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Public opinion on automated driving: Results of an international questionnaire among 5000 respondents

M. Kyriakidis *, R. Happee, J.C.F. de Winter

Department Biomechanical Engineering, Delft University of Technology, Mekelweg 2, 2628 CD Delft, The Netherlands

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ABSTRACT

This study investigated user acceptance, concerns, and willingness to buy partially, highly, and fully automated vehicles. By means of a 63-question Internet-based survey, we collected 5000 responses from 109 countries (40 countries with at least 25 respondents). We determined cross-national differences, and assessed correlations with personal variables, such as age, gender, and personality traits as measured with a short version of the Big Five Inventory. Results showed that respondents, on average, found manual driving the most enjoyable mode of driving. Responses were diverse: 22% of the respondents did not want to pay more than $0 for a fully automated driving system, whereas 5% indicated they would be willing to pay more than $30,000, and 33% indicated that fully automated driving would be highly enjoyable. 69% of respondents estimated that fully automated driving will reach a 50% market share between now and 2050. Respondents were found to be most concerned about software hacking/misuse, and were also concerned about legal issues and safety. Respondents scoring higher on neuroticism were slightly less comfortable about data transmitting, whereas respondents scoring higher on agreeableness were slightly more comfortable with this. Respondents from more developed countries (in terms of lower accident statistics, higher education, and higher income) were less comfortable with their vehicle transmitting data, with cross-national correlations between $\rho = -0.80$ and $\rho = -0.90$. The present results indicate the major areas of promise and concern among the international public, and could be useful for vehicle developers and other stakeholders.

1. Introduction

Road transport is an essential service in society, but the burden of traffic crashes and pollution is immense. US data show that automobile crashes led to 34,080 fatalities in 2012 (NHTSA, 2013a), where about 90% of the cases were attributed at least in part to driver error (Smith, 2013a). In 2012, the US petroleum use for road transportation was about 11 million barrels per day, which corresponds to approximately 60% of the total US petroleum consumption (Davis, Diegel, & Boundy, 2014). Moreover, the average commuter gets delayed 38 h per year due to traffic congestion (Schrank, Eisele, & Lomax, 2012). European data (European Commission, 2014) show that more than 28,000 people died on EU roads in 2012, and that four times as many people were permanently disabled. The fatality rates in high-income countries have been declining for the past decades, but the fatality rates in the low- and middle-income countries are actually increasing (World Health

* Corresponding author. Tel.: +31 15 27 83573.
E-mail address: m.kyriakidis@tudelft.nl (M. Kyriakidis).

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Organization, 2013). Current trends indicate that road traffic injuries will become the fifth leading cause of death by 2030, with the difference between high- and low-income countries further magnified (World Health Organization, 2013).

Automated driving systems have the potential to resolve these problems by increasing safety on public roads while decreasing traffic congestion, gas emissions, and fuel consumption (Anderson et al., 2014). Different levels of automation have been proposed with different definitions of the technological capabilities and human involvement. The most well-known are provided by BASt (Gasser & Westhoff, 2012), National Highway Traffic Safety Administration (NHTSA, 2013b) and SAE (On-Road Automated Vehicle Standards Committee, 2014), as shown in Table 1.

All three classifications start from the manual driving mode, where the driver executes all driving tasks, and each moves toward the fully automated driving mode, where no manual interaction is involved. In theory, fully automated driving (assuming "perfect" sensing of the environment, "perfect" decision-making algorithms, and "perfect" actuators) is the optimal solution in terms of safety, congestion, and emissions.

While automated driving systems have great potential to improve safety and efficiency of road transportation, many challenges have yet to be addressed, including the public perception, legal liability issues, and the security and control of the systems (Howard & Dai, 2014). The public opinion on automated driving determines the extent to which people will accept and purchase such systems, and it will define the way that car manufacturers will have to develop and market automated vehicles, as well as the necessary tax and insurance policies, and any investments in infrastructure.

1.1. Previous surveys on automated driving

Various researchers have previously conducted surveys on automated driving systems (Begg, 2014; Casley, Jardim, & Quartulli, 2013; Howard & Dai, 2014; KPMG., 2013; Payre, Cestac, & Delhomme, 2014; Power, 2012; Power, 2013; Schoettle & Sivak, 2014a, 2014b; Sommer, 2013). An early study by Underwood (1992) explored which intelligent vehicle technology would likely be deployed in North America. Results among 55 experts in the field indicated that, among the listed control systems, adaptive cruise control (ACC) would be the most popular feature. The experts expressed the opinion that the ACC would be installed in 5% of the vehicles by 2004, while it would reach 50% of market penetration by 2015. Automated braking would follow with a lag of 6 to 10 years, while lane-keeping assist would be introduced at an even later date. In addition, it was projected that by 2002 both frontal collision warning systems and back-up warning systems (e.g., blind spot detection) would reach 5% market penetration. Comparing those predictions with today's status, it can be claimed that the predictions were fairly accurate: ACC has been introduced in 1995 and is now available as an option by most car manufacturers (yet it has not reached the predicted 50% market share; Kyriakidis, van de Weijer, van Arem, & Happee, 2015). Advanced Emergency Braking (AEB), Forward Collision Warning Systems (FCWS) and Lane Keeping Systems (LKS) are also currently available on the market. Underwood (1992) found that the experts also believed that fully automated driving ("automatic chauffeuring with auto lane changing & merging") would achieve a 5% market share only between 2040 and 2075, and would *never* achieve a 50% market share.

Also before the turn of the twenty-first century, Bekiaris et al. (1996) studied user needs and their acceptance of technological systems that could assist drivers who are in an impaired state. A questionnaire was distributed to 407 people in nine European countries, and results showed that although most users would welcome being warned by a supportive assistance system, they expressed "a definite rejection of automatic driving".

Recent studies (Begg, 2014; Casley et al., 2013; Howard & Dai, 2014; KPMG, 2013; Missel, 2014; Payre et al., 2014; Power, 2012; Power, 2013; Schoettle & Sivak, 2014a, 2014b; Sommer, 2013; Youngs, 2014) display a somewhat more positive picture of the public opinion on fully automated driving. Nevertheless, people also indicate a non-negligible level of reluctance. Specifically, the global market research company Power and Associates have recently conducted various surveys on the willingness of US vehicle owners to purchase automotive emerging technologies. Their first study (Power, 2012), conducted in March 2012, surveyed 17,400 vehicle owners regarding their intention to purchase an autonomous driving mode, defined as "a feature that allows the vehicle to take control of acceleration, braking and steering, without any human interaction". 37% of the respondents answered that they "would definitely" or "would probably" be interested in purchasing such technology. However, the positive responses dropped to 20% after the respondents were informed about the estimated market price of $3000. The study also revealed that those vehicle owners with the highest interest in fully autonomous driving at market price were males (25%), those between the ages of 18 and 37 (30%), and those living in urban areas (30%). The second

Table 1
Alignment among BASt, NHTSA and SAE levels of automation (Smith, 2013b; Wending, 2014).

Source	Levels of automation					
BASt	Driver only	Assisted	Partly automated	Highly automated	Fully automated	Not addressed
NHTSA	No Automation (Level 0)	Function-Specific Automation (Level 1)	Combined Function Automation (Level 2)	Limited Self-Driving Automation (Level 3)	Full Self-Driving Automation (Level 4)	
SAE	No Automation (Level 0)	Driver Assistance (Level 1)	Partial Automation (Level 2)	Conditional Automation (Level 3)	High Automation (Level 4)	Full Automation (Level 5)