Consumer insights on innovative 3D visualization technologies
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Abstract
This white paper focuses on different technologies to create three dimensional instrument cluster content and consumers’ perceptions and preferences. We first summarize the state of the art of current 3D display approaches in the automotive industry, before a new way to visualize 3D content to the driver is introduced. Following the technical description, the results of a research clinic are presented, which focuses on the perceived advantages of the three compared technologies, 3D rendering, multi-layer display, and virtual image overlay.

1 Introduction
Over the last 100 years, the vehicle interior changed only very little in terms of general layout. Cars still feature a steering wheel, a number of pedals and in most cases a gear shift. However, the way the driver interacts with the vehicle changed dramatically especially over the last 25 years. Where analog dials and gauges were found in the interior, today’s vehicles offer full color, high definition displays, which provide a wide spectrum of re-configurability. These modern human machine interfaces (HMI) have a tremendous influence on the user experience (UX) of today’s cars. (van Laack 2014, p. 164)

Cluster displays can visualize 3D rendered graphics, which until now were mostly found in computer games or movies. But even though high-end 3D rendering is possible in the vehicle environment, this virtual 3D still appears to be somehow flat to the driver.

Graphical user interface and human factors experts see the benefit of creating real 3D graphics that are not just shown on a flat display, but appear to be physical and realistic. Using different spatial depths allows layering information in an intuitive way to immediately guide the drivers’ attention to what is important in each situation. Furthermore, a real 3D image can offer a perceived quality, which convinces users
they are actually looking at a physical object. (Ku 2014) Of course, the latter is the ultimate goal, for which a right technology needs to be identified.

In this paper we introduce a new concept to visualize 3D content based on the lessons learned from our state of the art review. We then test this concept against other display technologies in a consumer research clinic focusing on the consumers’ points and acceptance of these technologies. The research findings are presented and recommendations based on the customers’ voice are given.

2 Display Technologies for Spatial Depth

2.1 State of the Art

2.1.1 3D Rendering on a flat display

As mentioned in the introduction, live 3D rendering is a way to create fairly realistic 3D objects and scenes in a cluster or center stack display environment (see Figure 1). As the rendering is done during runtime, the behavior and lighting of all objects can be changed easily and according to the current situation. However, the spectator position, which is represented by the camera position in the 3D scene, is usually fixed. This means a user cannot change his or her perspective without using further input modalities, such as gaze-tracking. This kind of technology was already introduced to the automotive market and is already in mass production in several car-lines. For the purpose of this research paper the 3D rendering technology is seen as a baseline as it is also compatible with various display technologies. (Ruotsalainen 2011)

![Figure 1: Visteon's LightScape® Cluster with 3D rendering (Visteon 2016)](image)

2.1.2 Stereoscopic display technology

The most commonly known display technology, which is used to create a feeling of spatial depth, applies a stereoscopic principle. This approach shows a different image to the left and right eye of the viewer. This is either done using special eye glasses or in case of an autostereoscopic display certain lenses are placed on top of the display. This technology is known from the consumer entertainment industry, especially in the area of televisions. The automotive industry is only focusing on auto-stereoscopic displays, which means that a 3D effect is created without the use of special 3D glasses. (Neil 2005) A couple of challenges still need to be overcome. One is the fairly small head box or sweet spot, which means that the user’s head needs to be at a
specific point to actually see the 3D image. This head box can be enlarged by adjusting the shown content based on further inputs from a head tracking device, which certainly increases the complexity of the system. (Lee 2016) Another challenge comes from the human brain itself. As it is tricked into seeing 3D content by having different images presented to the left and right eye, some people might feel discomfort and nausea. (Ku 2014)

2.1.3 Multi-Layer display technology

An alternative approach to create the feeling of depth is using a layered display stack-up. Usually this consists of a transparent TFT, which is placed in front of a regular TFT with some distance. The backlight of the rear TFT is used to shine through the transparent one as well. Both display layers can show graphics, which combined can give the user a feeling of depth and 3D. Because this concept uses a real physical gap between both displays, the parallax the user perceives is real; the chance of nausea is far less than with the previously mentioned auto-stereoscopic technology.

Although the stacked setup of this approach looks favorable for the automotive space, it requires a very strong backlight to shine through both display layers. The structure of current transparent TFT displays also creates a slight blur on all content of the rear display. This is not an issue when the rear display is primarily used to show shapes and styling features, but as soon as text or numbers are displayed on the rear TFT, this becomes a concern. (Witehira 2005)
2.2 Technical Description

Through the state of the art research we identified the disadvantages and advantages of current technologies. Displays showing 3D rendered content are considered the current baseline. They show high end graphics, but are lacking a real depth effect. Autostereoscopic displays require a gaze tracking system to enlarge the head-box and allow the driver to move freely. Multi-Layer displays use a real parallax to create a 3D effect with depth, but due to the way the displays are stacked they require a lot of backlight and create unwanted blur of the rear display content.

Visualizing crisper images with regular automotive backlights without limiting the driver to view the display from a certain head position are some of the main topics this new concept should address.

Based on the principles of a combiner head up display an instrument cluster is developed to fulfill the identified requirements. For the purpose of this paper, this cluster will be referred to as the second generation Multi-Layer display or its internal moniker "Prism". In its basic setup it consists of two reconfigurable displays, one vertically and one horizontally, which are separated by a flat semi-transparent mirror. This mirror reflects the image of horizontal TFT display, creating a virtual image, which overlays with the vertical TFT. By using a semi-transparent mirror (i.e. 50 percent reflectivity) both display contents are visible to the user. The brightness of the virtual image depends on the reflectivity of the mirror and the illumination of the display.

**Figure 4: Concept principle of the second generation Multi-Layer cluster**

When both displays are turned on a user sees the image of the horizontal TFT as a virtual image at a distance “d” behind the semi-transparent mirror. This design parameter “d” allows defining the position of the virtual image in depth. The virtual image can be generated i.e. in the same plane as the vertical TFT, behind it or in front of it. With this setup a tremendous amount of design freedom is giving to create a user interface, which uses this depth. As the virtual image is generated through a real parallax between virtual layer and display, no nausea, headache or fatigue are expected.

In contrast to other concepts, which used a semi-transparent mirror to partially reflect a mechanical instrument cluster and overlay it with a digital image of a display, the second generation Multi-Layer cluster concept focuses on full re-configurability of the
content. It allows 2D and 3D visualizations of cluster content without the using any other mechanical elements or actuators. (Soltendieck 2010)

One of the disadvantages of the multi-layer display was that the content from the rear display would not appear very clear and rather blurry. This effect is caused by the transparent front TFT, which in fact is not entirely transparent, but has very thin circuit paths running through it similar to a chessboard pattern. Although they are very thin, they still cover parts of the light coming from the rear TFT and cause the unwanted blurriness. By creating a virtual image through reflection, this issue can be entirely overcome. In fact, high resolution displays can be used in both orientations, resulting in a very clear overlay with the same resolution.

![Figure 5: Package overview of the second generation Multi-Layer cluster concept](image)

The biggest disadvantage of the second generation Multi-Layer cluster concept is the rather large packaging size, which clearly depends on the display sizes used. For two 12.3” displays, the package size comes close to 300mm x 155mm x 140 mm. While this package is certainly larger than the one of current single or layered display solutions, this concept offers high definition resolution images with high contrast and low sunlight susceptibility.

### 2.3 Graphical User Interface

With the second generation Multi-Layer cluster concept human machine interface (HMI) developers are given a new greater freedom to create intuitive interfaces using the full scope of displaying layered information or 3D content.

The overlay of two graphics itself does not yet create the feeling of depth and 3D. More sophisticated design guidelines are necessary to establish this perception. Creating a 3D rendered vehicle turning on the front plane, while the rear plane shows in a physical distance some other background gives the user a slight spatial perception. To be able to create the effect of tubes, globes, squares or other more complex 3D-elements, a clever overlaying of graphical content is needed. Using different gradients and mixing transparent (black = light off) with non-transparent (color = light on) content creates the effect of seeing objects in 3D. For the design, the distance between the two image planes is crucial and because of this distance, head movement can even support the perception of depth. With this a reality like rendering can create a true depth experience for the user.
Another relevant aspect of designing a graphical user interface (GUI) for this kind of display is to adapt graphical animations to enhance the optical effect. Bringing content from the rear plane to the front plane needs to be done in a way that the user doesn't perceive a jump between planes, but a constant flow.

3 Research Clinic

3.1 Setup

As part of Visteon’s advanced product clinics, various cluster concept with and without 3D functionality have been evaluated by naïve participants of the last years. With the lessons learned from our past researches the new clinic was setup.

The results of previous research conducted by Ku and Tschirhart in 2014 has already shown that the auto-stereoscopic 3D is usually not preferred over “simple” 3D rendering. Another concern of current auto-stereoscopic displays is the lack of high definition resolution and the small head-box in which the image is visible in 3D. As a result auto-stereoscopic 3D displays were excluded from this research clinic and instead we the focus was shifted towards other technologies that can create a 3D perception.

In a first study, different fully reconfigurable clusters (with and without 3D effects) were compared with each other to gain insights on consumer preferences between 2D and 3D and to gather general feedback on the 3D clusters that were shown. In a second study, we compared different 3D methodologies to gather more specific feedback on acceptance, graphics/visuals, clarity, readability, information transfer, Innovation aspect, 3D representation, etc.

In this second study, we conducted 28 face-to-face interviews of around 25 minutes’ length to compare three advanced 3D clusters. The clusters were shown in random order to avoid sequence effects. The clusters were evaluated from the same distance and viewing angle. Gender split was 75 percent male and 25 percent female participants and an age range between 20 and 65 years with 22% under 32 years and a mean age of 41 years. To focus participants mostly on the presented technology, the GUIs were almost identical on all three devices.
Cluster 1: LightScape® (Cluster L)

The LightScape® (Figure 7) cluster offers high performance 3D graphics rendering on a 12.3” display. It currently uses a resolution of 2880x1080 pixels with 250dpi. This is equivalent to a “retina” display resolution at a viewing distance of about 46 cm (18”). Although this cluster offers an above state of the art resolution, the 3D rendering is only displayed on one layer and is therefore considered as baseline 3D rendered cluster.

![Figure 7: LightScape® cluster as it was used in the research clinic](image)

Cluster 2: Multi-Layer Cluster (Cluster ML)

The multilayer display used in this clinic uses two 12.3” displays stacked behind each other with a distance of about 8mm (see Figure 8). The resolution per layer is only half compared to the LightScape® display as it only offers 1440x540 pixels per display. The GUI content presented on this cluster is very similar to the one on the LightScape®, but it was adapted to be shown on two layers and to visualize depth where it is appropriate.

![Figure 8: Multi-layer display as it was used in the research clinic](image)

Cluster 3: Second Generation Multi-Layer cluster (Cluster P)

The second generation Multi-Layer cluster creates a 3D effect by using two reconfigurable displays separated by a flat semi-transparent mirror as described in the chapter 2.2. The GUI used for the other two cluster prototypes was adapted to this one accordingly, utilizing the distance between virtual image and vertical display to create a 3D effect (see Figure 9).
3.2 Clinic Results

When exposing consumers to 3D images in clusters, the results have been consistent over the last years in which Visteon conducted several clinics on this topic globally. For the user, especially in Germany and Europe, 3D “for the sake of having 3D” is not really relevant. It can show the technology advance of an OEM, but creates no real “added value”. Very often it is even considered as an “unnecessary gimmick” or even worse as “distracting” from the driving task and consumers’ are not willing to pay additional money for this technology or appreciate it. (see Figure 10)

General cluster expectations need to be met: The cluster being the main source of information in the vehicle and consumers are expecting information being brought to them in an effective, intuitive way so that they can concentrate on the main task within the vehicle - the driving task. This is especially apparent in Germany. Unnecessary “gimmicky” graphics and information displays that are overloaded with information give a rather negative impression. Understanding consumers’ expectations based on these general baselines helps to interpret the following findings on 3D Cluster usage and acceptance (see Figure 11).
Figure 11: General cluster expectations

The comparison of the three 3D clusters shows that the second generation Multi-Layer cluster combines the best of both worlds: “real” 3D effects with rather clear graphics (no blur effect on one layer) and quality. (see Figure 12)

- Among the 3 instrument panels presented, the Prism is the clear winner, followed closely by Lightscape’s virtual 3D.

Although Lightscape is very close from quality perspective (resolution, colors), Prism combines the best of two worlds: “Real” 3D effects with rather clear graphics (no blur effect on one layer) and quality. There is a polarity between those who like “virtual” (rendered) 3D effects and consider them more “real” than “2x2D” pictures and those that like the “real” depth of two layers.

Figure 12: Summary of preferences

This leads to highest ratings and acceptance on all dimensions tested, especially quality perception with 100% of respondents feeling that the second generation Multi-Layer cluster has a good or very good quality (ratings 4 and 5 on a 5-point scale) and “Premiumness” (93% would “agree” / “strongly agree” that the second generation Multi-Layer cluster has a higher premium feel). (See Figure 13)

The innovation factor is high on all three clusters, the second generation Multi-Layer cluster again slightly on the forefront with 89% of respondents feeling it to be “innovative” or “very innovative”, followed closely by the Multi-Layer cluster (86%) and LightScape® (79%). Reliability (a dimension closely related to the cluster being “easy to read”, immediately understandable), is highest for the 3D rendered LightScape® cluster (75% of the respondents assumed that it would be “reliable” or “very reliable” (4 or 5 on a 5-point scale)).
Figure 13: Evaluation of 3D Clusters: First Impression and Quality

3D effects are clearly higher rated on the two clusters with two layers as this is considered as “real depth” or “real 3D” (see Figure 14). This technology “shows what is possible” and brings more important information to the front. This kind of information transfer is highly appreciated with 82 percent of respondents rating it positively and 93 percent wanting this function in their own car. LightScape® is rather appreciated for the high resolution and the fact that the color scheme appears a bit more discrete and unobtrusive from perception. It is also considered as having no “real” depth (“fake” 3D effects).

Figure 14: Evaluation of 3D effects
4 Conclusion

As described above, consumers are willing to appreciate and value 3D if it offers them a real benefit (like warning them more efficiently of dangers or making them aware of important things that happen in their vehicle). If done right, 3D can thus add to quality and high tech appearance of a vehicle interior and leverage the image of an automaker. Given the choice between rendered 3D images and “real” depth, consumers are undecided. There are two groups, the one that likes 3D to be more unobtrusive and is still a little reluctant to “embrace” 3D fully and those, who love the feeling of “depth”. For the first group, the 3D renderings offered a great 3D effect without being “too much”. Especially the great resolution that is possible adds tremendously to the quality perception of the cluster and acceptance among consumers in both groups. Those who embrace 3D fully and see the advantages of bringing information from back to front to raise awareness clearly prefer the two-layer approach that gives a more “natural” and “real” impression of 3D. Both methods are a good way for 3D representation, the multi-layer approach is considered as more technological sophisticated and innovative (image gain) if the blurredness of the second layer can be overcome as with the second generation Multi-Layer cluster technology. This combines high resolution / quality perception (as no blurredness and good resolution on both images) with preferred 3D effects.

5 Literature References


6  Authors

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As human-machine interaction (HMI) and technical design manager in Visteon’s European design experience group, Dr. Alexander van Laack is responsible for developing strategies for the use of specialized, automotive-related HMI concepts. In his role, he leads driving simulated user experience research initiatives and is responsible for HMI and user experience concept implementation.

Dr. van Laack has more than eight years of automotive experience.

He previously held a position as research engineer at Ford Research and Advanced Engineering developing methodologies to measure user experience and quality perception of interiors and HMIs.

Dr. van Laack has a master’s degree in business administration and engineering, as well as a PhD in engineering, from the RWTH University of Aachen in Germany.

Judy Blessing

Judy Blessing brings 18 years of research experience to her manager position in market and trends research. Her in-depth knowledge of all research methodologies allow her to apply the proper testing and analysis to showcase Visteon’s automotive intellect to external customers and industry affiliates. Judy holds a German University Diploma degree in Marketing/Market Research from the Fachhochschule Pforzheim, Germany.

Judy Blessing has more than eleven years of automotive experience, investigating topics like consumer perceived quality, user experience, usability and advanced product research.

She previously held positions as researcher in different technology companies and research institutes, measuring consumer reactions to innovative products.
Ruddy Cittadini

As senior studio engineer in Visteon’s European design experience department, Ruddy Cittadini is responsible for the research and understanding of new technologies, and for the development and creation of physical prototypes.

With nine years of experience in the automotive industry, Ruddy Cittadini specializes in perceived quality, packaging, use of new technologies and prototype realization.

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About Visteon

Visteon is a global company that designs, engineers and manufactures innovative cockpit electronics products and connected car solutions for most of the world’s major vehicle manufacturers. Visteon is a leading provider of instrument clusters, head-up displays, information displays, infotainment, audio systems, telematics and SmartCore™ cockpit domain controllers. Visteon also supplies embedded multimedia and smartphone connectivity software solutions to the global automotive industry. Headquartered in Van Buren Township, Michigan, Visteon has approximately 10,000 employees at more than 40 facilities in 18 countries. Visteon had sales of $3.25 billion in 2015. Learn more at www.visteon.com.