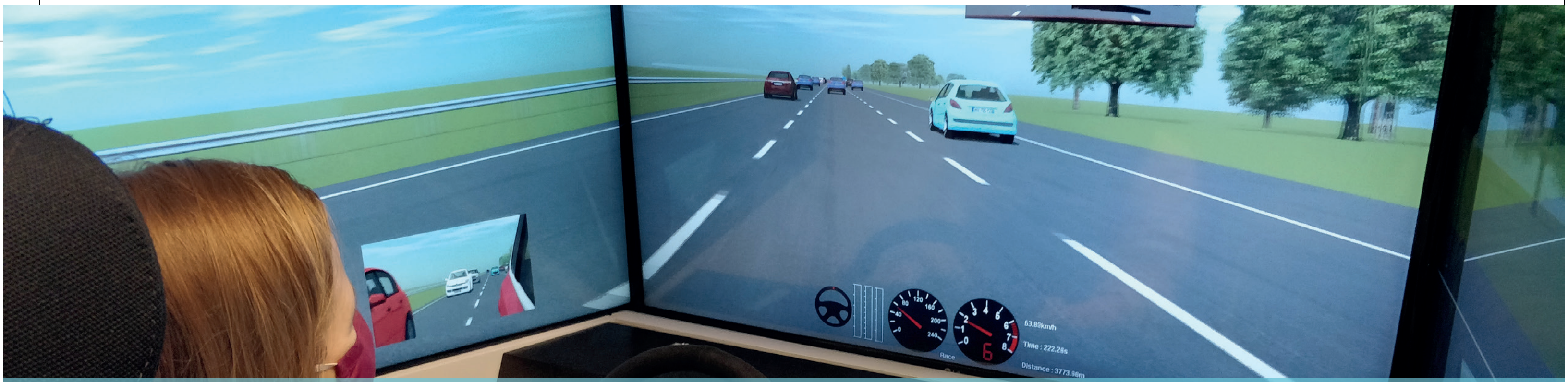

HOW WILL WE DRIVE IN THE FUTURE?

HUMAN DRIVING BEHAVIOUR IN TRAFFIC COMPOSED OF HUMAN-DRIVEN AND AUTOMATED VEHICLES

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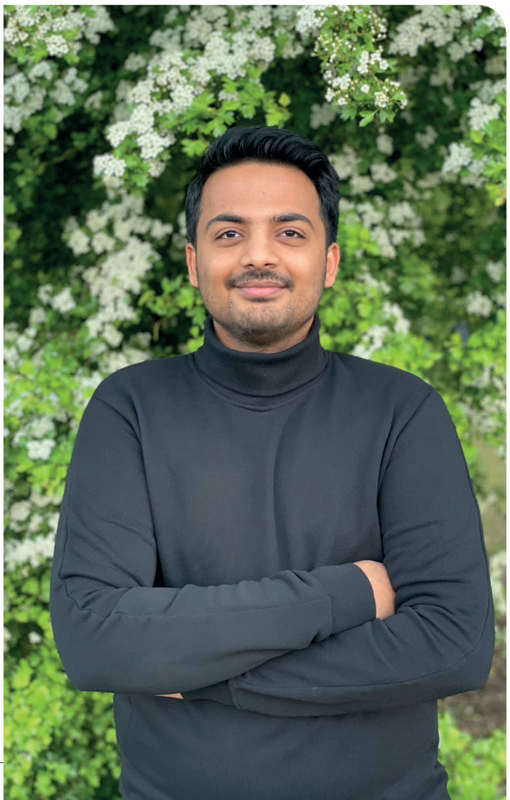
It is the year 2025. You are on the highway, driving your car on a relaxed Sunday afternoon. At a distance further downstream, a strange looking car appears into view. As you approach it from behind, you notice that it has various kinds of cameras and sensors looking at every direction. You drive closer and to your surprise, the driver's seat is empty! It is a self-driving car! You have heard about such cars increasingly driving on public roads, but this is the first time you encountered them closely. How would you respond in such a situation? Would you change your driving behavior? Will you prefer to maintain a large distance from the self-driving car? Perhaps alternatively, if you are the kind of person who highly trusts technology, you might even become more comfortable around this car and dare to drive closer to it. If needed, you may also choose to overtake it and cut in front of it (even a bit too closely, maybe) because you believe that self-driving cars can ensure safe distance and can brake appropriately when needed.



You are not alone. It is possible that several, if not most drivers, change their driving behavior when they drive around self-driving vehicles. In fact, recent virtual and real-world experiments and tests already suggest that human drivers are prone to changing their driving behavior in traffic environments having self-driving vehicles. These changes in behavior are termed as behavioral adaptations. Driving behavioral adaptations affect the safety and efficiency of road traffic. Their effect may be positive or negative, depending on the kind of behavioral adaptation. Of course, we do not need to wait until 2025. Semi-automated vehicles already drive today on public roads. Behavioral adaptations may already be happening today. Road authorities and policymakers, therefore, are concerned about the state of road traffic in the (near) future where automated vehicles (AVs) are expected to be a part of the traffic composition along with human-driven vehicles (HDVs).

SAFETY AND EFFICIENCY OF ROADS OF THE FUTURE

There have been several efforts aiming to predict the state of traffic safety and traffic flow in the future in such mixed (AV and HDVs) traffic situations. This is done with the use of simulations, where a stretch or a network of roads along with mixed traffic are modelled and several scenarios are tested to measure traffic safety and efficiency. Authorities use such prediction studies to help with crucial decisions on road infrastructure policy, and traffic and vehicle regulations. such simulation studies comprise of assumptions that can be explicit and many times implicit. One important aspect in simulations is defining HDV behavior. Most studies use existing mathematical human driving behavior models. However, such models are designed and calibrated for conventional traffic. Most existing studies assume human drivers to either behave in the same way as they do in completely human-driven traffic, or they make assumptions on certain aspects of driving based primarily on expectations. While these approaches are acceptable for making generic forecasting, they are certainly insufficient to drive specific policies and actions by policymakers. It is therefore imperative to specifically understand the driving behavior of HDVs in an automated environment, accurately accounting for the potential behavioral adaptations. My research aims to design and develop mathematical models to define human driving behavior in traffic consisting of both HDVs and AVs, therefore also capturing any potential behavioral adaptations.

BEHAVIORAL ADAPTATIONS

In the context of my research, behavioral adaptation is defined as the changes in driving behavior of human drivers when interacting with AVs in the surrounding traffic as compared to their driving behavior when interacting with conventional (human-driven) vehicles. There is already some evidence in literature that showing the changes in human driving behavior when in mixed traffic environments. It is interesting to see some specific examples. One research finds that human drivers are more comfortable following an AV as compared to following another human-driven car. This is attributed to AVs having less erratic acceleration behavior than HDVs. Another study finds that human drivers start imitating the behavior of the AVs driving alongside. For instance, driving alongside AVs that maintain short headways (gap when following another car) made human drivers also drive with shorter headways. A similar imitating behavior was observed when AVs had longer headways. One other study observed that recognisability of an AV did not have any effect. That is, human drivers responded to the behavior of the AVs rather than visibly identifying them as AVs. Other studies have also observed changing behaviors with respect to lane changes, with adaptations ranging from lower success rate of lane changes to increasing number of lane changes.

CORRELATION VERSUS CAUSATION

Several studies, with the help of experiments, test human driving behavior in different scenarios by varying certain aspects. For example, to study car-following behavior, researchers can increase the headways of AVs in different scenarios and observe the headways maintained by human drivers driving in the presence of such AVs. Suppose it is observed that human drivers start increasing their headways when AVs around them also increase their headways. While this may indicate behavioral adaptation, it may not be sufficient because the underlying causal mechanism is still unknown. A correlation between observed behavior and the specific set-up of the scenario needs to be further investigated. Studying human driving behavior has similarities with the science of human decision-making. Thus, my research also attempts to dive into the cognitive mechanisms underlying human decision making while driving, i.e., how humans perceive and process information, and use it to make driving decisions; all of this specifically while driving in traffic having HDVs and AVs.

PHD PROJECT

At this point in time, I have reviewed existing mathematical models of human driving behavior and am deliberating on how to incorporate factors and mechanisms that become relevant in mixed traffic in existing models. Last year, I conducted a driving simulator study with 115 participants who drove in a virtual environment in mixed traffic. Some of the aspects that I aimed to observe were recognisability of AVs, the behavior of AVs (their level of aggressiveness), characteristics of human drivers (for example, age, gender, driving style) and their trust in technology and AVs. Early results already indicate drivers changing their behavior with respect to AVs' levels of aggressiveness and the age and driving style of the drivers playing an important role in these behavioral adaptations. My future work would involve more experiments and field tests to collect empirical data and to design and calibrate mathematical models to describe human driving behavior in mixed traffic. ■

SAMEN PROJECT

My research is part of the SAMEN project, which aims to study the interactions in future traffic having both AVs and HDVs, and the resulting effects on traffic safety and efficiency. In this project, we work closely with 9 public and industry partners to insights to help ensure roads of the future are safer and smoother. For more information go to: https://www.tudelft.nl/en/ceg/samen/

F.t.t.b.:
Soni, S. (2020). Understanding Behavioural Adaptations of Human Drivers interacting with Automated Vehicles. Master Thesis.
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