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RESEARCH REPORT

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Sven Beiker, PhD

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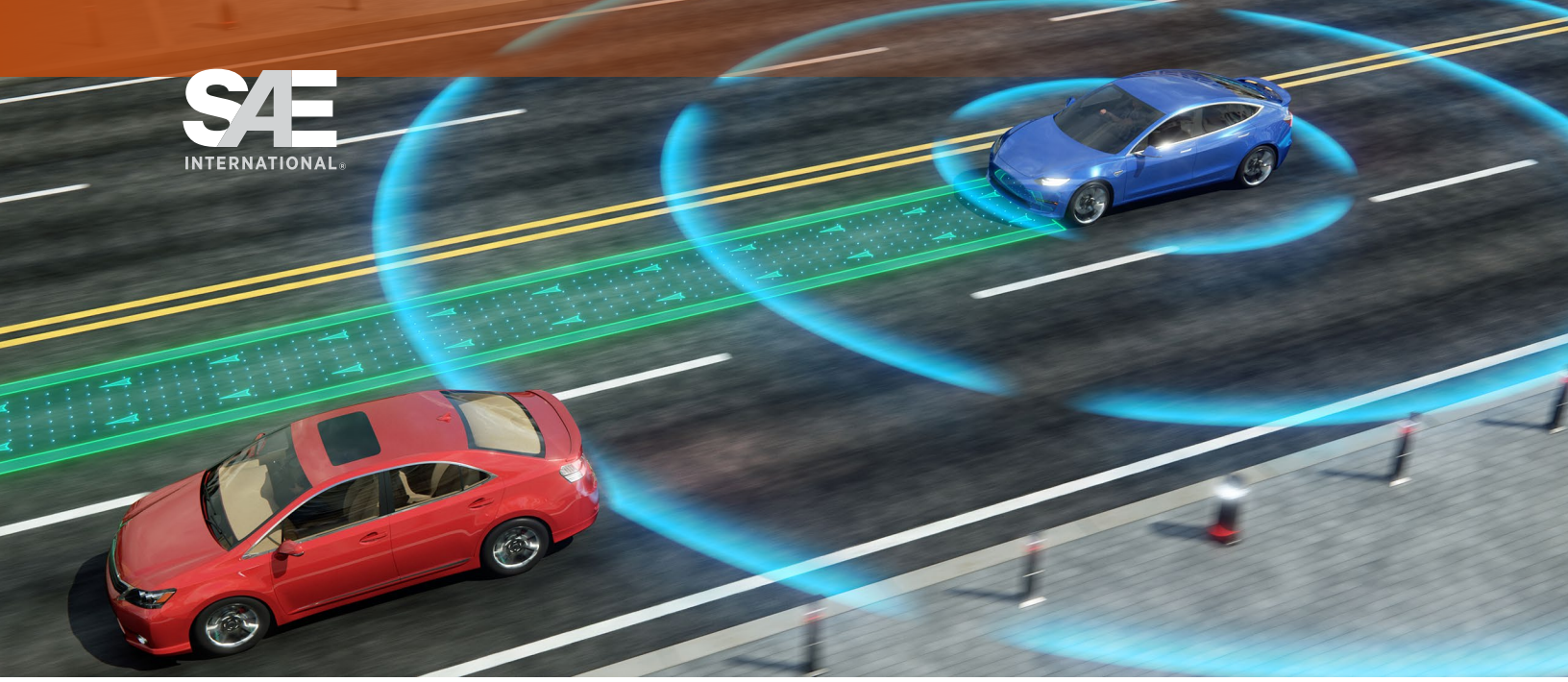
About the Editor

Sven Beiker, PhD, is the Founder and Managing Director of Silicon Valley Mobility, a mobility consulting and advisory firm that specializes in technical diligence, product roadmaps, and business models for mobility topics. The engagements span start-ups, investors, and corporations in the mobility and adjacent industries. In addition, Dr. Beiker is a lecturer at the Graduate School of Business at Stanford University, where he instructs students on strategies for start-ups and corporations in the field of automated, connected, electrified, and shared mobility.

With well over 20 years of experience gained during his tenure at McKinsey & Company, Stanford University, and the BMW Group, Dr. Beiker is dedicated to the future of the automobile and personal mobility. His mission is to improve sustainability, safety, efficiency, and convenience in vehicles and how consumers use them. He combines perspectives from technology, business, policy, and human factors.

Dr. Beiker also serves on advisory boards of several start-ups in the mobility space, as an advisor to the German American Chamber of Commerce in San Francisco, and as an advisor/co-editor to the Lecture Notes in Mobility of Springer Science+Business Media. He is a continuing contributor to the SAE EDGE Research Report series.

contents



Unsettled Issues Regarding Communication of Automated Vehicles with Other Road Users

Abstract

The impending deployment of automated vehicles (AVs) represents a major shift in the traditional approach to ground transportation; its effects will inevitably be felt by parties directly involved with vehicle manufacturing and use (e.g., automotive original equipment manufacturers (OEMs), public transportation systems, heavy goods transportation providers) and those that play roles in the mobility ecosystem (e.g., aftermarket and maintenance industries, infrastructure and planning organizations, automotive insurance providers, marketers, telecommunication companies).

The focus of this SAE EDGE Research Report is to address a topic overlooked by many who choose to view automated driving systems and AVs from a "10,000-foot perspective:" the topic of how AVs will communicate with other road users such as conventional (human-driven) vehicles, bicyclists, and pedestrians while in operation. This unsettled issue requires assessing the spectrum of existing modes of communication—both implicit and explicit, both biological and technological—employed by road users today.

NOTE: SAE EDGE Research Reports are intended to identify and illuminate key issues in emerging, but still unsettled, technologies of interest to the mobility industry. The goal of this report is to stimulate discussion and work in the hope of promoting and speeding resolution of identified issues. SAE EDGE™ Research Reports are not intended to resolve the challenges they identify or close any topic to further scrutiny.

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Introduction

The automation of driving is arguably one of the most intensely discussed topics in industry, academia, regulation, media, and the general public when it comes to the future of mobility and transportation. The overarching goal is to move people and goods more safely and efficiently and potentially at a lower cost. While many concepts have been shown and product announcements have been made, it is still unclear, when and (importantly) where those often called "driverless" vehicles might be deployed. However, while much of this challenge may lie in finding appropriate technology solutions, another important aspect is how such vehicles would—and ultimately will—interact with humans. Those include people inside and outside of the vehicle (i.e., passengers and any other human road users). This report identifies unsettled issues regarding such interactions of a "driverless" vehicle with other human road users. Throughout this report, the term "driverless" refers to the operating state of SAE Level 3 and 4, where a vehicle driver is not required to take control of the automated vehicle (AV) while it is operating in an automated mode [1].

To visualize pertaining aspects, the reader should imagine a scenario where a car approaches a crosswalk that a pedestrian is about to cross. Many people would suggest that "eye contact" is a very important method to communicate intent between those road users to ensure safety, albeit research has shown that it is not as effective as one might think [2]. And still, the question becomes how such intent can be communicated if a vehicle is driverless and eye contact or gestures—and other types of conventional nonverbal communication—are not possible, whether as an actual (or inadvertent) exchange of information or to provide road user reassurance (which also matters).

Much of those pertaining issues regarding external communication for AVs has already been discussed and many concepts have been shown and tested in public. Key aspects of communication challenges have already been identified, sometimes through research and unexpected situations. Those encounters and findings of various groups contribute to an "unsettled" (or "yet to be settled") issue in terms of how human-AV interactions should be designed. While there are groups (such as SAE International standards committees) currently investigating AV interaction solutions, as more AVs are tested, it becomes clear that even more focus regarding those concepts is urgently needed. This is not only to maximize safety and trust of road users toward AVs, but also to test such vehicles under real-world conditions with real-world interactions [3].

Some of the most general and also most debated questions are, for instance, what an AV should actually communicate to whom and in what way. A great deal of research, evaluation, and demonstration has already been conducted in this field, be it in industry, academia, or government, and initial standardization efforts have emerged. However, as appreciated as standardization efforts might be, several experts have started to voice concerns that it might be too early to define what such human-AV interactions should look (or sound) like. There can be a risk that, short of better knowledge, standards that are pushed too early might preclude opportunities to come up with even better solutions.

Many aspects of clarity, efficiency, practicality, and so forth need to be considered at this intersection of technology and psychology as more questions seem to arise the further such work progresses.

Therefore, in context of this SAE EDGE Research Report, a contemporary perspective seems to be in order. What questions are currently debated in this field and which of those require prioritization and standardization? This report seeks to provide clarity concerning the most pressing questions regarding external communication for AVs. This also means that this report does not aim to provide definitive answers. Its inherent purpose is to have practitioners agree on "asking the right questions" and providing directions that ultimately lead to answers.

External Communication for AVs: Motivation

As previously mentioned, a great deal of progress has occurred in the field of AVs. Concept demonstrations, test programs—even public pilots—all contribute to a very rich development environment. The community of forward-thinking researchers, engineers, social scientists, regulators, and others have learned from experience what it means when AVs encounter other road users without predefined rules or practices.

Some of those encounters have led to tragedy, such as a fatal accident in Tempe, AZ, in March 2019 when a pedestrian was fatally struck by an AV tested under human supervision. Whatever the causes and responsibilities were in this case, it is not known if the AV had external communication means beyond that of a conventional vehicle (i.e., it would not indicate whether it "sees" the pedestrian, whether it would let the pedestrian cross the street in front of it, or whether it would stop). Of course, one might argue that conventional vehicles also don't communicate with pedestrians (the drivers do, through the use of horns, turn signals, flashing lights, gestures, etc.), or that this particular AV itself was supposed to be operated or monitored by a human test driver. But still, this case—like many other accidents involving pedestrians—shows that additional external communication from the vehicle might have saved lives. And at the same time, one needs to ask the question if or how it might be possible to communicate information like "I will keep driving ahead" and/or "I don't perceive an object" to the right recipient. Those questions are the motivation for this report.

To expand on that motivation, one only needs to consider the rising numbers of pedestrian fatalities in the United States (US). From 2007 to 2016, they tragically increased from about 4,700 to almost 6,000 [4]. Of course, human error such as speeding, distraction, incapacitation, driving under the