IWG LITERATURE

UPDATE, CONCLUSIONS AND RECOMMENDATIONS

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IWG Literature

INTRODUCTION

With the introduction of more advanced and larger image sized, 2D HUD systems, new opportunities arise for displaying content more dynamically and immersive as well as displaying more content in general. We see systems using Augmented Reality (AR) that enable dynamic content are seen more and more and indicate a shift from just standard and statically displayed content (such as speed) to additional moving content (content highlight moving hazards) over a larger part of the windscreen.

Care has to be taken to provide information to the driver on such displays. This information typically is located in or around the line of sight of the driver. Newer HUDs also tend to facilitate a larger field of view (FoV), with a potential to block the driver's line of sight even more. For example, a larger display area can also mask a larger part of the environment with incorrectly designed, and behaving, content. Incorporating the human factor at an early stage in the design process can bring benefits to how the features are used, and when and where they ideally should be effective (in terms of location).

OEM's are now releasing more and more 'Augmented Reality'-like systems with larger FoVs to be able to show information more intuitively on the positive side (e.g. navigation), but on the negative side a lot more content can be placed in a larger area facilitating other features at the same time. This in turn will have implications on the driver perception, in particular on the attention and demand aspects and how fast drivers respond to events that happen in the real world.

The goal of this literature working group is to provide insights in how to structure the available information, select the relevant ones and translate that science in an understanding of how to work with (and implement) the information to aid the formation of new proposals.

The main research question is: How can this information benefit the safety of the driver?

While investigating potential topics (discussed in earlier sessions) and having shared and presented a few scientific articles, we can conclude there is a large amount of literature available around various topics related to HUD, but it is a real challenge to extract concrete requirements and their parameters which delays the information stream to support this proposal. While it is good to inform the various members in this area of R125, there can't be done a lot more than this at this stage, but what can we do with the literature in a more effective way and achieve a higher, more effective, impact?

EXAMPLE 1: VISUAL DEMAND PER LOCATION

Question: What is a safe user experience?

User experience is priority for an OEM, it is key to differentiation and consists of many aspects in its definition of UX that the OEM is responsible for. For example a good user experience could mean that the vehicle is capable of providing you with intuitive, adaptable information that takes your individual needs into account. An important part of that is design, the way how things look and feel. Another is ease of use.

For our group, safety is key and is also one of the main pillars of a good user experience. Safety is something we can translate into numbers in order to create our requirements. For example, a task time reduction can translate seconds into reduced stopping distance.

How Long Can a Driver Look? Exploring Time Thresholds to Evaluate Head-up Display Imagery

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EXAMPLE 1: VISUAL DEMAND PER LOCATION

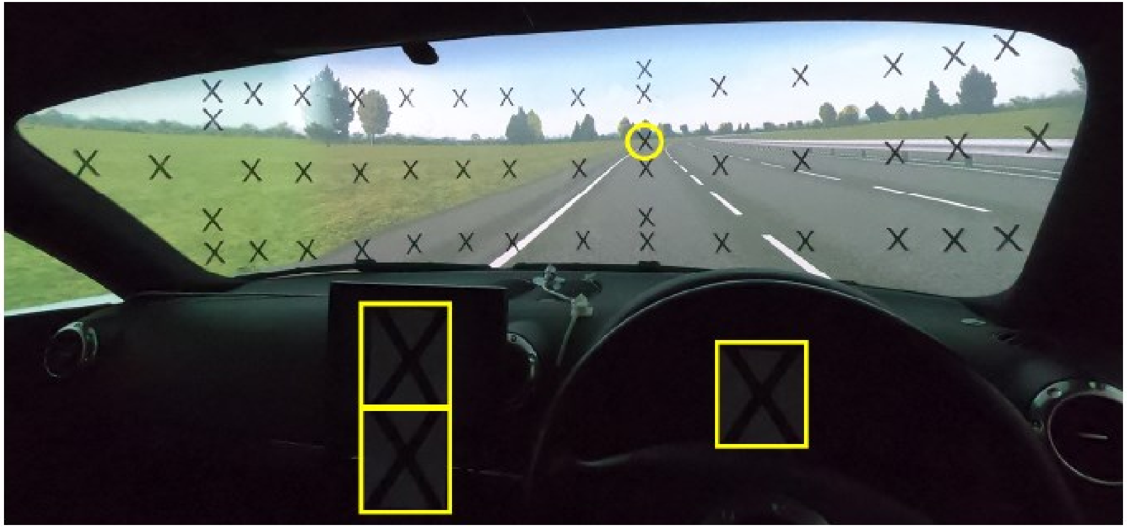

Figure 1: The 'X's indicate all 51 task positions. The yellow circle over the road environment denotes the task which was placed approximately over the lead vehicle. The yellow boxes are included to highlight the HDD positions.

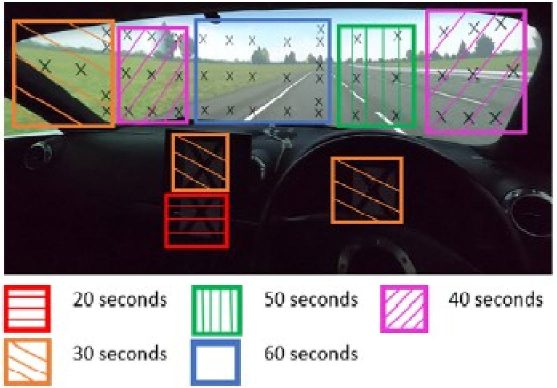

Figure 3: Task lengths for each position.

When presenting a visual detection task at different eccentricities, when does driving performance become unacceptable and how many seconds into the task does it first occur? N=60 participants

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EXAMPLE 1: VISUAL DEMAND PER LOCATION

Lateral

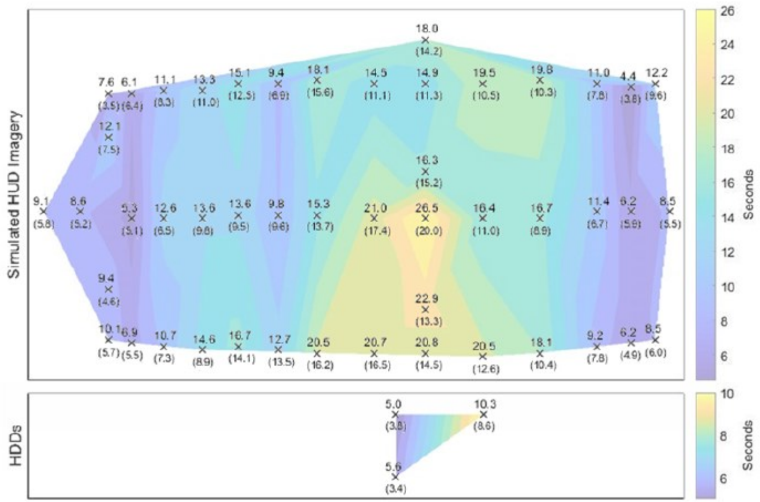

Figure 5: The mean time (in seconds) into the task where the participant's vehicle first exceeds the lane boundary (standard deviation presented in brackets). Each X indicates a display position. The results are positioned to reflect the locations outlined in Figure 1.

Longitudinal

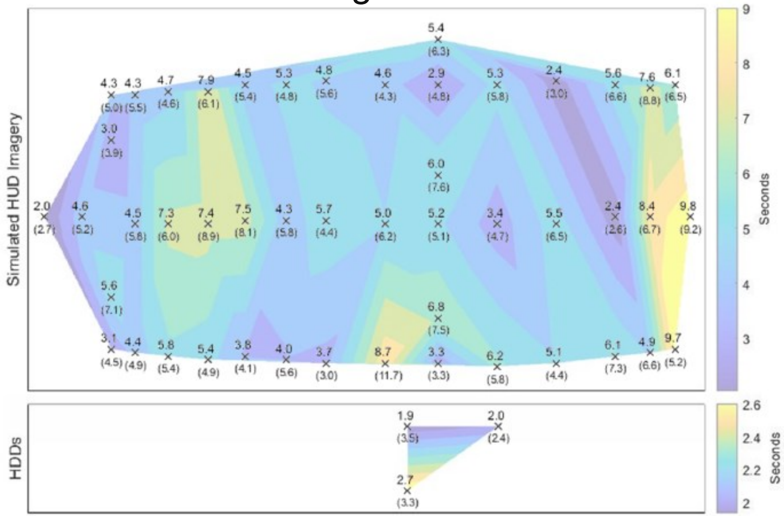

Figure 7: The mean time into the task (in seconds) where the TTC first goes under 1.5 seconds (standard deviation presented in brackets). Each X indicates a display position. The results are positioned to reflect the locations outlined in Figure 1

When presenting a visual detection task at different eccentricities, when does driving performance become unacceptable and how many seconds into the task does it first occur?

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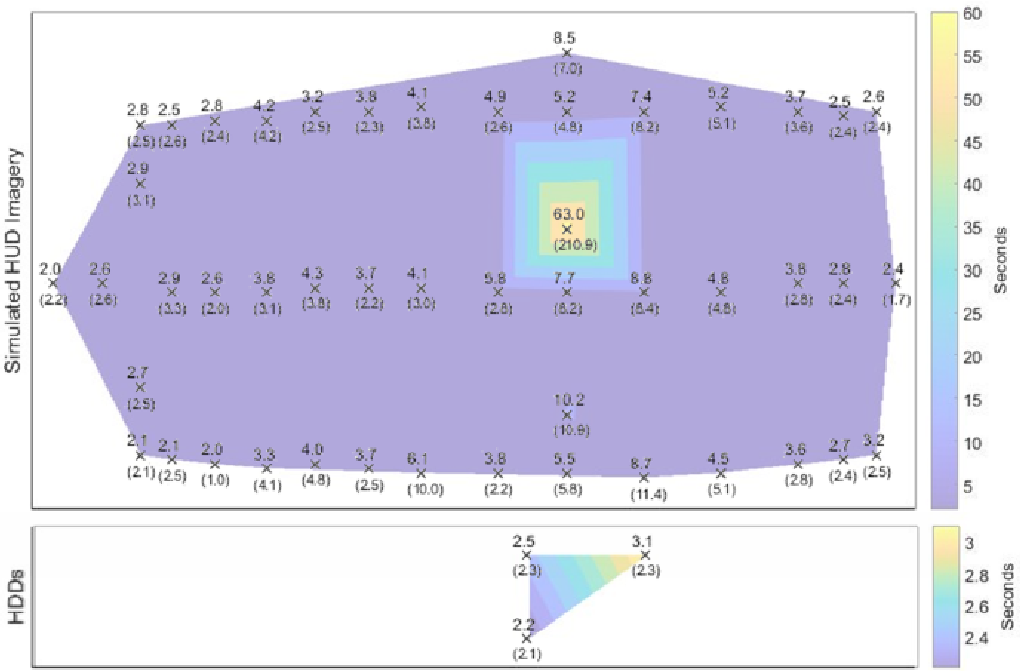
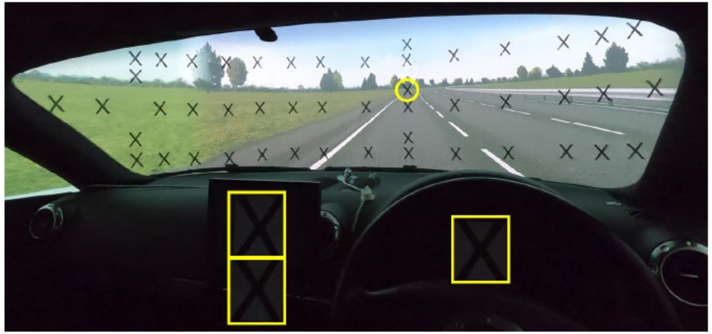
EXAMPLE 1: VISUAL DEMAND PER LOCATION





If presenting information at higher eccentricities cause negative dynamic driving task implications, should this information be prohibited or should vehicle capabilities e.g. ADAS features assist the driver in remaining safe vehicle control?

Figure 8: The participants' perspective on how long (in seconds) it would be acceptable to look towards each position (standard deviation presented in brackets). Each X indicates a display position. The results are positioned to reflect the locations outlined in Figure 1

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EXAMPLE 1: VISUAL DEMAND PER LOCATION

5 CONCLUSIONS

Further work is required to fully develop new criteria for HUD evaluation and assessment. However, according to the present measures, the present time criteria guidelines [21, 22] based on in-vehicle HDDs, may be needlessly restrictive when applied to HUD imagery. Regarding design implications, the results presented here suggest that HUD imagery could be more visually demanding and/or incur longer glances from drivers without degrading driving performance, as would likely occur with HDDs. The lateral driving performance results indicate that positioning imagery at a low eccentricity may enhance this effect, although this position may lead to obscuration of road elements, which will always be a critical design consideration of HUDs [5]. However, the longitudinal measure time thresholds show no clear pattern which would indicate such positioning. The participant perspective results demonstrate that some drivers may be willing to look to HUD imagery for extended lengths of time. Further work is still required to evaluate how long a driver can glance towards a range of different HUD images before other visual driving tasks and other driving performance measures are impacted.

- Research needs further work to develop new criteria for HUD evaluation and assessment
- Content design (OEM responsible) can be more visually demanding and incur longer glances without degrading driving performance (likely occurs with HDD)
- Research impacts OEM’s design considerations
- Research could lead to redefined criteria guidelines (current NHTSA are restrictive as mentioned in article)
- To get to this point reliably, the experiment needs to be repeated under more controlled, standardised and agreed conditions

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EXAMPLE 2: ACCOMMODATION

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Ergonomics. 2010 July ; 53(7): 892–903. doi:10.1080/00140139.2010.489968.

Effects of Age on Dynamic Accommodation

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Abstract

Visual accommodation plays a critical role in one's visual perception and activities of daily living. Age-related accommodation loss poses an increased risk to older adults' safety and independence. Although extensive effort has been made towards understanding the effect of age on steady-state accommodation, dynamic aspects of accommodation is still unknown. A study was therefore conducted to investigate age-related dynamic accommodative characteristics utilizing a modified autorefractor. Ten individuals from each of three age groups (i.e., younger group: 20 to 29 years old, middle-aged group: 40 to 49 years old, and older group: 60 to 69 years old) were recruited and their dynamic accommodation responses were examined. The laboratory experiment was designed to assess dynamic accommodation associated with an abrupt change from a constant far target (400 cm, 50 cd/m^2) to a near target (70 cm, 100 cd/m^2 or 20 cd/m^2), which aimed to simulate car dashboard reading behavior while driving. The results of the study indicated that age and target intensity both had a significant impact on dynamic accommodation. These effects were attributed to both the age-related physiological limitation of the eye as well as to central neural processing delay. A method of measuring dynamic accommodation and the implications of the study are discussed.

Accommodation is the ability of the eye to automatically change its focus from one distance to that of another (via the lens).

- View and monitor the driving environment
- Focus from information on cluster (speed) to real environment
- Focus from information on HUD (VID = 2.5-10m) to real environment

Focus on the effects of age on visual perception as it relates to dynamic visual accommodation.

Due to ageing, the eye lens hardens and the tension of the muscles loosens as well as slower transmission of brain activity.

- It takes longer to focus on presented information such as vehicle/driving information
- It also takes longer to respond e.g. hazard in real environment

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2908311/pdf/nihms212458.pdf

IWG Literature

EXAMPLE 2: ACCOMMODATION

Generally, light transmits external stimuli that trigger the accommodation process. To investigate dynamic accommodation both the effects of age and light need to be taken into account.

The study investigated the effects of age on this dynamic accommodation under different lighting conditions.

It was hypothesized that the advancing of age and varying light intensity of the visual target would lead to the change of one’s dynamic accommodative performance due to accommodation related physiological limitations of the aging eye as well as central neural processing delay.

30 participants, three age groups (20-29, 40-49, 60-69)

Accommodation tested with a mirror machine (see right)

Near target and far target distance based on normal range of the focal point from a driver’s point of view to the dashboard (0.7m) and the environment without focusing on infinity

A constant far target was presented at a fixed light intensity (50 cd/m2)
A near target was presented in two different light intensities (100cd/m2 and 20cd/m2)

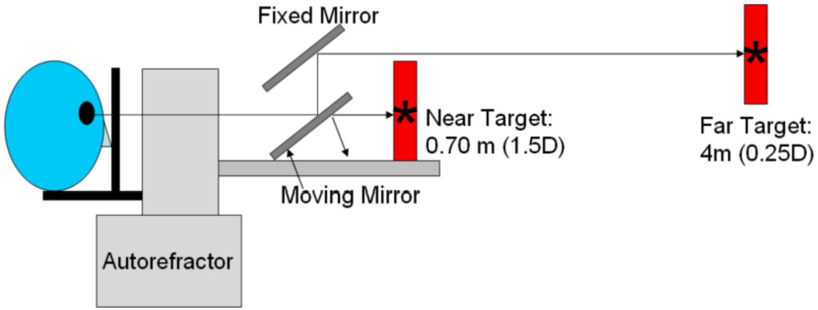


Figure 1.
The mirror machine

IWG Literature

EXAMPLE 2: ACCOMMODATION

Three age groups tested against two light intensities while accommodating from a far target to a near to simulate viewing the road scene to reading information from a cluster

Older adults (60-69) show the biggest delay in time to start and finish accommodation with a lower speed of accommodation compared to the other groups. This can be traced back to not only physiological causes (hardening of the lens), but also neurological (delayed processing time).

Results of each dynamic accommodative characteristic by target intensity and age group (mean ± standard deviation)

Target Intensity/ Age Group		MOA (Diopter)	RT (ms)	RTI (ms/m)	PV (Diopter/sec)
Bright	Young	1.271 ± 0.138	224 ± 30	318 ± 41	1.878 ± 0.625
	Middle	1.239 ± 0.121	350 ± 40	356 ± 34	1.127 ± 0.658
	Old	0.244 ± 0.121	423 ± 55	438 ± 107	0.550 ± 0.273
Dark	Young	1.003 ± 0.171	252.304 ± 38.252	369 ± 39	1.568 ± 0.541
	Middle	0.771 ± 0.167	411.235 ± 48.038	421 ± 41	0.752 ± 0.412
	Old	0.165 ± 0.086	521.390 ± 59.509	442 ± 89	0.374 ± 0.198

What can be understood from the effect of light is that content displayed with a certain light intensity, or even colour (pay attention to how colours blend in the background), can result in slower accommodation time due to the (reduced) sensitivity of the eye due to ageing.

Future study will further explore the accommodative performances of near-to-far target acquisition similar to when a driver accommodates from looking at the dashboard to reading a distant target (e.g., a road sign or nearby traffic). In this sense, realistic targets and proper levels of target intensity must first be discovered.

IWG Literature

EXAMPLE 2: ACCOMMODATION

Other studies presented previously:

Two studies (Inuzuka, Osumi and Shinkai, 1991; Kato, Ito, Shima, Imaizumi and Shibata, 1992) assessed age effects on recognition time at virtual image distances from 1 to 5 meters. Although recognition times were always higher for older drivers, recognition times began to increase at virtual image distances closer than 2.5m. Virtual image distances greater than 2.5 meters appeared to meet the needs of older drivers. Although not measured, this effect is attributed to the increased latency to make accommodative adjustments.

Another study (Charissis et.al) found similar results in a stereoscopic VR simulation testing various visibility conditions, where participants reported discomfort with focusing difficulties at distances of only 0.7m. Changing the HUD focal distance to 2.5m resulted in significant reported improvements. Switching to further focal distances (5m) further improved reported comfort. It can be concluded that users generally preferred a longer focal distance to reduce refocusing strain on the eyes.

Various conditions influence the outcome

- Content used
- Simulator vs real world
- Participant sample
- Testing methods and procedures

Inzuka, Y., Osumi, Y., and Shinkai, H. (1991). Visibility of head up display for automobiles. ***Proceedings of the 35th Annual Meeting of the Human Factors Society, 1574-1578.***

Kato, H., Ito, H., Shima, J., Imaizumi, M. & Shibata, H. (1992) Development of hologram head-up display (SAE Technical Report Paper No. 920600). Warrendale, PA: Society of Automotive Engineers.

Simulation V.Charissis, M. Naef: Evaluation of Prototype Automotive Head-Up Display Interface: Testing Driver's Focusing Ability through a VR Simulation

IWG Literature

EXAMPLE 2: ACCOMMODATION

Although this experiment does not give us direct answers to questions such as:
- How far should information be displayed for FVA?
- What are the brightness levels an FVA needs to facilitate?
- How long does it take to react on the presented information in a FVA?

It does give us an indication of how this can be tested and measured, and that there are no fixed levels due to interpersonal differences.

With standardised tests and procedures we can understand differences between individuals, and their range.
- In terms of accommodation, a difference of 100ms additional processing time for displayed content at a velocity of 100 km/h means 2.78 metres for an older driver (notice that in dark conditions the older vs younger group difference is 2.5x longer)
- This is an objective number that can be used to understand thresholds and limitations, and therefore contribute to safety in an objective way
- Using a standardised test still gives the OEM freedom to choose their display system and design their content
- Agreed thresholds (perhaps per user age group for this application) could then be met
- Provides better control over safety in FVA, or future, regulation

IWG Literature

SUMMARY EXTERNAL PRESENTATION

To further support literature findings and feedback to the IWG, additional expert knowledge was sourced to highlight the current challenges within various aspects of the scope mentioned in some of the slides before. Nayara Faria from Virginia Tech has presented a really good overview of assessing automotive AR from a human factors perspective.

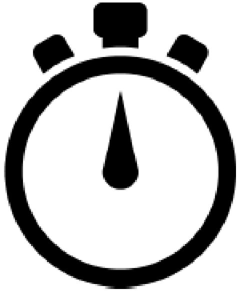
If AR is fundamentally different…

What does this mean for design and **evaluation**?

COGENT

Traditional Measures for User Interfaces?

Primary Task Performance



Time on Task

Accuracy / Errors

*But often AR is NOT the primary task. AR **supports** the primary task.*

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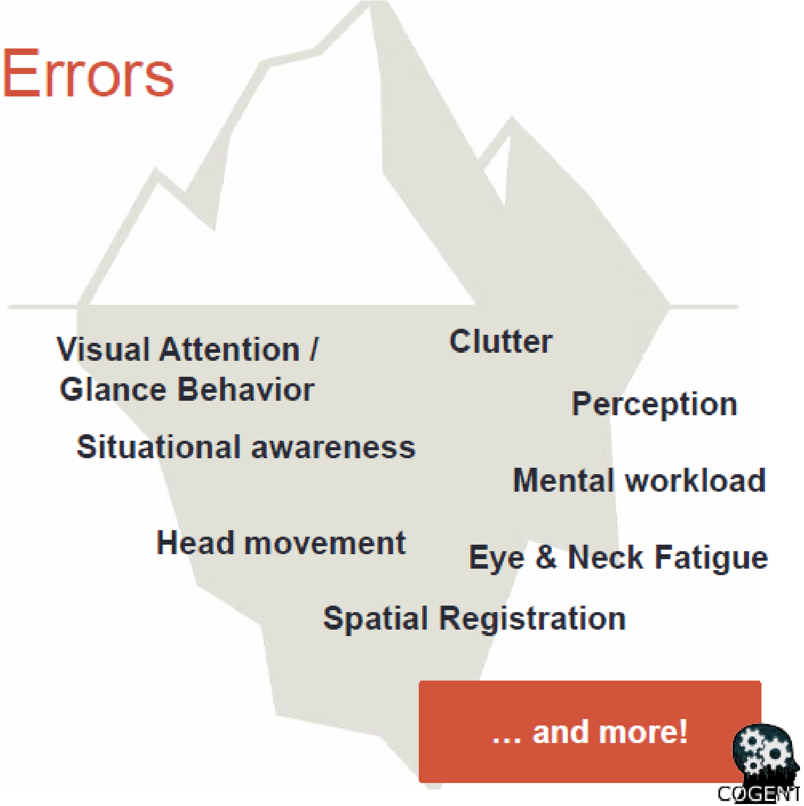
IWG Literature
SUMMARY EXTERNAL PRESENTATION

Beyond Time on Task & Errors

Performance on AR tasks is important,
…but only a small part of the bigger picture



Limits of Glance-Based Visual Attention Measures

HUD vs **HDD**

HUD use resulted in

- **increased** visual attention towards **display** (longer glances)
- evidence of **driving behavior benefits** (better vehicle control)

MI Smith, *Informing Design of In-Vehicle Augmented Reality Head-Up Displays and Methods for Assessment*. Virginia Tech, 2018
Smith, Missie, Joseph L. Gabbard, and Christian Conley. "Head-Up vs. Head-Down Displays: Examining Traditional Methods of Display Assessment While Driving." Procee[...] of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications. ACM, 2016.

COGEN

What does this mean?

- Assumptions about glance inconsistent
  - Suggesting HUDs are bad
- Data doesn't support 100 car study results
  - Longer off-road glances don't negatively impact driving behaviors
- Glance and vehicle control measures □ different results

- **EGDS More likely to fail HUDs**

EGDS methods for assessing visual distraction for driving need to be **reassessed** and **updated** to account for AR HUDs

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TL;DR

- Augmented reality in vehicles will be a fundamentally new driving experience where drivers **must** still attend to **both** the road and information provided by the display
  - **Perfect environment for dangerous and distracting interfaces**

- But **we currently do not know** how to effectively design and evaluate user interfaces in this space.

- Without new methods, researchers and practitioners are left to base user interface design and assessment on current understanding of traditional in-vehicle information systems.

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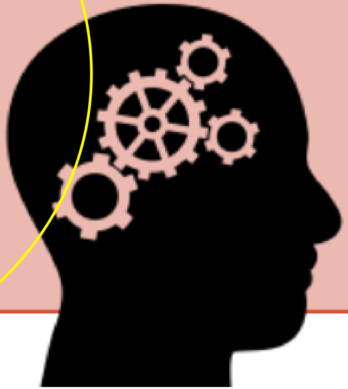
SUMMARY EXTERNAL PRESENTATION

Perception

- Registration
- Depth Perception
- Focus Distance
- Color Blending
- Visual Acuity
- Accommodation



Attention

- Cognitive Tunnelling
- Inattentional Blindness
- Clutter
- Occlusion
- Over-Reliance
- Context Switching
- Situation Awareness

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IWG Literature

CONCLUSION AND RECOMMENDATIONS

An IWG literature has been formed to understand how literature can support and add to the formation of the new proposal. Various scientific articles have been investigated to understand the scope and impact on this regulation from a human factor point of view. It can be concluded that literature can only provide information up to a certain extent.

Although many of these articles highlight challenges to overcome when it concerns the interaction between human and technology, concrete information that can be turned into requirements and guidelines is lacking due to various factors.

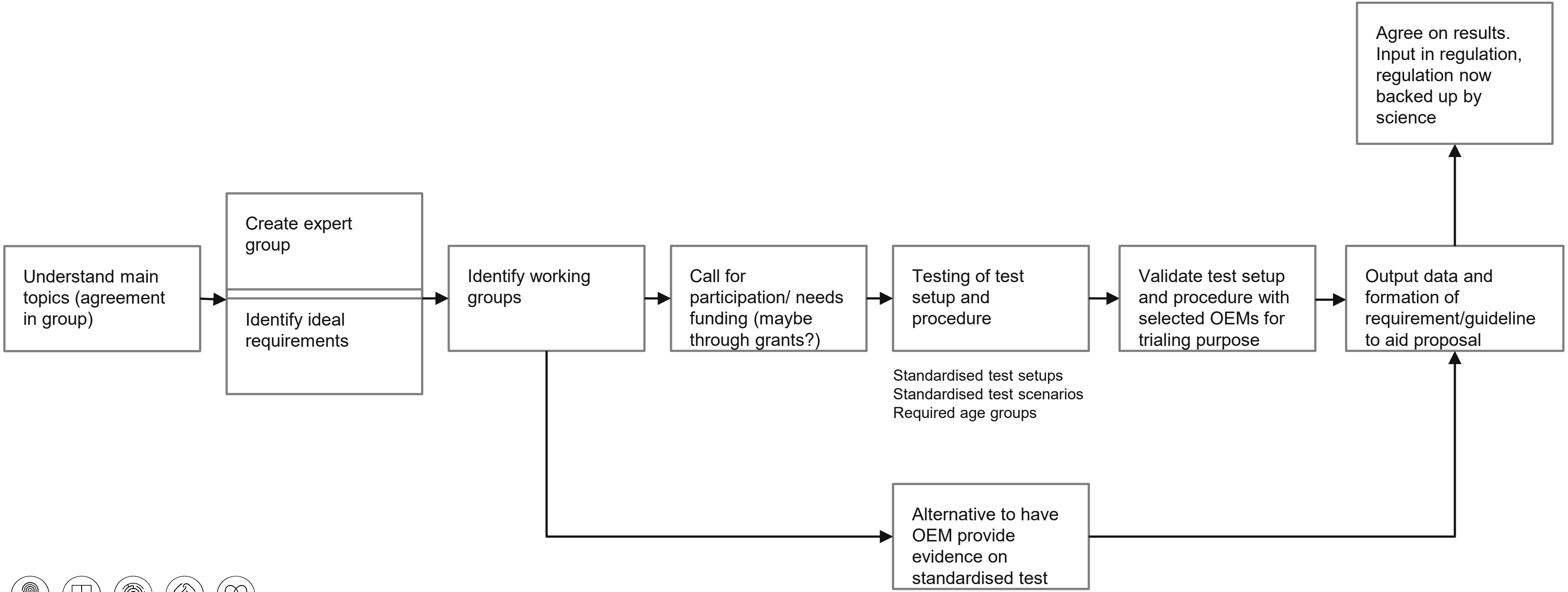
A solution is to introduce global standardised tests for evaluation starting from the perception part of human factors.

- This doesn’t control or impact content design by an OEM directly
- It provides inclusion of various user groups tested against agreed scenarios and methods that can be standardised
- It bridges the gap from literature to applied test for the generation of global requirements/guidelines
- A pilot trial should be carried out to understand whether this approach could be effective e.g. using the example of accommodation
- IWG will need expert representatives (from universities?) or other institutions to enhance and protect the quality of outcomes

IWG Literature

RECOMMENDED NEXT STEP

It is recommended to initiate a working group with experts (academic input is needed) to start working on standardised tests and procedures



Upcoming trend of AR glasses in driver position

2017

VentureBeat

Security ⌄ | Data Infrastructure ⌄ | Automation ⌄ | Enterprise A

Guest

AR smart glasses will become standard issue with self-driving cars

2020

Volvo Cars "ultimate driving simulator" uses latest gaming technology to develop safer cars

Nov 19, 2020 | ID: 275036

Using cutting-edge technology from the real-time 3D development platform Unity and mixed reality experts Varjo, the simulator involves driving a real car on real roads. It combines life-like, high definition 3D graphics, an augmented reality headset, and a full-body Teslasuit that provides haptic feedback from a virtual world, while also monitoring bodily reactions.

2022

VRSCOUT

News

The HoloLens 2 AR Headset Can Now Be Used While Driving

May 9, 2022 • by Kyle Melnick

"We think mixed reality information is the most intuitive information we could provide to enhance our customers' user experience," said Dr. Andro Kleen, head of the data science team at Volkswagen Group Innovation in an official **blog post**. *"Because what you see there, and what you need to process, is very close to what humans normally see and process. It's not so abstract."*