number of fatal PTW accidents nearly remains on a constant level. One reason why accidents happen to motorcyclists is that they were overlooked by other road users. Until now, the use of low (or passing) beam by day, is especially a feature of motorcycles and mopeds, but from now on there is an increasing number of multi-track vehicles with daytime running lights (low beam or equipped with dedicated daytime running lights) on the road since dedicated DRL are mandatory for new passenger car types in the European Union. Thus, it is feared that motorcyclists could be seen worse in the future, because low beam on the day is less visible than special daytime running lights. It is expected that by using daytime running lights in conjunction with an innovative arrangement powered-two-wheelers could become more visible and clear.

To examine this hypothesis different subjects rated various lighting configurations during the day and at night. Paired comparisons and an additional questionnaire show the benefits of daytime running lights used on motorcycles.

The present low beam has been rated significantly worse than new lighting configurations. In particular, the so-called T-design was estimated to yield very good visibility and among other things the shape and the size of the motorcycle was said to be reflected much better. An even better visibility became obvious when the T-design was combined with additional flashing helmet lights. However, due to some disadvantages, the hurdles for an introduction of flashing helmet lights in road traffic are high.

As a consequence, based on the test results, the T-design could be a promising candidate for a future lighting arrangement for motorcycles. However, this design would need changes and amendments to various international regulations. In addition, possible glare needs to be taken into account. The aspect of glare could be addressed by adaptive daytime running lights which have to be examined in further experiments - not only for powered-two-wheelers.

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