Factors for User Acceptance of Cooperative Assistance Systems

A Two-Step Study Assessing Cooperative Driving

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Abstract – **Improved sensor technologies and driver assistance systems offer the possibility for drivers to coordinate their driving maneuvers. Building on this development, a cooperative assistance system could make traffic safer and more efficient. This paper describes the methodology and results of a two-step study evaluating user acceptance factors of a future cooperative assistance system, focusing on passenger cars and heavy trucks. In order to achieve this, cooperative behavior during current traffic situations is evaluated. The analysis shows that one problem in today's cooperative traffic is to initially recognize the need for cooperation. Cooperative assistance systems that indicate a present possibility of cooperation could support cooperative behavior in traffic. In addition, evaluation of car versus truck drivers in this study shows a difference in their stress factors and cooperative behavior. This fact indicates that these two user groups should be considered separately in development of a human-machine-interface for a cooperative driver assistance system.**

Keywords— cooperative driving, acceptance, human-machine-interaction, cars and truck drivers

I. INTRODUCTION

Assistance for cooperative driving has the potential to make traffic safer and more efficient. Especially in difficult traffic scenarios, drivers could benefit from a cooperative assistance system. One of the most challenging driving maneuvers is merging from an on-ramp into heavy freeway traffic [1], [2]. Depending on the traffic level, drivers are forced to brake or change lanes in order to open gaps for the merging vehicle [3], [4]. This interrupts the traffic flow and can lead to hazards. However, active cooperative maneuvers — if conducted correctly — can reduce the forced aspects of a merging process and thus the potential of hazardous traffic situations. Turning at intersections requires the attention of several traffic participants and fast reasoning. Information has to be filtered, traffic movements and signals have to be interpreted and the final decision for an action must be made [5]. Time pressure makes the situation even more stress inducing [6]. Cooperative assistance could help drivers to overcome difficulties in such traffic situations.

In addition to the difficulty of traffic scenarios, the relationship between different types of road users can be challenging. In a study from [7] the relationship between car and truck drivers was analyzed. Trucks often impose stress on car drivers. For example, when truck drivers occupy the fast lane while passing another truck, car drivers have to change lanes or decelerate rapidly. Cooperative maneuver planning can reduce these obstructions through cooperative perception of traffic situations and C2X communication.

These technologies can also improve traffic situations, in which cooperation is not yet possible. For example, they allow sensor information from various vehicles to be shared and could prevent drivers from overtaking in spite of oncoming traffic that is not perceived. Accidents related to overtaking on country roads are the most severe accidents in Germany [8].

One important question concerning cooperative driver assistance systems is how to design the systems so that the driver accepts them. User acceptance is to a large degree responsible for the success of any information technology system and emphasizes the importance of research on user acceptance throughout the early stages in the development process [9].

A widespread model for describing user acceptance is the Technology Acceptance Model (TAM) introduced by Davis [9]. TAM names "usefulness" and "ease of use" as the two main variables that determine user acceptance of new technologies. Together with Venkatesh, Davis modified the original TAM to the Unified Model of Acceptance and Usage of Technology (UTAUT) [10]. In addition to TAM, it includes seven additional acceptance models. Rothensee [11] developed an acceptance model for ubiquitous computing systems (UbiTAM) based on the acceptance influence variables used in TAM and UTAUT. He further evaluates four directions that shape acceptance of ubiquitous computing applications: affective, control, uncertainty, and social beliefs. In this study, the UbiTAM model was used to develop research questions for identification of acceptance factors.

Today human drivers already act cooperatively in traffic situations. For example, besides the forced merging maneuvers explained in [1], also voluntary cooperative merging maneuvers exist among drivers. Drivers engage in a cooperative movement for the merging car, by changing lanes, also called "yielding" [12]. For developing a cooperative driver assistance system, it is necessary to understand how cooperative maneuvers are currently identified, planned and executed.

In this study, we investigate acceptance of cooperative driver assistance systems by car and truck drivers. Furthermore, their willingness to cooperate in various traffic situations was determined in order to gain insight for further development of cooperative assistance systems.

II. METHODOLOGY

The method consists of a two-step investigation. In a preliminary study, a structured guideline interview with car and truck drivers was conducted. For the interview, drivers were either invited to the institute or were contacted at freeway rest stops. The preliminary study identifies relevant factors to assess the users' acceptance. On this basis, the main study was designed to verify the relevance of the previously identified factors. A questionnaire was designed as a quantitative method. This online questionnaire, presented with the open source tool LimeSurvey [13], was used to collect the data and findings from the main study.

III. PRELIMINARY STUDY

A. Interview Guidline Construction

The UbiTAM identifies seven user beliefs that influence the acceptance of ubiquitous computing applications: pleasure, subjective norm, risk, usefulness, ease of use, control over the system, and trust [11]. The construction of the interview guideline was tailored to these seven beliefs. Questions relating to the first three beliefs were formulated to describe present cooperation patterns in traffic. Questions regarding ease of use, control over the system, risk and trust assessed the usage of future cooperative assistance system.

1) Pleasure: Rothensee determined a person's affective evaluation as an influence of his or her intention to use a new technology [11]. To be aware of this influence, we asked the participants to describe and explain positive or negative feelings during four different traffic scenarios (Table I.).
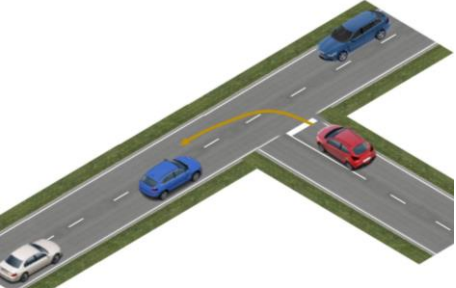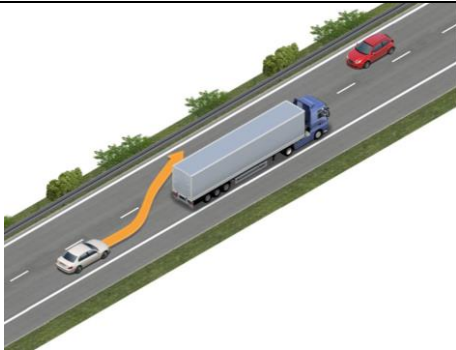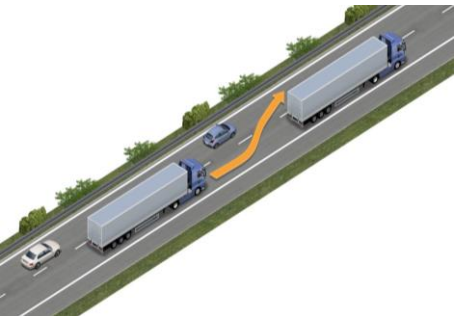
2) Subject Norm: Venkatesh and Davis [10] showed that social influences have an impact on an individual's behavior using new technologies. During the preliminary study, the participants were asked to describe their behavior, but also the behavior of others involved in the traffic situation. They were asked which factors impact their willingness to cooperate.

3) Risk: Predicting the outcome of an interaction with new technology is very difficult for users. "Therefore the adaption of new technology is inherently risky." [11, S. 54]. To understand if there are risks in possible cooperative traffic maneuvers that influence drivers' willingness to cooperate, we asked the participants for their reasons for neglecting cooperation in particular traffic situations.

4) Usefulness: Usefulness is one of the most influential factors for acceptance of new technology systems [9]. Thus, the participants were asked about the most useful aspects of a cooperative driving assistance system in each traffic situation.

5) Ease of Use: Summarizes the questions for which information is required to decide for or against cooperation easily, unambiguously and correctly.

TABLE I. FOUR TRAFFIC SITUATIONS THAT REQUIRE COOPERATION

Situation 1: Merging on freeways

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Situation 2: Turning left at intersections

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Situation 3: Passing on country roads

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Situation 4: Passing trucks on freeways

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6) Control over the system: Questions about the accepted level of automation were asked to determine the degree to which a cooperative assistance system should take actions for the driver or act submissively.

7) Trust: As a basis for automated cooperation, human trust in the system needs to be established. Reliance thereby describes the extent to which a person relies on the correctness of the autonomous system's behavior. Compliance resembles the extent to which a person agrees to the instructions of an autonomous system [14]. Imagining automated cooperative driving assistants, trust in these aids needs to be evaluated.

B. Procedure

As a foundation for the interview, a presentation including questions and pictures of the four traffic scenarios (Table I.) was displayed to the participants on a tablet PC. At first, participants were introduced to the concept of cooperative driving maneuvers in everyday traffic, to achieve a common understanding of the concept among all participants. Afterwards, each situation was explained to the participants; then the interviewer asked questions accordingly. The participants were asked to imagine the different perspectives (e.g. the driver merging onto the freeway) that are interacting in the cooperative scenarios. For each perspective specific questions motivated by the seven user beliefs were asked. Car drivers were interviewed in an office setting at the Chair of Ergonomics (TUM), whereas truck drivers were interviewed during their breaks on freeway rest stops. The interviews were recorded with a voice recorder and a logged paper questionnaire.

C. Participants

In total 7 (2 female) participants between the ages of 27 and 62 ($M = 45.14$; $SD = 14.61$) were interviewed for the preliminary study. Three of them were car drivers and four truck drivers.

D. Results

The recordings of the interviews were transcribed and the gathered comments were clustered by qualitative content analysis [15] into the categories shown in Table II. Besides stress factors, like eye contact between possible cooperation partners or traffic density, influencing factors on willingness to cooperate were found. For example, time of the day is one factor that the participants mentioned. The participants also described their own cooperative behavior in the four traffic scenarios. Among others, they flash headlights or use the turn signal to cooperate. In addition, the participants described behavior that allows cooperative intentions of others to be recognized. To coast or brake are one of them. Furthermore, the participants described, what they expect from a cooperative assistant system. For example driving behavior like maintaining speed or yielding should be orchestrated by a cooperative assistant system. The intention of the system or personal information from the cooperation partner are some information that should be displayed by a cooperative assistant system. The clustered answers provided a guideline for designing an online questionnaire for the main study.

IV. MAIN STUDY

A. Questionnaire Construction

The preliminary study identified relevant factors to assess the users' acceptance. On this basis, the questionnaire of the main study was designed to verify the relevance of the previously identified factors. Therefore, the participants rated the factors for each cluster (see section III. D. Results) using 5-Point Likert scales.

TABLE II.   RESULTS OF THE PRELIMINARY STUDY

Stress factors in the four different traffic scenarios:	
• Traffic density	• Slope of the road
• Behavior recognition	• Truck involved
• Speed	• Eye contact
• Distance	
Influencing factors on willingness to cooperate:	
• Recognition of cooperation possibilities	• Probability of success
• Visibility conditions	• Time pressure
• Cooperativeness of others	• Time of day
• Traffic density	• Reward
	• Distance
Description of own cooperative behavior in the four traffic scenarios:	
• Lane change	• Maintaining speed
• Turn signal	• Flashing headlights
• Steering behavior	• Wave
• Acceleration	• Brake
• Coasting	
Behavior that allows cooperative intentions of others to be recognized:	
• Yielding	• Wave
• Turn signal	• Acceleration
• Distance	• Coasting
• Eye contact	• Flashing headlights
• Steering behavior	• Maintaining speed
• Brake	
Cooperative behavior that should be orchestrated by a cooperative assistant system:	
• Brake	• Lane change
• Maintaining speed	• Acceleration
• Yielding	• Steering behavior
• Turn signal	• Wave
• Coasting	• Flashing headlights
Information that should be provided by a cooperative assistant system:	
• Traffic situation	• Connection status
• Distance	• Probability of success
• Intention	• Guidance
• Speed of others	• Time
• Environment	• Personal information
• Route-related information	

Besides the previously mentioned seven user beliefs, the UBiTAM identifies two personal factors that influence acceptance of ubiquitous computing applications: desire for control and control beliefs about technology. Users with a high desire for control could feel more stressed by overly controlling systems [11]. Users with high control beliefs about technology have an easier time using new technologies and thus accept them even more [11]. After inquiring on general demographic

data, the two personal factors were assessed using the standardized German *Internale-Externale-Kontrollüberzeugung-4 (IE-4)* scale [16] and technical competence was assessed using the German *Kontrollüberzeugung im Umgang mit Technik (KUT)* questionnaire [17].

The IE-4 scale consists of two subscales that correspond to the internal and external desire for control. The subscale consists of two items that were rated using a 5-Point Likert scale (ranged from 1 = "totally disagree" to 5 = "totally agree"). The KUT consists of eight items that were rated using a 5-Point Likert scale (ranged from 1 = "totally disagree" to 5 = "totally agree"). The three items are assigned to the three scales "internality", "technical externality" and "fatalistic externality".

B. Procedure

Data was collected by using an online questionnaire. It was implemented using the open source tool LimeSurvey, where, following demographic questions, the different scenarios were presented in permutated order. Participants were obtained from a database frequently used for these kinds of studies and contacted by e-mail.

C. Participants

A total of 76 (10 female) participants between the ages of 23 and 68 ($M = 43.41$; $SD = 12.94$) filled out the aforementioned questionnaire. Six of them did give up on the questionnaire at some point but were still included in the analysis since even the partial data was deemed useful.

In order to distinguish between different user groups for evaluation, the participants were divided into car drivers (50 participants = 65.8%) and truck drivers (26 participants = 34.2%). The car drivers averaged 17,120 ($SD = 12,703$) km a year and drove an average of 35.51% of their time on the highway, 31.84% on rural roads and 32.65% in the city. Truck drivers drove an average of 67 851 ($SD = 79 426$) km a year and $M = 4.06$ ($SD = 1.42$) days a week.

D. Results

To evaluate the influence of participants' desire for control and control beliefs about technology, the participants were divided into three groups depending on their achieved IE-4 and KUT values (low, middle and high; division between the 35th and 65th percentiles). Table III shows the distribution of the IE-4 and KUT values. Further analysis demonstrated differences between the distribution of car and truck drivers' IE-4 and KUT value.

The evaluation process for analyzing the participant answers was as follows:

- Descriptive statistics were calculated for each factor and item of the questionnaires. In addition, the Friedmann Test was used with Dunn-Bonferroni post-hoc pairwise comparisons and effect size according to Cohen to analyse the data.

- Differences between car and truck drivers were calculated by the Mann-Whitney Test.

- To evaluate the influence of participants' desire for control and technical competence, the Kruskal-Wallis Test was calculated with Dunn-Bonferroni post-hoc pairwise comparisons and effect size according to Cohen.

TABLE III.   GROUPS OF THE IE-4 AND KUT VALUES

IE-4			
	MD = 3.702	Perc.35=3.50	Perc.65=4.00
Group	**Value**	**People (n=73)**	**Equal Distribution**
Low	0-3.50	28	$\chi^2 = 1.836$, df = 2,
Middle	3.51-4.00	26	p = .399
High	4.01-5.00	19	
KUT			
	MD = 3.464	Perc.35=3.24	Perc.65=3.76
Group	**Value**	**People (n=72)**	**Equal Distribution**
Low	0-3.24	30	$\chi^2 = 2.986$, df = 2,
Middle	3.25-3.76	17	p = .225
High	3.77-5.00	25	

1) Stress factors: Analyzing the stress factors (scale ranging from 1 = *"not at all stressful"* to 5 = *"very stressful"*) in four traffic scenarios, the participants showed differences between the scenarios.

a) Merging onto freeways: The top three stress factors when merging onto freeways are "traffic density" ($M = 3.85$ $SD = 1.096$), "behavior recognition" ($M = 3.72$ $SD = 1.051$) and "speed" ($M = 3.67$ $SD = 1.151$). More than 60% of the participants listed these three factors as "stressful" or even "very stressful" while merging from an on-ramp onto freeways.

Compared to truck drivers, the car drivers perceived "distance" as very stressful when merging on freeways (Mann-Whitney U = 791.500, p = .019, effect size according to Cohen $r = 0.28$, small effect), also "speed" (Mann-Whitney-U = 792.500, p = .018, effect size according to Cohen $r = 0.28$, small effect).

b) Passing on country roads: More than 70% of the particpants indicated that the factors "slope of the road" ($M = 4.13 \pm 1.074$), "traffic density" ($M = 4.01$ $SD = 1.041$) and "distance" ($M = 4.06 \pm 1.033$) are perceived as "stressful" or even "very stressful" when passing on country roads.

Truck drivers perceived the "slope of the road" as less stressful compared to car drivers (Mann-Whitney-U = 792.000, p = .014, effect size according Cohen $r = 0.29$, small effect).

c) Turn left at intersections: "Slope of the road" ($M = 3.92$ $SD = 1.097$), "speed" ($M = 4.01$ $SD = 1.041$) and "traffic density" ($M = 4.01$ $SD = 0.942$) are the top three stress factors when participants turn left at intersections. Over 70% of them indicated that these three factors are perceived "stressful" or "very stressful".

d) Passing trucks on freeways: Compared to the other three traffic scenarios, the participants assessed passing trucks

on freeways as less stressful compared to the other scenarios. Only the factor "distance" ($M = 3.61$ $SD = 1.251$) scored a value over 60%.

2) Influence factors on willingness to cooperate: The descriptive statistic (Figure 1) revealed that the participants determined "recognition of cooperation possibilities" ($M = 3.79$ $SD = 1.125$) 71% of the time as having the highest impact on willingness to cooperate (scale ranging from 1 = "no influence" to 5 = "very high influence"). Followed by the factors "visibility conditions" ($M = 3.76$ $SD = 1.120$) and "cooperativeness of others" ($M = 3.49$ $SD = 1.048$). The factors "reward" ($M = 2.37$ $SD = 1.169$) or "time of the day" ($M = 2.74$ $SD = 1.289$) played a subordinate role (Friedmann Test: $\chi^2(8) = 99.843$, $p < .001$, n = 70).

The analysis concludes that car drivers were more likely to cooperate in the absence of "time pressure", compared to truck drivers (Mann-Whitney-U = 874.500, p = .001, effect size according Cohen $r = 0.40$; medium effect).
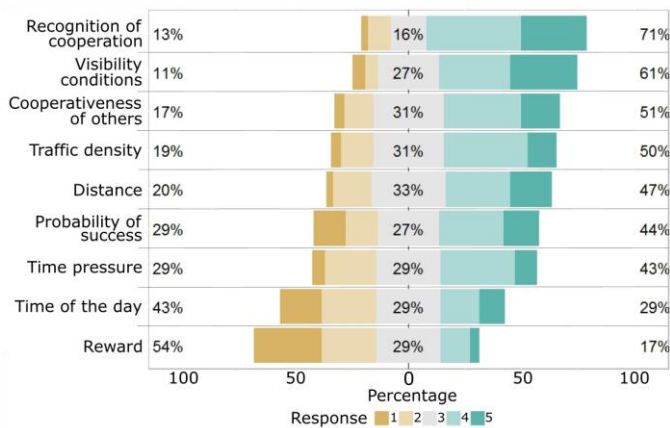

Figure 1 Influence factors on willingness to cooperate (n=70). *Scale ranging from 1 = "no influence" to 5 = "very high influence.*

Besides the predefined factors, the participants indicated further factors that influence their willingness to cooperate: weather, own emotional state or drowsiness, sex or vehicle type of the possible cooperation partner and security.

3) Behavior relevant in cooperative situations: The participants mentioned "yielding" ($M = 4.28$ $SD = 0.759$) and "signal" ($M = 4.50$ $SD = 0.872$) as the most relevant behavior factors (scale ranging from 1 = "irrelevant" to 5 = "very relevant"). "Maintaining speed" ($M = 3.35$ $SD = 1.302$), "coasting" ($M = 3.63$ $SD = 1.054$), "flasher" ($M = 3.35$ $SD = 1.278$), "accelerate" ($M = 3.61$ $SD = 1.926$) or "wave" ($M = 3.64$ $SD = 1.202$) are less relevant in relation to the other factors (Friedmann Test: $\chi^2(10)=85.597$, p<.001, n=70). Descriptive statistics are shown in Figure 2.

The analysis of car and truck drivers showed that truck drivers deem eye contact more relevant than car drivers (Mann-Whitney-U = 392.000, p = .011, effect size according to Cohen $r = 0.30$, medium effect).

Drivers with a high desire for control indicated that the behavior factor "yield" is more relevant (Kruskal-Wallis Test: $\chi^2(2)=8.164$, p=.017; n=71; effect size according Cohen $r=0.34$, medium effect), compared to drivers with a low desire for control.

4) Usefulness of cooperative driver asssistance system: More than 50% of the participants could imagine using a cooperative driver assistance system for passing on country roads ($M = 3.49$ $SD = 1.184$) and passing trucks on freeways ($M = 3.43$ $SD = 1.11$) (scale ranging from 1 = "not useful" to 5 = "very useful"). However, only 29% expressed that a cooperative assistant in the "turn left at intersections" scenario is useful ($M = 2.86$ $SD = 1.240$) (Friedmann Test: $\chi^2(3)=21.449$, p<.001, n=68).
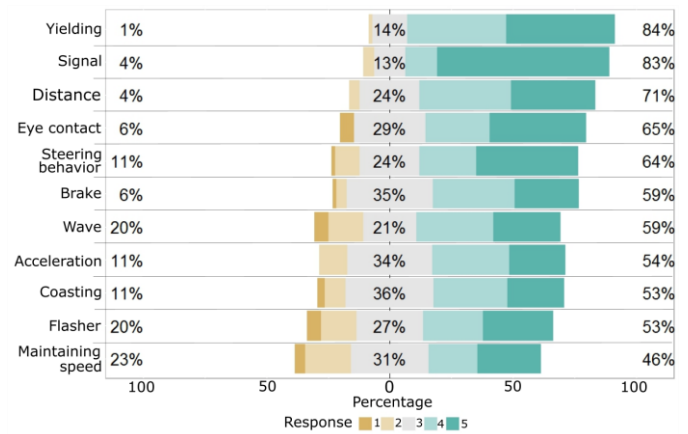

Figure 2 Behavior relevant in cooperative situations (n=70). *Scale ranging from 1 = "irrelevant" to 5 = "very relevant".*

Compared to truck drivers, the car drivers perceived a cooperative assistant for passing on country roads as very useful (Mann-Whitney-U=711.500, p=.026, effect size according Cohen $r=0.27$, small effect). Additionally, they saw a cooperative assistant for merging onto freeways as more useful (Mann-Whitney-U=686.500, p=.057 <.07, effect size according Cohen $r= 0.22$, small effect).

Furthermore, the participants named additional possible traffic scenarios for a cooperative driver asssistance system such as forming an emergency lane, narrow lanes and right turns in cities.

5) Behavior that should be performed by cooperative driver assistance systems: The participants indicated that they want at least assistance for "waving" ($M = 1.68$ $SD = 1.182$) or "controlling the flasher" ($M = 1.97$ $SD = 1.014$) (Friedmann Test: $\chi^2(9)=191.045$, p<.001, n=69) (scale ranging from 1 = "not useful" to 5 = "very useful"). Figure 3 shows the descriptive statistic of the items.
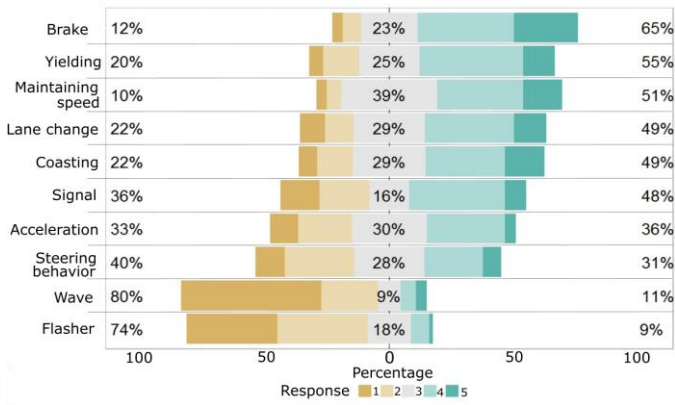
Figure 3 Behavior that should be performed by cooperative driver assistant system (n=69) *Scale ranging from 1 = "not useful" to 5 = "very useful".*

The analysis of possible differences between drivers with high and low desire for control showed (see Figure 4) that drivers with high desire were more likely to demand help during "coasting" (Kruskal-Wallis-Test: $\chi^2(2)$=8.317, p=.016, n=69 Post-Hoc-Tests (Dunn-Bonferroni): z=-2.869, p=.012, effect size according Cohen r=0.35, medium effect). A similar statement is true for assistance during "yielding" for other drivers (Kruskal-Wallis-Test: $\chi^2(2)$=7.983, p=.018, n=69, Post-Hoc-Tests (Dunn-Bonferroni): z=-2.784, p=.016, effect size according Cohen r=0.34, medium effect). Figure 4 shows the difference between the three driver groups.
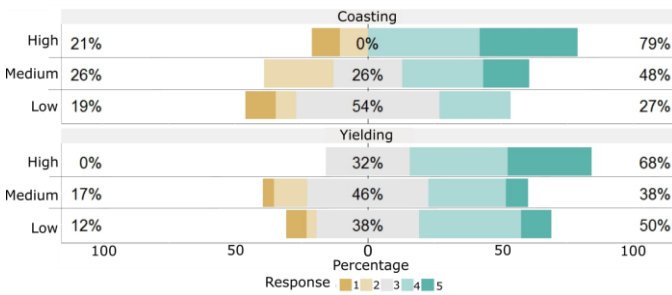

Figure 4 Behavior that should performed (IE-4; low (1): n=1, medium (2): n=24, high (3): n=19 *Scale ranging from 1 = "not useful" to 5 = "very useful"*

6) Information that should be provided by cooperative driver assistance system: Only 8% of the drivers would prefer to have no information from a cooperative driver assistance system at all ($M = 1.72$ $SD = 1.031$) (Friedmann Test: $\chi^2(11)$=150.808, p<.001, n=43) (scale ranging from 1 = "not important" to 5 = "very important"). 78% would like to receive information about the "traffic situation" ($M = 4.03$ $SD = 0.930$). Information on the "distance" is required by more than 70% of the drivers ($M = 3.90$ $SD = 0.831$). The detailed descriptive statistic is shown in Figure 5.

V. DISCUSSION

For this study, we chose a two-step study design, involving a structured guideline interview and an online questionnaire. The interview was based on Rothensee's UbiTAM [11], which delivered a solid foundation for generation of questions. The two-stage process with identification of acceptance factors in the preliminary study and rating of acceptance factors in the main study has proven sensible.

We analyzed differences between rating of possible acceptance factors regarding the two personal factors *desire for control* and *control beliefs about technology*. We identified these two factors with the IE-4 scale [16] and the KUT questionnaire [17]. The differences in the KUT results show less effect size than the results of the IE-4. It must be considered whether the KUT questionnaire is suitable for querying the control beliefs about technology in the context of cooperative driver assistance systems, since the KUT was originally developed for general technical devices. Therefore, the suitability for measuring the impact of control beliefs about technology on the acceptance of cooperative driver assistance with the KUT questionnaire should evaluated.

The rating of stress factors points out that car and truck drivers have a different perception of the traffic scenarios presented. Furthermore, truck drivers value different cooperative behavior than car drivers. Due to these differences, we suggest a separate consideration of these two user groups during development of human-machine interfaces for cooperative driver assistance systems.
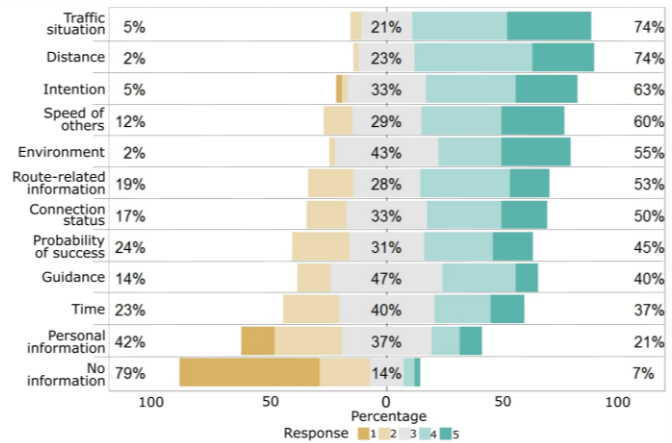

Figure 5 Information that should be provided by cooperative driver assistance system (n=43) *Scale ranging from 1 = "not important" to 5 = "very important".*

Apart from a generally different perception of traffic situations by car vs. truck drivers, we could not specifically confirm a higher stress level in car drivers when a truck is involved [7]. The stress factor "truck" was rated similarly by both driver groups. But all drivers rated three of the four traffic scenarios with high stress factors. Some stress factors during "merging on freeways", "passing on country roads" and "turning left at intersections" were rated by over 60% of the drivers as "stressful" and even "very stressful". A cooperative assistant could reduce some of these stress factors, e.g. distance and behavior recognition.

The majority of participants stated that recognition of possible cooperation influences their cooperativeness most. An assistance system indicating possible cooperative situations should already improve cooperativeness. Besides the identified

factors, in the preliminary study, drivers additionally indicated state of mind, mood and the properties of the cooperation partner (e.g. sex, vehicle type, etc.) as influencing factors of the willingness to cooperate in the main study. It would be desirable to examine the influence of these factors on implementation of a cooperative assistance system in further studies.

Signal and motion behavior are the highest rated indications of possible cooperation. They should be prioritized within the design of cooperation processes. Consciously used communication mechanisms such as flashing the headlights and waving are neither used frequently nor desired to be performed automatically by the system. Therefore, they seem inappropriate for the design of a cooperation assistant, although we assume that drivers would like other road users to use these mechanisms for communication more often. With the presented traffic scenarios in mind, the participants did not consider maintaining their speed as a behavior that is relevant in cooperative situations. However, they would like a cooperative system to perform this task. A bias deriving from known driver assistance systems, such as adaptive cruise control or limiter, could explain these results.

Since cooperative assistance systems are still in research and development, the participants have no experience with such a system. We started from the premise that the participants are able to project their thoughts in the traffic situations presented. Although we cannot ensure that all test subjects had the exact same situations in mind, the participants agreed in seeing the benefit of a cooperative assistant and the support it provides. Since the second part of the study consisted of an online study, a self-selection bias tends to be associated with the results [18]. Through the chosen methods, we were not able to assess implicit information, such as feelings or emotions [19].

VI. Conlusion

The main goal of this study was to identify and rate factors, influencing the acceptance and cooperativeness of car and truck drivers. Therefore, we conducted a two-stage study comprising a structured guideline interview to assess the acceptance factors and an online study to rate these. The results give a detailed impression of how car and truck drivers see the cooperation scenarios presented, what influences their willingness to cooperate, which behavior is relevant in a cooperation, which behavior should be supported and which information should be given by a cooperative driving assistant. These results will be used for our future development of cooperative human-machine interfaces.

Acknowledgment

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