Investigating the acceptance on the road to connected-autonomous vehicles

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Abstract. Connected-autonomous vehicles are a developing technology which may prove to be the next big evolution in transportation. As of now, several major car manufacturing companies are developing and testing their own prototype passenger autonomous cars with plans to eventually release the technology to market. Despite enthusiastic speculation about the potential benefits of connected-autonomous vehicles, to date little is known about the factors that will affect users' acceptance or rejection of this emerging technology. Gaining acceptance from end users will be critical to the widespread deployment of connected-autonomous cars. This paper describes a focus-group study conducted by means of an online questionnaire distributed to university students in Greece, followed by a comprehensive statistical analysis of opinions regarding user acceptability, security and safety concerns, and intension to have or use connected-autonomous vehicles for their future transportation needs.

Keywords: transportation systems, autonomous vehicles, connected-autonomous vehicles

1 Introduction

As prototypes of highly autonomous vehicles have emerged, public and media interest in the possible implications of ubiquitous intelligent and automated driving cars has grown. Speculative benefits of the advent of self-driving cars have included increased safety, fewer traffic problems, and a windfall of work or leisure time in the vehicle [1].

Initial reports have suggested the public has begun to embrace the portrayal of connected and automatd driving cars in which the human has no supervisory control. The public opinion on connected-autonomous driving determines the extent to which people will accept and use such systems, and it will define the way that car manufacturers will have to develop and market connected-autonomous vehicles, as well as any investments in infrastructure.

On the other hand even if appropriate interfaces can be designed to keep drivers in the loop, it remains unclear whether consumers would accept a connected-automated vehicle that could perform all driving tasks, did perform most driving tasks, yet demanded a high amount of monitoring workload. Monitoring workload may negatively impact acceptance, as engagement with secondary tasks seems to be viewed as a primary end-user benefit of vehicle automation [2].

Initial deployment of self-driving cars could be slowed or harmed if the technology is received with disappointment. Trust in automation is influenced by expectations and attitudes that develop before a person uses a system [3], thus it will be important to understand acceptance before the arrival of connected-autonomous vehicles on markets [4].

Various researchers have previously conducted surveys on public opinion about automated driving systems. A recent study [5] carried out a survey on public opinion about automated driving among 5000 respondents from 109 countries. Results showed that respondents were found to be most concerned about software hacking/misuse, and were also concerned about legal issues and safety. Also almost 70% of respondents estimated that fully automated driving will reach a 50% market share between now and 2050.

Another study [6] investigated the public opinion about autonomous and self-driving vehicles among 1533 respondents in US, UK, and Australia. The study showed that 57% of the respondents had an overall positive opinion on those vehicles. A large number of respondents expressed concerns about the technology of self-driving vehicles. In particular, 26% of the US respondents were "very concerned" about system / equipment failure and vehicle performance in unexpected situations, while the corresponding percentages for UK and Australia were 15% and 16%, respectively. Legal liability, hacking of the automated systems, and privacy due to data sharing were other areas of concern.

Underwood [7] investigated the opinion of 217 experts on automated vehicles who participated in the Automated Vehicles Symposium 2014. Respondents considered legal liability and regulations as the most difficult barriers toward the deployment of fully automated driving vehicles, whereas social and consumer acceptance were regarded as the least difficult barriers.

In this context the implementation of Connected-Autonomous Vehicles (CAVs) faces considerable

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unresolved challenges such as public perception, legal liability issues, data privacy and security protection and control of the systems. The technology to support autonomous cars remains limited and inadequate, and a host of other difficulties stands in the way of widespread deployment of autonomous vehicles. Only recently have the human factors dilemmas for autonomous vehicles begun to receive their due consideration [8].

Several factors, which are expected to be crucial for consumers' choice of whether or not to accept Connected-Automated Vehicle (CAV) technology, can been identified. They have to do with trust in CAV technology and understanding of CAV technology including perceived safety, perceived environmental benefits, perceived comfortability, perceived costs and savings, perceived reliability and perceived complexity.

In the present study user acceptability, concerns, and willingness to buy connected-autonomous vehicles are investigated. Moreover, as current research focus primarily on Western countries with developmental status in terms of Gross Domestic Product (GDP) per capita, this study captures the opinions concerning connected-autonomous vehicles in a Mediterranean European low income country (Greece). Specifically, for this research we implemented a 25-question online survey among 50 university students.

The rest of the paper is structured as follows. Section 2 presents the background for this work related to connected vehicles, intelligent systems and autonomous driving focusing on data privacy and security protection. In Section 3, survey method and respondents of the survey are described. In Section 4, details of the survey results are reported. Concluding remarks and outlooks for future work are drawn in section 5.

2 Background

2.1 Connected vehicles

Smart mobility nowadays is a fundamental research area. The main challenge is to develop systems that can communicate with the vehicle and so the user is able to receive information from the surrounding environment and infrastructure, which can have influence in the vehicle performance such as traffic information, parking management, car pooling, etc.

On this context, Intelligent Transportation Systems (ITS) can enable numerous mobility, safety and environment protection applications. For instance, drivers can be provided with safety warnings, as regards weather and road conditions or lane change issues. Important ITS research efforts exist in USA, Europe, Japan and China, whereas ITS technology development and internet-connected vehicles is currently a pertinent research theme [9].

The vision of internet-connected vehicles that are managed and coordinated with the transportation infrastructure by suitable autonomic systems, leads to enhanced vehicular service provision and optimized transport operations, given a set of strategic, operational and technical objectives, such as improved traffic control and transport policies enforcement. An integrated ITS requires efficient solutions to several technical challenges and also the evolution and synthesis of different technical approaches, concepts and tools, namely service-oriented computing, autonomic service management, and communication protocols between vehicles (V2V) and vehicles and infrastructure (V2I).

The above technologies raise questions as to how data privacy protection and security will be addressed in internet-connected vehicles environments [10]-[11]. The highly or fullyconnected-automated vehicle will process data and make decisions: this raises ethical issues which have to be solved in a societal dialogue. In this context programmed algorithms will make decisions in conflicting situations, such as a choice between two unavoidable crash scenarios. How will the decision be taken? What "best driving behaviour" should be reflected by the system?

2.2 Intelligent systems and vehicles

Intelligent Vehicle Systems (IVS) consist of electronic, electromechanical and electromagnetic devices that are controlled by software-based control systems. These intelligent vehicle technologies are applied to vehicle safety systems and self-evaluated feedback systems [12]. A Control Area Network (CAN) vehicle bus connects the various electronic units, such as OBU and telematics sensors, collecting as much information from the current vehicle's movement and surrounding vehicles' movement as possible, and estimate real-time feedback to provide solutions and suggestions to the driver.

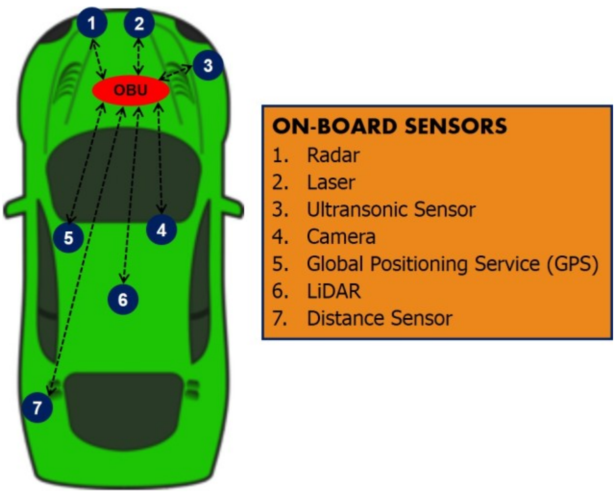

Fig. 1. An example of a typical Intelligent Vehicle used for data collection.

Intelligent vehicles are usually equipped with multiple sensors to enable various processing with ample and representative data collection from various components of the vehicle and the driver behaviour. An example of an intelligent vehicle equipped with multiple sensors is illustrated in Fig. 1, which contains in-vehicle camera sensors, vehicle dynamics sensors, range sensors and a GPS unit.

In this context driving experience is improved through the automated calculation of physiological features while driving. This information is obtained by continuously recording electrocardiogram, electromyogram, skin conduction and respiration, and used in IVS to provide feedback to the driver suggesting behaviour to improve relief and relaxation.

In order to prevent risk, IVS can divert an incoming cell phone call to the mail box if it is determined that the mental or emotional load of the driver is above average, for instance during high stress, and address the needs of a driver who is more prone to distraction in low stress situations. Many interesting capabilities exist for features of IVS, but driver behaviour modelling and driver style classification play an important role in autonomous vehicle research, which also forms part of vehicle intelligence.

2.3 Autonomous driving

Automated driving technology has the potential to fundamentally change road transportation by increasing safety on public roads while decreasing traffic congestion, gas emissions, and fuel consumption. According to their technological capabilities and human engagement, different levels of automation have been proposed. The most well-known are provided by SAE where automated vehicles (AVs) can be classified ranging from manual driving (Level0), where the human driver executes all of the driving tasks, to fully automated driving (Level5), where no human interaction occurs [5], according to the following definitions:

- **Level0 – Driver only:** The human driver performs all aspects of the dynamic driving task.
- **Level1 – Assisted automation:** A driver assistance system performs either steering or acceleration / deceleration, while the human driver is expected to carry out the remaining aspects of the dynamic driving task.
- **Level2 – Partial automation:** One or more driver assistance systems perform both steering and acceleration / deceleration, while the human driver is expected to carry out all remaining aspects of the dynamic driving task.
- **Level3 – Conditional automation:** An automated driving system performs all aspects of the driving task (in conditions for which it was designed), but the human driver is expected to respond appropriately to a request to intervene.
- **Level4 – High automation:** An automated driving system performs all aspects of the dynamic driving task (in conditions for which it was designed), even if the human driver does not respond appropriately to a request to intervene.
- **Level5 – Full automation:** An automated driving system performs all aspects of the dynamic driving task under all roadway and environmental conditions.

Moreover, while automated driving systems have great potential to improve safety and efficiency of road transportation, many challenges are yet to be addressed, including the public perception, user acceptance, legal liability issues, and the security and control of the systems.

Auto makers, in particular, face challenges in designing the appropriate legal and regulatory framework so that new technologies are used properly and for the benefit of society. Upon this direction European Union is funding research on automated road transport as a priority in the Horizon2020 where some key elements of the discussions on political and technical aspects are the questions of how data protection and cyber security can be secured.

2.4 Data protection and security issues

The regulatory environment relating to cyber security, data privacy, and liability issues is of particular importance in the development of automated vehicles. Data protection and privacy in transportation, in particular in connected vehicles environments, as required by current applicable legislation as well as policies and professional ethics, is a relatively new challenge research area [13].

In general, digital services will be available in vehicles, as they are anywhere else. The "connected car" has the capability to generate, store and transmit users' personal data, such as their route to work, time of driving, favourite music, appointments or favourite restaurants. These data have a significant potential for other uses. As third parties can access and use sensitive driver and driving data, legislation seems necessary to protect personal privacy of consumers in connected vehicles.

Automated vehicles are extended vehicles, meaning that they have external software and hardware extensions as some of their features. These extensions are developed, implemented and managed by the vehicle manufacturer. The connection between the in-vehicle system and the manufacturer's central server has to be secure, so that all data transfers are protected from unauthorised disclosure and manipulation. Uncontrolled, unrestricted access to vehicle data in the on-board network by third parties directly and indirectly jeopardises the safety of the vehicle, occupants and other road users.

However, from a certain level of vehicle automation on, it might be difficult to establish the exact cause of an accident and to prove if it is due to a defect with the automated vehicle or the behaviour of the driver. The new possible causes created by automation might interfere with the very objective of liability regimes to apportion risks, therefore an adaptation of liability law to the new technologies and a European harmonisation of the regimes concerning the liability of owners and/or drivers of automated vehicles seem necessary.

Different types of transportation applications (i.e. traffic control, safety) may need different types of data, and the applicable privacy algorithms need to be designed accordingly. The development of privacy-preserving environments requires the alignment and compliance among privacy artifacts, i.e. service providers' enterprise goals, privacy policy, user preferences, and data protection policies, introduced in the central system and service environment.

3 Research analysis

3.1 Survey approach

The research methodology was based on empirical data collected through an online questionnaire survey. The population in this study was the number of both undergraduate and postgraduate students in the Department of Informatics and Telematics at Harokopio University of Athens (HUA).

The study was conducted in two phases: a pilot study and a questionnaire. The questionnaire was pilot-tested with 5 randomly selected students from the Harokopio University of Athens (HUA). Based on the feedback from the pilot test, the questionnaire was refined and a revised final questionnaire was developed. The purpose of the survey had been explained to the respondents and motivated them to reply personally. Also the confidentiality of the results had been stressed. In total, 49 students, i.e. about 10% of the population, completed the survey. The responses were gathered between 20 March 2017 06:00 and 27 March 2017 12:00 Central European Time.

To explore the above study, Technology Acceptance Model (TAM) was used to predict public acceptance of connected-autonomous vehicles. Technology Acceptance Model (TAM) was first introduced and developed by Fred Davis in 1986.

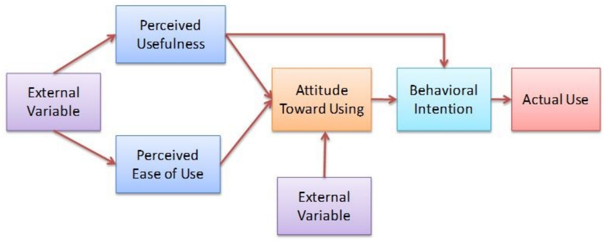

Fig. 2. Original Technology Acceptance Model (TAM).

According to Fig. 2, one's actual use of technology system is influenced directly or indirectly by the user's behavioral intentions, attitude, perceived usefulness of the system, and perceived ease of the system. TAM also proposes that external factors affect intention and actual use through mediated effects on perceived usefulness and perceives ease of use. Two cognitive beliefs are posited by TAM: perceived usefulness and perceived ease of use. Perceived Usefulness indicates the extent to which individuals believe the use of particular systems would improve their job performance, whereas the factor perceived ease of use indicates to which extent individuals believe the use of particular system will be free by effort [14]-[15].

3.2 Respondents

Four different demographic groups were considered including gender, age, employment and travel modes (Fig. 3). In the above online survey the majority of respondents were between 18 and 30 years old (63%). Of the 50 university students sampled, 20% were female and 80% male whereas 61% were employed (full-time or part-time), and 39% were not currently employed. Majority of the respondents travels by public transportation (59%).

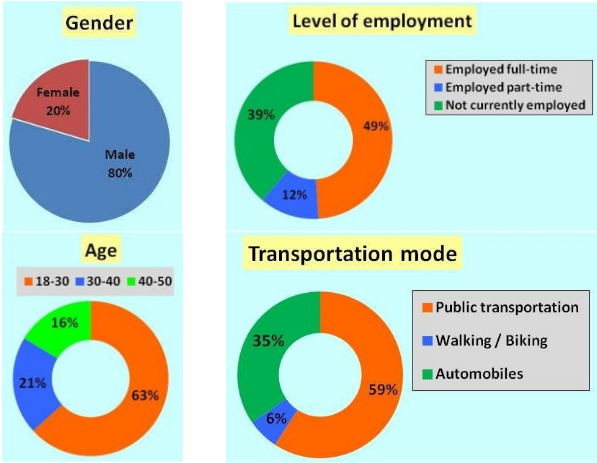

Fig. 3. Demographic attributes of the respondents.

Furthermore 84% of the respondents had heard of the connected-automated vehicles before, which is almost at the same level compared to the findings (87%) obtained by [16].

4 Results and discussion

In the present study user acceptability, concerns, and willingness to buy connected-autonomous vehicles are investigated. In this context, from the seven reasons that people would be unlikely to ride in a connected-autonomous vehicle (CAV) for everyday use (Fig. 4), respondents indicated cost (33%) and road transportation safety (23%) whereas security protection and insurance / liability issues were their smallest concerns.

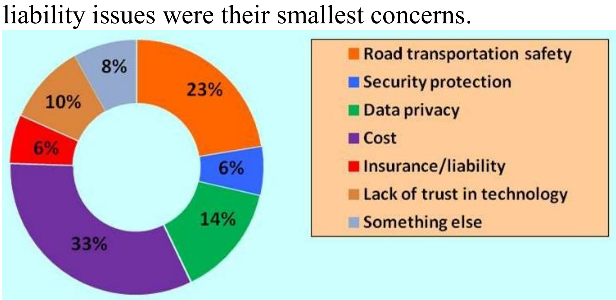

Fig. 4. Reasons that would be unlikely to ride someone a Connected-Autonomous Vehicle (CAV) for everyday use.

Furthermore in responding to the questions about the perceived usefulness of Connected-Automated Vehicles (CAVs), the majority of the respondents indicated that connected-autonomous vehicles will be useful in meeting their driving needs (about 60%) and feel safer on their driving trips (almost 50%), as depicted in Fig. 5.

On the other hand the majority of the respondents (47%) stated neutral to the indicator "I would be proud if people saw me using a connected-autonomous vehicle".

Furthrmore 45% of the respondents indicated that they are somewhat true or very true against the statement "People whose opinions I value would like using connected-autonomous vehicles".

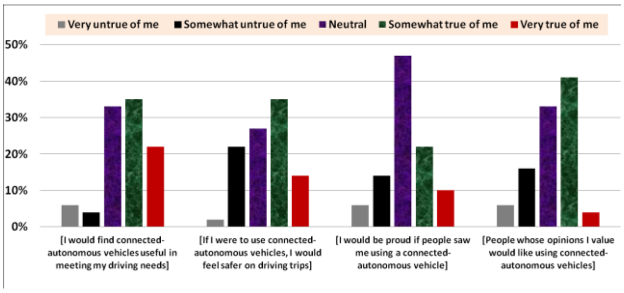

Fig. 5. Perceived usefulness of connected-autonomous vehicles.

Regarding the questions about the perceived ease of use of Connected-Automated Vehicles (CAVs) the majority of the respondents indicated that they are somewhat true or very true against the statements "Learning to operate a connected-autonomous vehicle would be easy for me" (67%), "Interactions with connected-autonomous vehicles would be clear and understandable to me" (75%) and "It would be easy for me to become skillful at using connected-autonomous vehicles" (72%), as depicted in Fig. 6.

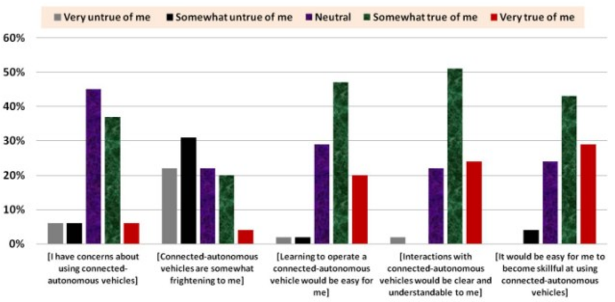

Fig. 6. Perceived easy of use for connected-autonomous vehicles.

On the other hand the majority of the respondents (45%) stated neutral to the indicator "I have concerns about using connected-autonomous vehicles". Finally over 50% of the respondents answered that connected-autonomous vehicle technology is not somewhat frightening to them.

In responding to the questions of "How concerned are you that your data would be kept private when using connected-autonomous vehicles" and "How concerned are you that your data would be kept resilient to common cyber security threats when using connected-autonomous vehicles", almost two thirds of the respondents answered that are moderately or extremely concerned about these issues, as shown in Fig. 7.

Moreover almost 50% of the respondents answered that safety issues concerning connected-autonomous vehicles will influence somewhat positively or very positively their desire to have or use one whereas the corresponding percentage about system security protection and data privacy issues was 30%.

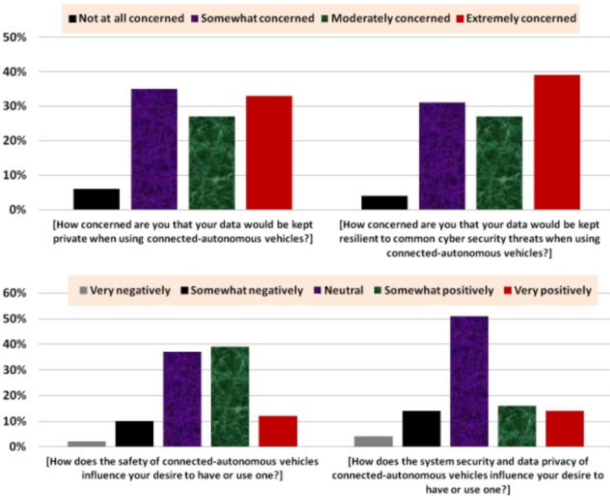

Fig. 7. Security and safety issues of connected-autonomous vehicles.

Based on the above statements, safety, data privacy and security issues against common cyber security threats could be some of the key factors influencing public attitudes towards connected-automated vehicles. This was supported by the responses from the people surveyed.

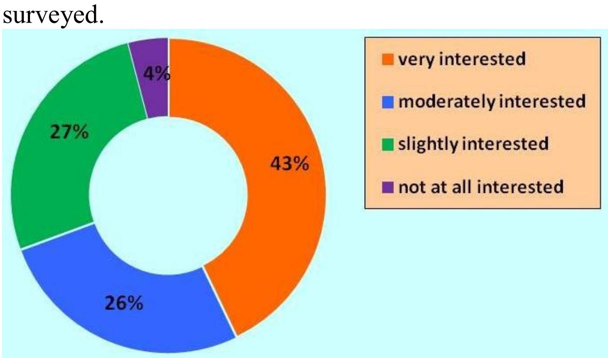

Fig. 8. Intension to have or use connected-autonomous vehicles.

Furthermore our survey results showed that almost 70% of people nowadays would be very interested or moderately interested in having or using connected-autonomous vehicles for their transportation needs (Fig. 8).

5 Conclusions

Around the world, industry and research groups are working on technologies which are transferring driving tasks from human drivers to a computer. Being an important part of the Internet of Things (IoT), intelligent transport systems, autonomous driving systems and connected vehicles will not only increase road safety, but can also help reduce congestion and raise fuel efficiency.

Various recent studies have documented the public opinion on automated driving technology. Most of these studies focused on measuring the public opinion in Western, higher income countries. In the present study, we investigated public opinions concerning connected-autonomous vehicles in a Mediterranean European country (Greece), via an online survey among undergraduate and postgraduate students in the Department of Informatics and Telematics at Harokopio University of Athens (HUA).

Our survey results showed us people's perception of connected-autonomous vehicles. We found that there was a significant lack of trust about safety, data privacy and system security protection issues concerning connected-autonomous vehicles affecting their desire to have or use one. Further projects might study what exactly causes this mistrust, as well as how to gain the trust of potential connected-autonomous car customers.

It is important to note that our present findings should be interpreted carefully, because highly and fully automated vehicles are not currently available on the market. Hence, the results of our survey rely to a large extent on people's imagination regarding the operation of automated cars in the future. In this direction real demonstrations are needed in the future to test connected-autonomous vehicles (e.g. in operational speed and under different road/weather/traffic conditions) in order to convince the public what connected-autonomous cars can do in real conditions.

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