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Context-Dependent Information Elements in the Car: Explorative Analysis of Static and Dynamic Head-Up-Displays

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ABSTRACT

Head-up-displays (HUDs) illustrate a particular static number of information elements in the driver's primary field of view. Since the display can obscure the reality, a dynamic HUD presents context-dependent information elements. To become familiar with a user-optimal number of information elements and its essential information elements, we conducted a user study with $n = 183$ participants. We focused the context on an urban, a rural and a highway trip. Afterwards, a within-subject experiment using a high-fidelity driving simulator ($n = 27$) reveals the following: Dynamic HUDs significantly lower the average over speeding by 3.45 km/h compared to static HUDs. This speed above the speed limit equals 15.33% of the average speed in urban areas. Steering angle and speed can capture the context. Practitioners can use these findings to decrease the number of information elements in HUDs, thereby possibly increasing traffic safety.

Keywords

Information elements, context-dependent, head-up-displays.

INTRODUCTION

Nowadays, car manufacturers install head-up-displays (HUDs) in several mid-class and high-end cars. HUDs allow information elements to be displayed on the windshield and thus in the driver's primary field of view (Häuslschmid, Pfleging and Alt, 2016a). In many studies, the driver's attention to road traffic increases with shorter accommodation and adaptation times (Gengenbach, 1997; Gish and Staplin, 1995; Häuslschmid et al., 2016a; Mutschler, 1995). Research and technology are trying to extend the display to the entire windshield (Häuslschmid et al., 2016a). Since the driver's higher priority is to pay visual attention to the tasks of navigation, trajectory control and anticipation (Gengenbach, 1997), it is not possible to display just any number of information elements at the same time on the windshield. Research on HUDs demonstrates that the driver is distracted by unnecessary information (visual clutter) or the display of obscure parts of the reality (Gish et al., 1995). Instead of the static HUD, a dynamic HUD displays an element featuring less or an equal amount of information. However, displaying too many information elements in the driver's view can be critical. Since the display can obscure reality, the number of information elements is crucial. To understand a user-optimal number of information elements and essential information elements, we conducted a user study and implemented the first dynamic HUD. This paper deals with the question of context-dependent prioritization of the displayed information elements via a dynamic HUD in order to illustrate only the currently essential aspects, instead of presenting all information elements with a static HUD. In this paper, we focus on the driving situation in terms of the context of different types of trip classes. In literature, the types of trip classes are urban, rural and highway (André, 2004). Each trip class stands for a particular context that we are focusing on.

RELATED WORK

Current vehicle HUDs use the display to inform the driver. The top-5-rated information elements by Schneid (2009) are the tachometer (90%), navigation instructions (97%), driver-assistance systems such as recognized traffic signs (speed limits, 78%), night vision (73%) and warnings (68%), e.g., lane departure (Pfannmüller, 2017). However, there is no specific ranking for the trip classes on which we are focusing.

To display the speed via the HUD leads to positive effects on one's attention to traffic, especially on long, somewhat straight stretches at high speed (highway, main road), since long distances allow little distance not to look at the road (Mutschler, 1995). Bubb, Bengler, Breuninger, Gold and Helmbrecht (2015) recommend an analog pointer model for displaying the speed. HUDs currently used in vehicles use digital speed displays, but ergonomic research results do not cover this and are often necessary because of lack of space.

The trip classes possess particular speed characteristics in Europe. A characteristic urban trip averages a speed of 22.5 km/h, with high traffic density and a high stop rate. A rural trip averages 47.5 km/h, with low traffic density and an average stop rate. A highway trip has an average speed of 92.8 km/h, with low stop duration and medium traffic density (André, 2004).

Research findings state a preference for a contact-analog display for navigation instructions (Bubb et al., 2015; Israel, 2012; Pfannmüller, 2017; Schneid, 2009). To implement such a display, Bark, Tran, Fujimura and Ng-Thow-Hing (2014) suggest integrating a small paper airplane graphic element that the driver can follow. Alternative approaches stem from the area of augmented reality. Schneid (2009) and Bolton, Burnett and Large (2015) examine an arrow projected onto the street. Wiesner, Ruf, Sirim and Klinker (2016) explore an illustration of the course of the road ahead in the HUD.

Many manufacturers are already offering the speed limit information element through traffic sign recognition and map material (Schneid, 2009). The sign is an integral part of the HUD and is permanently presented.

On static HUDs, several HUDs of car manufacturers present too many details, such as the name of the current road, current gear position, temperature, revolutions per minute or next service (Schneid, 2009). Additional applied elements—mostly in specific cars such as sports cars—are current lateral acceleration, audio information, oil temperature, tank contents, fuel economy, and coolant level (Schneid, 2009).

The studies also look at other HUDs that require a windshield projection. Applications include distance-to-the-vehicle-in-front displays and visualization of adaptive cruise control systems (Charissis, 2014; Langlois, That and Mermillod, 2016; Park, Yoon, Lee and Kim, 2015). Moreover, there are studies on contact-analog warning symbols in HUDs (Häuslschmid, Schnurr, Wagner and Butz, 2015; Tonnis and Klinker, 2006; Tonnis, Sandor, Klinker, Lange and Bubb, 2005). Three-dimensional arrow symbols help to avoid imminent danger by alerting one to a potentially hazardous situation. Another subject of the investigation is selection dialogs that the driver can operate while driving. Weinberg, Harsham and Medenica (2011) present a well-accepted option for this.

Häuslschmid et al. (2016a) create a categorization concept that clusters information elements in the same area of the windshield. This idea has been further developed into a presentation concept to facilitate driver orientation (Häuslschmid, Shou, O'Donovan, Burnett and Butz, 2016b).

Mutschler (1995) concludes from experiments by Okabayashi, Sakata, Fukano, Daidoji, Hashimoto and Ishikawa (1989) and Lino, Otsuka and Suzuki (1988) that a speed indicator leads to positive effects on the eye-sighting time on the road only at high speed. Cheng, Doshi and Trivedi (2007) and Mutschler (1995) formulate approaches for a contextual display. In the past, warnings were used when the permissible speed was exceeded. Kim, Wu, Gabbard and Polys (2013) showed an improved response time when using a HUD when warning of possible collisions during lane changes.

The interplay of these information elements and the situational adaptation of information content and quantity are open questions.

METHODOLOGY

We conducted design science to develop a head-up-display for a high-fidelity driving simulator (Hevner, 2007). As a basis for part relevance, we reviewed the literature according to Webster and Watson (2002) and Fettke (2006). We searched the databases *IEEE Xplore*, *ACM Digital Library* and the *OPAC* catalog of the university library. The search string was: *Head up display* AND *automotive*. Out of the 92 hits (42 IEEE Xplore, 27 ACM Digital Library, 23 OPAC), 32 papers were classified as relevant because of page limitation; the Related Work section investigated the essential ones. We selected a paper as relevant by ranking the number of keywords in the title and abstract. Exclusion reasons were the weak quality of work such as missing method, work on head-mounted displays and problems in three-dimensional space. For the part rigor, we implemented a user study as groundwork to strengthen the artifact. To evaluate the object, we conducted a driving simulator experiment and applied the AttrakDiff2 to compare artifact usability and design by measuring the hedonic and pragmatic quality (Hassenzahl, Burmester and Koller, 2003). The studies themselves describe further details regarding the methodology.

EXPLORATIVE STUDY

We implemented a user study to exploratively examine the user-optimal number of information elements for the three types of trip classes. For each trip class, we asked for the essential information element and ranked them.

The user study uses a questionnaire (Bühner, 2012) to collect the drivers' wishes for displayed information elements in the HUD. The target group is anyone in possession of a valid driver's license.

Study Design and Setup

The questionnaire consisted of four parts: one demographic data and each trip class (three). After a brief description of the situation regarding HUDs, we requested demographic data (age, gender, driver's license and driving experience) of the participants. This was followed by the questionnaires on the highway, rural and urban trip classes. Each level contains the same three questions about the desired number of information elements, an evaluation of various information elements, and the inclusion of our own evaluated proposals. The evaluation questions use a unipolar five-point Likert scale from "Not important at all" to "Very important" (Menold and Bogner, 2014; Greving, 2009). We then ranked information elements proposed by the participants.

Population and Procedure

From 20 October to 13 November 2017, we conducted an online survey via LimeSurvey. Participants in particular were visitors to the day of the Open Door and students of the Technical University of Munich. In addition, we advertised the survey on the SurveyCircle platform (SurveyCircle, 2017).

Of 210 participants, 183 completed the questionnaire. We dropped six participants who did not have a driver's license since they were not relevant to this study. The population resulted in 74 females and 103 males, ranging in age from 18 to 74 (M = 32.48, SD = 11.54) with an average driving experience of 14.38 (SD = 10.96) years, each driving an average of 9,733 (SD = 10,819) km/year.

We excluded outliers with an anomaly index greater than three in order to evaluate the number of information elements (three cases).

Items must be ordered according to their level of recommendation to get a sorted set. Jannach, Zanker, Felfernig and Friedrich (2010) use a multi-attribute utility theory. This method first calculates for each element *p* its *contribution* using one of the previously described ways, depending on the viewing dimension. Looking at the elements in multiple *dimensions* requires a *utility*-specific weighting across all dimensions as calculated by multiplication and summation across all dimensions, as described in the following formula from Jannach et al. (2010).

$$utility(p) = \sum_{j=1}^{\#(dimensions)} interest(j) * contribution(p, j)$$

The weighting factors can be set individually for each information element. The result of the calculation allows a weighted comparison of items in multiple dimensions. By assigning the recommendation factor to the individual elements, sorting can then be used to establish a sequence of recommendations for further selection.

We coded the given free-text answers, ranked them by their frequency and weighted them with the mean of the importance of each participant.

Results

For the **number of information elements,** Friedman's two-factorial analysis of variance by rank among connected samples depicts a significant difference among the three types of trip classes at a significance level $\alpha = 5\%$. At 2.86 (SD = 1.17), the urban trip class indicated the lowest number of information elements. The data have a skewness of .43 (SE = .184) and kurtosis of .02 (SE = .366). The result of the rural trip class has the lowest number of information elements, 2.48 (SD = 1.02). The data have a skewness of .59 (SE = .184) and kurtosis of .62 (SE = .366). At 3.04 (SD = 1.07), the highway trip class has the highest mean. The data have a skewness of 1.17 (SE = .184) and kurtosis of 3.43 (SE = .366). The skewness and kurtosis indicate a not normally distributed data set. The Friedman's test is non-parametric, and hence is not necessary.

We determine no significant correlation (Kendall-τ-b and Spearman-ρ) between driving experience, age, or gender and the number of information elements.

Subsequent post hoc tests (Dunn-Bonferroni tests) show that rural and urban ($z = 5.441$, $p = .000$, $r = .41$) as well as rural and highway ($z = -3.324$, $p = .003$, $r = .23$) differ significantly with a large and an intermediate effect (Cohen, 1992). The effect size results in a weak effect for the comparison of highway and urban as well as a medium impact for the comparison of highway and rural. The difference between highway and urban is not significant ($z = 2.117$, $p = .103$, $r = .16$).

The **type of information elements** for the three trip classes are ranked by the participants as follows: *urban*: (1) speed, (2) navigation, (3) speed limit, and (4) warning symbols; *rural*: (1) speed, (2) navigation, (3) speed limit, and (4) warning symbols; and *highway*: (1) speed, (2) speed limit, (3) navigation, and (4) warning symbols.

Since an evaluation by all respondents is missing in comparison to the other elements, we have not taken participant suggestions into account. Therefore, we cannot calculate from the available data the comparable mean of their relevance.

The most frequent request in the highway trip class is for a distance warning to the vehicle ahead ($n = 27$, $M = 4.19$, $SD = .88$). The participants grade it as very important. Traffic information is proposed almost as frequently in this situation, which is almost equal in importance ($n = 24$, $M = 4.17$, $SD = .89$). Hints and warnings of the lane change assistant were requested more often ($n = 13$, $M = 4.15$, $SD = .99$).

For the rural trip class, the participants additionally name the obstacle and danger warnings ($n = 12$, $M = 4.67$, $SD = .49$) and an indication of the route ahead ($n = 12$, $M = 4.08$, $SD = 1.0$) as an information element.

For the urban trip class, the focus is on traffic information ($n = 12$, $M = 4.25$, $SD = .62$).

ARTIFACT

For the artifact, we implemented three essential information elements from the user study: speed, speed limit and navigation. As an additional element from practice, we implemented an energy consumption feedback.

As a **speed information element,** we can apply a pixel-based speed display that combines several elements—e.g., an integrated marker showing the currently permitted maximum speed. Such integration of two displays not only saves space in the HUD but allows the relevant information to be recorded much faster. The driver can see at a glance whether the speed arrow is above or below the speed limit. In the case of two separate displays, on the other hand, he would have to read off and compare the values one after another.

However, if the cruise control system is active, the speed display is of considerably less importance and the display of an analog pointer model is no longer necessary since the speed changes only minimally. Therefore, only the specified speed together with an icon symbolize the cruise control system on the speedometer.

As a **navigation information element,** we implemented the classical turn-by-turn display navigation information as suggested by the user study and Schneid (2009). This element presents the driver with the next navigation step and the distance still to be driven.

The basis for this paper is the turn-by-turn displays that are currently used in cars featuring HUDs. Since the model does not contain a 3D component, no contact-analog display is therefore possible. The screen is consistent with the navigation system with arrow symbols for the next turn. For HUDs, Tangmanee and Teeravarunyou (2012) recommend folded arrows instead of orthogonal symbols. However, to ensure consistency, we used the orthogonal elements. In addition, a bar graphically shows the reduction of the route to the next navigation point by its filling and numerically using the distance in meters. Figure 1b) illustrates the navigation information element.

A **speed limit information element** is another relevant information for the driver (Own user study and Schneid, 2009). Schneid (2009) recommended a high similarity to real traffic signs for the presentation. Therefore, this paper uses an adapted symbol that partially inverts the color scheme, increasing the transparent areas of the HUD without loss of information. Figure 1c) presents the implemented speed limit information element.

As an **additional information element**, we implement an energy consumption feedback according to the Eco-Foot from Jamson, Hibberd and Merat (2015). The Eco-Foot presents an optimal (green), too low (blue), or too much (red) acceleration depending on the angle of the gas pedal. The user survey and the literature consistently depict that users do not want such information elements in the HUD. Nevertheless, we use this element as a symbol for an unnecessary element in practically applied HUDs nowadays (see Figure 1d).

We implemented two displays—a static and a dynamic HUD. The static HUD includes all four information elements at the same time (see Figure 1). On the other hand, a dynamic HUD consists of a navigation, speed and speed limit element. The speed limit element only appeared when the driven speed was higher than the allowed limit. Hence, we have two constant information elements (speed and navigation) and one dynamic (speed limit) for the trip classes. This rounding to an integer value fulfills the criteria from the user study.

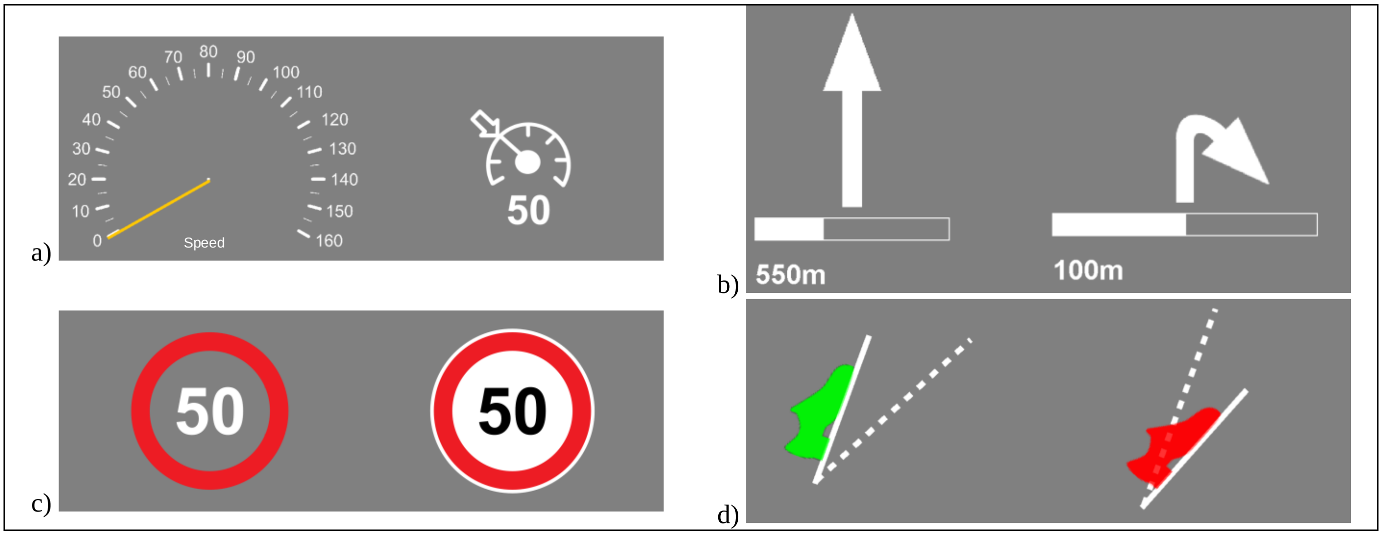

Figure 1. Implemented information elements for the HUDs: a) Speed and cruise control, b) Examples for turn-by-turn navigation, c) Speed limit and d) Energy consumption feedback

EVALUATION EXPERIMENT AND ATTRACTIVENESS

To measure the attractiveness of the static and dynamic HUD, we conducted the AttrakDiff2 questionnaire (Hassenzahl et al., 2003). For the statistical evaluation, we adduce a level of significance $\alpha = 5\%$.

Experiment Design and Setup

We conducted a within-subject design experiment in a high-fidelity driving simulator. The dependent variables were steering angle, current speed, speed limit, and duration of speeding. We recorded the trips of the subjects in order to compare the effect of the dynamic and static indicators on compliance with the maximum permissible speed. At the mean distance of 20.7 milliseconds, we gathered the time-stamp, current speed and speed limit. For analysis, the duration T of the speed violation per test person in seconds was calculated for each test person from the number of measuring points with speed violation and the average time difference of the measuring points in each case for both treatments. For each test person for each of the dynamic and static HUD, we determined the mean MG and the standard deviation SG of its speeding violation in km/h. For the independent variable, we used the static and dynamic HUD.

After each round of the experiment, the participants had to complete the AttrakDiff2 questionnaire with additional demographical data to identify differences among them such as gender or age. Also, we asked the participants about the number of information elements. They were again subdivided into highway, rural and urban classes. A five-point Likert scale ranges from “Much too few” (-2) to “Just right” (0) to “Much too many” (2). As an incentive for the participants, we offered free cookies and coffee.

Experiment Environment

The environment is a high-fidelity **driving simulator** that uses the OpenDS simulation software (Math, Mahr, Moniri and Müller, 2013). The simulator cockpit consists of a Mercedes dashboard with tachometer and revolution counter replaced by a Nexus 9 tablet. The car has an automatic transmission (Wager, McHenry, Whale and Bräunl, 2014). We use the original Mercedes steering wheel with ClubSport Wheel Base V2 Servo and ClubSport Pedals V3 from Fanatec. The software displays side and back mirrors. The projection system consists of three projectors with a resolution of each 1280 x 1024 pixels. The images are edge-blended to provide a total horizontal view of 120° with a 5.6 m radius on a cylindrical screen with 45° to each other in front of the driver. To provide a fluent illustration of the tachometer the data are updated every 20 milliseconds.

In this study, the **driving task** takes place on a mostly one-lane urban section with traffic lights and pedestrian crossing, 1-lane-rural section, and 2-lane-highway section. All trip classes had light traffic and proper environmental conditions.

Figure 2 illustrates a) the driving simulator, b) the driven route, c) the static HUD, and d) the dynamic HUD.

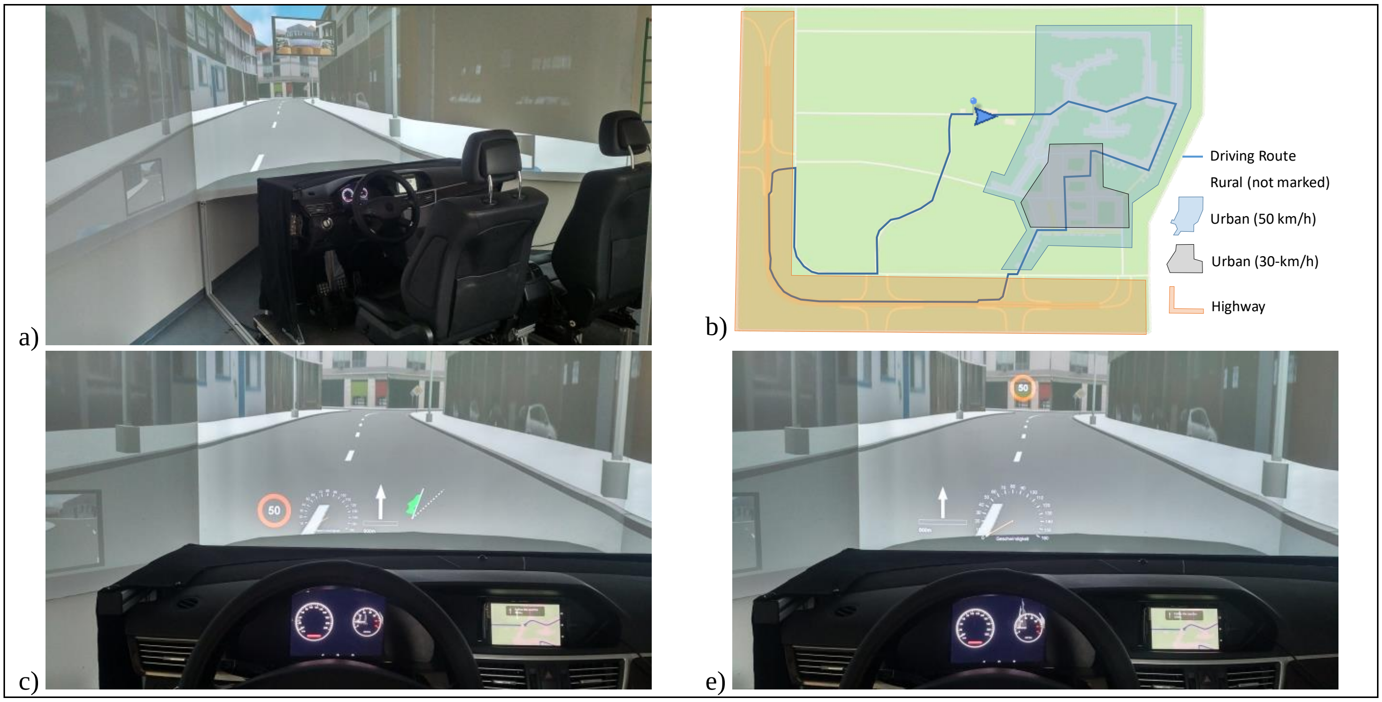

Figure 2. Driving scene: a) Driving simulator, b) Driving route, c) Static HUD, d) Dynamic HUD

Population and Procedure

Participants were primarily from the university to ensure a homogenous sample and represent a subset of that segment of the population that will most often come in contact with HUD. We conducted a pre-experiment to avoid biases (Van Teijlingen and Hundley, 2001). From 14 to 17 November 2017 for the experiment, we recruited through a direct approach on campus $n = 27$ participants (20 male and 7 female) aged from 19 to 33 ($M = 23.96$, $SD = 3.6$) with an average driving experience of 5,919.4 (SD = 6,699.9) km/year. We incentivized them with coffee and snacks.

Participants receive verbal and written explanation of the study before signed and gave consent. Then they filled out a demographic questionnaire. We instructed them to focus on safe driving, to follow the traffic rules and the HUD.

Afterward, we let them become familiar with the driving simulator. First, the participants drove one round with the static HUD. Second, they drove one round with the dynamic HUD. After the first and second rounds, the participants filled out two post-questionnaires on demographic data, AttrakDiff2, and one question for verifying the number of information elements from the user study.

Results

The **AttrakDiff2** results overall in the marginal difference between the static and dynamic HUD. Both are classified as practical (static = 2.22, dynamic = 2.33), clear (static = 5.44, dynamic = 5.30), manageable (static = 5.81, dynamic = 5.15), predictable (static = 2.19, dynamic = 2.37), direct (static = 5.56, dynamic = 5.59), simple (static = 2.04, dynamic = 2.30) and presentable (static = 5.52, dynamic = 5.56). The dynamic HUD has the following minor improvements: novelty (static = 4.30, dynamic = 3.52), originality (static = 4.67, dynamic = 3.52), innovation (static = 4, dynamic = 3.33), and courage (static = 4.22, dynamic = 3.81). At the same time, the participants perceived the dynamic HUD as slightly less manageable (static = 5.81, dynamic = 5.14) and more challenging (static = 2.96, dynamic = 3.59) compared to the static one.

The findings of the **experiment** result in significantly influence on the average time above speeding which several values documented.

Dynamic HUDs have a significantly lower average time above speeding compared to static HUDs ($t = 2.820$, $p = .009$). Drivers with a dynamic HUD pay more attention to the speed limit and the time in seconds above speeding is significantly lower (M_T = 51.68, SD_T = 24.16) than a static HUD (M_T = 60.16, SD_T = 18.44). The effect size is medium, r = .48 (Cohen, 1992).

There was significant improvement in terms of the amount of excess (t_{MG} = 5.29, p_{MG} = .000) when using the dynamic HUD (M_{MG} = 5.12, SD_{MG} = 2.54) toward a lower limit than allowed speed compared to the static HUD (M_{MG} = 8.57, SD_{MG} = 3.33). In contrast to the time of the speeding violation, the magnitude of the excess can be used to detect a substantial effect with an effect intensity according to Cohen (1992), r = .72. The standard deviation of the average speed violation decreases significantly (t_{SG} = 3.99, p_{SG} = .000) by a substantial effect (r = .62).

Figure 3 illustrates a 3.45 km/h lower average speed above the speed limit for the dynamic HUD than for the static HUD.

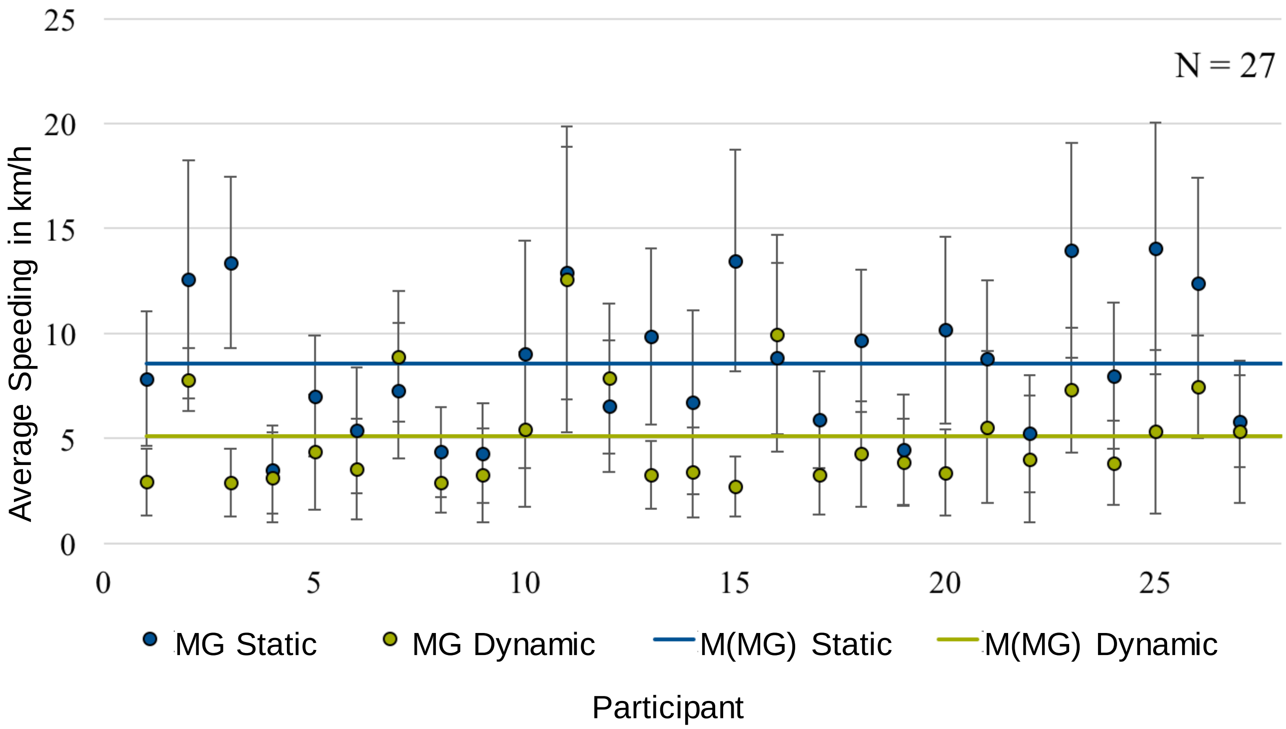

Figure 3. Evaluation of the Mean Speeding of Each Participant

The verification of the user study by asking the participants about the number of information elements reveals a slight deviation from "just right" (zero). The deviations are as follows: $highway_{dynamic}$ = -.222, $highway_{static}$ = .296, $rural_{dynamic}$ = -.037, $rural_{static}$ = .111, $urban_{dynamic}$ = .185, $urban_{static}$ = .407. In total, the dynamic HUD is closer to the mean of the scale compared to the static HUD. This result is not at the edge of the scale, but rather in the vicinity of the desired number.

DISCUSSION

In this paper, we identified a user-optimal number of elements for the different trip classes: two for the urban, two for the rural, and three for the highway. For the rural class, we used the phrase "curvy" rural road in the mind of the participants a complicated and technically challenging route, similar to what forest roads or mountain roads induce. Such a route requires increased driver attention to the route and to potential hazards, so glancing at the HUD only allows for a smaller number of recorded elements. Monotonous driving characterizes highway driving at constant speeds. The lower mental demands and the predictability of the upcoming route based on the previous route may allow additional information to be placed on the windshield. In urban driving, the lower speed as well as the recurring short breaks at traffic lights or similar play a role in information processing, so that it seems possible to pick up more elements than on the highway.

For the type of information element in all three trip classes, speed is the crucial variant for the user, whereas navigation is ranked two, and speed limit is ranked three on the rural and urban trip classes. Instead of the highway trip class, users prefer the speed limit as rank two and the navigation as rank three. The switch in the ranking of information element navigation explains that the user expects fewer frequent changes in the routing in highway driving. This result confirms the findings partly from Schneid (2009). Tachometer (speed), navigation instructions, and speed limit are also top-rated, but the order differs depending on the context. Further, navigation instructions are ranked higher by Schneid (2009) than in our study. The difference might be because we told the participants to follow the traffic rules, and this can let them assume speed is more important.

In this paper, we present a static and dynamic HUD. The results of the evaluation provide some inferences. The small difference in attractiveness evinces users to accept a dynamic HUD to a similar extent as a static HUD. The result indicates the need for further study on contextual displays.

The contribution to traffic safety represents the central realization of this paper. Just by changing the display, time as well as the amount of speeding could be reduced. The results thus extend the findings of Cheng et al. (2007). In particular, in the urban section of road that was driven at 30 km/h, the indication of the speed transition leads to a reduction of the speed. The high significance and effect size of this effect, while maintaining their attractiveness, speak in favor of users' acceptance of the system. A reduction of excessive speed might lead to fewer accidents and support the need for improved driver assistance in maintaining the maximum permissible speed. The positive effect from Mutschler (1995), Okabayashi et al. (1989), and Lino et al. (1988) caused by the speed limit sign might be the same, but we also showed two additional elements. The speed limit is presented prominently in the cluster from (Häuslschmid et al., 2016b). This illustration might have an additional effect, which we did not measure.

The statements on the number of information elements support the results of the user study and substantiate that current HUDs display too much information at the same time. It is possible to dispense with a permanent display of the speed limit and an energy consumption feedback display in the HUD. The reduction to two or three elements seems to be closest to the user request. Further elements should only be displayed as required, instead of showing several information elements (Charissis, 2014; Langlois et al., 2016; Park et al., 2015; Schneid, 2009).

Using the dynamic HUD, participants tended to be more likely to experience driving errors compared to the static indicator on the first unexpected display of the speed alert. However, the prominent presentation was not known by the participants and that the errors are therefore likely to be attributed to the surprise effect. In the course of the route, no further difficulties appeared.

LIMITATIONS

The population is very young. Seniors people may experience different outcomes because of habituation effects. Moreover, there is no gender balance. Due to this restriction, we cannot make valid subgroup evaluation. The simulator implementation has only a small number of information elements and recommendations. The interpretation of the recommendations, the design of the display elements and other parameters come from personal assessments and are therefore not thoroughly evaluated. However, they are based on the results of the literature search and during numerous tests developed. The surroundings of the driving simulator itself, e.g., it is impossible to have a physical windshield. Lack of depth perception of the HUD and the simulator reinforced this effect. In consequence of the resolution, the analog speed display cannot be displayed much smaller without causing pixelation effects. The tested display is not sufficiently dynamic in the sense of the presented model. A full-dynamic display requires further elements and recommendations.

The number of participants is small. The population has less older adults. All participants completed the experiment with the same sequence of displays (static first, then dynamic). Therefore, there might be learning effects in the habituation to the simulator and the HUD. The rides took place in a simulated environment with sunny weather, excellent visibility, and low traffic. Although the chosen route covered the desired driving modes according to André (2004), the entire lap only took about five minutes. Consequently, the driven sections are short and the ride is varied.

CONCLUSION AND FUTURE WORK

In this study, we analyzed given information in different contexts to reduce the number of presented information elements on HUDs. Therefore, we enriches the information with a relevance score at all times. This score uses factors like current speed, steering activity or limit exceedance for calculation. As a result, the display adapts context-dependent to the current driving situation. Therefore, based on existing insights into HUDs, and a conducted user study, we developed a dynamic HUD. The user study revealed that a maximum of two or three elements could be picked up by drivers with a brief look at the HUD. A final evaluation with a driving simulator experiment shows that a reduced display with two fixed information elements and the additional information of energy consumption feedback is equally attractive, oriented closer to the user's wishes compared to classical HUDs and thereby contributes to road safety by significantly reducing the speeding.

We suggest implementing more information elements and combining this with knowledge-based recommender systems in order to reduce the number of information elements to a total of three. This study already points out how to get a sorted set of the most recommended information elements. Further studies could extend this research by measuring driver distraction.

In summary, the dynamic display is more suitable in several areas than a static HUD, and research should examine this more closely.

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