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Social Perception of Autonomous Vehicles

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Abstract
The technology of autonomous vehicles is gaining more and more emphasis these days. In the near future the technological developments will make it possible for vehicles to travel on the roads without human intervention. However, downstream users have differing views on this new mode of transport. The aim of our research was to explore the opinions of different social generation groups and traffic groups about fully autonomous self-driving (SAE Level 5). In our research, we conducted an online self-report questionnaire survey. The questionnaire was completed by 223 people. The results were analyzed from several perspectives. The results showed that opinions and expectations in the field of autonomous vehicles differed by generation group, gender and primary mode of transport.

Keywords
autonomous vehicle, social perception, transport mode, data analysis

1 Introduction

The technology of self-driving vehicles is gaining more and more emphasis these days. Technological developments will make it possible in the near future (Bazilinskyy et al., 2019; López-Lambas and Alonso, 2019) to travel on roads without human intervention. The SAE has formulated 6 levels of autonomous driving (Warrendale, 2018). SAE Level 0 means driving completely with human intervention. At Level 5 of autonomous driving, one does not have any driving role in the vehicle, even if sitting in the driver's seat. At this level, the system can automatically drive the vehicle anywhere and in any conditions. However, achieving Level 5 is only possible through a systematic, uniform, and balanced approach (Wang et al., 2021). The introduction of inadequate regulation in the wrong time and manner may hamper the proliferation of autonomous vehicles (Mordue et al., 2020).

Several studies have addressed the emergence and spread of self-driving vehicles and their effects (Hamadneh and Esztergár-Kiss, 2022; Lengyel et al., 2021; Orgován et al., 2021; Silva et al., 2021; Zarkeshev and Csiszár, 2019). According to research conducted in a Chinese passenger car fleet, with the advent of self-driving vehicles, greenhouse gas emissions will not change significantly in the medium term (Liu et al., 2019). This is due to the uncertainty in the forecast of fuel consumption of vehicles. Based on research with road traffic as well as traffic density waves, the emergence of autonomous vehicles may stabilize traffic flow (Ma et al., 2021). The emergence of autonomous vehicles is likely to change not only private transport but also public transport. As a result of research carried out on the example of a Hungarian sample, savings are expected not only in the number of vehicles but also in the number of drivers with the advent of self-driving vehicles (Nagy and Horváth, 2020).

However, self-driving technology and the degree of automation are viewed differently by society. Accurate knowledge of these factors is essential for the promotion and acceptance of the introduction and spread of technology.

Research on the social perception of autonomous technology has shown that the higher the level of automation, the more properties and powers a given system has (Frischknecht, 2021).

In the field of transport systems, more research has been done to explore social expectations and judgments (Henézi and Horváth, 2021). In a real autonomous vehicle travel experiment, the results showed that people's opinions are significantly related to people's age, personal income, monthly fuel cost, and experience with autonomous vehicles (Shi et al., 2021).

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The relationship of age and willingness to accept shows that younger people are more accepting than older people (Liu et al., 2019). However, older people's willingness to accept also increases if they make a successful test drive in an autonomous vehicle (Hartwich et al., 2019). This is also the case for pedestrians and drivers. In terms of place of residence, the acceptance rate of urban individuals is higher (Deb et al., 2017). Another factor is that pedestrians rated autonomous vehicles as less risky than car occupants in terms of risk perception (Hulse et al., 2018).

Acceptance of autonomous vehicles is enhanced by the ease of use and usefulness of the technology (Panagiotopoulos and Dimitrakopoulos, 2018), its environmental impact (Wu et al., 2019) the trust in the technology (Choi and Ji, 2015), and a sense of security (Hardman et al., 2019). It also increases the willingness to accept that drivers will not have to pay attention to driving while traveling, and other occupations may be available (Noruzoliaee et al., 2018).

In a summary study, Jing and colleagues demonstrated the acceptance of autonomous vehicles with 6 behavioral theories (perceived ease of use, attitude, social norm, trust, perceived utility, perceived risk, compatibility) and 6 nonbehavioral theories (safety, performance-value ratio, mobility, value of travel time, symbolic value, environmental friendliness) (Jing et al., 2020). The connection with the same theory of behavior was revealed by Günthner and Proff (2021). Their research also found that expectations change with age (Günthner and Proff, 2021). For 50–59 year olds, the most important factors were ease of use and social norms, for 60–69 year olds trust in utility and technology, and for 70–90 year olds the trust in technology.

In terms of road safety perception, those who currently show positive behavior on the roads will also improve road safety by using autonomous vehicles (Deb et al., 2017).

At the same time, price is a determining factor in the proliferation of autonomous vehicles. A homogeneous period (transport with autonomous vehicles only) can only be achieved by reducing vehicle access prices (Talebian and Mishra, 2018).

In the field of mode-specific research, an American study examined the perception of autonomous vehicles for pedestrians and cyclists. The result showed that for most attributes, respondents' expectations did not differ in their interaction with autonomous vehicles (AVs) as pedestrians or cyclists (Rahman et al., 2021).

In the result of literature research, we summarized that the social perception of autonomous vehicles is influenced by a number of factors. At the same time, we did not find any results about how these expectations differ between each mode of transport, what the main differences are. In addition, during the literature review, the age grouping was evaluated based on the authors' own decisions.

The aim of our research was therefore to examine whether there is a difference in the perception of autonomous vehicles between each generation in terms of age grouping. Our further aim was to determine whether the differences in the opinions of those using each mode of transport differ on the topic of self-driving vehicles. In our research, we examined the main expectations of different age groups and transport groups towards technology.

2 Methods

In our research the data are completely anonymized. We used an online questionnaire survey. We tried to formulate and ask questions that were understandable to everyone. The completeness of the questionnaire was tested in advance on a small sample (10 people) and the necessary modifications were made. The questionnaire was distributed online on web pages accessible to all. The months of October, November 2021 were available to complete the questions.

The questionnaire consisted of a total of 24 questions, which were divided into 3 sections. The survey contained directed, non-textual questions. The questions did not include any questions that respondents were required to complete. Before the questions, a short introductory text included instructions for completing the questionnaire and the concept of a self-driving vehicle. In this study, a self-driving vehicle was a vehicle at Level 5 of the SAE classification.

The first section concerned the general travel characteristics of users. There were questions with which we explored the respondents' daily travel characteristics and modes of transport. The second stage concerned the assessment of autonomous transport. The questions also included a ranking of the characteristics expected of autonomous vehicles and an assessment of the opportunities and problems they encounter during transport. The third stage concerned the social characteristics of the respondents (for example: gender, age, highest level of education).

In the first section, "Which modes of transport do you take on an average working day? Please rank the tools below! (1: least characteristic, 7: most characteristic; 0: not used)", the mode of transport with a value of 7 was considered the primary mode of transport in the analytical part of the questionnaire focusing on modes of transport.

In the survey 72 people (32.3%) chose walking, 10 people (4.5%) chose cycling, 1 person (0.4%) chose motorcycling, 8 people (3.6%) chose traveling in a car, 62 people (27.8%) preferred to drive a car and 52 people (23.3%) preferred public transport. For 18 people, the primary mode of transport was not clearly identifiable. In the case of the evaluation by mode of transport, we neglected motorcyclists and unidentifiable primary transport users.

The following question related to the assessment of the general opinion on autonomous vehicles: What is your opinion about autonomous vehicles? (Clearly positive; rather positive; neutral; rather negative; clearly negative; don't know).

The assessment of expectations for autonomous vehicles was based on the following question. What are your expectations about autonomous vehicles? Please rank the following factors! (1: least relevant, 7: most relevant): safety; comfort; environmentally friendly; travel time; cheap accessibility; reliability; legally well regulated.

Based on the answers we weighted the factors. The least relevant factor received a value of 1 and the most relevant factor a value of 7. We aggregated the values. The calculation method is presented with a group of pedestrians.

72 people chose walking as primary mode of transportation. Taking this into account, the maximum values for each expectation factor was 504 points, if 72 people ranked the same factor as the most relevant. The values for each factor were calculated using the following equation as Eq. (1):

$$gy_t = \sum_{h=1}^{7} t_h \times r_h, \quad (1)$$

where:

- gy_t: score for a given factor for pedestrians
- t: factor (value: safety; comfort; environmentally friendly; travel time; cheap accessibility; reliability; legally regulated)
- h: ranking position (value: $1 \rightarrow 7$)
- t_h: the number of those who ranked the t–t_h factor in the h–t_h place
- r_h: ranking value (value: $1 \rightarrow 7$), r = h

Using the correlation, pedestrians associated safety with 438 points out of a maximum of 504 points.

We assessed the age groups with generational distribution. Currently, the literature distinguishes several generational divisions worldwide (Jha, 2020; Nemes, 2019). In our research we distinguished 6 generations (Komár, 2017):

- Veteran generation (1925–1942);
- Baby Boomers (1943–1960);
- Generation X (1961–1981);
- Generation Y (1982–1995);
- Generation Z (1996–2010);
- Alpha Generation (2010–).

3 Results

The questionnaire was completed by 223 people. Respondents included 159 (71.3%) women and 64 (28.7%) men. Regarding the age generations, the majority of the respondents were from the Z generation: 113 Z (50.7%), 58 Y (26%), 46 X (20.6%) and 6 Baby Boomers (2.7%) generations. The highest levels of educational attainment were also similar to age. 93 (41.7%) with a high school degree, 12 (5.4%) with a vocational school degree, 69 (30.9%) with a bachelor's degree, 48 (21.5%) with a university degree, while 1 person had a higher education.

With the exception of 7 respondents (4.1%), everyone heard about the concept of self-driving vehicles. Respondents have a more positive opinion about autonomous vehicles: 21 people (9.4%) were clearly positive, 71 people (31.8%) were more positive, 70 people (31.4%) were neutral, 41 people (18.4%) rather negative, 9 people (4%) had a clearly negative opinion. 11 people (4.9%) did not form an opinion on the issue. The appearance of the first self-driving vehicles on Hungary's roads was predicted by 132 people (59.2%) for 2030 or the years before. Opinions are divided on where they appear. 58 people (26.1%) considered the technology to be more urban, 89 people (40.1%) more long-distance, and 75 people (33.8%) considered the technology applicable in both traffic scenarios.

The expectations for autonomous vehicles are summarized in Table 1. The cells in Table 1 show how relevant each factor was perceived by respondents to be an important aspect in relation to self-driving vehicles. The maximum score was 1561 points. 1 indicates the most relevant factor and 7 indicates the most negligible factor.

The results show that safety is the most important part of the expectations for self-driving vehicles. This factor received 80.1% of the maximum score that ranked respondents first. This is followed by reliable operation, en-

Table 1 Expectations for self-driving vehicles

Factor	Score	Rate	Rank
Safety	1251	80.1%	1
Reliable operation	877	56.2%	2
Environmentally friendly	782	50.1%	3
Comfort	728	46.6%	4
Legally well regulated	594	38.1%	5
Travel time savings	584	37.4%	6
Cheap accessibility	550	35.2%	7

vironmental friendliness, convenience, legally well-regulated and time-saving savings. In the last place is cheap accessibility, which received 35.2% of the maximum score.

Fig. 1 shows the general opinion on autonomous vehicles by mode of transport. Public transport users had the most positive opinion. In this mode, 40.8% of respondents had a more positive opinion and 6.1% a clearly positive opinion. Self-driving vehicles were judged most negatively by cyclists. In this case, 22.2% of cyclists rated the technology more negatively. The proportion of clearly negative responses was 0% for car passengers, cyclists and pedestrians.

The requirements for autonomous vehicles are shown in Table 2 and Table 3 for each mode of transport. Tables 2 and 3 also show each score and priority order. For example, in the case of pedestrians, the maximum score for the factors was 504 points, of which safety received 438 points, making it the most important parameter among pedestrians.

In each case, the most relevant factor was safety, however, the other factors followed a different order of importance according to users. In the case of pedestrians and car drivers, the most negligible factor was legal regulation. Among those who currently ride a bike in everyday life, comfort was in the last place. Saving travel time for car passengers and low-cost accessibility for public transport users came last.

Fig. 2 includes generational differences. In the case of baby boomers, there was no opinion that would have judged self-driving technology to be clearly negative or rather positive. Based on the responses of individuals in this generation, self-driving technology was rated equally negative and positive. Among the opinions of Generation X, the majority were neutral (45.2%), Generation Y (46.4%) and Generation Z (45.9%) rated the technology of self-driving vehicles as positive.

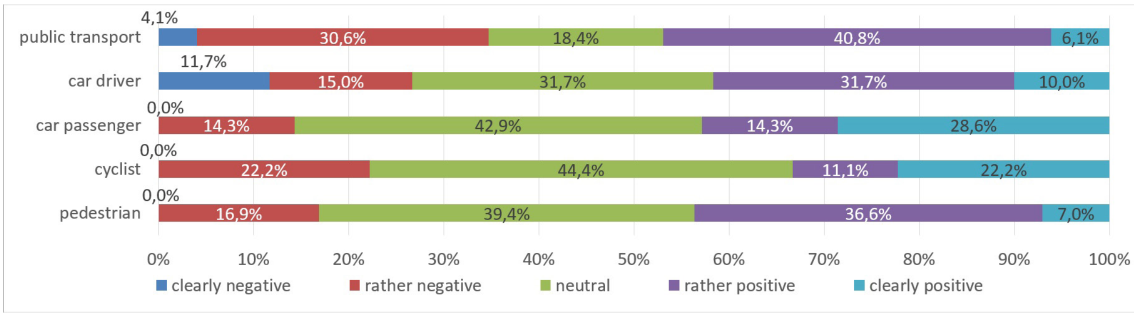

Fig. 1 Assessment of autonomous vehicles by mode of transport

Table 2 Expectations for autonomous vehicles by transport mode 1

Factor	Pedestrians (max. score: 504)			Cyclists (max. score: 70)		
	Score	Rate	Rank	Score	Rate	Rank
Safety	438	86.9%	1	50	71.4%	1
Comfort	275	54.6%	4	17	24.3%	7
Environmentally friendly	288	57.1%	3	35	50.0%	3
Travel time savings	199	39.5%	6	30	42.9%	4
Cheap accessibility	203	40.3%	5	30	42.9%	4
Reliable operation	321	63.7%	2	37	52.9%	2
Legally well regulated	193	38.3%	7	25	35.7%	6

Table 3 Expectations for autonomous vehicles by transport mode 2

Factor	Car passenger (max. score: 56)			Car driver (max. score: 434)			Public transport (max. score: 364)		
	Score	Rate	Rank	Score	Rate	Rank	Score	Rate	Rank
Safety	39	69.6%	1	331	76.3%	1	320	87.9%	1
Comfort	31	55.4%	4	212	48.8%	3	177	48.6%	4
Environ-mentally friendly	33	58.9%	3	210	48.4%	4	204	56.0%	3
Travel time savings	24	42.9%	7	179	41.2%	5	146	40.1%	6
Cheap accessibility	25	44.6%	6	155	35.7%	6	128	35.2%	7
Reliable operation	36	64.3%	2	221	50.9%	2	223	61.3%	2
Legally well regulated	26	46.4%	5	151	34.8%	7	173	47.5%	5

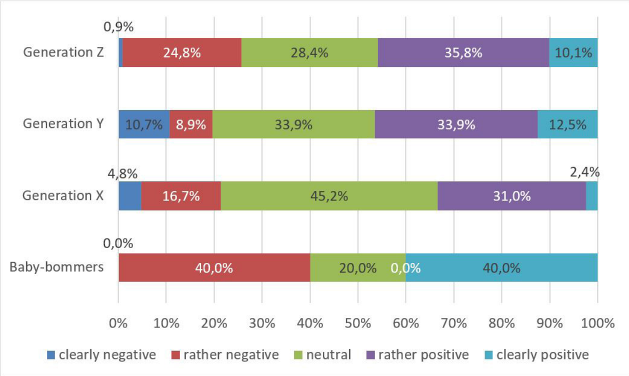

Fig. 2 Assessment of autonomous vehicles by generation

Table 4 and Table 5 include the expectations for self – driving vehicles per generation. For each generation, safety received the most points. Proportionally, safety was the most important for those in the Baby-boomer generation (85.7%) and least common for those in the Y-generation (75.4%). However for the other aspects the order of expectations varies from generation to generation. In the case of baby boomers the last aspect was cheap accessibility and reliable operation. In the case of Generation X also cheap accessibility was the last. In the case of Generation Y legally well regulated was the last. In the case of Generation Z cheap accessibility was again in the last place.

Table 4 Expectations for autonomous vehicles by generation 1

Factor	Baby boomers (max. score: 42)			Generation X (max. score: 322)		
	Score	Rate	Rank	Score	Rate	Rank
Safety	36	85.7%	1	258	80.1%	1
Comfort	27	64.3%	3	123	38.2%	4
Environmentally friendly	30	71.4%	2	156	48.4%	2
Travel time savings	22	52.4%	4	102	31.7%	6
Cheap accessibility	17	40.5%	6	80	24.8%	7
Reliable operation	17	40.5%	6	137	42.5%	3
Legally well regulated	19	45.2%	5	109	33.9%	5

Table 5 Expectations for autonomous vehicles by generation 2

Factor	Generation Y (max. score: 406)			Generation Z (max. score: 791)		
	Score	Rate	Rank	Score	Rate	Rank
Safety	306	75.4%	1	659	83.3%	1
Comfort	181	44.6%	4	425	53.7%	4
Environmentally friendly	188	46.3%	3	433	54.7%	3
Travel time savings	175	43.1%	6	324	41.0%	6
Cheap accessibility	178	43.8%	5	313	39.6%	7
Reliable operation	236	58.1%	2	514	65.0%	2
Legally well regulated	142	35.0%	7	350	44.2%	5

In terms of gender, men (49.2%) were more positive about self-driving technology than women (41.2%) (Fig. 3).

The order of gender expectations is shown in Table 6. Both men and women ranked safety first. The safety-related value for safety was 81.3% for men and 80.4% for women. For the other factors, slight rank differences can be observed. The last place for men is the saving of travel time, for women the cheap accessibility.

4 Discussion

Knowledge of the societal expectations on autonomous vehicles is essential for the effective introduction of technology. Based on the results, the assessment of autonomous vehicles is overall positive. 41.2% of respondents rated the technology positively.

Considering the age generations, the Y generation of the respondents had the most positive opinion about the self-driving vehicles. 46.4% of those in the generation thought the technology was more positive or clearly positive. Generation X had the least positive opinion about the technology (33.4%). This is a surprising result in view of the fact that the majority of respondents predict the appearance of self-driving vehicles on Hungarian public roads before 2030, so this age group is likely to encounter

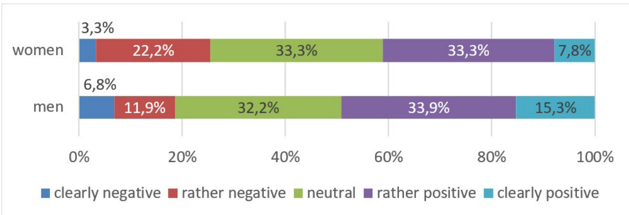

Fig. 3 Assessment of autonomous vehicles by gender

Table 6 Expectations for autonomous vehicles by gender

Factor	Men (max. score: 448)			Women (max score: 1113)		
	Score	Rate	Rank	Score	Rate	Rank
Safety	364	81.3%	1	895	80.4%	1
Comfort	220	49.1%	3	536	48.2%	4
Environmentally friendly	208	46.4%	4	599	53.8%	3
Travel time savings	163	36.4%	7	460	41.3%	5
Cheap accessibility	172	38.4%	6	416	37.4%	7
Reliable operation	242	54.0%	2	662	59.5%	2
Legally well regulated	180	40.2%	5	440	39.5%	6

the technology in everyday life. Based on the responses, it can therefore be concluded that there is a difference in the assessment of autonomous vehicles based on this generation grouping of age groups.

Similar to the results revealed in the literature, we also revealed gender differences in the assessment of self-driving technology. Similar to the results abroad, men were more positive about the technology among the respondents. However, we found only small differences in the order of expectations for autonomous vehicles in terms of gender.

Regarding the assessment of self-driving technology as a mode of transport, the groups had slightly but different opinions. The most positive opinion was given by users of public transport (46.7%), which is a surprising result. With the spread of autonomous technology, the role of the driver will disappear completely. However, anyone who still uses public transport puts the control function in the hands of another person. We recommend a detailed examination of the reasons for this result later. Based on the results, the respondents had a different opinion based on the primary modes of transport.

The order-based evaluation of the factors examined showed that society considers safety to be the most important consideration for this new technology. This was also shown by a global and detailed analysis of the responses. Based on the respondents' assessment, safety received 80.1% of the maximum score. Safety was also the most important in every transport mode, but pedestrians (86.9%) and public transport users (87.9%) rated the importance of the factor much higher than the other groups. Safety was also the most important aspect in the breakdown by age group and gender. These results show that respondents uniformly consider the role of safety to be paramount for self-driving vehicles.

5 Conclusion

In our research, we examined the social perception of self-driving vehicles. This topic is a priority nowadays. Based on the current pace of vehicle development and according to both international and domestic opinions, the first fully self-driving vehicles on the roads are expected to be around 2030. Getting to know and analyzing the social perception and expectations on technology is essential.

In our research, based on the opinions of the respondents, we found that people's opinions and expectations vary by mode of transport, generation and gender. As a common point, respondents highlighted the safety factor, which means that safe daily transport for people will continue to be essential in the future.

Our research included a number of limitations that we suggest for detailed study later. First, the questionnaire was surveyed under uncontrolled conditions. For this reason, an assessment of the reliability of the responses could not be made either. Data collection under controlled conditions may modify the results. Second, data collection was based on self-reporting, which may also have skewed the results. Third, we did not develop representativeness requirements for data collection. The results have shown that there is a number of potential for further detailed analysis of the topic area. By conducting a nationally representative survey (age, gender, mode of transport), the expectations and opinions on self-driving technology would become accurately explored. Based on all this, we recommend the questions described in the methodological survey for a detailed and extensive examination.

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