Exploring Virtual Depth for Automotive Instrument Cluster Concepts

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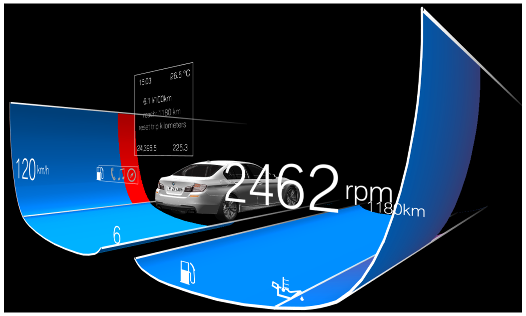

Figure 1: Three dimensional concept layout for an automotive instrument cluster.

CHI 2014, April 26–May 1, 2014, Toronto, Ontario, Canada.
ACM 978-1-4503-2474-8/14/04.
http://dx.doi.org/10.1145/2559206.2581362

Abstract
This paper compares the user experience of three novel concept designs for 3D-based car dashboards. Our work is motivated by the fact that analogue dashboards are currently being replaced by their digital counterparts. At the same time, auto-stereoscopic displays enter the market, allowing the quality of novel dashboards to be increased, both with regard to the perceived quality and in supporting the driving task. Since no guidelines or principles exist for the design of digital 3D dashboards, we take an initial step in designing and evaluating such interfaces. In a study with 12 participants we were able to show that stereoscopic 3D increases the perceived quality of the display while motion parallax leads to a rather disturbing experience.

Author Keywords
Stereoscopic 3D; Motion Parallax; Automotive User Interfaces; User Experience

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous.

Introduction
Analogue car dashboard evolved over decades. They are not just representing the corporate identity of the

manufacturer but are the result of careful considerations with regard to the driving tasks. Important information that needs to be frequently perceived - for example, speed - are displayed prominently at the center, while, in general, less important information, such as the number of kilometers driven, is displayed in the periphery of the dashboard. At the same time, certain parts of the dashboard may become more important, depending on the context, for example, as the car is running low on gas or the engine temperature is too high. Yet, the static nature of analog dashboards is rather restricted when it comes to presenting this information to the driver.

With the advent of fully digital displays, dashboards can reach a new quality by being able to take into account the driving situation and by increasing the user experience. This trend becomes even more pronounced as auto-stereoscopic displays become available for the car. For instance, Häkkilä et al. show that 3D displays increase the UX for mobile phones [3]. Furthermore, Broy et al. found advantages in attractiveness for the stereoscopic variant compared to a monoscopic display in the automotive context [1]. An overview of other benefits of 3D displays are shown by McIntire [5]. The overall trend to increase the driving experience through novel display technology is also reflected by the fact that Mercedes recently deployed a 3D display in the F125 concept car.

Today, no commonly agreed guidelines as to how novel, digital dashboard should be designed to optimally support both the driving task and the user experience. In this work, we take a first step by investigating the influence of different display layout concepts and their spatial representation on the user experience. Therefore, we developed three display layout concepts, that differ in their appearance from well-known and classic (i.e., tube layout) to novel and modern. For generating a 3D impression of the concepts, we implemented a monoscopic representation, which allows to add motion parallax and stereoscopic 3D (S3D) as depth cues. In an initial user study with 12 participants we compared the developed designs in 2D and 3D representations with each depth cue. The results show that the S3D increases the perceived quality of the display while motion parallax should be applied carefully to not make the UI appear too crowded.

Instrument Cluster Concepts

To investigate the influence on user experience we created three different dashboard designs for stereoscopic displays following guidelines from Broy et al. [2]. The first design represents a classical dashboard as known from cars without digital displays (cf., Figure 2). The second design is a modern version with abstract representations of each part of the interface (cf., Figure 3). The third design does not rely on the circular instruments but rather uses planes to visualize the information (cf., Figure 4).

Item
Current speed
Revolutions per minute
Oil temperature
Tank level, remaining range and current consumption
Current time of day and temperature
Trip and total odometer
Distance to the vehicle ahead
Tank menu
Phone menu
Music menu
Navigation menu

Table 1: The items that mandatory need to be present in each design.

To make the concepts comparable, we designed them to display the same types of information. In addition, each design contains a menu structure with four entries. Note that the the menu is located roughly at the same position in all layouts to ensure comparability while interacting. A list of all features can be found in Table 1.

To control the menu, four buttons on the steering wheel are used, namely, *back*, *select*, *left* and *right*. If no menu is active, the *left* and *right* buttons are used to cycle between the options (i.e., tank, phone, music, or navigation). When pressing *select* the highlighted menu is activated. With an active menu, the *left* and *right* buttons are used to navigate through the menu. The *select* button is used to perform an action (e.g., reset trip odometer or call the selected contact). To visually support the distinction between menu selection and within menu interaction, the object containing the menus moves towards the user upon entering a menu. In the following we provide a detailed description of the three designs.

Classic

The first design transfers the look of analogue gauges into a digital display. The choice of colors and materials intends to mimic high-class real world materials such as chrome for the gauge edges, carbon fiber for the background and red illuminated glass for the dials. There are five gauges – three small ones for the tank level on the left, oil temperature on the right, and menu information in the middle. The two larger ones show the speed and revolutions. The speed gauge contains the menu icons while the RPM gauge holds the digit of the current gear. The ACC icon is displayed above the menu gauge.

Figure 2: Classic design as 2D presentation.

Circles

Maintaining the association with analogue gauges, the *Circles* design displays speed and revolutions by filling the area between the inner and outer circle of the tilted blue wire-framed gauges clockwise. Tank level and oil temperature are visualized through narrower areas, filling counterclockwise. The left and right gauges contain a numeric display of current speed, respectively, revolutions and current gear, while the upper semicircle holds the ACC and turn indicator icons. The lower circle serves as indicator for the currently selected menu of the car computer and contains time of day, temperature, and odometers. When selecting another one of the four menus, the circle rotates by ninety degrees. The center cube holds those four menus on its four lateral sides and also rotates by ninety degrees, if another menu is selected.

Figure 3: 2D presentation of the design *Circles*

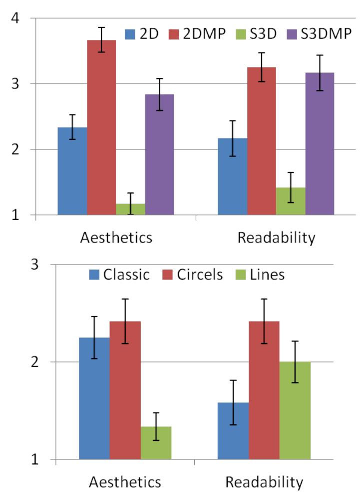

Figure 5: Bar charts of means and standard errors of the ranks pertaining readability and aesthetics for the tested depth cues (top) and designs (bottom). Note that the lower the bars the better the ranking is.

Lines

The third design visualizes speed and revolutions in horizontal areas, filling from front to back (i.e., expanding in the third dimension). The display is divided into two shells, the one on the left showing speed, the right one showing tank level, oil temperature and revolutions, as well as a gear digit in the lower middle, a small bar in the middle containing menu icons and a square frame holding the menu. Instead of an ACC icon, there is a 3D car model, appearing in the left shell if the distance to the vehicle ahead falls below a given threshold.

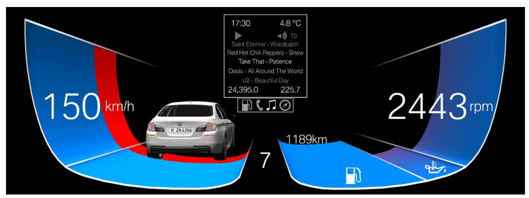

Figure 4: 2D presentation of the design *Lines*

Exploring User Experience of Virtual Depth for IC Concepts

Apparatus

The 3D models of the display concepts were created using Blender[1]. The we exported them to fbx files and used them in Unity3D[2], which provided a framework for input handling and animations. Stereoscopic visualization was achieved using NVidia 3D Vision on an Asus G75VW notebook, whose display supports the necessary refresh rate of 120Hz for shutter glasses. The glasses participants had to wear during the experiment, synchronize with the display and show an image for each eye at 120 Hz.

For implementing motion parallax, TrackIR[3] was used, interfacing with Unity3D through the Unity-TrackIR Plugin. TrackIR consists of an USB device which both IR LEDs and a camera to record IR reflections and a *target*, providing three semicircular reflecting areas in a set distance. The target was attached to a baseball cap, which had to be worn by each participant during the experiment and thus enabled the software to track their head in 6 degrees of freedom (*DOF*).

We conducted a lab study with 12 participants (4 female, 8 male) aged from 22 to 32 ($M = 25.0$, $SD = 3.1$). We recruited the participants through our internal mailing list. All of them were familiar with automotive user interface development, its requirements, and challenges.

Study Setup

The study setup consisted of a car seat with a Logitech steering wheel and pedals as well as an ASUS shutter notebook displaying the instrument cluster. We used the TrackIR motion parallax system to generate the motion parallax. Since using motion parallax requires head tracking, the participants wore the cap for the tracking device. Furthermore, they had to wear shutter glasses for the stereoscopic 3D effect. To achieve comparable conditions, the participants wore both at each condition.

Procedure

After participants arrived in the lab, we first calibrated the TrackIR system. Then we introduced them to the input device (i.e., buttons at the steering wheel). In total, we had twelve conditions: three designs (*Classic*, *Circles*, and *Lines*) with the four depth cue settings (*no effect (2D)*, *motion parallax (2DMP)*, *S3D*, and *S3D with motion parallax (S3DMP)*). The order of the conditions varied for

[1]Blender - www.blender.org

[2]Unity - www.unitiy.org

[3]TrackIR www.trackir.fr/

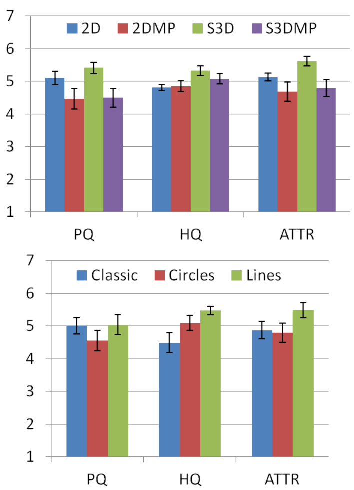

Figure 6: Bar charts of means and standard errors of the AttrakDiff's dimensions PQ, HQ, and ATTR for the tested depth cues (top) and designs (bottom).

each participant using latin square. In each condition, we presented them five different tasks (e.g., selecting a song or switching the gears) which they should conduct and gave them time to playfully explore the interfaces afterwards. Each participant performed these tasks with all twelve conditions. After each condition, the participant filled in a AttrakDiff mini [4] questionnaire. After all conditions, the participants ranked the designs from 1 (best) to 3 (worst) and the depth cue settings from 1 (best) to 4 (worst) regarding aesthetics and readability.

Results

A summary of the means and standard deviations is shown in Table 2.

Readability and Aesthetics

The *S3D* version received the highest rankings (cf., Figure 5). Looking deeper in the results of the ranking, we use a Friedman analysis of variance (ANOVA). Regarding aesthetics, the Friedman ANOVA shows statistically significant differences for the designs, $X^2(2, 12) = 8.167$, $p < .017$, as well as the depth cues, $X^2(3, 12) = 23.6$, $p < .0101$. We use Bonferroni corrected Wilcoxon tests for follow up pairwise comparisons. The Wilcoxon tests show significant differences comparing the designs *Lines* with *Circles*, $p < .012$. Regarding the tested depth cues, *2DMP* is rated significantly worse than *2D*, $p < .001$, and *S3D*, $p < .002$, and *S3D* is ranked significantly better than *S3DMP*, $p < .002$. The ranking pertaining readability is not statistically significant for the designs, $X^2(2, 12) = 4.167$, $p = .125$, but for the depth cues, $X^2(3, 12) = 16.5$, $p < .001$. Pairwise Wilcoxon tests show that *S3D* is significantly ranked better than *2DMP*, $p < .005$, and *S3DMP*, $p < .008$. These results show that participants do not like the motion parallax depth cue regarding aesthetics and readability.

Design & Cues	Mean			SD		
	PQ	HQ	ATTR	PQ	HQ	ATTR
Classic 2D	5.33	4.27	5.04	0.98	1.03	1.01
Classic 2DMP	4.42	4.15	4.38	1.37	1.03	1.43
Classic S3D	5.60	4.98	5.38	0.80	1.32	1.13
Classic S3DMP	4.69	4.54	4.71	1.15	1.09	1.16
Circles 2D	4.92	5.06	5.00	1.13	0.75	0.90
Classic 2DMP	4.23	4.96	4.46	1.42	0.92	1.45
Classic S3D	5.08	5.25	5.42	0.92	0.83	0.90
Classic S3DMP	3.98	5.10	4.29	1.49	0.88	1.32
Lines 2D	5.06	5.13	5.33	1.13	0.42	0.86
Lines 2DMP	4.73	5.44	5.21	1.51	0.65	1.12
Lines S3D	5.54	5.75	6.04	0.90	0.51	0.69
Lines S3DMP	4.81	5.58	5.38	1.12	0.93	1.23

Table 2: Results of AttrakDiff mini.

User Experience

The *S3D* version received the highest scores in all dimensions (cf., Figure 6). Since a Kolmogorov-Smirnov test shows that the data for the three AttrakDiff's dimensions pragmatics quality (PQ), hedonic quality (HQ), and attractiveness (ATTR) is normally distributed, we conduct a repeated measures ANOVA.

For PQ, the ANOVA shows statistically significant differences for the depth cues, $F(3, 33) = 9.059$, $p < .001$, but not for the designs, $F(2, 22) = 1.274$, $p = .300$. A pairwise comparisons of the depth cues conditions, using LSD, shows that PQ for *2D* was rated significantly higher than *2DMP*, $p < .037$ and *S3DMP*, $p < .03$, but significantly lower compared to *S3D*, $p < .039$. Moreover, the PQ is significantly lower for *2DMP* than *S3D*, $p < .003$, and *S3D* has a significant higher PQ than *S3DMP*, $p < .002$. The ANOVA shows statistically significant differences for the factor depth cues, $F(3,33) = 5.012$, $p < .006$, as well as for the tested designs, $F(2,22) = 4.219$, $p < .028$, in regard to the dimension HQ. LSD post-hoc tests reveal statistically significant differences for comparing the designs *Classic* with *Lines*, $p < .015$. Regarding the factor depth cues, we found statistical significances comparing *2D* with *S3D*, $p < .002$ and *2DMP* with *S3D* $p < .026$. Analyzing the ATTR, the ANOVA shows statistically significant results for depth cues, $F(3,33) = 6.397$, $p < .002$, but not for the designs,$F(2,22) = 2.214$, $p = .133$. LSD post-hoc tests show that *S3D* received statistically significant different ratings than *2D*, $p < .007$, *2DMP*, $p < .01$, and *S3DMP*, $p < .01$. *S3D* is perceived as the depth cue with the highest UX among all tested depth cues.

Discussion

The results show that the depth cues have a stronger influence on the perceived quality of the display than the tested design concepts. The *Classic* design has the advantage of a *well-known appearance* (P5), while the more modern design *Lines* offers a *novel and exciting experience* (P3). With regard to the depth cues, participants rated S3D as more compelling, attractive, and usable than any other depth cue, including 2D. They mentioned the increased attractiveness generated through the S3D impression as well as the *clarity of the element's arrangement in space* (P10). However, the participants mention the possible risk of distracting the driver from his security-related primary task. In general, motion parallax performed poorly regarding usefulness, attractiveness, and readability. This depth cue appears *too busy and nervous* (P5). Due to this characteristics, motion parallax is judged as too hazardous, pertaining visual and mental load. However, the participants liked the intuitive zoom, which encourages us to investigate this effect in more detail for automotive UIs.

Conclusion and Future Work

In this work, we investigated the effect of different concept layouts of an automotive instrument cluster and depth cues (S3D and motion parallax) on the perceived quality pertaining usability and attractiveness. Since classic designs raise a familiar and secure feeling, modern designs foster an exciting experience. Moreover, a well-considered use of S3D increase attractiveness and perceived usability. In contrast, motion parallax evokes a nervous appearance of the interface. For future work, we investigate the use of our modern designs with S3D displays in real driving conditions. In particular, we will complement our findings by investigating the influence on the driving performance. Thereby, we aim to use autostereoscopic displays and tracking systems that do not require any head gear.

References

[1] Broy, N., André, E., and Schmidt, A. Is stereoscopic 3d a better choice for information representation in the car? In *Proc. of AutoUI '12*, ACM (2012), 93–100.

[2] Broy, N., Schneegass, S., Alt, F., and Schmidt, A. Framebox and mirrorbox: Tools and guidelines to support designers in prototyping interfaces for 3d displays. In *Proc. CHI 14* (2014).

[3] Häkkilä, J., Posti, M., Koskenranta, O., and Ventä-Olkkonen, L. Design and evaluation of mobile phonebook application with stereoscopic 3d user interface. In *CHI '13 EA*, 1389–1394.

[4] Hassenzahl, M., Burmester, M., and Koller, F. Attrakdiff: Ein fragebogen zur messung wahrgenommener hedonischer und pragmatischer qualitt. In *Mensch & Computer* (2003), 187–196.

[5] McIntire, J. P., Havig, P. R., and Geiselman, E. E. What is 3d good for? a review of human performance on stereoscopic 3d displays. In *Proc. of Head- and Helmet-Mounted Displays XVII*, SPIE (2012).