Too busy to indicate? Indicator usage depending on task demand in urban lane change manoeuvres

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Abstract: Driver intention recognition for Advanced Driving Assistance Systems (ADAS) is having a major impact in recent driver-vehicle-interaction research. The knowledge of the drivers` intention enables to develop ADAS that are providing assistance specifically in appropriate situations and avoid false alarms when no assistance is required. The present study is using data acquired during an on-road field test, including 60 participants who drove an instrumented vehicle in standardized trips on urban arterial roads. In total 2,400 km of recorded data was analysed focusing on the indicator usage. The collected data is showing natural driving behaviour since analysed lane changes were performed by drivers that were not aware of the instrumented vehicle. In total, 2,787 lane changes were classified according to lane change manoeuvre type and indicator usage. To analyse possible effects of task demand, based on the task-capability interface model, three factors were determined to retrieve a task demand index. This index was labelled for every lane change manoeuvre. Results show a relatively high indicator usage rates independent from the specific lane change manoeuvre and task demand index. The findings of this study suggest, that indicator can be seen as a strong and reliable parameter to assess driver`s lane change intention. However, setting the indicator is usually done only about 2 seconds before the actual lane change, so this parameter should only be used as a final classificatory to ensure the driver's intention. Further implications for predicting driver's intention for lane change manoeuvres on urban roads are discussed in the final part.

Keywords: lane change manoeuvre, indicator usage, driver intention

1. Introduction

The lane change manoeuvre is a driving task which poses high demands on the driver (Schiessl 2008) and which frequently leads to driving errors and accidents. Germany registered 13 % of accidents with personal injury on motorways associated with lane change manoeuvres and 5 % on roads within built-up areas in 2011 (Statistisches Bundesamt 2012). Advanced Driver Assistance Systems (ADAS) can assist drivers in these situations (Bengler et al. 2014). To ensure that ADAS are accepted and used in everyday driving situations, the systems must provide reliable assistance and meet the driver`s needs (Jentsch 2014). False ADAS alarms, e.g. in situations where the driver has no intention to change the lane, could annoy, distract and confuse drivers. As a consequence, ADAS would be disregarded or disabled and the potential safety benefit would be lost. Driver intent information is supposed to reduce the mismatch between driver expectations and system reactions (Beggiato & Krems 2012, Beggiato 2014). Over the last decade, various research activities have therefore focused on predicting drivers` intention, especially for lane change manoeuvres (Schroven & Giebel 2008, Henning 2010).

Results show that the best algorithm performances are obtained by data fusion of 1) driver behaviour, 2) sensor information about the environment and 3) vehicle parameters (Morris et al. 2011). One often discussed promising parameter is the indicator usage although previous studies show that it is rather unreliable. In a blind observational study, 2,000 lane changing vehicles were observed at different places and recorded 52 % of lawful turn signal usage (Ponziani 2012). Similar values are reported by Lee et al. (2004) with 44 %, ranging from 11 % to 94 % for different lane change manoeuvre types and Beggiato (2013) reported an indicator usage of 89 % for lane changes on urban roads.

The aim of this paper is to investigate how the indicator usage rate (IUR) is influenced by task demand and environmental conditions. For this evaluation, lane change manoeuvres were divided into eleven types (Beggiato 2013) with the task demand (Fuller 2005) of each situation taken into account. With this procedure, insights into indicator usage rates in general and their dependence on the type of lane change and the task demand can be retrieved. Results can be used for further ADAS specification as well as implications for driver intention models for urban lane change scenarios.

2. Research design and procedure

The present study was conducted as secondary data analysis of an on-road field test carried out in the framework of the German research initiative UR:BAN. The original purpose of the study was the real-time prediction of lane change manoeuvres using driving parameters, data from the vehicle environment as well as driver behaveour such as glances to the mirrors and indicator usage (Beggiato 2017). A total of 60 participants drove an instrumented test vehicle (VW Touran) in real-road conditions without experimenter on an urban route in the city of Chemnitz (Fig. 1, left).

The route had a total length of 40 km with an average driving time of 62 minutes. It was composed of two rounds with 20 km each, consisting of 1) a 2.5 km long two-lane stretch (A-B) with a speed limit of 50 km/h, 2) a 13.7 km long two-lane stretch (B-C-D) with a speed limit of 70 km/h and 3) a 3.8 km long one-lane stretch (D-A) with a speed limit of 50 km/h. All 60 trips were performed during daytime.

The test vehicle was equipped with 6 cameras (Fig. 1, right), providing views to the driver as well as outside views to the traffic situation ahead, behind and in the blind spot area of the test vehicle. Drivers were instructed to drive as usual and were also told that the study aims at recording naturalistic driving data for different driving manoeuvres. After this field study, the manoeuvres were annotated and categorized into lane change manoeuvre types (LCMT). The environment was classified by using Fuller`s task-capability interface model (2005). The factors environment, other road users and duration of the manoeuvre were chosen to assign a task demand index (TDI). Doing so, conclusions about indicator usage depending on the task demand of specific driving situations can be drawn. To ensure a high standard of consistency

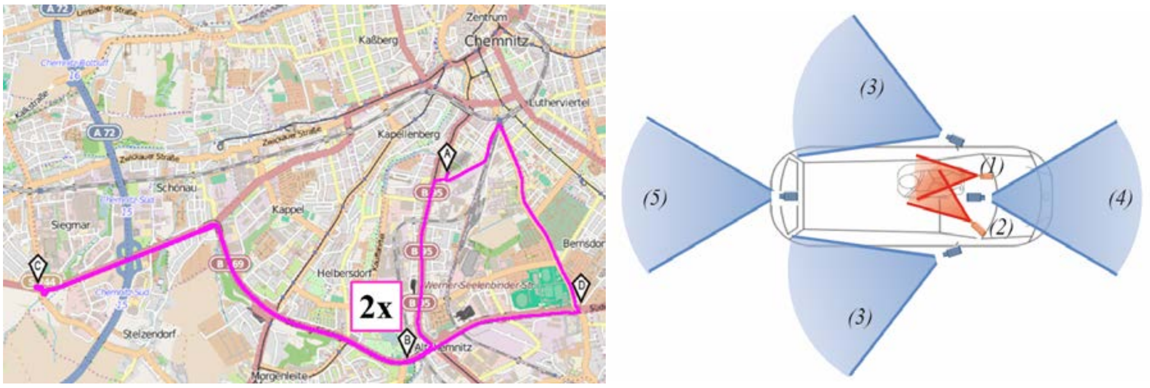

Figure 1: *Route (openstreetmap) and camera views of the research vehicle: (1) driver, (2) interior, (3) blind spots, (4) front and (5) rear camera view*

and quality, all annotations and classifications were created by three persons. Judgement errors and subjective decisions were minimized applying cross checks between the annotators before starting the annotation process.

For video analysis and annotation the software ELAN was used. For this study, all vehicles that were driving in the same direction and were visible on one of the 4 external camera images were annotated. Situations with trucks, buses or special vehicles (e.g. road sweepers) and oncoming traffic were excluded from the analysis. To ensure consistency in the annotated data, situations with limiting visible conditions caused by technical or environmental influences were also excluded. Technical problems are e.g. superimposition through auto aperture shift due to different lighting conditions or a lack of resolution of the cameras. Environmental problems were caused by the blinding sun, raindrops, dirt on the windscreen. Furthermore, problems arose when several cars completed a lane change at the same time. In this case, only the vehicle that was closest to the instrumented vehicle was annotated.

The data analysis procedure can be divided into two general steps: First, the categorization into manoeuvre types and second, a classification of all situations to process a TDI for each situation. The categorization into LCMT follows Lee et al. (2003). He stated a set of 11 motives for lane changes on interstates and U.S. highways that can be clustered in the following LCMTs: Lane change because of a slow vehicle, return to preferred driving lane, enter a road, exit a road, tailgating, merging vehicle, manoeuvre to avoid rough road surface, lane drop, additional lane, unintendedly and other reasons. Since the focus of this study is on urban roads, those manoeuvre types were slightly adjusted to the following types: 1) slow lead vehicle, 2) return, 3) enter, 4) tailgating, 5) merging vehicle, 6) lane drop, 7) added lane, 8) unintended, 9) road barrier and 10) lane release. Roads with an additional lane like a slip road or a turning lane were defined as a lane change resulting to an added lane. “Road barrier” is defined as an obstacle that blocks a lane, e.g. construction sites or broken-down vehicles. The type “lane release” refers to lane changes from the left to the right lane without visible reasons. In Germany the usage of the right lane outside of towns is mandatory (StVO 2015). While in built-up areas vehicles up to 3.5 tones admissible total weight can choose the lanes freely (StVO 2015), the usage of the right lane on urban roads is still a common behaviour for the majority of German drivers.

The next step was to determine the TDI-level for every lane change manoeuvre. The TDI is composed of three factors: other road users (traffic density), environment (weather) and the duration of lane change (road position and trajectory). Depending on the influence of each factor, zero to 0.50 points were distributed. Traffic density

Table 1: *Lane change duration depending on lane change manoeuvre types*

	Manoeuvre types										
	Added lane	Slow lead vehicle	Lane release	Enter	Un-intended	Return	Tail-gating	Road barrier	Lane drop	Merging vehicle	In total
N	918	590	548	407	124	84	46	28	28	14	2787
M [sec]	2.46	2.32	2.67	2.78	3.04	2.45	2.69	3.08	2.92	2.22	2.56
SD [sec]	0.84	0.84	0.88	0.94	0.96	0.86	0.88	1.59	1.68	0.54	0.91

was subdivided into surrounding traffic without any direct influence (zero points) including overtaking a slow lead vehicle with large distances (e.g. due to an anticipatory driving style). If a sufficient distance of a car ahead or following was not met 0.25 points were distributed. Tailgating vehicles ahead or following vehicles at high velocity 0.50 points were given. Weather conditions were distributed as follows: optimal weather with no influence on driving behaviour zero points. Partially restricted viewing conditions (e.g. blinding sun, fog, rain or twilight) 0.25 points and restricted viewing conditions (e.g. heavy rain, dense fog or darkness) 0.50 points.

Worrall & Bullen (1970) stated, that a lane change starts when a vehicle first crosses the lane marking and ends once the vehicle has completely crossed that line again. The found values are shown in Table 1. While ANOVA shows a significant effect of lane change manoeuvre type (ANOVA, $F [9, 2777] = 15.95$, $p < .001$), Post hoc test reveals that lane changes caused by slow vehicles ahead and merging vehicles are driven faster than manoeuvres caused by a road barrier or by the type "unintended".

Determining the points for the lane change duration it is assumed that a particularly long time to change lanes shows a relaxed ride (zero points). As an example, this can be also observed in data since unintended lane changes or manoeuvres caused by road barriers have significantly longer lane change durations. Manoeuvres caused by road barriers have also longer lane change durations but with a standard deviation of almost the double than for other manoeuvre types. Those values indicate a strong dependence on traffic conditions or the moment the barrier is recognized by drivers.

With decreasing lane change duration a higher task demand is assumed (Rasmussen 1983). With this consideration in mind the TDI input for duration was determined. Lane changes above the mean duration were given zero points. Durations between mean value and half the mean value were given 0.25 points and durations below 0.50 points. Table 2 shows the final classifications for the task demand index. After analysis all results were added. A score of zero points indicates a very low TDI. 1.50 points is the highest possible score for the TDI.

3. Results

Table 3 shows the types of lane change, indicator usage rate (IUR) and number of all changes. Overall, 2,787 lane changes were identified and classified into 10 types. The mean IUR is 87 % with a minimum of 82 % (road barrier) and a maximum of 91 % (entering a road). The variance of the IUR between the LCMTs is quite small. When considering the IUR of other publications with a rate of 44 % or 52 % (Ponziani 2012, Lee et al. 2004) the IUR in the present study is remarkably high. Beggiato (2013) reported an IUR at nearly the same level (89 %). The most common manoeuvre type is "added lane" with a share of almost one third of all annotations (32.9 %) followed by slow lead vehicles (21.2 %) and lane releases (19.7 %). The last LCMT of the big four is the lane change to enter a road with 14.6 percent of all events.

Table 2: *Task demand index depending on traffic density, weather and duration of lane change*

Points	Traffic density	Weather	Duration
0.00	No influence by surrounding traffic	Optimal	> *M*
0.25	Existing surrounding traffic	Partially restricted viewing conditions	> 0.5 *M* < *M*
0.50	Tailgating and/or high relative velocities	Restricted viewing conditions and lane influence	< 0.5 mean

The reasons for a lane change caused by tailgating, road barriers, lane drop or a merging vehicle are less common and represent only four percent of all lane changes.

Table 3 also provides data about the IUR, depending on the TDI. It can be noted that the IUR does not depend on the TDI. Values of 1.00 and 1.25 can be neglected as the numbers of events are too small to generate reliable results. It can be concluded that task demand seems to have no influence on IUR. Regarding LCMT and IUR depending on TDI 86 percent of all events have taken place in the highlighted cells with most events categorized as the LCMT added lane and a TDI 0.25.

Table 3: *Indicator Usage Rate (IUR) depending on the lane change type and TDI*

	0.00		0.25		0.50		0.75		1.00		1.25		Total	
	IUR	N	IUR	N	IUR	N	IUR	N	IUR	N	IUR	N	IUR	N
Added lane	89%	333	85%	484	82%	89	82%	11	100%	1			86%	918
Slow lead vehicle	84%	173	85%	254	88%	123	79%	34	100%	6			85%	590
Lane release	84%	166	85%	299	87%	70	100%	12			100%	1	85%	548
Enter	85%	150	94%	191	95%	57	100%	7	100%	2			91%	407
Unintended	88%	69	86%	50	75%	4	0%	1					86%	124
Return	81%	26	83%	48	88%	8	50%	2					82%	84
Tailgating	100%	1	95%	19	85%	20	83%	6					89%	46
Road hazards	40%	5	88%	17	100%	6							82%	28
Lane drop	83%	6	94%	18	50%	2	100%	2					89%	28
Merging vehicle	100%	6	86%	7	0%	1							86%	14
In total	86%	935	87%	1387	87%	380	84%	75	100%	9	100%	1	87%	2,787

In order to draw a conclusion about the influence of the TDI on IUR, the classification of the annotated lane changes according to the previous presented points-system is shown in Table 4. It depicts that the large majority of the recorded lane changes took place without influence of surrounding traffic and viewing conditions.

Table 4: *Classification of all demands according to the numbers of events*

TDI	Traffic density	Weather	Duration
0.00	2,345	2,556	1,207
0.25	376	222	1,495
0.50	66	9	85

4. Discussion

Previous studies report an indicator during lane change manoeuvres between 44 % and 52 % on U.S. roads and 89 % on German roads with participants driving an instrumented vehicle. In this present study, road users used the indicator in 87 % of all lane changes, which is quite similar to the results Beggiato (2013) found earlier. A reason for this could be cultural differences in driving behaviour. Using TDI-scores, based on the task-capability interface model by Fuller, the main result of this study is that the indicator usage rate is almost constant for all task demands. Automated behaviour pattern of the driver (Sturzbecher 2012) might be the explanation for this finding. Using the indicator seems to be a highly automated behaviour in the present study as it is shown frequently in normal driving situations. For a deeper understanding, further research is needed, whether there is a personality, age related or regional influence on indicator usage and if there are thresholds for task demands where drivers start compensating difficulties in handling traffic situations by not using the indicator.

The findings of this study suggest that the indicator can be seen as a strong and reliable parameter to assess the driver`s lane change intention. However, setting the indicator is usually done only about 2 sec before the actual lane change (Beggiato 2013), so this parameter should only be used as a final classification to ensure the driver’s intention. Other parameters like glances and data from the environment, including traffic, have to potential to give an earlier indication for intended lane change manoeuvres and should therefore be further investigated.

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