Towards Safe Encounters between Pedestrians and Autonomous Driverless Vehicles: Comparing Adults and Children's Perceptions of External Human Machine Interface Design Features

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ABSTRACT

Recent developments in autonomous vehicle technologies have raised questions about how to achieve efficient communication between pedestrians and autonomous vehicles. External Human Machine Interfaces (eHMI) have been proposed as one mechanism for making pedestrians aware of the intentions of driverless vehicles. Children are especially vulnerable in traffic, yet few studies have addressed how to accommodate young pedestrians. We therefore conducted a study soliciting the reactions of 10 children (7-15 years old) and 10 adults as a control (20-30 years old) on eHMI design concepts proposed in the literature. In the first phase of the experiment participants were shown different eHMI concepts though a set of static and animated images, while the second phase subjected the participants to an immerse virtual reality experience of three different eHMIs. The results indicate that both children and adults preferred text-based interfaces. The results also suggest that children are more accepting of eHMIs than adults.

CCS CONCEPTS

• **Human-centered computing** → Visualization; Visualization techniques.

KEYWORDS

eHMI, Autonomous cars, Pedestrians, Design for children, Traffic, Safety

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1 INTRODUCTION

Self-driving features are becoming increasingly common in cars. The Society of Automotive Engineering (SAE) classifies autonomous cars according to 6 levels, ranging from 0 (No Driving Automation), to 5 (Full Driving Automation) [32]. Most cars developed today include capabilities at level 1 or 2. At the same time some manufacturers such as Aurora Innovation have announced plans to produce cars at level 4 this year [19]. Recent technological developments have triggered important questions related to the security of pedestrians in their meeting with increasingly driverless vehicles. One line of inquiry that has received some attention among researchers involves improving the communication between pedestrians and autonomous cars so that autonomous cars more effectively can relay their intentions to pedestrians and cyclists. Cyclists and pedestrians need to be able to understand and fully trust information from an autonomous car. Trust is a key prerequisite to achieve wider acceptance of self-driving technology.

External Human Machine Interfaces (eHMIs) have been suggested as a possible way to facilitate the communication between autonomous cars and pedestrians [3]. An eHMI is typically attached to some exterior part of the car such as the front bumper, roof, or doors. Suggestions documented in the literature include light strips, symbols, text, and holographic projections, ghost driver protocols [23], slow pulsing light bands [13], full car body visualizations [31], fluid motion visualization [12], and 360 degree visualizations [34]. We therefore conducted an experiment to further explore such proposals by soliciting user feedback on a selection of eHMI concepts. This study focused on children as this comparatively speaking appears to be an understudied cohort in previous work.

2 BACKGROUND

Vehicle-pedestrian communication is an important topic to examine as it is paramount to ensure safety for all road users [25]. The interaction between the driver and the pedestrian allows both parties to coordinate their actions. To make crossing decisions pedestrians typically obtain information either through vehicle cues (speed, distance), or non-vehicle cues (eye contact, hand gestures, facial expressions, etc.). Non-vehicle cues such as a driver's gaze and gestures are therefore instrumental for a pedestrian to understand whether he has been noticed. With the introduction of self-driving cars, this interaction is no longer possible due to the lack of an active driver in the front seat. Additionally, it is demanding to develop car technology that can recognize non-verbal pedestrian cues. It is claimed that it can take many years to develop self-driving technology capable of recognizing non-verbal cues from pedestrians [19].

Children have been shown to exhibit different traffic behavior than adults [17]. This makes children more vulnerable in the traffic [14]. According to the World Health Organization around 186,300 children under the age of 18 die from traffic accidents every year. It is thus important to ensure that eHMIs also are effective for child pedestrians. In one study [6] the researchers first examined the views of children relating to the identification of an autonomous vehicle through a brainstorming and drawing session. Next, they investigated which type of signals children understood most through an interactive questionnaire. The results of their study indicated that children should be aware of the autonomy of an autonomous vehicle, and that the use of known traffic signs improved their understanding.

In another study [9] the researchers did include both children and adults for gaining insight to the differences between the two groups. The authors concluded that children were more hasty and likely to take bigger risks when interacting with an autonomous vehicle than adults. They were also found to be over-reliant on the features of the eHMI even when misinterpreting the display. Haimerl et al. [15] addressed eHMIs in the context of users with intellectual disabilities.

A recent review of the literature [26] showed that most studies related to pedestrian-AV communication showed a clear benefit of having an external interface present in the vehicle. Furthermore, the authors concluded that there was a lack of standardized interface evaluation procedures.

Several studies have explored the preferred type of interface. Results by [22] indicated that conventional signals such as lights and beeps were preferred over text-based messages and speech. In contrast, [5] found that participants more accurately responded to a text-based design as opposed to other modalities including lights, smileys, and projections. In an earlier study [4] the same research group developed a novel interface incorporating eyes on a car. Their study indicated that the pedestrians made the correct crossing decision more quickly when this interface was applied. They claimed that pedestrians felt safer crossing a street if the approaching car had eyes looking at them.

The designs described by Stadler et al. [33] were pictorial. In addition, the study incorporated the use of VR in the experiments. Stadler et al. pointed out VR allows for safe testing of prototypes in a controlled environment thereby avoiding exposing participants to dangerous traffic situations. Moreover, [26] commented that VR studies provide added realism through immersion. Immersion can also be achieved with panorama viewers [27]. Of the 13 related papers identified, 7 utilized VR in the experiments. Other relevant iHMI issues include how a vehicle can simultaneously communicate with multiple pedestrians in its vicinity [36], factors affecting pedestrians crossing decisions [8], and how pedestrians react to contradictory information [20].

3 METHOD

3.1 Experimental design

The study consisted of two parts. In the first part participants were presented with image material visualizing various ideas of eHMIs in vehicles including smileys, eyes, text, lights, and projections (see Dey et al. [10] for a taxonomy of eHMI interfaces). The text prompts included "walk" and "don't walk". A total of 10 images were shown to the participants. Some of the images were static and others were brief animations (gif). The images were taken from various publications (described in previous sections) as well as concepts developed by Mercedes and Nissan. The images were presented on the display of a Personal Computer. Examples of images used are shown in Figure 1.

For the second part of our study the participants were shown a video through a Virtual Reality headset. We reused the video created by De Clercq et al. [7]. This video shows three different eHMI designs on different cars driving down a street. The cars are observed from the pedestrian's point of view. To focus the study, the video was cut to 2 minutes and 51 seconds.

3.2 Participants

A total of 20 participants were recruited. The participants included 10 children and 10 adults. The group of children (4 boys and 6 girls) were in the range of 7-15 years with a mean age of 10.2 years. The children were convenience-sampled through friends and family with parental consent. The 10 adults were recruited at the authors' university. They were in the range of 20-30 years with a mean age of 25.6 years (7 female and 3 male).

3.3 Equipment

The equipment included a 13-inch Macbook Air personal computer, a Trust GXT 720 Virtual Reality headset for 6 inch smartphones, and an audio recording device (Apple iPhone Xs audio recorder).

3.4 Pilot test

A pilot test was conducted to train the facilitators, and to validate the feasibility of the experimental procedure. Two questions were changed as these were difficult to understand. In addition, the pilot revealed a need to trim the length of the video.

3.5 Procedure

The participants were given a verbal introduction to the topic and information about the procedure. The participants were invited to ask questions. All participants gave their consent to participate and were informed of their right to withdraw at any time. In addition, the guardians of the children also gave their consent for the children to participate. No personal information was collected except the audio recordings of the adult participants. The audio recordings were immediately deleted after the subsequent review session as described in our data handling plan. The data handling plan was designed according to the institutional privacy and ethics regulations. Note that no audio recordings were made of the children for their protection. Their responses were transcribed on-the-fly to guarantee absolute anonymity.

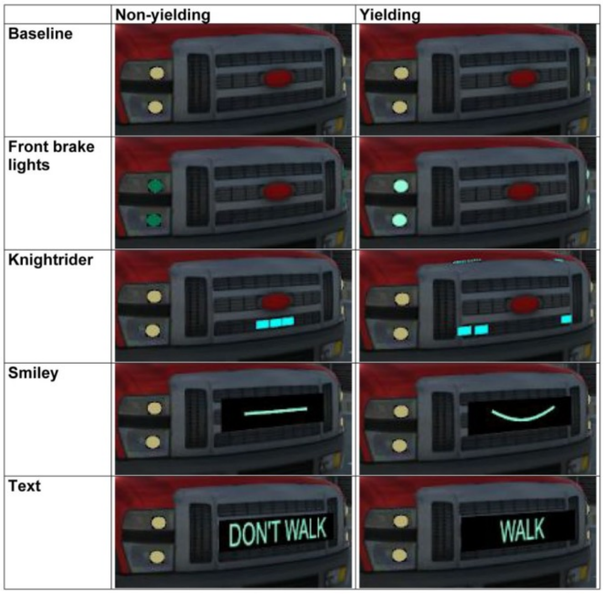

Figure 1: "From top to bottom: (1) baseline, (2) front brake lights, (3) Knightrider (in the yielding state, the bar moved from left to right, from the perspective of the participant), (4) smiley, and (5) text" by De Clercq et al. [7] is licensed under CC BY 4.0.

Using the arrow keys the participants were able to decide the duration of each content-slide, as well as freely cycle back and forth between individual slides as they wished. Having seen the material, the participants were given a questionnaire containing five questions. Each question comprised a 5-point Likert scale. Thereafter, the participants were asked four open-ended questions related to the material.

In the VR part of the study the video was played twice to the child participants to ensure that the child participants had a sufficient understanding of the experiment. First, the video was played in fast-forward mode (2x speed) with the facilitator simultaneously explaining the scenario. Afterwards, the participants watched the video at regular speed through VR glasses. After having watched the video the participants were asked 10 questions related to the video and one question probing potential perceived sense of dizziness. Also, in this part the adults' responses were recorded while the children's responses were transcribed on-the-fly.

Throughout the entire process the facilitator guided the child participants through both sets of questionnaires (both open and closed questions), ensuring that they had a satisfactory understanding of each question giving additional explanations as needed. The adult participants completed the questionnaire without assistance from the facilitator. Both phases were conducted during the same session eliminating the need to link session data [29]. The experiments were conducted in a Norwegian cultural context.

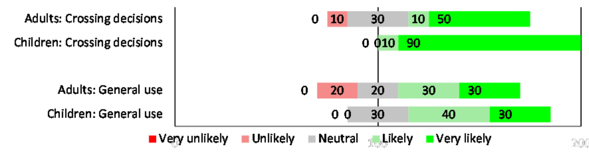

Figure 2: Perceived likelihood of eHMI adaptation (%).

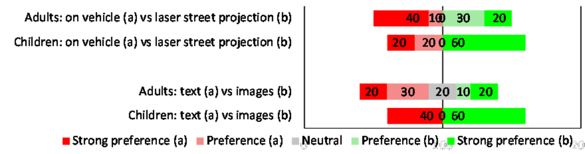

Figure 3: Diverging stacked bar-graph showing information preferences (%).

4 RESULTS

4.1 Image viewing session

Figure 2 shows that, regarding general use, 70 percent of children and 60 percent of adults regarded eHMI adaptation as either likely or very likely. 60 percent of adults and 100 percent of children determined that the specific adaptation of eHMIs in crossing decisions was either likely or very likely. A Mann-Whitney test reported that the difference in crossing decisions of children and adults were statistically different (W = 28.0, p = .044, ES = -0.44). Note that the effect size (ES) is given by the rank biserial correlation.

Figure 3 shows that a majority (60 %) of children preferred images, and a majority (50 %) of adults preferred text, although this difference was not statistically different. Next, a majority (60 %) of children preferred information to be projected on the ground, while the adult responses are more divided between preferences for ground projection and on-vehicle displays. These differences across the groups were not statistically different.

The interviews revealed that the adults were positive about the prospect of eHMIs but had some reservations regarding the need for such interfaces. Parking was mentioned as a specific circumstance by both adults and children. One participant stated: "When the car wants to park it can start reducing the speed and use some kind of an alarm." Situations where multiple cars are parked near houses were also pointed out as a relevant use-case for eHMIs.

Some children suggested that eHMIs could be useful in situations related to law enforcement. One child described how a police-car eHMI can tell people to "stay there!", or "don't leave the car!" When asked about the modality preferences several adults and children indicated that a combination of text and an image would be helpful especially if a pedestrian is unfamiliar with the language of the text.

4.2 Immersed viewing session

Figure 4 shows that text was most preferred by both groups, while adults preferred the "nightrider" interface over the smiley interface,

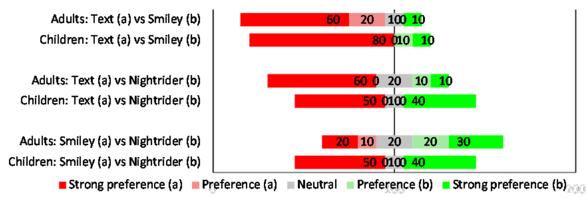

Figure 4: Modality preferences (%).

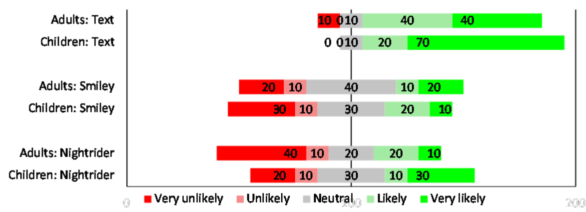

Figure 5: Perceived interface clarity (%).

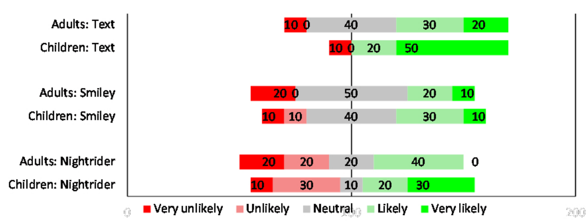

Figure 6: Perceived interface safety (%).

while a narrow majority of children preferred smiley over nightrider. No statistical differences were detected between the groups.
Figure 5 shows that text was perceived as the clearest interface among both groups (90 percent of adult participants and 80 percent of child participants), while the perceived clarity of nightrider and smiley were more divided.
Figure 6 shows that most participants (in both groups) perceived text to be the safest interface (70 % of adult participants and 50 % of child participants). This was followed by nightrider. Both groups found smileys to be the least safe option. The adults were slightly more critical of the safety of nightrider and smiley compared to children, although no significant difference was detected.

The interviews confirmed the questionnaire results as most adults reported that they preferred the text option. One participant explicitly pointed out that the text option was the clearest one to understand. Also, most of the children confirmed that they preferred the text option. One child stated: "I liked text. Because you get more out of it. With images, you don't understand as much."

When asked about possible improvements some adults asked for clearer text. Several respondents in both groups suggested that it could be useful with a combination of text and visualizations.

One child pointed out that not all people will understand the English text (the language used in the examples) if they speak other languages, and that the text would have to be translated. Several children also suggested the use of sounds.

5 DISCUSSION

Both children and adults thought that eHMIs are likely in the future, however children were more positive regarding such systems for making road crossing decisions. One possible explanation of this observation could be that adults have more experience with traffic and hence see more problems with alternative solutions. Children, however, are more open minded and less influenced by prior experiences. Our observations do not agree with those in previous studies which did not find any statistical differences between adults and children regarding general eHMI use [6, 9]. However, it must be noted that the experimental conditions in the current study were not equivalent to those in [6, 9] which also may explain the different results.

One possible explanation for the children's preference for information projection on the street as opposed to the adult preference for on vehicle information display, could be that children are affected by the "coolness" factor of laser projection, while the adults are more pragmatic in their assessments.

One practical issue not addressed by the participants is that of readability and contrast [16] as an eHMI display needs to be readable under very different light conditions from pitch black to strong sunlight. With strong sunlight certain display technologies may not provide sufficient contrast to be visually perceivable [18, 28, 30]. However, results of experiments indicate that eHMI users prefer cyan [11].

Regarding preferences of information conveyed via text versus images the adults were divided with a slight majority preferring text, while most of the children exhibited a preference for images although this difference was not significant. Many studies of text versus images have been conducted. Some claim that visual learning has a more enduring impression on memory [21]. Moreover, it is believed that the recognition of low complexity images (such as traffic signs) is faster than reading text, and rapid response times are essential in the traffic. Simple images consume less display real estate compared to text and are therefore often utilized with small form factor devices such as smartphones. However, another argument in favor of text is that imagery such as icons needs to be learned [1]. For example, it is required that drivers pass a theoretical test demonstrating that they are familiar with all the traffic signs and visual symbols, while pedestrians do not necessarily have undergone the same training – especially children. During the first interview both adult and child participants stated that the most preferred method of eHMIs would be a combination of text and images. Several studies argue for the benefits of such redundant coding [24].

After the VR experience most adults and children asserted that they preferred text over the smiley and knightrider visualizations. Interestingly, the children's responses to VR experience were different from the image viewing experience. One possible explanation to this difference could be that the children were first mesmerized by the coolness factor of the projections displayed in the fixed images, while when presented with a more realistic scenario in the VR session they made a more realistic assessment of the implications of the designs. It is also possible that the facilitator unintentionally affected the responses during the demonstration section resulting in an observational bias.

A combination of text and images appears to be a promising compromise as it includes the necessary information, while keeping children engaged. In a practical setting, the size of the display also needs to be taken into consideration as both text and images consume more display real estate and could cause information overload.

The interviews indicate several use-cases where eHMIs may increase the sense of security for both adults and children. One such example is children running out from behind parked cars on to the road. Some children suggested that sounds, such as talking cards, could be useful with eHMIs. This idea has also been explored by Merat et al. [22] who observed positive responses to the inclusion of familiar sounds in eHMIs. Nonetheless, there are challenges related to the introduction of sounds in eHMIs due to the sheer number of cars one might encounter in a typical large city. Specifically, children may find it particularly difficult to identify where the sound is coming from in a high traffic environment such as a busy and noisy intersection.

5.1 Limitations

One should be careful in placing too much weight on the results presented herein as the sample size was relatively small, yet within the limits of what is the norm in studies of Human-Computer Interaction [2]. Furthermore, it is also challenging to include children in such experiments due to typical short concentration spans. Moreover, as some explanation was occasionally needed it is possible that the facilitator has influenced participants with leading questions resulting in bias. This is especially a challenge in the VR session as the children received a training session, while the adults did not.

Two adult participants removed their eyeglasses during the VR session. Although both individuals clarified that they could see comfortably, it is possible that their vision has been affected. The experiments were conducted in a Norwegian-culture traffic context and the results may not necessarily reflect perceptions in other cultures [18, 35].

6 CONCLUSION

We have contrasted children's and adults' preferences for information presented on eHMIs in traffic situations involving autonomous vehicles through simulations using innovative visualization concepts presented in the literature. The results indicate that both adults and children prefer text as the main method for communicating the intent of an autonomous vehicle. Children were found to be more accepting of eHMIs in crossing decisions as compared to adults. The results are based on a small sample size and a limited set of visualization concepts. Moreover, the ecological validity of the simulation-based experiment has its limitations. Further study is needed to find safe and trusted methods for communication between especially young pedestrians and semi- or fully autonomous vehicles to prevent accidents and injury to humans.

REFERENCES

[1] Gerd Berget and Frode Eika Sandnes. 2015. On the understandability of public domain icons: effects of gender and age. Universal Access in Human-Computer Interaction. Access to Today's Technologies: 9th International Conference, UAHCI 2015, Held as Part of HCI International 2015, Los Angeles, CA, USA, August 2-7, 2015, Proceedings, Part I 9. Springer International Publishing, 2015.

[2] Kelly Caine. 2016. Local Standards for Sample Size at CHI. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16). Association for Computing Machinery, New York, NY, USA, 981–992. https://doi.org/10.1145/2858036.2858498

[3] Juan Carmona, Carlos Guindel, Fernando Garcia, and Arturo de la Escalera. 2021. eHMI: Review and guidelines for deployment on autonomous vehicles. Sensors 21.9 (2021): 2912.

[4] Chia-Ming Chang, Koki Toda, Daisuke Sakamoto, and Takeo Igarashi. 2017. Eyes on a Car: an Interface Design for Communication between an Autonomous Car and a Pedestrian. In Proceedings of the 9th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '17). Association for Computing Machinery, New York, NY, USA, 65–73. https://doi.org/10.1145/3122986.3122989

[5] Chia-Ming Chang, Koki Toda, Takeo Igarashi, Masahiro Miyata, and Yasuhiro Kobayashi. 2018. A Video-based Study Comparing Communication Modalities between an Autonomous Car and a Pedestrian. In Adjunct Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '18). Association for Computing Machinery, New York, NY, USA, 104–109. https://doi.org/10.1145/3239092.3265950

[6] Vicky Charisi, Azra Habibovic, Jonas Andersson, Jamy Li, and Vanessa Evers. 2017. Children's Views on Identification and Intention Communication of Self-driving Vehicles. In Proceedings of the 2017 Conference on Interaction Design and Children (IDC '17). Association for Computing Machinery, New York, NY, USA, 399–404. https://doi.org/10.1145/3078072.3084300

[7] Koen De Clercq, Andre Dietrich, Juan Pablo Núñez Velasco, Joost de Winter, and Riender Happee. 2019. External human-machine interfaces on automated vehicles: Effects on pedestrian crossing decisions. Human factors 61.8 (2019): 1353-1370.

[8] Mark Colley, Elvedin Bajrovic, and Enrico Rukzio. 2022. Effects of Pedestrian Behavior, Time Pressure, and Repeated Exposure on Crossing Decisions in Front of Automated Vehicles Equipped with External Communication. In Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22). Association for Computing Machinery, New York, NY, USA, Article 367, 1–11. https://doi.org/10.1145/3491102.3517571

[9] Shuchisnigdha Deb, Daniel W. Carruth, Muztaba Fuad, Laura M. Stanley, and Darren Frey. 2019. Comparison of child and adult pedestrian perspectives of external features on autonomous vehicles using virtual reality experiment. Advances in Human Factors of Transportation: Proceedings of the AHFE 2019 International Conference on Human Factors in Transportation, July 24-28, 2019, Washington DC, USA 10. Springer International Publishing, 2020.

[10] Debargha Dey, Azra Habibovic, Andreas Löcken, Philipp Wintersberger, Bastian Pfleging, Andreas Riener, Marieke Martens, and Jacques Terken. 2020. Taming the eHMI jungle: A classification taxonomy to guide, compare, and assess the design principles of automated vehicles' external human-machine interfaces. Transportation Research Interdisciplinary Perspectives 7 (2020): 100174.

[11] Debargha Dey, Azra Habibovic, Bastian Pfleging, Marieke Martens, and Jacques Terken. 2020. Color and Animation Preferences for a Light Band eHMI in Interactions Between Automated Vehicles and Pedestrians. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20). Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3313831.3376325

[12] Debargha Dey, Brent Temmink, Daan Sonnemans, Karijn Den Teuling, Lotte van Berkel, and Bastian Pfleging. 2021. FlowMotion: Exploring the Intuitiveness of Fluid Motion Based Communication in eHMI Design for Vehicle-Pedestrian Communication. In 13th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '21 Adjunct). Association for Computing Machinery, New York, NY, USA, 128–131. https://doi.org/10.1145/3473682.3480279

[13] Debargha Dey, Azra Habibovic, Melanie Berger, Devanshi Bansal, Raymond H. Cuijpers, and Marieke Martens. 2022. Investigating the Need for Explicit Communication of Non-Yielding Intent through a Slow-Pulsing Light Band (SPLB) eHMI in AV-Pedestrian Interaction. In Proceedings of the 14th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '22). Association for Computing Machinery, New York, NY, USA, 307–318. https://doi.org/10.1145/3543174.3546086

[14] Victoria Gitelman, Sharon Levi, Roby Carmel, Anna Korchatov, and Shalom Hakkert. 2019. Exploring patterns of child pedestrian behaviors at urban intersections. Accident Analysis & Prevention 122 (2019): 36-47.

[15] Mathias Haimerl, Mark Colley, and Andreas Riener. 2022. Evaluation of Common External Communication Concepts of Automated Vehicles for People With Intellectual Disabilities. Proc. ACM Hum.-Comput. Interact. 6, MHCI, Article 182 (September 2022), 19 pages. https://doi.org/10.1145/3546717

[16] Fredrik Hansen, Josef Jan Krivan, and Frode Eika Sandnes. 2019. Still Not Readable? An Interactive Tool for Recommending Color Pairs with Sufficient

Contrast based on Existing Visual Designs. In Proceedings of the 21st International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '19). Association for Computing Machinery, New York, NY, USA, 636–638. https://doi.org/10.1145/3308561.3354585
[17] Irena Ištoka Otković, Aleksandra Deluka-Tiblja, Sanja Surdonja, and Tiziana Campisi. 2021. Development of models for children—pedestrian crossing speed at signalized crosswalks. Sustainability 13.2 (2021): 777.
[18] Philip Joisten, Ziyu Liu, Nina Theobald, Andreas Webler, and Bettina Abendroth. 2021. Communication of Automated Vehicles and Pedestrian Groups: An Intercultural Study on Pedestrians' Street Crossing Decisions. In Proceedings of Mensch und Computer 2021 (MuC '21). Association for Computing Machinery, New York, NY, USA, 49–53. https://doi.org/10.1145/3473856.3474004
[19] Keith Kirkpatrick. 2022. Still waiting for self-driving cars. Commun. ACM 65, 4 (April 2022), 12–14. https://doi.org/10.1145/3516517t
[20] Merle Lau, Meike Jipp, and Michael Oehl. 2021. Investigating the Interplay between eHMI and dHMI for Automated Buses: How Do Contradictory Signals Influence a Pedestrian's Willingness to Cross? In 13th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '21 Adjunct). Association for Computing Machinery, New York, NY, USA, 152–155. https://doi.org/10.1145/3473682.3480284
[21] Katie Lindner, Greta Blosser, and Kris Cunigan. 2009. Visual versus auditory learning and memory recall performance on short-term versus long-term tests. Modern Psychological Studies 15.1 (2009): 6.
[22] Natasha Merat, Tyron Louw, Ruth Madigan, Marc Wilbrink, and Anna Schieben. 2018. What externally presented information do VRUs require when interacting with fully Automated Road Transport Systems in shared space?. Accident Analysis & Prevention 118 (2018): 244-252.
[23] Dylan Moore, G. Ella Strack, Rebecca Currano, and David Sirkin. 2019. Visualizing implicit eHMI for autonomous vehicles. In Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications: Adjunct Proceedings (AutomotiveUI '19). Association for Computing Machinery, New York, NY, USA, 475–477. https://doi.org/10.1145/3349263.3349603
[24] Jane Rosenlund, Enhancing Learning through Visual Supports, https://www.activespeechpathology.com.au/blog/2020/8/31/enhancing-learning-through-visual-supports
[25] Dirk Rothenbücher, Jamy Li, David Sirkin, Brian Mok, and Wendy l. Ju. 2016. Ghost driver: A field study investigating the interaction between pedestrians and driverless vehicles." 2016 25th IEEE international symposium on robot and human interactive communication (RO-MAN). IEEE, 2016.
[26] Alexandros Rouchitsas and Håkan Alm. 2019. External human–machine interfaces for autonomous vehicle-to-pedestrian communication: A review of empirical work. Frontiers in psychology 10 (2019): 2757.
[27] Frode Eika Sandnes. 2016. PanoramaGrid: A Graph Paper Tracing Framework for Sketching 360-degree Immersed Experiences. In Proceedings of the International Working Conference on Advanced Visual Interfaces (AVI '16). Association for Computing Machinery, New York, NY, USA, 342–343. https://doi.org/10.1145/2909132.2926058
[28] Frode Eika Sandnes. 2016. Understanding WCAG2. 0 color contrast requirements through 3D color space visualization. Stud. Health Technol. Inform 229 (2016): 366-375.
[29] Frode Eika Sandnes. 2021. HIDE: Short IDs for Robust and Anonymous Linking of Users Across Multiple Sessions in Small HCI Experiments. In Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems (CHI EA '21). Association for Computing Machinery, New York, NY, USA, Article 326, 1–6. https://doi.org/10.1145/3411763.3451794
[30] Frode Eika Sandnes. 2021. Inverse Color Contrast Checker: Automatically Suggesting Color Adjustments that meet Contrast Requirements on the Web. In Proceedings of the 23rd International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '21). Association for Computing Machinery, New York, NY, USA, Article 72, 1–4. https://doi.org/10.1145/3441852.3476529
[31] Dominik Schlackl, Klemens Weigl, and Andreas Riener. 2020. EHMI visualization on the entire car body: results of a comparative evaluation of concepts for the communication between AVs and manual drivers. In Proceedings of Mensch und Computer 2020 (MuC '20). Association for Computing Machinery, New York, NY, USA, 79–83. https://doi.org/10.1145/3404983.3410011
[32] Society Automotive Engineering International. 2018. Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles." SAE international 4970.724 (2018): 1-5. https://www.sae.org/standards/content/j3016_202104/
[33] Sebastian Stadler, Henriette Cornet, Tatiana Novaes Theoto, and Fritz Frenkler. 2019. A tool, not a toy: Using virtual reality to evaluate the communication between autonomous vehicles and pedestrians. Augmented Reality and Virtual Reality: The Power of AR and VR for Business (2019): 203-216.
[34] Rutger Verstegen, Debargha Dey, and Bastian Pfleging. 2021. CommDisk: A Holistic 360° eHMI Concept to Facilitate Scalable, Unambiguous Interactions between Automated Vehicles and Other Road Users. In 13th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '21 Adjunct). Association for Computing Machinery, New York, NY, USA, 132–136. https://doi.org/10.1145/3473682.3480280
[35] Florian Weber, Ronee Chadowitz, Kathrin Schmidt, Julia Messerschmidt, and Tanja Fuest. 2019. Crossing the Street Across the Globe: A Study on the Effects of eHMI on Pedestrians in the US, Germany and China. HCI in Mobility, Transport, and Automotive Systems: First International Conference, MobiTAS 2019, Held as Part of the 21st HCI International Conference, HCII 2019, Orlando, FL, USA, July 26-31, 2019, Proceedings 21. Springer International Publishing, 2019.
[36] Marc Wilbrink, Manja Nuttelmann, and Michael Oehl. 2021. Scaling up Automated Vehicles' eHMI Communication Designs to Interactions with Multiple Pedestrians – Putting eHMIs to the Test. In 13th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '21 Adjunct). Association for Computing Machinery, New York, NY, USA, 119–122. https://doi.org/10.1145/3473682.3480277