First Steps towards a View Management Concept for Large-sized Head-up Displays with Continuous Depth

Renate Haeuslschmid
University of Munich (LMU)
Munich, Germany
renate.haeuslschmid@ifi.lmu.de

Yixin Shou
IAV GmbH
Munich, Germany
yixin.shou@gmail.com

John O'Donovan
University of California, Santa Barbara
Santa Barbara, CA, USA
jod@cs.ucsb.edu

Gary Burnett
University of Nottingham
Notthingham, UK
gary.burnett@nottingham.ac.uk

Andreas Butz
University of Munich (LMU)
Munich, Germany
butz@ifi.lmu.de

ABSTRACT

Windshield displays (WSDs) are the big siblings of Head-up displays (HUDs). They are assumed to cover the entire windshield and to allow displaying content at continuous depth, eventually. This creates a large and unstructured 3D space for information display – raising the question what to display where. To address this question, we developed a view management concept for WSDs in left hand drive cars which proposes zones and areas for specific information. As driving is a safety-critical task, we designed the initial concept with the driver's perceptual abilities in mind. Subsequently, we gathered insights into the driver's needs and desires from a formative study. We asked participants where they would place different types of information after inspiring their imagination by a 3D driving scene and WSD information on a Google Cardboard. The improved concept respects both the drivers' needs and desires and their perceptual abilities and can serve as a basis for view management concepts of future WSD.

Author Keywords

Head-up display; windshield display; in-vehicle display; augmented reality; view management

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation (e.g. HCI): User Interfaces

INTRODUCTION

Head-up and windshield displays present information within the driver's field of view (FoV) and closer to the driving scene [30]. HUDs have been proven to be distracting and to affect the primary task [16], yet, they improve information access and reading speeds compared to classic head-down displays (HDD), such as the instrument cluster or the central information display [40]. The increasing amount of information available in the car and the increasing number of smartphone-related accidents – caused by the desire to be online and connected at all times [18] – highlight the need for further research and development on these displays.

Figure 1. Full windshield display presenting world-fixed information

While the virtual image of a standard HUD floats above the car's hood approximately 2 m in front of the driver, WSD can potentially show a 3D augmented reality (AR) view, such as the example view in Figure 1. In AR, information that refers to the environment can be placed close to its referent (world-stabilized) and integrated naturally into the real world. AR concepts were already introduced to in-car displays on HDDs [10]. They are expected to feel naturalistic and to be understood fast, but require an extension of the small HUD image [10, 14, 15]. In other domains, an enlargement of display size and the associated FoV has been shown to be beneficial for cognition and user performance. Further, it was shown that a large display with increased viewing distance improves performance compared to its smaller and closer version, with both covering the same FoV. Yet, when enlarging display size the user interface can not be simply scaled up [39]. The large size and the display at different depths also create new opportunities for unregistered information display [26], as discussed by Gabbard et al. [10]. This, however, raises important design questions: Where and how far away should we display information such as fuel consumption, incoming E-Mail or calls, or historical information about the city we are driving through?

A good view management concept provides rules for the placement of information and ensures an appropriate arrangement that avoids clutter and overlap which could distract the

Automotive'UI 16, October 24-26, 2016, Ann Arbor, MI, USA

DOI: http://dx.doi.org/10.1145/3003715.3005418

driver and impact driving performance [1]. Developing such a concept, however, requires a careful balance between safety-critical constraints and subjective information from human-centered evaluations. In this paper, we present a concept that considers the drivers' tasks, context, resources, and abilities, but also their desires, to develop a generalizable view management that supports efficient information recognition and comprehension. Our concept is adapted to left hand drive cars and proposes zones and areas for specific information types, ranging from pre-attentive and safety-critical messages, to attentive, less critical information such as personal email. We describe results of a formative study that compares participants' desired positioning of information with that of our view management concept.

THE DRIVER'S TASKS AND VISUAL PERCEPTION

Driving occupies up to 90% of the visual channel [7] depending on the driving situation. Also reading digital information loads the visual channel and thereby competes for resources with the driving task. HUDs can be expected to cause all types of distraction [10] – visual, cognitive and manual distraction – and an overload of these channels. More specific types of distraction associated with HUDs are cognitive capture [35], attentional tunneling [36], and inattentional and change blindness [16]; leading to a concentration on the HUD and the unintended ignorance of the real world situation behind it.

However, a WSD can also support the driving task by presenting supportive content related to the driver's primary or secondary tasks. Secondary tasks are mandatory and associated with the primary task, such as the control of the indicator and the windshield wipers [10]. Standard HUDs present mostly primary-task or secondary-task related information. Nowadays, the presentation of tertiary-task related content, e.g., entertainment and personal information, becomes more prominent and asks for a new costs-benefits-calculation: Users always want to be online and connected [18] and the increasing numbers of smartphone-related accidents underlines the need to consider this type of information display.

The Driver's Field(s) of View

Although many proposed applications use large parts of, or the entire windshield, the driver's FoV and the associated perceptional abilities have often been neglected in these designs. Perception deteriorates considerably from the center (0°) to the boundaries of the FoV. We distinguish four subfields: the central (< 2 °), the foveal (<10°), the peripheral (>10°) and the useful or functional field of view [14]. The functional FoV varies depending on anxiety, the visual resolution, and the task and processing demand [8]: a medium task workload reduces the FoV to 92% and a high mental workload to 86% [29]. This suggests to display less information in a highly demanding situation and to place important information rather centrally.

The major part of the windshield is covered by peripheral vision. Humans rely on peripheral vision for safe driving (e.g., detection of hazards, feeling of speed) [6]. But what exactly does peripheral vision mean for view management? There are mixed opinions about the display of information in the periphery, suggesting to place information at high eccentricities with care [15, 18]. Symbols placed far off the driver's normal line of sight can be recognized without a direct look but are perceived in less detail [19]. Reports about reaction or response times on peripheral stimuli vary considerably from no or slight increases to completely missed information [15, 22]; the latter increasing together with eccentricity. To counter these problems, information design has to be adjusted.

Information Recognition and Placement

A lot of research has been done to identify the best location for HUDs. Gish et al. performed an extensive literature review on this topic [11]. The best HUD location is determined by the detection and response times to appearing stimuli or by measuring the secondary task performance while showing constant primary task performance (often assumed, not measured).

Tsimhoni et al. [34] displayed names at 15 HUD positions; distributed around the driver's line of sight in an area of 10° horizontally and 5° vertically. The best secondary task performance was measured at the central position (0°) and at 5° to each side; while primary task performance varied only slightly (up to 10%). Subjects claimed to prefer the position at 5° to the right. In a similar study by Tsimhoni [33], participants had to perform a detection and a reading task; names were displayed at 8 HUD positions. While detection time was not significantly influenced by the position, response time increased with the horizontal eccentricity. Only a central placement (0°) leaded to a deterioration of the primary task performance; due to occlusion. The preferred position at 5° to the right of the center is confirmed in this study as well as in a similar study using triangles [38]. Also Isomura et al. [21] tested a divided attention task and reported a degradation in secondary task performance when the task was positioned more than 30° off the central task. Lino et al. [24] compared the performance when a HUD was placed at 0°, 10° and 20° and found that secondary task performance was impeded only at the highest angle and when the primary task became more demanding.

Lamble et al. [23] used the time to collision as a measure of the impact of various secondary task positions on the driver's ability to trace the headway to a leading car. They compared several commonly tracked in-vehicle positions (such as rear view and side mirrors) and found that detection thresholds were higher in vertical than in horizontal locations at the same eccentricity, suggesting an elliptical FoV. Further, it was confirmed that the lower part of the visual field has a higher resolution than the upper one; which results in lower reaction times at equal eccentricities. Surprisingly, they found that, the common HUD area (4°) leads to worse detection thresholds than the area above the center stack (17°). Hence, the authors recommended the surrounding area (15-20°) as the best location for a secondary task.

Detection and response times as well as primary and secondary task performance are of high relevance for our concept. It has to be ensured that important information such as urgent warnings are superimposed at a location which facilitates a fast response. In contrast, high response times on ambient information are acceptable. In general, response times can increase with the task-level to which a piece of information is

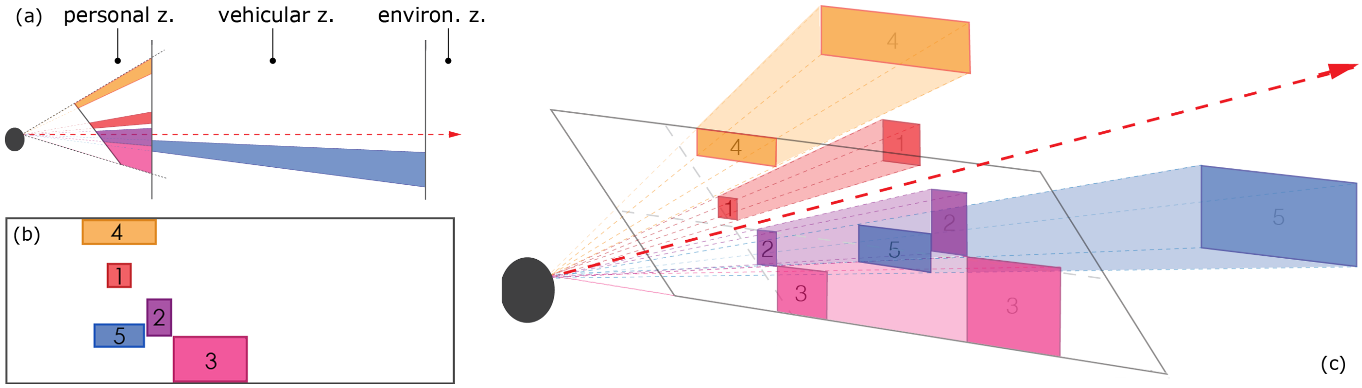

Figure 2. The 3D spaces for unregistered placements are visualized in (a) side view, (b) driver's view, and (c) as a 3D space. The following areas are depicted: (1) notification area, (2) reading area (in close distance only), (3) personal area, (4) ambient area, (5) and vehicular area. All areas and zones for registered information – registered warnings, depth-registered text, and the environmental area – are excluded from this graphic.

related. Yet, especially when frequent glances at the display are expected, e.g., when reading text, a display location has to be chosen which ensures that primary and secondary task performance are not impeded.

Depth Perception & Registration in Depth

One major advantage of HUDs is the distant presentation of their image at approximately 2 m (1.3 m behind the windshield); this corresponds to the driver's resting focus at 2 to 3 m and has been found to support the extraction of information from the display [10]. Further, the lowered distance between the drivers' focus point (e.g., on a leading car) and the HUD image decreases the driver's response time and the physical strain of the eye accommodation. To extend these benefits HUD and AR researchers recommend to place information in spatial relation to its referent [26, 30]. In the AR and VR community this placement strategy is often called registered, world-fixed or object-space. The automotive community refers to it by the terms contact-analog and registered placement.

A registered presentation makes use of the gestalt laws of connectedness, proximity and common fate [12] and is expected to reduce the driver's cognitive and visual workload and reaction time. Further, recognition is enhanced as spatial transformations between the display and the outside scene are unnecessary [26]. Studies found contradictory results when comparing task performance of unregistered and registered placements: while Tönnis et al. [5] reported that registered placement outperforms other frames of reference (e.g., bird's eye view) regarding reaction times and understanding, Häuslschmid et al. [15] have not found differences on the reaction time between screen-fixed and world-fixed warnings on hazards. Instead, a considerably improved monitoring of the road situation was found. Though, most of the research on AR HUDs was performed with a simple computer display (corresponding to one depth layer for the HUD and the road scene) or with one additional depth layer instead of a display that provides a real depth-registered presentation. It remains unclear, how depth-registered information moving towards the driver (along with optic flow) is perceived by drivers.

Depth is crucial for safety as it is necessary for the determination of distances to surrounding objects – but generally underestimated in AR scenes [10]. When judging depth, humans rely on a large set of monocular and binocular cues, but most depth cues relevant for a registered placement are monocular. For an unimpaired perception and safety, depth cues of the real world and the augmentation have to be consistent [10]; e.g., information that overlays a traffic sign should be perceived at the same distance – neither before nor behind. Further, registration has to be accurate in position (compensating the driver's head movements, the car's vibration and the slope of the road), size and orientation to support a natural and realistic view and further enhance perception [1, 32].

Yet, all WSD and HUD concepts and prototypes we found, focus on one placement approach – screen-fixed or world-fixed. We did not find a concept which merges both presentation styles. The world-fixed approach is widely desired and appropriate for information related to the outside scene but inappropriate for information which has no obvious spatial relation. Gabbard et al. [10] also point at this problem and suggest to display primary-task related information such as wayfinding on a world-fixed HUD and information that is related to driving but not to objects in the surroundings on a screen-fixed HUD. While they suggest that a world-fixed display should cover the driver's entire FoV, they also recommend to limit AR applications for entertainment and social interaction to tertiary task locations – such as the center stack.

VIEW MANAGEMENT FOR VARIOUS DISPLAY SETTINGS

In this section we present related work on view management from different domains and devices: AR and VR head-mounted displays, large-sized and multiple display settings, multi-layered displays and stationary displays.

View Management for Head-Mounted Displays

The AR and VR community refers to the world- and screen-fixed placement by the *frames of reference* object space and viewport space. The standard HUD represents a viewport space [27]. While information in the viewport space is visible at all time and to all extent, it can be hidden in the object space due to the viewer's position and orientation [28]. As follows, it is not surprising that the viewport space generally outperforms the object space, yet, the object space is superior when combined with large displays – such as a WSD. Though, the driver can obviously not adjust his position or orientation only to access information. Hence, for the WSD we need to combine the ensured accessibility of the viewport space with the simplified comprehension of the object space.

The user space aligns information according to the user's position, orientation, attention, or gaze and is thereby closely related to gaze-based interfaces. Bell et al. [4] proposed an AR application which displays and hides information depending on the user's attention. Such approach could help to reduce clutter on WSDs and driver distraction while the same amount of information is provided and manual interaction is reduced.

View Management for Stationary Displays

Large-sized wall displays often present information at a varying level of detail – depending on the user's distance to the display (e.g. [3, 13]). When a person is far from the display, it serves as ambient display presenting information on a low level of detail. The closer the user comes to the display, the higher becomes the level of detail and the more sophisticated interaction is enabled. Three zones are commonly suggested for this distance-based view management and interaction: ambient zone, notification zone, and interaction zone. These zones relate to Hall's theory of Proxemics about interpersonal distances when communicating with others [17]. Based on the observations of humans and animals, he suggested four zones: The *intimate zone* comprises the closest area around a person (< 45 cm) and relates to (intimate) body contact, but also whispering and smell. People interact in the *personal zone* (45 to 120 cm) with intimate and common friends; physical contact is possible. People who have a business-type relationship interact in the *social zone*. This zone is used for informal (120 cm) to formal communication (360 cm); body contact is avoided but facial expressions are recognizable. The *public zone* (360 - 750 cm or infinity) is applied when one speaks to an audience; verbal conversations are difficult but supported by gestures.

We applied these zones to our concept, though, it has to be noted that the driving scenario differs from a wall-display scenario: The driver is seated in a closed car (separated from the other road users) and is in a fixed position to the display.

APPROACH

Now, that this paper is positioned in the context of related work, we describe the concept that we derived from it. We define *areas* – 2D spaces facing the driver – and *zones* – adding the third dimension (depth) – which together define 3D spaces for the display of information according to its task-relevance and context. Häuslschmid et al. [14] identified relevant contexts, which influenced our concept below.

Separation into Display Zones

Tan et al. [31] found that a mixed display distance can impair performance. Yet, a separation into several zones was found to be advantageous for other, distance-based display setups (e.g. [3, 13]). Considering these findings, our view management concept proposes just three display distances to be evaluated in our user experiment. These distances are further informed by the theory of Proxemics [17], which is well established in the field of psychology for suggesting ranges of interpersonal interaction. The theory has previously been applied to large-sized wall displays for distance-based view management and interaction design. While it is not an ideal match to our problem setting, it was helpful for several design decisions in our concept. In particular, we separated the 3D space into the following zones, as shown in Fig. 2.

The 70 cm distance between the driver and the windshield is the minimum distance for information display and will be treated as 0 cm in the following. Hall's intimate zone hence cannot be used, which is fair, given that it is reserved for intimate contacts and close friends, a distinction the car cannot make. The **personal zone** (0 to 50 cm) seems appropriate for information such as private messages. As follows, such private information is in close distance to the driver, just as in real life, which makes it very accessible for interaction, such as answering a message.

From 50 cm to 290 cm, corresponding to the social zone for business-type interaction, we suggest to place information related to the own vehicle; such as fuel consumption, speed or technical issues. The **vehicular zone** meets (partially) the dimensions of a car, suggesting that the information would be floating above the car's hood. Furthermore, this range is supported by the standard HUD distance of approx. 130 cm, as standard HUDs primarily display information about the car and navigation as well.

Finally, we propose to use Hall's public zone as **environmental zone**. This zone ranges from 290 cm to infinity and displays information related to the environment in a world-fixed manner; such as route information and points of interest.

As a first step, we only propose and evaluate these zones. A follow-up study should examine if more fine-grained layers should be used within these zones. In the environmental zone, it is very likely that a continuous depth is most appropriate.

Separation into Display Areas

As a next step, we subdivided the windshield into several areas regarding the context and priority of the content: the task levels and the reaction times in specific areas. When defining these areas, it is important to avoid overlay and corresponding clutter. For the concept, screen-fixed areas have to be laid out next to each other to ensure that the presented information is well-perceptible. A curved alignment around the driver can further enhance recognition and task switching; this needs to be verified for a car setup [9].

The prevention of overlap becomes more complex when world-fixed information is displayed simultaneously. Such information is meant to be placed spatially close to environmental objects – and this may fall into one of the defined areas and thereby create overlaying information. This is of course not only the case for environmental objects 'appearing' in such area but also for objects which move into such area (due to the object's own motion or optic flow) and also for two or more pieces of registered information, e.g. when information about another car encounters information about a POI. To solve this problem, layout and dynamic view management algorithms have to be applied. Yet, occlusion can probably never be controlled completely due to the complexity of the road scene.

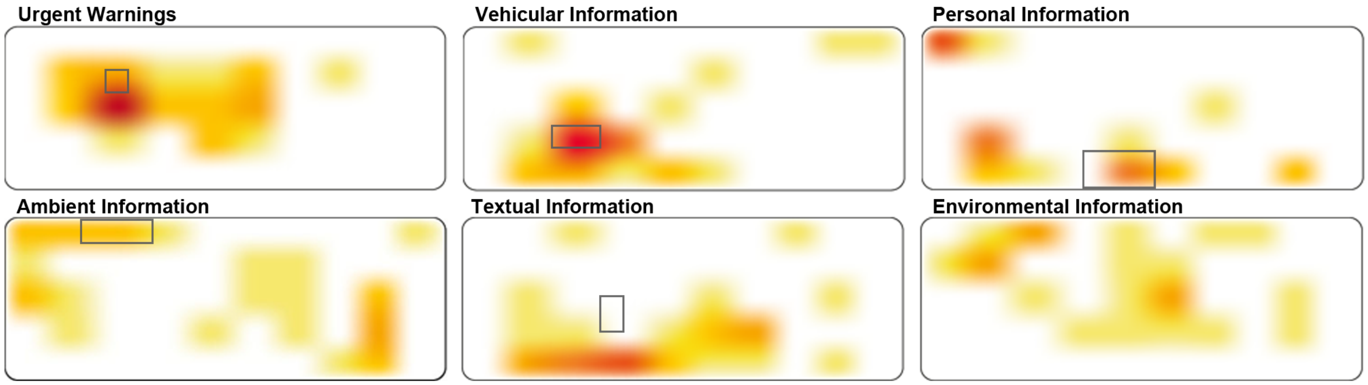

Figure 3. Areas preferred by our participants for display of information types. The darker the shade, the more participants chose this area. Grey boxes represent the concepts' suggestions, with the exception of environmental data, which is distributed in the concept.

For a WSD view management concept, we propose the following areas (see Fig. 2). The amount of information displayed in these areas can vary; some areas may be empty (e.g. no warnings need to be displayed) while others display constant information (e.g. speed).

The **notification area** (Fig. 2 (1)) superimposes urgent warnings which are related to the primary and potentially the secondary task but have no relation to the outside world; e.g. drowsiness warning. Urgent warnings related to the outside world should be registered to the referent; e.g. crash warnings. The area (for unregistered warnings) is placed in the central FoV due to the requirement of low reaction times. To avoid occlusion and primary task degradation, the area is shifted upwards so that it ends 2.5° above the driver's line of sight. All urgent warnings are located in the personal zone, as it has been found that primary information is preferred to be placed in a close distance [37]. We suggest a dimension of 5° x 5° – corresponding to a size of 6 x 6 cm at the distance of the windshield (70 cm). An appearance of an urgent warning might be most efficient when other WSD information is hidden simultaneously.

The **vehicular area** (Fig. 2 (5)) presents exclusively information about the own car; e.g. fuel consumption and speed. We suggest to place this area centered below the driver's central FoV and to size it with 10° on horizontally (-5 to 5°) and 5° vertically (-2,5° to -7,5°). The area is located in the vehicular zone and thereby corresponds in distance, location and size to the standard HUD. This area is proven to support fast response times which is important for the primary and secondary task related content.

The **personal area** (Fig. 2 (3)) presents information that is in any way related to the driver; e.g. entertainment functions or messages. It is likely that the driver wants to interact with the content which suggests a placement that is appropriate for buttons, controllers, and gestures. Entertainment functions require interaction and are commonly provided in the center stack. We suggest to use the area above the center stack (approx. 10° to max. 25° horizontally and -7.5° to the bottom edge vertically) for the presentation of tertiary task related information of personal interest. According to Gabbard et al. [10], "tertiary tasks often require both physical reaching and greater visual distraction". This area has been recommended also by Lamble et al. [23] since it allows for good road tracking – which is important for interaction due to high eyes-off-the-road times or frequent glances [10] – and facilitates the least tiring manual interaction as it is close to the quiescent arm and shoulder position [9].

The **ambient area** (Fig. 2 (4)) comprises everything that is not of particular interest or of low priority; e.g. current time, date or weather. For ambient information, fast detection and response times are not required but eyes-off-the-road time should be low. We suggest to place ambient information in the same distance as personal information but on the top edge of the windshield (about 5° high and 15° wide, centered above the driver's line of sight). Though, as only little is known about this area, we point at the need to examine this area in a user study. As the top visual field is of lower resolution and as recommended for peripheral information, we suggest to present symbolic information in larger dimensions in this area.

To create a balance between a driver's desires and a driver's safety by avoiding smart-phone use, we introduce a **reading area** (Fig. 2 (2)) which supports the reading of continuous texts on the WSD. The considered texts – e.g. E-Mail or SMS – is related to tertiary tasks. Reading is an attentive, visually and cognitively demanding task that requires many glances when executed in a divided attention scenario. Hence, text should be displayed only on demand and in consideration of the current road situation. Since good detection and response times have been reported for the area to the right of the driver's focus point, we propose to place texts at 5° to 10° horizontally and 0° to max -7,5° vertically. Alternatively, the HUD area could be used for text display; meaning that the HUD information is hidden and the text displayed until the driver finished reading. Further, we consider two options for depth: either (1) the personal zone as most texts will be of personal interest or (2) within the environmental zone – registered with the driver's current focus point (e.g., on the lead car) to enable the fastest possible switching – since an offset in depth can impair text reading performance [31]. According to Orlosky et al. [25], users of HMDs prefer to place text in the background of the HMD screen, closer to the world.

The **environmental area** ranges throughout the environmental zone and presents content that is related to the surroundings in a world-fixed manner; e.g. the headway to the lead car or

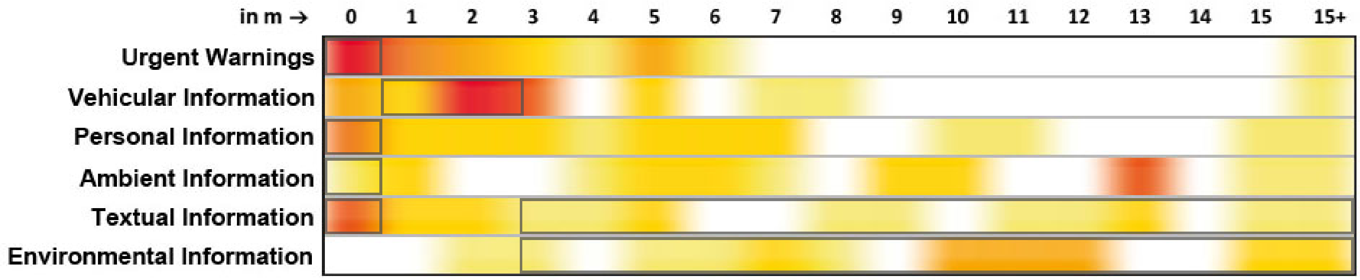

Figure 4. Distances preferred by our participants. Dark shades indicate a high count of participants. Grey boxes represent the concepts' suggestions.

points of interest. This area is related to all task levels; though, considering that the driver should not be overwhelmed by the amount of information, primary-task related information takes priority. We suggest that the most relevant area is the middle field from the very left to the right side, as the driving scene normally falls into this area. This area could shrink in its horizontal dimension at higher speeds, e.g., on the highway. The upper part is relevant mostly for traffic signs.

FORMATIVE STUDY

We conducted a brief formative study in order to inform and balance our concept, considering relevant research and the driver's needs and desires. We recruited 21 participants (6 female) with a mean age of 27 years (SD = 6). As the look and feel of information placed on such a novel 3D display is hard to imagine or even to develop from scratch, we decided to present a driving scene and example WSD information to the participants on a Google Cardboad with an attached Huawei Mate 7. This setup provides a FoV of 70° and a display resolution of 1920 x 1200 px (960 x 1200 px per eye). We created phone apps in Unity 3D that consist of a spherical image of a real street scenery, a 3D car model and individual sets of augmenting information (e.g., Fig. 1).

The study procedure was scripted in order to ensure that every participant will experience the same. After welcoming our participants, we asked them to put on the Google Cardboard which constantly displayed a 3D driving scene without additional content. When participants were familiar with it, the study conductor superimposed additional information which was placed across almost the entire windshield and in several distances (similar to Figure 1). The information was visible for 5 s only and participants were asked to memorize it and report it in a questionnaire. By this, we ensured they will not try to understand rules beyond the distribution. We repeated this procedure five times (overall 6 times) with different sets of five pieces of information each and different distributions. After a break of 5 to 10 min we asked our participants to report where they would place information in a questionnaire.

RESULTS & DISCUSSION

In a questionnaire we listed 5 types of information: personal, vehicular, environmental, ambient, and textual information, as well as urgent warnings; examples for each type have been shown during the study. The questionnaire contained two basic drawings which represent the windscreen from the drivers point of view and from a side view with a scale (0 m to 15 m and *environment*). As expected, the placement concepts of our 21 participants vary considerably; due to this and the limited amount of participants we did not perform a statistical analysis. We could not derive a repeating pattern which was delivered by several participants. Yet, there is accordance regarding some positions and information types.

Analyzing the **distances** (see Fig. 4, we found that only 13 of 21 used the entire scale. 7 participants restricted WSD information to a distance of max. 10 m and 3 out of this group to 5 m. Surprisingly, these participants limited also environmental information to this distance. Further, 9 participants proposed two or three depth levels only; no participant decided for only one layer. This shows that there are mixed opinions about the use of several depth layers or even continuous depth.

Regarding the **areas** (see Fig. 3), participants seemed to be equally hesitant in spreading information across the entire provided space. 8 participants limited the information to the left and middle area of the windshield; 7 of them did not use the entire distance range. Many participants placed content on the edges and in the corners of the windshield – far off the driver's line of sight. The location directly at the driver's focus point was avoided, though, the close region around it was used by all but 2 participants.

Participants confirmed the suggested location for **urgent warnings** (notification area). A distance of *median=1 m* and a placement directly within and slightly above the driver's line of sight are preferred by our participants.

Participants also agreed on the location for **vehicular information**. A distance of *median=2 m* and the location below the driver's line of sight was proposed by the participants.

According to our participants, **personal information** should be displayed in a range from 0 m (windshield) to 7 m. The *median=3.5 m* is considerably higher than the proposed distance (up to 50 cm) and falls into the range of the vehicular zone. This suggests a reconsideration of the order of the zones. Participants placed personal information mostly in the top left corner and on the bottom edge of the windshield, specifically to the left of the standard HUD position and above the center stack. Either way, personal information was placed in the left half and the middle part of the windshield.

Surprisingly, the distance range of **ambient information** is very large *(median=9 m*. The gap between this and the proposed distance (up to 50 cm) shows a need of revision – not only for the distance. About half of the participants placed ambient information in the right half of the windshield. The remaining participants placed it at the top left edges of the windshield – which is similar to what we proposed.

The distance chosen for **texts** is similar to the one chosen for personal information *(median=3.5m)*. We proposed two options for the depth: the display within the personal zone (50cm) or an in-depth registration to the driver's focus point. The first approach seems to be more suitable to the participants' preferences, especially when personal and vehicular zones are switched. Further, texts were placed in the lower area of the windshield, close to the steering wheel and the center stack. This area is not suitable as it can be occluded by the steering wheel [20]. Yet, adjacent areas – e.g. with the hood in background – should be considered for further improvements.

Environmental information was placed in a distance of *median=10 m*; further two participants want it to be placed further away. The suggested zone begins at a distance of 2.9 m and therefore matches the distance preferred by participants. Though, it is unclear if they would enjoy a registered presentation which exceeds 10 to 15 m. Regarding the area, hot spots are the middle area of the windshield as well as the top left corner. These hot spots could refer to buildings or traffic and road signs. We proposed a wide area which reaches from the left to the right boundary of the windshield. This area matches with the results but further research is needed to find out how drivers experience content far off their line of sight.

LIMITATIONS & FUTURE WORK

We presented a view management concept for windshield displays that suggests zones based on the theory of Proxemics. Since information reading on a WSD is fairly different from interpersonal communication, we needed to reassign Hall's zones to in-car contexts and online communication.

To develop a natural and intuitive interface layout we considered the driver as a whole. Though, every driver is different what suggests that individual interfaces may be need. Yet, a consistent system promotes memorability and reduces switching times [2, 9]. Hence, if such interface ought to be individual or not, the proposed concept can serve as a default setting.

In a first formative study, we presented different information layouts integrated into a 3D driving scene to foster the participants' imagination and creativity. We displayed these scenes for a short time only to avoid influencing – which is confirmed as successful by the considerable differences between the presented layouts and the results of the questionnaire.

This work presents a view management concept that is based on a broad and extensive literature study and reports an initial formative study on it. A deeper study that incorporates a large set of participants needs to investigate on the recognition, response times and distraction of such view management concept. We chose to present the knowledge we gathered so far to the automotive user interfaces community so that the researchers who have access to appropriate technology – which can be various kinds of displays – may base further studies on our findings and answer the following open questions:

- How much information can be displayed without safety-critical impacts on the primary task?
- Is a curved or a flat area alignment more appropriate?
- What extensions are required to apply Proxemics theory to a closed vehicle scenario?
- Do several depth layers rather support or impede information uptake? Could information switch depth layers without disturbing or irritating the driver?
- Does display-on-demand e.g., gaze-dependent – scaling or (dis)appearance – distract the driver more or less than a higher amount of information which is constantly visible?
- Does registered information distract the driver more than screen-fixed information? How does it feel for the driver when information changes in depth (e.g., comes closer)?

CONCLUSION

WSDs are developed along with autonomous driving. One may suggest that WSDs are no longer needed when autonomous driving is launched, though, until cars drive fully autonomously and handovers are no longer necessary, the WSD could keep drivers engaged in the forward FoV and thereby enhance the handover process.

A concept for the view management for a HUD or WSD will be needed as soon as technology provides a larger display size. However, little prior work on view management for WSDs has been done. This paper presented a discussion of related research from several domains, a first concept draft based on that research, and a brief formative study of the novel view management concept. Participant's preferences for information layout was compared against our layout concept and an analysis of the similarities and differences pointed out needs for improvement, open questions and several pathways for future work on this problem, including the need for extension of existing visual layout theories, such as Proxemics, to the WSD design and driver attention scenario.

REFERENCES

1. 2001. User Interface Management Techniques for Collaborative Mobile Augmented Reality. *Computers & Graphics* 25, 5 (2001), 799 – 810.
2. Miyoshi Ayama and Masato Sakurai. 2003. Changes in Hue and Saturation of Chromatic Lights Presented in the Peripheral Visual Field. *Color Research & Application* 28, 6 (2003), 413–424.
3. Till Ballendat, Nicolai Marquardt, and Saul Greenberg. 2010. Proxemic Interaction: Designing for a Proximity and Orientation-aware Environment. In *ACM International Conference on Interactive Tabletops and Surfaces (ITS '10)*. ACM, New York, NY, USA, 121–130.
4. Blaine Bell, Tobias Höllerer, and Steven Feiner. 2002. An Annotated Situation-awareness Aid for Augmented Reality. In *Proceedings of the 15th Annual ACM Symposium on User Interface Software and Technology (UIST '02)*. ACM, New York, NY, USA, 213–216.
5. U. Bergmeier and C. Lange. 2008. Acceptance of Augmented Reality for Driver Assistance Information. In *Proceedings 2nd International Conference on Applied Human Factors and Ergonomics, Las Vegas*.
6. Mark W. Cannon. 1987. Recent Advances in Understanding Peripheral Vision. In *Proceedings of 30th Annual Meeting of the Human Factors Socitety*, Vol. 30. 601–60.

7. A. S. Cohen and R. Hirsig. 1990. Zur Bedeutung des fovealen Sehens für die Informationsaufnahme bei hoher Beanspruchung. Verlag TÜV Rheinland GmbH, 47–58.
8. D. Crundall, G. Underwood, and P. Chapman. 1075-1087. Driving Experience and the Functional Field of View, Vol. 28(9). Perception, 1999.
9. Barrett M. Ens, Rory Finnegan, and Pourang P. Irani. 2014. The Personal Cockpit: A Spatial Interface for Effective Task Switching on Head-worn Displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, USA, 3171–3180.
10. J. L. Gabbard, G. M. Fitch, and Hyungil Kim. 2014. Behind the Glass: Driver Challenges and Opportunities for AR Automotive Applications. *Proc. IEEE* 102, 2 (Feb 2014), 124–136.
11. K. W. Gish and L. Staplin. 1995. Human Factors Aspects of Using Head Up Displays in Automobiles: A Review of the Literature. National Highway Traffic Safety Administration (NHTSA) (report no: DOT HS 808 320), Washington, DC.
12. E.B. Goldstein. 1999. *Sensation and Perception (5th Edition)*. Brooks/Cole Publishing.
13. Saul Greenberg, Nicolai Marquardt, Till Ballendat, Rob Diaz-Marino, and Miaosen Wang. 2011. Proxemic Interactions: The New Ubicomp? *interactions* 18, 1 (Jan. 2011), 42–50.
14. Renate Haeuslschmid, Bastian Pfleging, and Florian Alt. 2016. A Design Space to Support the Development of Windshield Applications for the Car. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 5076–5091.
15. Renate Haeuslschmid, Laura Schnurr, Julie Wagner, and Andreas Butz. 2015. Contact-analog Warnings on Windshield Displays Promote Monitoring the Road Scene. In *Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '15)*. ACM, New York, NY, USA, 64–71.
16. Richard F. Haines. 1991. *Presbyopia Research: From Molecular Biology to Visual Adaptation*. Springer US, Boston, MA, Chapter A Breakdown in Simultaneous Information Processing, 171–175.
17. Edward Twitchell Hall. 1966. *The hidden Dimension*. Doubleday & Co.
18. Renate Häuslschmid, Sven Osterwald, Marcus Lang, and Andreas Butz. 2015. Augmenting the Driver's View with Peripheral Information on a Windshield Display. In *Proceedings of the 20th International Conference on Intelligent User Interfaces (IUI '15)*. ACM, New York, NY, USA, 311–321.
19. M. J. M. Houtmans and A. F Sanders. 1984. Perception of Signals Presented in the Periphery of the Visual Field. *Acta Psychologica* 55, 2 (1984), 143–155.
20. Yasuhiro Inuzuka, Yoshimasa Osumi, and Hiroaki Shinkai. 1991. Visibility of Head Up Display (HUD) for Automobiles. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, Vol. 35. SAGE Publications, 1574–1578.
21. Arihiro Isomura, Koichi Kamiya, and Katsunori Hamatani. 1993. Driver's Cognition in Peripheral Field of View. SAE Technical Paper 931876.
22. N. Kishishita, K. Kiyokawa, J. Orlosky, T. Mashita, H. Takemura, and E. Kruijff. 2014. Analysing the Effects of a Wide Field of View Augmented Reality Display on Search Performance in Divided Attention Tasks. In *Mixed and Augmented Reality (ISMAR), 2014 IEEE International Symposium on*. 177–186.
23. Dave Lamble, Matti Laakso, and Heikki Summala. 1999. Detection Thresholds in Car Following Situations and Peripheral Vision: Implications for Positioning of Visually Demanding in-car Displays. *Ergonomics* 42, 6 (1999), 807–815.
24. T. Lino, T. Otsuka, and Y. Suzuki. 1988. Development of Heads-Up Display for a Motor Vehicle. SAE Technical Paper 880217, 15–23.
25. Jason Orlosky, Kiyoshi Kiyokawa, and Haruo Takemura. 2014. Managing Mobile Text in Head Mounted Displays: Studies on Visual Preference and Text Placement. *SIGMOBILE Mob. Comput. Commun. Rev.* 18, 2 (June 2014), 20–31.
26. Marina Plavšic, M Duschl, M Tönnis, H Bubb, and Gudrun Klinker. 2009. Ergonomic Design and Evaluation of Augmented Reality based Cautionary Warnings for Driving Assistance in Urban Environments. *Proceedings of Intl. Ergonomics Assoc* (2009).
27. Nicholas F. Polys, Doug A. Bowman, and Chris North. 2011. The Role of Depth and Gestalt Cues in Information-rich Virtual Environments. *Int. J. Hum.-Comput. Stud.* 69, 1-2 (Jan. 2011), 30–51.
28. Nicholas F. Polys, Lauren Shupp, James Volpe, Vladimir Glina, and Chris North. 2006. The Effects of Task, Task Mapping, and Layout Space on User Performance in Information-Rich Virtual Environments *(Computer Science Technical Reports)*. Virginia Tech.
29. Esa M. Rantanen and Joseph H. Goldberg. 1999. The Effect of Mental Workload on the Visual Field Size and Shape. *Ergonomics* 42, 6 (1999), 816–834. PMID: 10340026.
30. Akihiko Sato, Itaru Kitahara, Yoshinari Kameda, and Yuichi Ohta. 2006. Visual Navigation System on Windshield Head-up Display. In *In Proceedings of 13th World Congress on Intelligent Transport Systems*. IEEE.
31. Desney S. Tan and Mary Czerwinski. 2003. Effects of Visual Separation and Physical Discontinuities when Distributing Information across Multiple Displays. In *In Proceedings of Interact 2003*. 252–255.
32. Marcus Tönnis, Marina Plavšić, and Gudrun Klinker. 2009. Survey and Classification of Head-Up Display Presentation Principles. In *Proceedings the 17th World Congress on Ergonomics*. International Ergonomics Association.
33. Omer Tsimhoni. 2000. Display of Short Text messages on Automotive HUDs: Effects of Driving Workload and Message Location. UMTRI Human Factors (report no. UMTRI-2000-13).
34. Omer Tsimhoni, Paul Green, and Hiroshi Watanabe. 2001. Detecting and Reading Text on HUDs: Effects of Driving Workload and Message Location. In *11th Annual ITS America Meeting, Miami, FL, CD-ROM*.
35. Nicolas J. Wards and Parkes Andrew M. 1995. *The Effect of Automotive Head-Up Display on Attention to Critical Events in Traffic*.
36. Christopher D. Wickens, Robin Martin-Emerson, and Inge Larish. 1993. Attentional Tunneling and the Head-up Display. In *Proceedings of the 7th Annual Symposium on Aviation Psychology*. 865–870.
37. B. L. William Wong, Ronish Joyekurun, Hoda Mansour, Paola Amaldi, Anna Nees, and Rochelle Villanueva. 2005. Depth, Layering and Transparency: Developing Design Techniques. In *Proceedings of the 17th Australia Conference on Computer-Human Interaction: Citizens Online: Considerations for Today and the Future (OZCHI '05)*. Narrabundah, Australia, Australia, 1–10.
38. Herbert Yoo, Omer Tsimhoni, Hiroshi Watanabe, Paul Green, and Raina Shah. 1999. Display of HUD Warnings to Drivers: Determining an Optimal Location. UMTRI Human Factors (report no. UMTRI-99-9).
39. Beth Yost, Yonca Haciahmetoglu, and Chris North. 2007. Beyond Visual Acuity: The Perceptual Scalability of Information Visualizations for Large Displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07)*. ACM, New York, NY, USA, 101–110.
40. Liu Yung-Ching and Wen Ming-Hui. 2004. Comparison of Head-up Display (HUD) vs. Head-down Display (HDD): Driving Performance of Commercial Vehicle Operators in Taiwan. *International Journal of Human-Computer Studies* 61, 5 (2004), 679 – 697.