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Intelligent Front Brake Light

Expert Opinion from the Point of View of Accident Analysis

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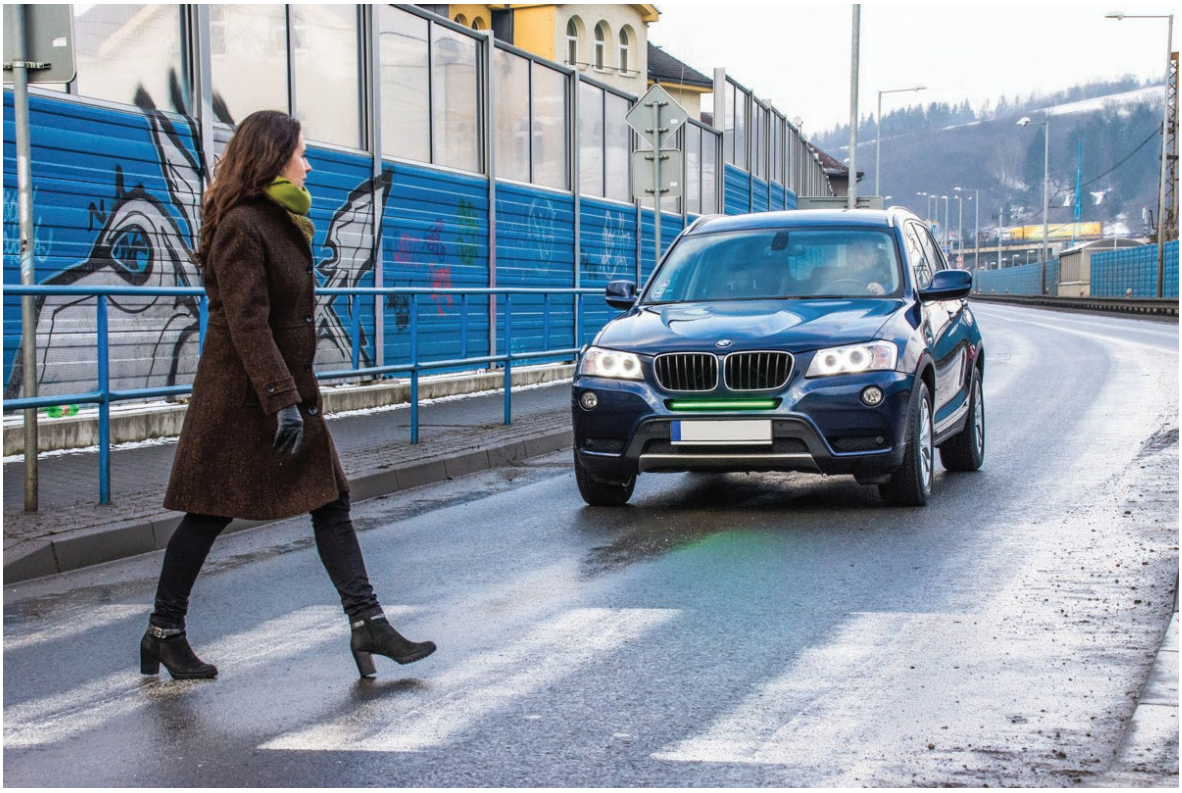

Preface

Several partial projects have already been implemented as part of an overall project aimed at researching the road safety effects of a frontal brake light. Their results are available as documents at **www.vorderebremsleuchte.com** (German) or **www.frontbrakelights.com** (English).
This existing expert opinion is complemented by another important element which is that it is the first of its kind to consider the front brake light in terms of professional technical analysis of accidents.

The fact that this research has concluded that a front brake light could prevent accidents and deaths already today is an exemplary result.

In addition, the idea of combining a front brake light in future generations of vehicles with pedestrian recognition or with the emergency brake assist, which is already available in today's modern vehicles, is being developed. In such a case, the use of the front brake light would be controlled completely and precisely so that the signal illuminates only when the vehicle still has the time to actually stop.

Putting the front brake light to the road transport practice would be another specific contribution – not only to the implementation of the European Parliament's resolution called „Saving lives: boosting car safety in the EU"
(https://www.europarl.europa.eu/doceo/document/A-8-2017-0330_DE.html),
but also to setting the objectives of the Federal Government's road safety program 2021-2030
(https://www.bundesregierung.de/breg-de/suche/verkehrssicherheitsprogramm-1919544),
which committed itself to a substantial reduction in the number of road accident victims and serious injuries in the above-mentioned period.

The research management thanks the authors for their contribution, as well as other authors such as Dr. Dieter-L. Koch and Jörg Ahlgrimm for their many inputs.

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1 Introduction

The idea of a frontal brake light was born as early as 1920. By having defined the concept and carried out a laboratory study in 2016 as well as a field test in 2017, the designers of the “front brake light” want to obtain approval for this additional brake light. [1][2][3]

It is necessary to verify that this solution which is/—intended to reduce road accidents—does not involve risks besides its advantages. On the other hand, despite the improvement of some critical situations, an ill-conceived implementation of such an additional lighting device on a road vehicle could also cause problems [4]. Still, the safety effect of the front brake light should be publicly discussed and verified from a scientific point of view [5]. A field study has already examined the effect that the front brake light can have on perceived traffic safety [6].

From the point of view of accident analysis, the strengths and weaknesses, as well as the potential of the front brake light, shall be explained in this work. Last but not least, for a part of the virtual test of intelligent brake lights mounted on vehicles, the impact of this device should be examined in situations such as turning left at fork crossings or at road junctions to avoid collisions between two vehicles.

Figure 1
An example of a front brake light

2 Light colour and an operation mode

Based on the research by Keidl, Monzele, and Bans (published in [3]), green is preferred for the light signalling function, because, on the one hand, other colours would not be allowed under various directives, white light is already emitted by headlamps, and on the other hand, the green colour is mentally and physiologically the most preferred in terms of perceptibility.

The designers are also aware of the association with the green signalling light on traffic lights as well as related events and they believe it is a possible advantage. In its prototypical design, the front brake light should first include an additional light source that is integrated with the reversing brake light. In this way, preliminary observations of the front of a vehicle can only be used to determine whether the brake turns on or not. The choice of the signal strength of the brake light which varies depending on the braking force has not yet been technically implemented, but the designers take it into account. [3]

From the point of accident analysis, it seems reasonable if a driver activates the green light in the front of a vehicle to signalise to other road users that he/she gives them the way. On the other hand, from the point of view of accident analysis, but also in the future, it should be examined how intelligent control can ensure that the green signal of the front brake light is not misinterpreted, while e.g., under certain circumstances, the signal could also be suppressed.

3 Advantages

The website www.vorderebremsleuchte.com describes some situations in which the front brake light could be beneficial. These situations include:

1. **Turning left**
   Decreasing traffic speeds in both directions is obvious.
2. **Changing a traffic lane**
   Better recognition of whether merging a vehicle is possible.
3. **A narrow road**
   Decreasing traffic speed in both directions informs whether it is possible to enter a narrow road.
4. **Crossroads**
   By illuminating the front brake light, the driver with the right of way can signal and claim the right of way with less risk.

5. **Preventing a frontal collision**
   In the event of heavy braking, the reaction of the next vehicle may be observed and in the absence of a braking signal, the vehicle may e.g., turn, if the traffic situation allows.
6. **Overtaking**
   The interruption of traffic overtaking in both directions is more visible and in a shorter time.
7. **Scene of an accident**
   Pedestrians on the road can assess whether they are spotted by other road users or whether they are obliged to try to step aside.
8. **Road law-emergency vehicles**
   Drivers of emergency vehicles can estimate at fork crossings/road junctions whether drivers who are obliged to give way will stop.
9. **Pedestrians**
   Pedestrians could interpret the brake signal on the front of a vehicle as an invitation to cross the road.

(For a critical observation of a communication situation between a passenger vehicle and a pedestrian, see Chapter 4).

Furthermore, the designers also see an advantage in the progress of automated journeys and the participation of electric cars in road traffic. Communication with other road users, which so far comes from the driver, may be partially taken over by the front brake light in the case of automatic vehicles. The reduced audibility of electric cars can be partially compensated by greater visual visibility and communication. [7]

However, the last argument has been used since the introduction of AVAS (Acoustic Vehicle Alerting System) only in certain situations. The EU directive states that electric cars are obliged to automatically generate an audible warning signal "at least from the start of the car up to the speed of approximately 20 km/h, and during reversing." [8]

4 Disadvantages

The introduction of the front brake light in its current form could also be related to some disadvantages in terms of accident analysis or it might, given the potential risk of an accident, exacerbate situations in which the brake lights may appear to be advantageous, as the signal of the front brake light may be misinterpreted.

For example, a pedestrian might understand the green front brake light as an invitation to cross the road, or a driver of another vehicle might assume that he/she was given way, even if the driver equipped with the front brake light might have only wanted to adjust his/her speed. The repeatedly illuminating front brake lights might, in fact, be perceived as disturbing and confusing. Every driver of a vehicle is responsible for regulating the speed that must be constantly adjusted to speed limits, traffic flows, etc. Frequent adjustments of speed by braking might be consequently perceived as disturbing by the traffic in front of him/her and/or in the opposite direction, should the green front brake light often be turned on on these occasions. In any case, this restriction already applies to the rear brake lights which the drivers behind the vehicle must become accustomed to, if the driver of the vehicle in front of them keeps using a brake instead of depressing the accelerator pedal for speed adjustment.

Nevertheless, to achieve the required positive impact on road safety, the population must manage such a technical change as the front brake light and also go through the habitual phase. Without sufficient information, some road traffic participants would probably not know how to deal with the green signal in the front of a vehicle, or what function this green light mounted on the vehicle has. Combined with restless flashing, especially in heavy traffic, it could also lead to irritations. In addition, it is necessary to imagine that too much attention could be paid to the front brake light. Road traffic participants could pay attention to the behaviour of other drivers so that they could better estimate their behaviour, thus overlooking other potentially dangerous situations or also disrupting the flow of traffic by incorrect or inadequate reactions.

Technical faults in the front brake lights could even lead to accidents that would not otherwise have occurred. The designers propose an evasive manoeuvre for the following vehicles in the absence of a brake signal (e.g., emergency braking and the end of a traffic jam). If the signal does not turn on despite the brake being applied, other road traffic participants could unnecessarily turn off the road.

5 Optimized front brake light design

As seen in most photos on the designers' website, these prototypes of the front brake lights are LED lighting devices mounted mostly as a beam above the plate number. The light signal illuminates analogously to the rear brake lights. As stated before, a technical failure might result in serious consequences; for this reason, the occurrence of any malfunction should be ruled out. This could be carried out using several series of LED strips not connected in series. The strips could be placed either above/below each other or from the centre to both sides. Another case could also facilitate the recognition of an existing fault.

Additionally, the brake light must be shaped in a way that the other road users are not blinded or the view is not focused only on the front of the vehicle. [9]

Another improvement of the front brake light that could contribute to increasing traffic safety is the design of an adaptive brake light. The information alone on whether a vehicle decelerates or not is unlikely to be sufficient to positively impact the rate of traffic accidents. For example, by increasing the intensity of the light or the changing number of lights used for different decelerations, some problems that might for instance arise from a misinterpretation of speed regulation could be eliminated.

While modern vehicles can sometimes observe their surroundings through sensors, the front brake light signal could also be targeted (only) on the road users noticed by the vehicle. The situations described in Chapter 4, in which the pedestrian misinterprets the brake signal, could probably be eliminated this way.

6 Advantages of the front brake light

If a vehicle is not moving, we can assume that the front brake light does not impose any risks. On the contrary, for example, at pedestrian crossings and/or crossroads, it must be assumed that the front brake light, already in the form of a prototype, has a great potential of increasing traffic safety in terms of accident analysis without any expected adverse side effects, because other road users can recognise much more easily and much sooner whether the nearest stationary car will move; when the front brake light is off, the other road users may already recognise its intention to start, even before the stationary vehicle starts to actually move. At the same time, a constantly illuminated green front brake light signals that the stationary vehicle will not move as long as the front brake light is shining green.

From the point of view of accident analysis, a positive effect of the front brake light is therefore expected at all fork crossings, road junctions as well as in car parks.

Especially in situations when turning left, the introduction of a front brake light might have a positive effect in terms of avoiding collisions or reducing the severity of accidents. Traffic in the opposite direction can decide to reduce its speed as soon as a driver turning left releases the brake or the front brake light does not illuminate. The accidents of drivers turning left are affected by the fact that in urban traffic, there are relatively high differential speeds between the participants in a collision. This is because the time taken to recognise that a driver turning left may be a danger (to the point of collision) may be so short, depending on the design of the crossroad, that the recognition time for the reaction challenge may be shorter than a usual reaction time. Due to this, it might not be possible for the driver who has the right of way to react to the oncoming driver turning left.

In connection with this fact, the analytical experience from the reconstructions of accidents of drivers turning left implies that the drivers coming out of a crossroad often recognise too late that the turning driver has started the turning process and, therefore, a defensive action in the form of yaw or emergency braking in traffic moving forward is only used when a counterparty to a possible collision has already entered the opposite corridor. By releasing the brake and based on the front brake light signalling that the driver turning left could possibly collide or could enter a dangerous section, time for a warning notice is generated, which allows the oncoming road user to react earlier to the driver turning left or to a situation that has obviously been evolving into a dangerous one.

Whether and to what extent an extension of the warning alert time can be achieved by using the front brake light or by it not illuminating in an event of an accident with drivers turning left, also depends on the construction solution or, to be more specific, on the dimensions of areas of regular crossroads. Furthermore, knowledge of normal acceleration rates at starting, as well as speeds of different types of vehicles when turning, is needed to assess the potential of the front brake light in increasing road safety. This could result from the fact that by using the front brake light, vehicles turning left will likely reduce both the accidents of drivers turning left and also the differential speed of the participants to the accident.

For familiar or normal road sections which drivers turning left go through in the crossroad and/or road junction areas from starting to the point of collision, the average turning speeds and thus the average recognition times can be calculated using normal accelerations from the starting point during which the drivers turning left are seen by the traffic in the opposite direction as a danger.

Based on this, the extension of the warning alert time may be determined again, resulting from a vehicle turning left being equipped with the front brake light. This way, it is possible to assess the potential of avoiding accidents with drivers turning left using a frontal brake light. To assess the relevance of the potential of avoiding accidents or reducing the severity of the accidents of drivers turning left by using the front brake light, more statistical data on the frequency of this type of accident caused by a driving error of a participant turning left is necessary.

6.1 Statistics of accidents when turning

According to the Federal Statistical Office [10], in 2019, there were a total of 300,143 police-recorded accidents with injuries which are divided into seven types of accidents. The number of accidents with injuries when turning (41,118) is smaller than the number of accidents in longitudinal traffic flow (75,554), accidents when turning/crossing (65,446) and road accidents (54,348), but it is greater than the number of other accidents (39,463), speeding accidents (14,413) and accidents in static traffic (9,801). Concerning the rate of accidents with injuries in built-up areas, the accident when turning is the third most common type of accident.

The results of researches in the publications of the Federal Statistical Office [10] are given in Table 1. The type of accident "When Turning" was taken into account and the numbers were divided according to the categories "In a Municipal Area" and "Outside a Municipal Area".

Table 1: Statistics concerning accidents "When Turning"

	Accidents with injured persons				Casualties			
	Total	with dead	with slightly injured	with severely injured	Total	Dead	Severely injured	Slightly injured
In a municipal Area	32.995	100	4.744	28.151	40.017	101	5.063	34.853
Outside a municipal area	8.123	109	2.140	5.874	13.624	112	2.826	10.686
In total	41.118	209	6.884	34.025	53.641	213	7.889	45.539

Traffic accident statistics for 2019 further show accidents at junctions such as fork crossroads and road junctions.

Table 2: Statistics by "Fork Crossroads" and "Road Junctions"

	Accidents with injured persons				Casualties			
	Total	with dead	with slightly injured	with severely injured	Total	Dead	Severely injured	Slightly injured
Fork Crossroad in a municipal Area	46.834	160	6.562	40.112	59.836	164	7.163	52.509
Fork Crossroad outside a municipal area *	8.123	131	2.226	6.404	14.630	137	2.999	11.494
In total **	55.596	291	8.788	46.517	74.467	301	10.162	64.004
Road junction in a municipal area	44.837	153	6.631	38.053	53.520	155	6.973	46.392
Road junction outside a municipal area *	14.782	200	3.424	11.158	23.206	212	4.393	18.601
In total **	60.157	356	10.134	49.667	77.476	370	11.467	65.639

* without a highway ** with a highway

Out of the Federal Statistical Office data, it is necessary to find out how many accidents happened in 2019 due to making wrong decisions when turning left (Table 3: Statistics by cause of accident "Errors When Turning Left").

Table 3: Statistics by cause of accident "Errors When Turning Left".

	Accidents with injured	Injured			
		Total	Dead	Severely injured	Slightly injured
In a town	15.893	20.295	40	2.924	17.331
Outside a town	5.260	9.157	93	2.180	6.884
In total	21.153	29.452	133	5.104	24.215

The accident statistics [10] also imply who participated in the accidents when turning left. (Table 4: Statistics by the guilty and a counterparty to the road accident)

Table 4: Statistics by the guilty and a counterparty to the road accident

Predominantly guilty	Participant	Accidents with injured persons	
		In a Municipal Area	Outside a Municipal Area
A passenger car	A motorbike **	6.652	2.579
A truck	A motorbike **	293 + 82 = 375	89 + 67 = 156
A motorbike **	A passenger car	2.583	1.700
A motorbike **	A truck	98 + 45 = 143	70 + 44 = 114
Nákladné auto	A passenger car	1.960 + 936 = 2.896	1.517 + 790 = 2.307
A passenger car	A truck	1.053 + 612 = 1.665	921 + 835 = 1.756

** with an official plate number Source: Federal Statistical Office [10]

According to the ADAC Accident Research Report 2016, "Accidents When Turning" account for approximately 8% of total accidents. In addition, the frequency of accidents involving a passenger vehicle/a passenger vehicle to passenger vehicle/motorcycle is 1:1.4. In addition, the severity of accidents (seriously injured/killed) with a car/motorbike constellation is noticeable, as it is 3.5 times higher than with a passenger vehicle/a passenger vehicle accident. [11]

6.2 Average distance travelled by drivers turning left from the start up to a collision

According to the guidelines for the construction of urban roads, the width of a two-lane road in major traffic roads is generally between 5.50 m and 7.50 m. With local roads, the width is between 4.50 m and 6.50 m. The road/pavement should generally be 6.0 m wide. [12]

In the following part, it is assumed that the width of the road at crossings remains constant and the width of the lane (with the designation of lanes) is between 2.75 m and 3.75 m.

In simple terms, it is possible to assume an average distance travelled when turning to the opposite driving corridor as a combination from a straightforward start over approx. the length of the passenger car, or across the width of the lane of the road to be entered and the following 1/8 of the circular path, while the resulting distances travelled depend on the dimensions of the vehicle and the road.

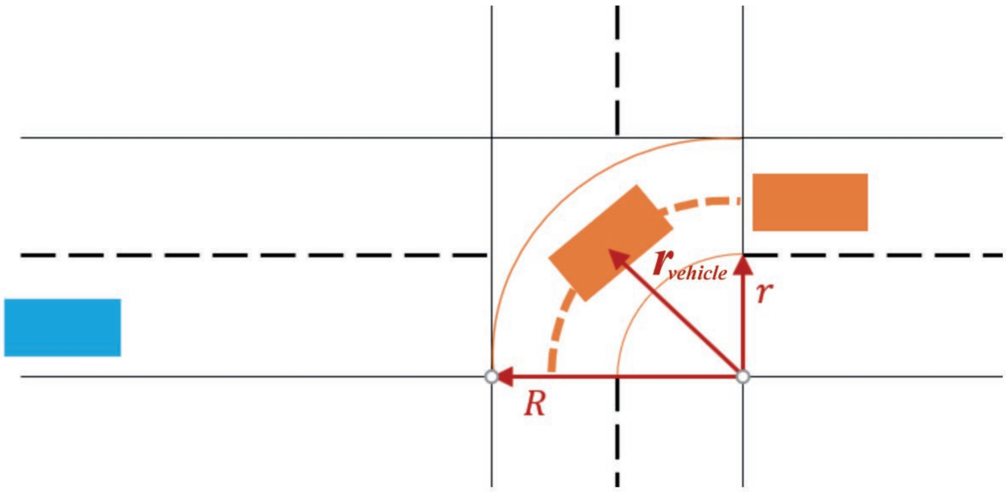

Figure 2
Schematic image of a crossroad with a driver turning left

$$r_{vehicle} = \frac{R + r}{2}$$

As the width of the vehicle and the lane may vary, the radius of the distance (r) for vehicles turning left in a circle results in $r_{vehicle}$ = **around 4 to 5.5 m** (the value that is counted: 4.125 m to 5.625 m). To determine or delimit the average distance to the entrance to the opposite corridor, the formula for the circumference of a circle may be used and take into account the proportion of the total circle (1/8).

$$S_{circle} = \frac{2\pi \times r_{vehicle}}{8}$$

For an average distance that the vehicle turning left travels from the entrance to the dangerous section in the opposite direction to the usual collision point, the values vary from approximately 3 to 4.5 m. Before entering in the opposite direction, drivers turning left usually drive straight through another section of the road. This road section partially depends on the length of the vehicle or geometrically depends primarily on the width of the lane where the vehicle is about to turn into. For this reason, the calculation can be based on a usual or average overall width of the road section (S_{total}) from approximately 7 m to 9 m, which the driver turning left will travel on average from the start to the collision point.

6.3 Typical accelerations at starting, speeds and times up to reaching the point of collision

The accelerations at starting [13] given in Table 5 for various means of transport (passenger car, truck, motorbike) are the basis for the calculation of normal or statistically expected starting speeds of the means of transport.

Table 5: average accelerations at starting of various vehicles

Type of a vehicle	Acceleration at starting (a) in **m/s²** (rounded figures)
A passenger vehicle	1.5 to 2.5
A truck	1.0 to 1.6
A motorcycle	2 to 5

Since the accelerations at starting and the distance of the turning vehicle to the entrance to the corridor of another potential participant in the accident are known, the average speed can also be calculated using the accelerations at starting.

$$V = \sqrt{(2xaxs)}_{total} \; x \; 3{,}6 \;\; [in \; km/h]$$

Table 6: Average speeds at starting after 7 to 9 m of a run-up/starting distance

Type of a vehicle	Speed (v) in **km/h** after 7 m to 9 m (rounded to the next integer)
A passenger vehicle	16 to 25
A truck	13 to 20
A motorcycle	19 to 35

The values that were found out can be used for determining the starting time (t) up to reaching the point of collision. This may be calculated using the formula of $t = 2x\frac{S_{total}}{v}$

Table 7: Average starting times of drivers turning left after 7 to 9 m of a run-up/starting distance before a possible collision

Type of a vehicle	Starting time before a collision (t) in **s** (rounded figures)
A passenger vehicle	2.6 to 3.2
A truck	3.2 to 3.6
A motorcycle	1.9 to 2.7

6.4 Influence of the front brake light on accidents when turning

In case of accidents when turning left, the traffic in the opposite direction cannot detect the entry of a turning vehicle into the critical driving channel of the opposite direction in a usual way when the vehicle turning left starts to move. This is because the total driving distance of the vehicle turning left up to the point of collision first consists of a relatively straightforward starting movement that runs almost parallel to the longitudinal axis of the road. This means that the detection of the lateral movement of a vehicle turning left by a vehicle in the opposite direction only takes place when the vehicle turning left enters the opposite lane.

From the point at which the traffic in the opposite direction can safely recognize the procedure when turning, the driver turning left is supposed to drive through the middle of normal crossroads according to the average distances shown in subchapter 6.2 and, at a turn, the distance of usually about 3 to 4.5 m up to the point of collision. Considering normal or the above-given possible speeds when turning, the driver also needs about 0.5 to 1.2 s extra. This time of danger identification corresponds to or is even slightly shorter than the usual reaction delay times as empirically determined [14] and as usually stated in the Judicature [15], considering that 98% of driver response times after evaluations [16] is around 0.1 to 1.1 seconds and only 2% is below 0.5 s.

The fact that in case of accidents when turning left, the time from the reaction challenge through danger recognition up to the collision may be shorter than delayed reaction time, explains why when turning left, often there is no or an insufficient defensive reaction of the vehicle in the opposite direction. This, again, results in a situation that the initial speed of the oncoming vehicle can no longer be reduced by pre-collision braking when the oncoming vehicle has not been able to identify the vehicle turning left in time.

For all cases, from the analytical point of view, the front brake light offers significant potential for avoiding an accident or at least reducing the severity of the accident, because when it does not illuminate or the green front brake light turns off, it becomes much more visible to the driver who has the right of way, i.e., the oncoming road user, that the vehicle turning left no longer stands still or does not apply brakes at all. This leads to the fact that the driver with the right of way in the opposite direct traffic can recognize the beginning of the overall starting time of the turning vehicle by recognizing the front brake light illuminated on the turning car.

This warning by front brake lights turning on or not turning on allows an extension of the defence time, so that the accidents with the crossing vehicles or the vehicles turning left are completely prevented. This is possible, because instead of an average of 0.5 to 1.2 seconds in which the driver leaving a crossroad straight may recognize that the oncoming vehicle is turning left before the collision, the driver leaving the crossroad straight can recognize or accept that the vehicle might turn left–seeing the front brake light on the turning vehicle in up to 3.2 seconds (which is up to 3.6 s with trucks (see Table 7)) before the vehicle turning left enters the corridor of the vehicle leaving the crossroad straight. If normal reaction times of about 0.8 to 1.1 seconds are subtracted from this time needed for identification, the resulting defensive time is about 2.1 to 2.4 seconds (i.e., up to 2.8 s. in case of a turning truck). Such defensive time is enough for modern vehicles to stop on dry pavement at a speed of 50 km/h.

At fork crossings and road junctions where such situations are expected and drivers will use the potential of the front brake light, accidents of the turning vehicles clashing with oncoming traffic in a municipal area could be completely prevented and outside a municipal area, the accident rate and severity of accidents would be reduced.

7 A Model Example

The following model example is based on a real accident that involved a collision between a turning passenger vehicle and a motorcycle. The passenger vehicle turning left collided with the oncoming motorbike in the opposite direction that had the right of way. In this example, it is fictitiously assumed that the motorbike rider follows regulations or behaves in a usual way, i.e., he/she does not exceed the speed limit or does not exceed it by more than 20%. The pre-collision positions in the traffic situation, as well as schematic directions of movements, are shown in the following Figure 3.

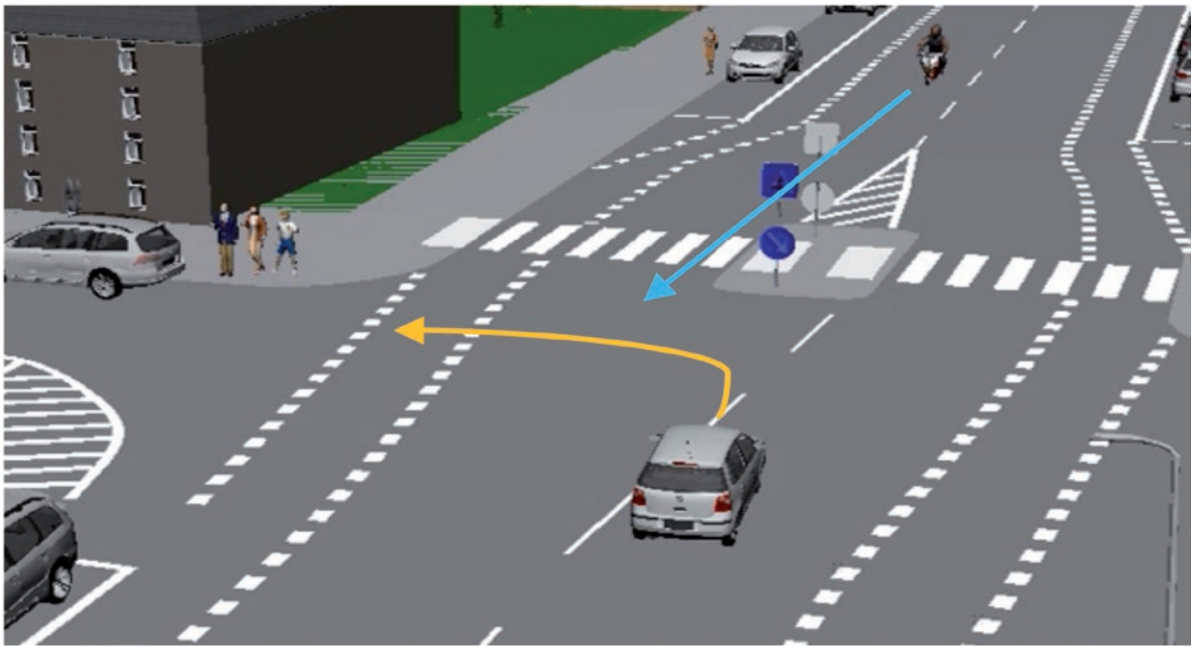

Figure 3
The pre-collision position of both vehicles immediately before the passenger vehicle turns left with a schematic illustration of the movement directions of the motorcycle and the passenger vehicle by means of arrows showing a typical situation when turning left.

The reconstruction of the real course of the accident and another animation of a case when the passenger vehicle is equipped with a front brake light were carried out in PC-Crash. The comparison of the courses is supposed to explain a practical use of the brake light.

A model example: The vehicle is turning left without a front brake light

In a real case, the motorcycle collided head-on with the front right corner of the passenger vehicle turning left, which made the motorcycle rider fly over the passenger car, fall on the pavement asphalt, hit the curb with his head and suffer the most severe injuries.

Figure 4
A view in the driving direction of the motorcycle rider with the final position of the passenger car and the final position of the motorcycle.

For a motorcycle rider, the passenger vehicle should be visible as a vehicle turning left and primarily recognisable as a danger if the passenger vehicle has not already entered the driving lane of the motorcycle. Most likely, the passenger vehicle will stand almost parallel to the longitudinal axis of the road, so that the beginning of the passenger car's start barely attracts any attention of the oncoming vehicle, as shown in the following animated pictures of the moments t = -3.0 s and t = -2.5 s, i.e., about 3 and 2.5 seconds before the future collision from the point of view of the motorcycle rider.

Figure 5
The animation of the view of the driving direction of the motorcycle rider—on one side about 3.0 s before the collision when the passenger car was stationary (the figure on the left) and about 0.5 s later, when the passenger vehicle started to move, made about 0.3 m and reached a speed of almost 4 km/h.

The visualisations of the motorcycle rider's view in the animation make it clear that the motorcycle rider is still unable to recognise the beginning of the passenger car's start from being stationary. No sooner than 1.5 seconds before the beginning of the collision, does the starting movement of the passenger vehicle and related danger become obvious to the motorcycle rider.

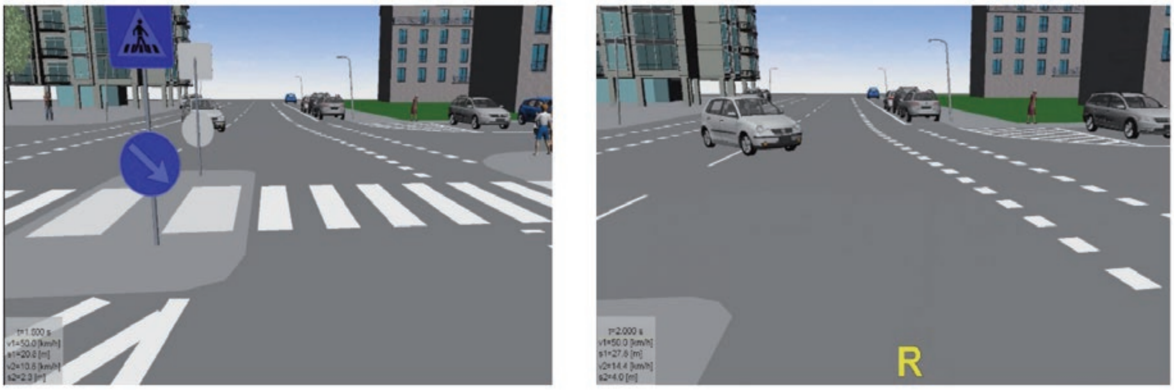

Figure 6
The animation of the view in the driving direction of the motorcycle rider-on one side about 1.5s before the collision when the passenger starts to cross the central line between the directional lanes (figure on the left) and about 0.5 s later when the motorcycle rider is able to safely recognise the reaction challenge (the figure on the right), whereas the passenger vehicle that has started turning left has already travelled 4 m at almost 15 km/h.

After a reaction delay which usually lasts one second, the motorcycle starts to decelerate. The remaining braking time of 0.5 s is not enough to stop the motorcycle travelling at 50 km/h. If we assume a value of 6 m/s2 for the deceleration of the motorcycle, the speed of the motorcycle after 0.5 seconds of its braking time is still less than 40 km/h (the value we are counting on is rounded to the following integer in km/h: 38 km/h).

However, the motorcycle could not have avoided the collision, because the time and the distance to prevent the collision were not sufficient. The motorcycle rider would have had to react earlier to the passenger vehicle, or stop earlier, or arrive at the dangerous spot much later, so that the passenger vehicle turning left had left that dangerous section. So far, there has been no incentive for the motorcycle rider to react earlier because the passenger vehicle was stationary and waiting. The driver of the passenger car might have non-adequately begun starting the car because he/she did not see the motorcycle behind a traffic sign on the construction lane splitting. However, it is also possible that the driver of the passenger vehicle misjudged the speed of the motorcycle and moved off, having wrongly assumed that he/she could still safely turn before the motorcycle.

A model example: The vehicle is turning left with the front brake light

Irrespective of the cause of the driving error of the driver of the passenger vehicle, the motorcycle rider should be able to avoid an accident only if he/she could detect the starting of the passenger vehicle. This, however, has not been possible for the motorcycle rider only by looking at the front part of a passenger vehicle. In such a case, the advantage of the front brake light should be for a driver to timely count on the start of the vehicle turning left or to recognise this action sooner.

The animation with the front brake light makes it clear that the motorcycle rider might notice the start of the passenger vehicle much earlier, even much longer before the passenger vehicle enters its driving lane, because illuminating the front brake light—which was about 3 seconds before the collision in the example without the front brake light—is clearly seen by the oncoming driver. This is also illustrated by the following animated pictures to the periods of t = -0.5 s and immediately after illuminating the front brake light, i.e., about 3 seconds before the collision in the example without the front brake light.

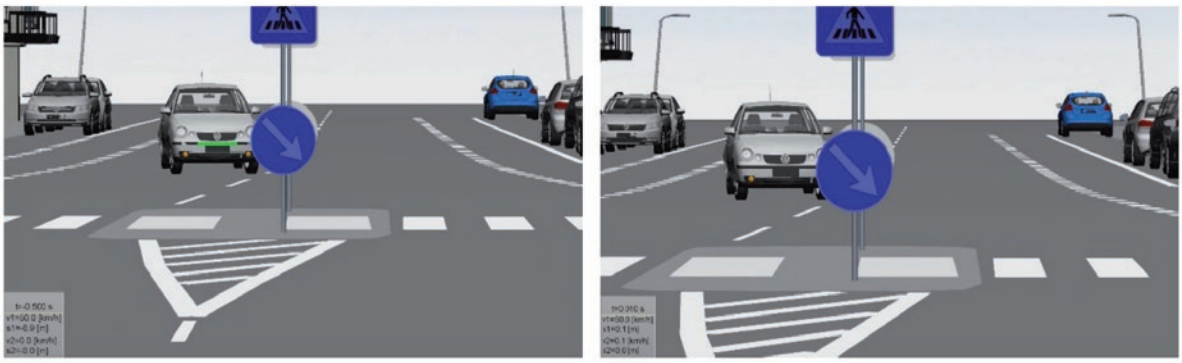

Figure 7

The animation of the view in the driving direction of the motorcycle rider on one side about 0.5 s before illuminating the green front brake light mounted on the front of the passenger vehicle (the figure on the left) and about 0.5 s later, when the passenger car has begun to move, i.e. it has no significant speed yet (the figure on the right [represents t = -3 s in the animation) without the front brake light]).

The visualisation of the motorcycle rider's view explains that based on the illumination of the front brake light, the motorcycle rider can recognise the beginning of the movement of the passenger vehicle right in the beginning—not as late as 1.5 seconds before the collision, or the rider can foresee it thanks to the front brake light. This way, the potential danger inflicted by the turning passenger vehicle becomes obvious for the rider much earlier, so he/she can get ready, brake and adjust to the situation. With an adequate reaction, this may prevent a collision, because earlier braking extends the time the motorcycle rider needs to reach the place of collision.

Based on this fact, the passenger vehicle turning left may leave the dangerous section before the motorcycle rider with the right of way heading straight, before the motorcycle rider comes close.

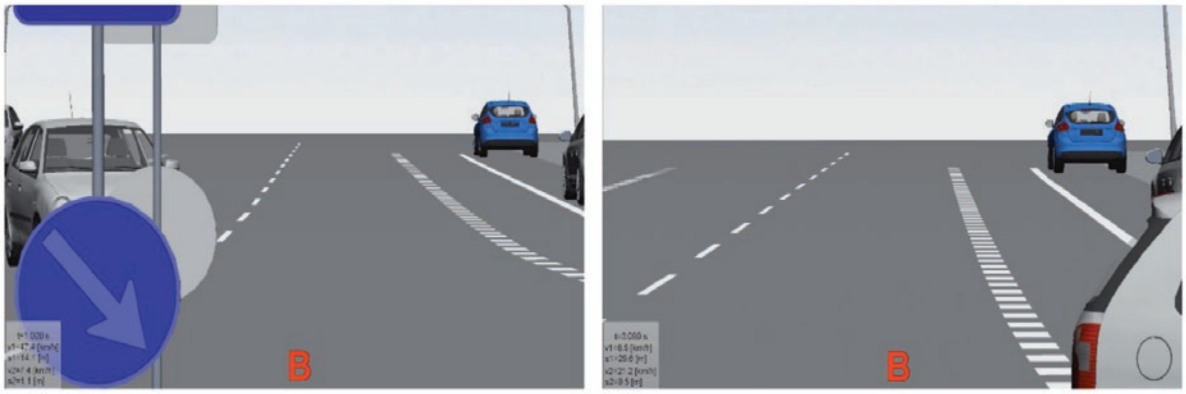

Figure 8
The animation of the view in the driving direction of the motorcycle rider on one side about 1 s after the visible illumination of the front brake light, i.e. after the reaction delay time has elapsed, that is at the beginning of the possible defensive braking of the motorcycle from the speed of about 50 km/h (figure on the left), as well as shortly before the motorcycle reaches the potential danger section about 2 seconds later (figure on the right), when the passenger vehicle may leave the crossing or the section before the motorcycle, because if braking, the motorcycle rider can reach the danger section later and the motorcycle cannot reach any significant speed (less than 7 km/h) by then.

For a positive result of the illustrated example of the scenario, it is crucial for the motorcycle rider with the right of way to start braking in time. This rider may base his/her decision on the intention of the driver of the passenger vehicle to turn, as signalised by the illumination of the front brake light as early as 2.8 seconds before reaching (the potential) point of collision. Therefore, the rider may start decreasing the speed of the motorcycle right after the reaction delay time of one second. The motorcycle could theoretically even stop before the point of collision. Based on the fact that this passenger vehicle can then leave the crossroad area, this would not be necessary in terms of time. In any case, the collision would be prevented in terms of time and place, if the motorcycle rider would have responded to the illumination of the front brake light mounted on the passenger vehicle.

Therefore, this example demonstrated that it is already quite possible to allow an earlier reaction to the oncoming vehicles by using the front brake light. This way, the drivers in the direct traffic direction often could avoid these collisions with the drivers turning left. In most cases, at least reducing the severity of such collisions could be assumed, if the drivers in the direct traffic direction could react to the drivers turning left earlier, so that their collision speed would be decreased.

8 Summary

The front brake light can contribute to traffic safety. Primarily in situations when drivers turn left, both in and outside a municipal area, it is a clear advantage for the traffic in the opposite direction, because when seeing the illuminated front brake light, they can sooner foresee the turning intention and thus react earlier.

An earlier reaction allows the prevention of the accident or reduction of the frequency or severity of the accidents. Even in parking lots, using the front brake light can be expected to reduce the number of accidents, because the principle of mutual attentiveness can be clearly communicated in this way.

Also, in other everyday situations, the front brake light may contribute to both real and felt safety. For instance, when changing a driving lane, the traffic behind may signalise that they are braking, which allows merging. "My partner, I am braking for you and I will let you merge in."

To prevent critical situations which could be inflicted by the front brake light, intelligent turning on is offered concerning the sensors already existing in the vehicles today. Pedestrians may be purposefully shown the green brake light only if it is secured that the vehicle will stop in time.

In Berlin, on 31st May 2021

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