

# Increasing driver awareness through translucency on windshield displays

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# Increasing Driver Awareness Through Translucency on Windshield Displays



**Figure 1:** Concept of translucent road objects: Using large-scale windshield displays and video streams (e.g., from a lead vehicle), the objects around the driver can be made translucent. The idea is that this supports the driver in anticipating for example pedestrians who plan to cross the road.

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## Abstract

When driving a car, important objects (e.g., pedestrians) are often hidden by surrounding vehicles which can delay drivers' reaction times. In this paper we therefore explore how an augmented reality enabled windshield display can improve the drivers' capabilities. By overlaying of what is behind nearby vehicles onto the own windshield, these vehicles can be rendered translucent. In a simulator experiment we evaluate the influence of three levels of opacity on driver and braking behavior. Results indicate a trend of translucency decreasing the required braking time.

## Author Keywords

Windshield displays; translucent cars; augmented reality; driving safety.

## CCS Concepts

•**Human-centered computing** → **Mixed / augmented reality**; *Displays and imagers*; *Interactive systems and tools*; *Interface design prototyping*;

## Introduction

According to the World Health Organization, road accidents are the ninth leading cause of death and will continue to rise if no counteraction is taken [7]. This highlights the need to increase traffic safety. The driver's view is often restricted by other road users or objects (e.g., other cars) which lim-

its the driver's ability to early react to moving pedestrians or bicyclists behind them. Our goal is therefore to explore how this limitation can be reduced through augmented reality (AR) by means of a fully registered windshield display (WSD, [4]), which makes nearby vehicles translucent and, thus, allows the drivers to see what is behind them.

#### *Research Questions and Contribution*

In this paper we explore the influence of making objects translucent through an AR-enabled windshield display on driving behavior. We focus on the relationship between the level of opacity of nearby obstacles (vehicles) and traffic safety and want to find out to what extent traffic safety can be increased by implementing AR-WSDs in vehicles to make other nearby vehicles translucent? To answer this question, the following sub-questions are formulated:

- How does driver reaction time change when making nearby vehicles translucent?
- How does making nearby vehicles translucent affect the feeling of safety for a drive?

#### **Related Work**

Connected cars will be able to share data, potentially enabling windshield displays to show a live feed of what is behind nearby cars on the windshield and thereby having those cars appear translucent. However, until now most in-car augmented reality research focuses on navigational tasks: Car brands such as BMW have already implemented augmented reality driving assistance features and investigated the possible risks involved [6]. Research on the combination of augmented reality, car-to-car communication, and windshield / head-up displays, is still in its infancy and mostly focusing on technical aspects. The technology that our research is based upon is already at an early stage, however today's head-up displays are still relatively small

and limited in capabilities which fatigues drivers [10]. Similarly, car-to-car technology is only taking off slowly.

The idea of making parts of the environment translucent is already around for a few years: Gomes et al. investigated the idea of making the lead vehicle transparent but mainly focused on technical aspects regarding car-to-car communication and generating the correct image [3]. Rameau et al. show the possibility of embedding a live wireless video stream (of the lead vehicle in front of the driver) in the windshield of a car [8]. However, they did not evaluate the influence on driving behavior and safety. In contrast, Tachi et al. investigated the idea of making parts of the driver's own vehicle translucent to reduce blind spots [9], similar to BMW [1]. Yasuda & Ohama instead looked at making the environment translucent with a special focus on walls for instance at intersection [11]. Lindemann & Rigoll investigated subjective perceptual aspects of making parts of the environment translucent [5]. Blankenbach suggests that see-through techniques could improve traffic safety [1], but head-up displays must grow in size to enable this, which happens to be the current trend.

To our knowledge, prior work did not extensively evaluate the impact of combining these technologies on driver behavior and driving safety. As a first step, we want to understand how making the environment translucent affects driving behavior.

#### **Concept**

Similar to Gomes et al. [3], the idea of our concept is to employ the video streams of cameras in the surrounding of the car (connected via Car-to-X communication to other cars and infrastructure) and render them in a way that the content blends into the driver's view on the windshield display. Thus, the driver's view is augmented by overlaying objects

(e.g., the lead vehicle, see Figure 1) with what is behind them. This creates a sense of translucency of these objects, which can be adjusted for instance with regard to the level of translucency. We expect that this helps the driver to anticipate objects which are expected to cross the car's trajectory (e.g., crossing pedestrians) and, thus, helps to reduce reaction time and improve driving safety.

## Experiment

We conducted a controlled within-subject experiment in order to investigate how making the environment translucent helps to decrease the driver's reaction time to events where objects suddenly appear which need to be avoided.

### *Pilot Study*

First, we conducted a pilot study with three external participants to identify potential points for improvement with regard to procedure and measurements. This study focused on the entire procedure: We evaluated aspects related to participant comfort, objective and subjective measurement, along with technical details. We used the feedback from this study to streamline and improve the process of conducting the main experiment.

### *Method and Participants*

In a within-subject experiment, we investigated how three different levels of opacity (independent variable, levels: 10%, 60% and 100%) affect the driver's braking behavior as one indicator of situation awareness. We recruited 20 participants (10 female, 10 male) through local mailing lists and personal invitations. The participants were aged between 18 and 24 years and held a valid drivers license.

### *Apparatus*

We used a static driving simulator developed by Green Dino [2] for our experiment (Figure 2) and prepared three routes, each with at least four and maximum seven situ-

ations where we measured the reaction time to occurring events. At every measuring point we confronted the drivers with a situation in which they had to prevent a collision by braking (e.g., pedestrians crossing, trucks backing up, etc.). On each route the driver experienced a different opacity level of for the surrounding cars (i.e., the cars with in the driver's field of view). Every participant drove each route. While the order of the routes was fixed, we counterbalanced the order of the opacity levels using a Latin Square.

### *Procedure and Setup*

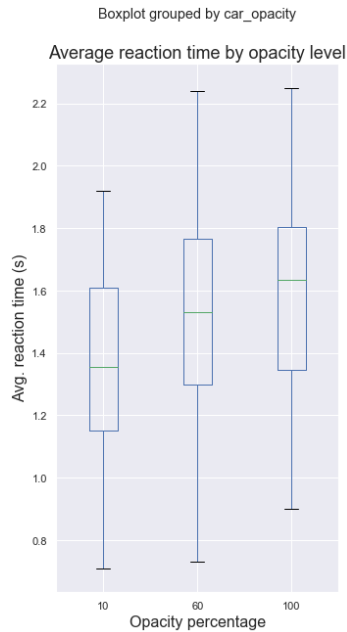
We welcomed the participants in our lab and asked them to fill in a consent form and a basic demographic questionnaire. Next, we introduced the participants to the simulation environment and let them drive for a while to get accustomed to the simulator. For the main part of the experiment, we asked the driver to ride along each of the three different routes (conditions) where we varied the object translucency per route. We balanced the order of the opacity levels using a Latin Square. As dependent variables, after each trajectory driven in the simulator, we asked the participants about their feeling of safety on a five-point Likert scale. In addition, we measured the driver's reaction time. The reaction time was calculated as the time difference between the moment when the braking situation occurred and the moment when the participant started to brake. After the experiment we conducted additional semi-structured interviews about the experiment and the concept itself. Here, we focused on the feeling of safety, the improvement of the experiment and the concept itself. Control variables are gender, age, and drivers licence possession.

## Results

Our preliminary experiment shows that the reaction time slightly decreases with increasing translucency (i.e., with decreasing opacity) of nearby vehicles (Figure 3). We cal-



**Figure 2:** A participant is driving during the experiment.



**Figure 3:** The reaction times decrease with increasing translucency. However, these differences were not significantly different in our preliminary experiment.

culated a one-way repeated measures ANOVA to determine whether there were statistically significant differences in reaction times for the three opacity conditions. There were no outliers and the data was normally distributed, as assessed by box plot inspections and a Shapiro-Wilk test ( $p > .05$ ), respectively. The assumption of sphericity was violated, as assessed by Mauchly's test of sphericity,  $\chi^2 = 435.638$ ,  $p < .001$ . Therefore, we applied a Greenhouse-Geisser correction ( $\epsilon = 0.998$ ). While Figure 3 shows a trend regarding reaction times, the analysis did not elicit statistically significant changes in response times over different opacity levels,  $p = 0.076$ .

Looking at the drivers' feeling of safety, our results indicate a slight increase in safety perception at an opacity level of 60% compared to 10% and 100%. However, the data contains many outliers and is far from being normally distributed.

## Discussion

Our data analysis suggests that the average reaction time slightly decreases as opacity level decreases, but we did not find a significant relation between those two variables. A possible explanation for this is a low opacity might increase the driver's demand by having to focus too much on additional objects in the environment. Since the results from the safety survey during the experiment were widely spread, we cannot draw conclusions from this data. A possible explanation is that the questions were subjective and depended on too many external variables.

### Limitations

We conducted the study in a simulation environment, which may have created a rather unrealistic perception of the concept. As the subjective feedback some participants mentioned to be relatively unaware of the concept. Due

to technical limitations, there was also no possibility to let a lead vehicle drive in front of the participant continuously. This would have yielded to more consistent results since each reaction time measurement would have been directly related to vehicle opacity. Some measuring points were missed, either because of a premature or late braking response. This might be caused by participants focusing mainly on the middle display of the simulator, indicating that it felt unnatural to look at the other screens. The diversity of the 'dangerous' situations was rather low which made participants quickly recognize and anticipate the patterns of 'dangerous' situations, which might have influenced the results. Furthermore participants of the sample were rather young, suggesting that a follow-up experiment should be conducted with a larger variety of participants. We acknowledge that our experiment was a very early exploration beyond technical limitations, of which some already have been explored [3]. For a future (real-world) experiment we suggest to implement a car following situation where the opacity of the lead vehicle can be changed.

## Conclusion & Further work

In this paper we present first insights in how users perceive and react to AR windshield displays which make objects in the environment translucent. With our preliminary study, we gain initial insights in how such a technology affects the driver. While further studies are required to investigate the impact of this approach in the real world, we hope to stimulate a discussion on how to use windshield displays for safety purposes when driving manually by bridging the gap between research on car-to-X communication for increased traffic safety, advanced AR uses for windshield displays, and real-time image processing applications. Combining these relatively new technologies allows for an interesting perspective for future use cases of large-scale windshield displays.

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