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Research Article

Segmented trust assessment in autonomous vehicles via eye-tracking

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ABSTRACT: Previous studies have identified trust as one of the key factors in the technology acceptance of autonomous vehicles. As these studies mostly investigated the population in general, little is known about segment-specific differences. Furthermore, the widely used survey methods are less able to capture the deeper forms of trust—which neuroscientific methods are much better suited to capture. The main objective of our research is to study trust as one of the key factors of technology acceptance related to autonomous vehicles by using neuroscientific methods for specific consumer segments. Real-time eye-tracking tests were applied to a sample of 113 participants, combined with a posttest self-report. The tests were carried out under laboratory conditions during which our subjects watched videos recorded with the internal cameras of autonomous vehicles. Based on the fixation count, total fixation duration, and pupil dilation, we empirically verified that the trust level of all five identified segments is relatively low, while the trust level of the "traditional rejecting" segment is the lowest. An increase in trust level can be shown if the subjects receive extra information about the journey. Another important finding is that the self-reported trust level is not always congruent with the eye-tracking analysis results; therefore, combined approaches can lead to greater measurement validity.

KEYWORDS: autonomous vehicles (AVs), technology acceptance, trust, eye-tracking

1 Introduction

Several theoretical models have been created to test consumer acceptance of new technologies: The most commonly used models in the literature are the Technology Acceptance Model (TAM) (Davis, 1989; Venkatesh and Davis, 2000; Venkatesh and Bala, 2008) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003, 2012), whose many additional completed versions (TAM 2, TAM 3, UTAUT 2) are well known. All these models aim to capture the factors that influence behavioral intention to use a given technology.

In research on consumer acceptance of autonomous vehicles, the TAM and UTAUT models are also the most widespread (Keszey, 2020; Koul and Eydgahi, 2018; Müller, 2019; Smyth et al., 2021). These models were originally applied to measure the acceptance of technologies adapted in a corporate environment; thus, the examined variables are dominated by functionality (e.g., performance expectancy, effort expectancy) rather than emotional factors. In cases where the models were used for the acceptance of consumer innovations, several emotional factors–typically, perceived risk, hedonistic experience, and trust–were also included.

In the case of the technology acceptance of autonomous vehicles, trust is of particular importance (Panagiotopoulos and Dimitrakopoulos, 2018; Walker, 2018) since, on the one hand, traveling by car is a situation of high risk (Liu et al., 2019), and on the other hand, the news featuring accidents caused by autonomous vehicles has a considerably negative effect on the spread of technology (Kenesei et al., 2022). An increasing number of authors in the literature consider that to understand the acceptance of autonomous vehicles, trust, as a key factor, also needs to be examined (Meyer-Waarden and Cloarec, 2022; Panagiotopoulos and Dimitrakopoulos, 2018; Zhang et al., 2021). Although the literature is controversial regarding the effect of trust because, on the one hand, a lack of trust and perceived risk decrease behavioral intention (Kapser and Abdelrahman, 2020; Wang et al., 2019; Zhu et al., 2020), on the other hand, not every study has verified this connection (Choi and Ji, 2015; Liu et al., 2019). Kenesei et al. (2022) intend to resolve this contradiction by interpreting trust as a multidimensional phenomenon. Thus, behavioral intention can be influenced in different ways by the extent to which a consumer trusts the technology, the manufacturer of the given vehicle, or the policy makers who guarantee the safety of the system. An individual's level of trust is not constant; it may change because of the external environment, weather conditions, and unique situations and incidents (e.g., a pedestrian crossing or a sharp bend). The trust level of the passenger is influenced by the general reliability of the system (Desai et al., 2012), the difficulty of the driving task (Manzey et al., 2012), the frequency and type of occasionally occurring errors (Hoff and Bashir, 2015), and how clearly the vehicle is able to communicate and signal a given situation and its reaction to it (Koo et al., 2015).

Widely used models of trust (Integrative Model Of Organizational Trust (Mayer et al., 1995), Conceptual Model Of Trust In Automation (Lee and See, 2004), and Model Of Trust In Automation (Hoff and Bashir, 2015)) typically apply question-based methods. Nevertheless, the use of only question-based

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methods is highly limited in the case of autonomous vehicles (Keszey, 2020; Lukovics et al., 2023).

Furthermore, it is important to emphasize that consumers' attitudes related to autonomous vehicles are not unanimous; i.e., it is practical to investigate this issue in different consumer segments (Sharma and Misha 2022). Significant differences have been found in consumer attitudes according to age (Park and Han, 2023), size of household (Sharma and Misha, 2022), level of education, attitude toward sustainability, and openness to innovation (Potoglou et al., 2020).

We aim to investigate the manifestation of trust in autonomous vehicles through physiological responses and to determine the differences among predefined user segments. Real-time eye-tracking tests were conducted under laboratory conditions where participants watched a self-driving car video recorded inside an autonomous vehicle to simulate a passenger experience. This study was conducted on a sample of 113 participants; incomplete data from 11 of the 113 participants were discarded, resulting in 102 data sets for modeling purposes. The eye-tracking session was further combined with posttest interviews, where participants were asked to share their experiences concerning the video. The number and total duration of fixations were examined, as well as pupil movement through following the individuals' eye movements.

The novelty of this research lies in the methodology, as applying eye camera tests for grasping trust and doing so with a segmented approach is a new combination of widely accepted methods in the literature. The theoretical contribution of our study is to link the segmented approach and trust in the adoption of self-driving vehicles.

2 Literature review

2.1 Trust in consumer acceptance of autonomous vehicles

Trust is a complex and diverse concept (Hámori, 2004) with various conceptual approaches, most commonly based on belief (Doney et al., 1998; Nagy and Schubert, 2007) and risk (Das and Teng, 2004). Regarding the risk-based approach, Das and Teng (2004) compare and systematize different definitions in their study, in which they take into account the definitions formulated by Boon and Holmes (1991), as well as by Bradach and Eccless (1989), who claim "trust as a state of involving confident positive expectations about other's motives with respect to oneself in situations entailing risk" (Boon and Holmes, 1991; Das and Teng, 2004), and "trust is a type of expectation that alleviates the fear that one's exchange partner will act opportunistically" (Bradach and Eccless, 1989; Das and Teng, 2004). Trust is defined not only at the individual level but also at the organizational (Fenyvesi et al., 2013) and social levels (Csepeli et al., 2004). For the purposes of our research, the approach proposed by Kumar (1996) is also important; he mostly interprets trust as reliability accompanied by commitment, which is well fit in the research on trust related to autonomous vehicles.

The presence or lack of trust may have a significant effect on consumer acceptance of radical innovations, including autonomous vehicles (Shariff et al., 2017; Sheng et al., 2019). Therefore, understanding trust in autonomous vehicles and the factors influencing trust are of particular importance, which many authors have sought to systematize, typically following traditional questionnaire methodology (Table 1).

Table 1 Most important factors influencing trust in autonomous vehicles

Ref.	Factor influencing trust level
Sheng et al. (2019)	– External environment – Environmental conditions (e.g., weather) – Incidents considered more dangerous (e.g., pedestrian crossing)
Hoff and Bashir (2015)	– Reliability of system – Time and difficulty of error – Type of error
Manzey et al. (2012)	– Difficulty level of task at the time of error – Level of automation at the time of error
Koo et al. (2015)	– Communicating the reason for action to the driver – Information transmission – False alarms
Shariff et al. (2017)	– Ethical dilemmas – Social dilemmas

Hergeth et al. (2016) and Wickens et al. (2015) and argue that trust in automation and reliance on automation are frequently linked, as trust in an entity (be it human or machine) typically increases one's propensity to depend on them compared to situations where a trust relationship is absent. This finding is closely associated with the findings of Muir and Moray (1996), who claim that people tend to use automated systems that they trust and reject those that they do not (Hergeth et al., 2016).

2.2 Eye-tracking trust in autonomous vehicles

Eye tracking has been proposed as a promising method for measuring trust in autonomous vehicles (Azevedo-Sa et al., 2021; Lu and Sarter, 2018, 2019; Raats et al., 2020; Strauch et al., 2019; Walker el al., 2019). It has been found to be effective in inferring trust levels and can provide a continuous, real-time measurement of trust (Lu and Sarter, 2018, 2019). Azevedo-Sa et al. (2021) further supported this by proposing a framework for modeling and estimating drivers' trust in automated driving systems, which includes eye-tracking signals as a key component. There are different results regarding whether consumers' level of trust in vehicles can be connected to eye movement behavior. Several researchers have concluded that individuals with a high level of trust pay less attention to the road compared to those who do not trust the technology (Hergeth et al., 2016; Körber et al., 2018); however, Gold et al. (2015) did not identify such connections. Walker et al. (2018) found that the extent of trust can be efficiently deduced from the direction of attention.

In measuring trust level with an eye-tracking method, the number and duration of fixations are considered to be the two primary measures (Bagheri and Jamieson, 2004; Hergeth et al., 2016). Generally, the greater the fixation count and the longer the total fixation duration are, the lower the assumed trust level (Lu and Sarter, 2019, 2020; Moray and Inagaki, 2000). Lu and Sarter (2019) observed longer total fixation durations when subjects trusted self-driving less since, in this case, they analyzed each element much more carefully. If people trust automation and thereby that the machine completes a given task reliably, they tend to check the system less frequently (which can be indicated by the fixation count). This finding supports the results of both Bagheri and Jamieson (2004) and Moray and Inagaki (2000).

Based on the number and total duration of fixations, Hergeth et al. (2016) found that there is a negative correlation between eye movement and both dispositional trust and trust based on contextual self-reports. They showed that people who have a higher trust level pay less attention to the autonomous system, while the research subjects' trust related to automation significantly increased in the last measurement compared to the initial measurement.

In addition to fixation count and total fixation duration, there is evidence in the literature about the importance of analyzing pupil dilation size. If the subject's pupils dilate or frequent blinking is observed, this indicates a greater degree of involvement (Varga, 2016). Furthermore, when a subject is under stress, sympathetic nervous system activity increases the pupil diameter (Sheng et al., 2019). Additionally, pupil diameter correlates with perceived risk (thereby the level of trust in automation) during critical incidents (He et al., 2022; Perello-March et al., 2019).

The findings regarding the measurement of trust level with eye-tracking are summarized in Table 2.

Overall, it can be concluded that much important information can be gathered over the course of eye-tracking tests by analyzing the number and duration of fixations, as well as pupil dilation size, as these physiological responses can be important indicators of individuals' confidence in autonomous technology, and we can also draw conclusions regarding which areas attracted the most attention from the subjects.

However, survey methods are the most widely applied measurements for examining the whole population – without paying attention to group-level differences or peculiarities of given segments. Therefore, it is still undiscovered how trust becomes apparent in physiological reactions and whether any differences can be detected among groups with distinct characteristics. This indicates a research gap in understanding the nuanced aspects of trust in the context of autonomous vehicle technology acceptance.

3 Materials and methods

As the first step of our research, we classified our respondents into five predefined segments using a preliminary filter questionnaire. These five consumer segments① were defined in the Hungarian market by Nagy et al. (2022). These segments show some similarities with the well-recognized Roger's (2003) innovation adaptation personas – but in an autonomous vehicle context. A description of these segments is provided in Table 3. A total of 113 voluntary participants were invited to participate in the eye-tracking study, for which valid data were obtained for 102 patients. Following the methodological guidelines of eye tracking (Pernice and Nielsen, 2009), we aimed to compile as representative a sample as possible; however, despite our efforts, our sample cannot be considered fully representative.

As a general rule, to guarantee the reliability of the results, the literature recommends that the study group should have more than 30 respondents (Pernice and Nielsen, 2009). This finding aligns with Strzelecki's (2020) systematic literature review of eye-tracking methodology, which revealed that the rounded mean value is 30 participants in the whole set of papers. However, the acceptable sample size may vary depending on the research objectives (Eraslan et al., 2018; Pernice and Nielsen, 2009; Shadiev and Li, 2023). This is also consistent with Strzelecki's (2020) results, where the standard deviation of the sample size across the 58 analyzed studies was 12.32, ranging from a minimum of 5 to a maximum of 58. Due to the accuracy and diligence of our research, we will consider our groupwise sample size as a limitation, even though many eye-tracking studies have been published with sample sizes of 18 or fewer participants (Bozkir et al., 2021; Curtell and Guann, 2007; Dickershof and Smith, 2014; Djamasbi et al., 2013; Dunn et al., 2023; Egusa et al., 2008; Guann and Curtell, 2007; Habuchi et al., 2008; Ibourk and Al-Adwan, 2019; Kim et al., 2016; Lu and Sarter, 2020; Orlosky et al., 2019; Rele and Duchowski, 2005; Wang et al., 2021; Xu et al., 2008).

Table 2 Indicators of trust level in eye movement

Ref.	Indicator of trust level in eye movement
Körber et al. (2018) Hergeth et al. (2016) Walker et al. (2018)	High trust level = less attention to road Lower trust level = more attention to road
Lu and Sarter (2020) Lu and Sarter (2019) Hergeth et al. (2016) Bagheri and Jamieson (2004) Moray and Inagaki (2000)	Higher trust level = shorter total fixation duration Higher trust level = less fixation Lower trust level = longer total fixations duration Lower trust level = more fixation
Sheng et al. (2019)	Pupil diameter increases as a result of sympathetic nervous system activity under stress
Varga (2016)	If the subject's pupils dilate, it refers to higher involvement.
He et al. (2022)	Pupil diameter correlates with perceived risk

Table 3 Number of subjects involved in the study for each group

Name of segment	General description of the segment	No. of participants	No. of dataset
Open-minded adventurer	A segment of predominantly young men who are the most open and explicitly looking forward to AV.	23	22
Uncertain optimist	A segment of mainly young women who are open to AV and curious but not as dedicated as the previous segment.	25	25
Reserved observer	They are generally hesitant about AV, but if it starts to spread they would like to try it.	23	21
Mistrustful doubter	They are less interested in AV and would only try it once it has become widespread.	21	17
Traditional rejector	Mainly older and predominantly female segment who are the most dismissive of AV.	21	17
Total		113	102

① Traditional rejectors, open-minded adventurers, uncertain optimists, mistrustful doubters, and reserved observers.

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Furthermore, it should be noted that for the 4th and 5th segments, individuals who, based on the preliminary questionnaire, already exhibited a rejecting attitude toward autonomous vehicles had to be convinced to participate in the eye-tracking study. This posed an obvious challenge.

During the eye-tracking measurement—using a Tobii Pro eye camera—the participants were asked to watch a video shot inside an autonomous vehicle. The video was compiled from publicly available sequences according to two aspects:

1) Different situations are shown from different positions.

2) The eye movements observed at the beginning and at the end of the video can be compared to some extent; therefore, we selected the first and last sections of the video in such a way that the subjects can watch the ride from the same angle and have relatively more time to become involved in the given situation.

The recording consisted of 5 different sequences, within which we defined 29 areas of interest (AOI) (Table 4).

In terms of the data collected via eye cameras, four important measures can be defined:

– Average fixation duration: how long a fixation lasted on average within the given AOI.

– Fixation count: number of fixations within the given AOI.

– Total fixation duration: total length of fixations within the given AOI.

– Pupil diameter (right/left): the change in right and left pupil diameter within the given AOI.

To analyze the eye camera data, we examined several types of data extracted with the software. In Sections 4 and 5, we briefly review and interpret the most important results and conclusions.

Table 4 Names of the AOIs defined in the video and the frames characterizing each section

Section	Defined AOI	Visual appearance
Section 1②	AOI1: section 1 – windshield AOI2: section 1 – left window AOI3: section 1 – left mirror AOI4: section 1 – electronics AOI5: section 1 – right window AOI6: section 1 – right mirror AOI7: section 1 – steering wheel AOI8: section 1 – control panel AOI9: section 1 – tablet	
Section 2③	AOI10: section 2 – window AOI11: section 2 – steering wheel AOI12: section 2 – windshield AOI13: section 2 – seat	
Section 3④	AOI14: section 3 – electronics AOI15: section 3 – steering wheel AOI16: section 3 – control panel AOI17: section 3 – windshield	
Section 4⑤	AOI18: section 4 – left window AOI19: section 4 – steering wheel AOI20: section 4 – windshield AOI21: section 4 – mirror	
Section 5⑥	AOI22: section 5 – left window AOI23: section 5 – left mirror AOI24: section 5 – electronics AOI25: section 5 – right window AOI26: section 5 – right mirror AOI27: section 5 – steering wheel AOI28: section 5 – control panel AOI29: section 5 – windshield	

② https://www.youtube.com/watch?v=O69YEWpSacU&t=516s

③ https://www.youtube.com/watch?v=O69YEWpSacU&t=516s

④ https://www.youtube.com/watch?v=__EoOvVkEMo

⑤ https://www.youtube.com/watch?v=qAZ6tJSj9T4

⑥ https://www.youtube.com/watch?v=ILzsK65UAtk&t=375s

4 Results

We first analyzed the fixation counts related to the external and internal AOIs in each group (Fig. 1). The results indicate that in the case of each group, more fixations were located on external AOIs, and it can also be observed that the most fixations on average regarding both external and internal areas of interest can be seen in the case of the 'traditional rejectors' segment. This finding also proved to be true in terms of the entire video (analyzing all AOIs collectively), as 'traditional rejectors' had the highest fixation count in that case based on the results. Overall, during the video, watching the external environment proved to be more important than watching the internal environment since the frequency of the fixations also refers to the degree of importance.

Based on the literature, we can assume that participants with lower levels of trust tend to pay more attention to the external environment than to the internal environment, and mistrust can be assumed for all groups on this basis. As the majority of the fixations were located on the windshield during the entire video in the case of each segment, the greatest attention was given to the external environment and the actions taking place there, which assumes a lower trust level for each group in terms of trust.

Fig. 2 shows that at least 52% of the total fixation duration on the presented AOIs was on the windshield in each group, but this proportion was the largest in the traditional rejector group, with 56% of the total fixation duration occurring there. It is followed by the steering wheel, which was viewed by the 'uncertain optimists' and 'mistrustful doubters' segments for the longest time, with 22% of the total fixation duration on the mentioned AOI element. Overall, the right and left windows were watched by the 'open-minded adventurers' in the greatest percentage (8%) of the windows during the virtual ride, and the same applies to the right and left mirrors (3%) collectively.

Fig. 3 shows the moment when the tablet displaying the route plan appears in the bottom right-hand corner of the video. We can see that the appearance of the tablet received considerable attention, which correlates with the quantified results since the longest fixations on average were located on the tablet among the

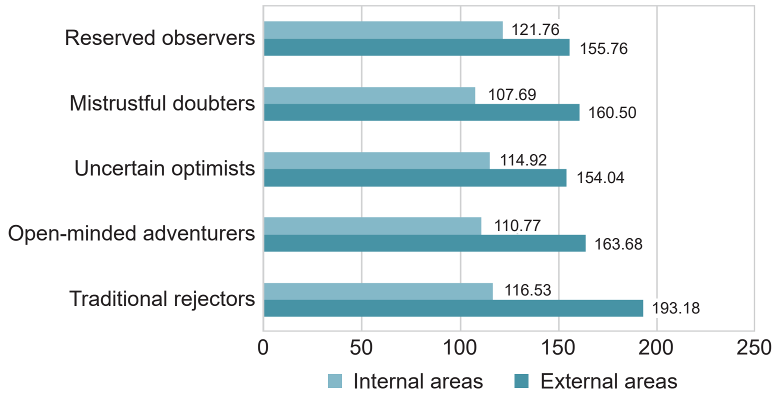
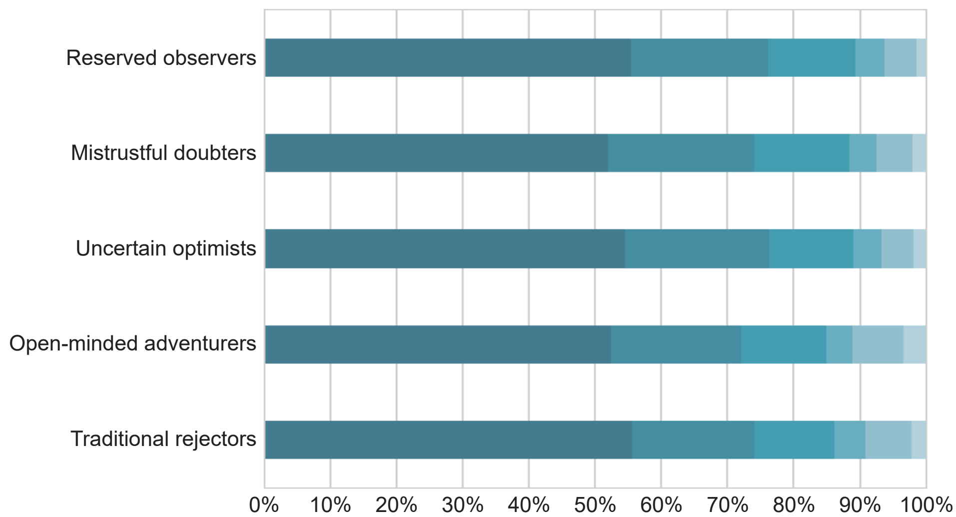


Fig. 1 Fixation count on average regarding the external and internal environment during the full video.



	Traditional rejectors	Open-minded adventurers	Uncertain optimists	Mistrustful doubters	Reserved observers
Windshield	56%	52%	55%	52%	55%
Steering wheel	18%	20%	22%	22%	21%
Control panel	12%	13%	13%	14%	13%
Electronics	5%	4%	4%	4%	4%
Window	7%	8%	5%	5%	5%
Mirror	2%	3%	2%	2%	1%

Windshield Steering wheel Control panel Electronics Window Mirror

Fig. 2 Percentage of total fixation duration between the studied AOIs by group.

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Fig. 3 Appearance of the tablet displaying the route plan. Note: turquoise – traditional rejectors; yellow – open-minded adventurers; pink – uncertain optimists; green – mistrustful doubters; purple – reserved observers⑦.

internal elements inSection 1; thus, the subjects' eyes were fixated on this element for the longest time on average.

Examining the average duration of fixations (Fig. 4), we can conclude that, on average, the longest fixations were typically located on one of the external AOIs, except in the case of the 'mistrustful doubters' segment, where the average fixation duration was the same for both the external and internal areas. Fitts et al. (1950) state that longer fixations can usually be observed when the tasks are more difficult or require more involvement.

Changes in the average duration of the fixations were also observed in Sections 1 and 5 (i.e., whether deeper involvement characterized the subjects at the end of the video compared to the beginning). We can conclude that in Section 1, the subjects mostly paid attention to one element for an excessively long period in terms of both the external and internal areas, while their eyes were fixated on the other areas involved in the test only sporadically. In contrast, in Section 5, we can see in both cases that the average fixation duration is much more equalized in the case of both the external and internal elements. Moreover, the average fixation duration was considerably longer for the external elements in Section 5 than for those in Section 1, i.e., we can assume a deeper involvement level by the end of the video. An increase in the average fixation duration indicates a decrease in the fixation count, which implies that the subjects became accustomed to the self-driving situation by the end of the video; therefore, their level of trust in the technology could have increased to some extent.

As shown in Section 2, the degree of trust can be efficiently deduced from the direction of gaze. Overall, the analysis of the quantified data confirmed that greater attention was given to external elements, which is illustrated by Fig. 5, which shows the current position of the gaze of the 102 subjects involved in the research at a particular moment in Section 1 of the video.

Furthermore, it also suggests that the priorly assumed trust level could not be verified for each segment with eye movement data, which may mean that mistrust also occurs among those segments that otherwise have a high trust level based on their assessment.

Apart from fixation count and duration, we examined another factor, pupil dilation size, in our research. Pupil dilation can indicate the state of excitement that the subject characterized with and the degree of involvement. If the subject's pupils dilate, it refers to higher involvement and higher excitement (Varga, 2016). Table 5 presents the average size of pupil dilation, which shows that the largest pupil dilation occurred in the 'traditional rejector' segment for the windshield (left: 3.2163 mm; right: 3.2450 mm) and the steering wheel (left: 3.2239 mm; right: 3.3443 mm). For the other four segments, this phenomenon can be observed for the steering wheel and the control panel. For all groups, the largest pupil dilation occurred while watching internal elements, i.e., deeper involvement is indicated in the case of these elements. Table 5 also shows that the average size of pupil dilation is the largest in the case of windows and mirrors in the segment of open-minded adventurers.

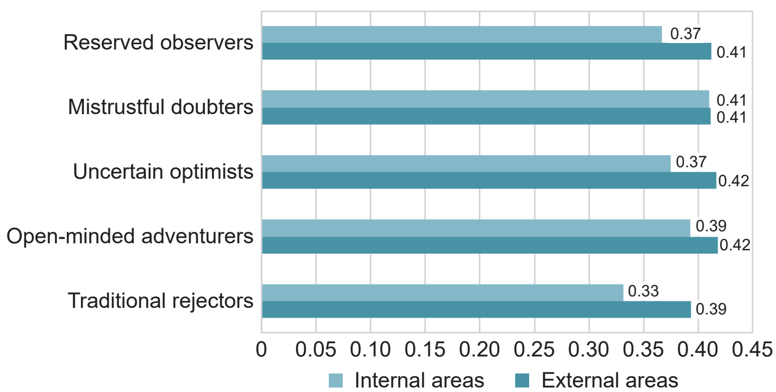

Fig. 4 Average fixation duration related to the external and internal environment during the full video.

⑦ Source of picture: https://www.youtube.com/watch?v=O69YEWpSacU&t=516s

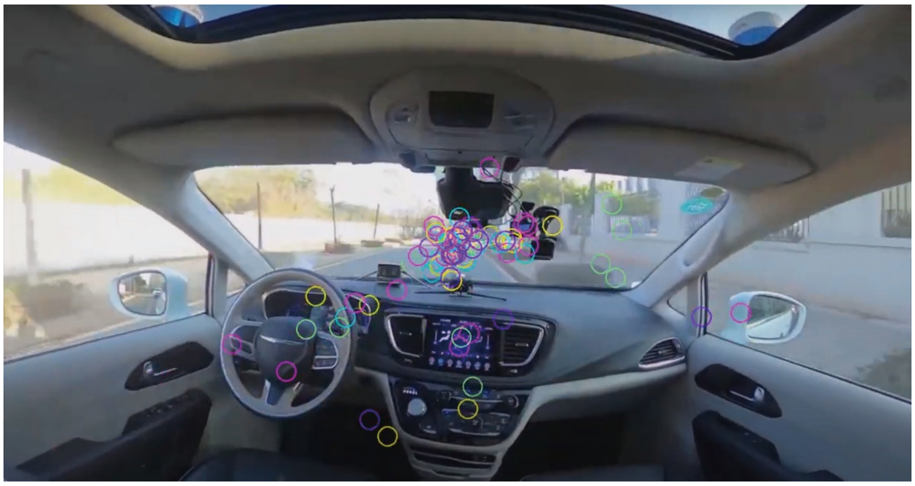

Fig. 5 Eye movements observed in Section 1. Note: turquoise – traditional rejectors; yellow – open-minded adventurers; pink – uncertain optimists; green – mistrustful doubters; purple – reserved observers⑧.

Table 5 Average pupil dilation in the case of AOIs included in the study during the full video

Segment	Pupil	Windshield	Steering wheel	Control panel	Electronics	Window	Mirror
Traditional rejector	Left	3.2163	3.2239	3.0109	2.8480	2.3608	1.6368
	Right	3.2450	3.3443	3.0826	2.8768	2.4325	1.7030
Open-minded adventurer	Left	3.2216	3.3308	3.2993	2.8374	2.5685	2.0188
	Right	3.2302	3.4053	3.3464	2.8059	2.6047	2.0372
Uncertain optimist	Left	3.2351	3.3910	3.2680	2.7820	2.1231	1.3938
	Right	3.2781	3.4684	3.3177	2.8115	2.1740	1.4333
Mistrustful doubter	Left	3.4270	3.6198	3.6159	2.3522	2.5242	1.5493
	Right	3.3995	3.6185	3.6020	2.3388	2.5297	1.5537
Reserved observer	Left	3.0652	3.1026	3.1227	2.4354	2.1154	1.1927
	Right	3.0821	3.1707	3.1671	2.4699	2.1419	1.2191

Posttest interviews were also conducted with each participant, and the results were compiled via eye-tracking analysis. In the case of the ‘traditional rejectors’ segment, the issue of mistrust was a central topic during the interviews, and this mistrust also emerged in analyzing the eye camera data; thus, we can say that the level of trust based on self-reports is reflected in the results obtained based on the eye camera data. In the case of ‘open-minded adventurers’, we can identify a clearly positive attitude based on the posttest interviews; however, this finding is not supported by the eye movement data, as the members of this segment – like all other segments – paid more attention to the external environment. Among the segments, ‘open-minded adventurers’ paid the most attention to mirrors and windows. After watching the video, these participants’ opinions remained very positive, and they claimed they were looking forward to the appearance of autonomous cars. ‘Uncertain optimists’ reported having an initial fear of accidents that decreased after watching the video. In the case of this group, the self-moving steering wheel was given great attention; however, they also paid the most attention to the external wheel. ‘Mistrustful doubters’ reportedly were afraid of the system making a wrong decision; however, during the posttest discussion, many of them mentioned that seeing the safe movement of the car decreased their skepticism. Furthermore, the eye tracking data indicated that the average fixation duration was the same for the external and internal AOIs, but overall, the greatest attention was given to the elements of the external environment. Reserved observers were admittedly afraid of the lack of control; most of them claimed that they watched the road as if they were driving, which was confirmed with eye tracking data, as they had the longest fixations in terms of external AOIs (Table 6).

5 Discussion

The data analysis (Table 7) showed that the greatest attention throughout the entire video was paid to the external AOIs, and the most fixations were observed in the case of traditional rejectors. This finding supports the findings of Lu and Sarter (2019, 2020), Hergeth et al. (2016), Bagheri and Jamieson (2004), and Moray and Inagaki (2000), who all have claimed that individuals with a low trust level can be characterized by a higher fixation count. Furthermore, the frequency of fixations also indicates the degree of importance. Thus, we can conclude that overall, observing the external environment during the video proved to be more crucial than observing the internal environment. Based on these findings, we can also infer that self-reported trust levels do not always align with eye-tracking results. This is evident as members of groups theoretically possessing higher levels of trust tended to gaze outward rather than inward.

Regarding the cumulative length of fixations, we can state that at least 52% of the total fixation length fell on the specified AOI areas, with the windshield receiving the highest percentage for all groups. Notably, the traditionalist-rejector group exhibited the greatest proportion, as 56% of the total fixation length was

⑧ Source of picture: https://www.youtube.com/watch?v=O69YEWpSacU&t=516s

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Table 6 Summary of the main results

Segment	Eye camera data collection	Posttest self-report discussion
Traditional rejector	– Mistrust can be validated with eye movement data	– Clearly, rejecting opinion and negative feelings still after watching the video
Open-minded adventurer	– In addition to external environment, attention to windows and mirrors – Mistrust can be assumed	– Anticipation, interest
Uncertain optimist	– In addition to external environment, great attention to steering wheel – Mistrust can be assumed	– Sense of safety, futuristic feelings – Steering wheel
Mistrustful doubter	– Average fixation duration was the same in the case of internal and external environment – Highest attention to external environment, mistrust can be assumed	– Showing the video managed to decrease the skepticism of many subjects
Reserved observer	– Longest fixations on external AOIs – Mistrust can be assumed	– Continuous attention, as if the subject was driving

Source: own construction

Table 7 Comparison of the main results and conclusions with those of other studies

This study	Connection with previous research results
In the case of individuals with low trust level there is higher fixation count.	In line with the results of Bagheri and Jamieson (2004), Hergeth et al. (2016), Lu and Sarter (2019, 2020), Moray and Inagaki (2000).
In the case of individuals with low trust level there is higher total fixation duration.	In line with the results of Bagheri and Jamieson (2004), Hergeth et al. (2016), Lu and Sarter (2019, 2020), Moray and Inagaki (2000).
Providing extra information in a visually appealing form increases trust	In line with the results of Józsa and Hámornik (2011), Koo et al. (2015).
The research subjects' trust regarding automation significantly increased in the last measurement compared to the initial measurement.	In line with the results of Hergeth et al (2016).
No clear connection can be shown between the direction of gaze and the trust level for the different segments.	Contradicts with the results of Hergeth et al. (2016), Körber et al. (2018), Walker et al., (2018), who showed that subjects with a high trust level tend to pay less attention to the road.
For all groups, deeper involvement and more positive feelings/responses occur while watching the internal elements.	If the subject's pupils delate, it refers to higher involvement (Varga, 2016). When the subject is under stress, sympathetic nervous system activity increases the pupil diameter (Sheng et al., 2019).

directed at the windshield. This observation aligns with the finding that individuals with lower levels of trust tend to have a greater cumulative length of fixation (Bagheri and Jamieson, 2004; Hergeth et al., 2016; Lu and Sarter, 2019; Moray and Inagaki, 2000).

The tablet appearing in the internal space was given particular attention, which indicates that on-screen information about the journey can provide a better traveling experience and influence trust (Koo et al., 2015), and it can be claimed that the human eye is indeed most attracted by the most informative areas of a stimulus (Józsa and Hámornik, 2011). The data analysis indicated that in Section 5 of the video, the subjects' gaze was fixated on several elements for a longer time compared to Section 1, which allows us to conclude that they became accustomed to the self-driving situation by the end of the ride, which is in line with the findings of Hergeth et al. (2016).

Based on the results of the present research, we can state that no clear correlation can be shown between the direction of the gaze (i.e., whether the subjects paid more attention to the internal or external environment) and the trust level for the different consumer segments, as all groups uniformly paid more attention to the external environment.

Some researchers argue that we can effectively infer the level of trust from the direction of gaze. According to Hergeth et al. (2016), Körber et al. (2018), and Walker et al. (2018), individuals with high levels of trust tend to pay less attention to the road than those who do not trust autonomous technology. Gold et al. (2015) did not find this correlation, which is also applicable to the present study, as all groups uniformly focused more on the external environment. Moreover, we can deduce from this that the assumed level of trust was not confirmed by eye-tracking data for all groups, suggesting that distrust may be observed among those who claim to have a high level of trust. However, as the more informative areas of a stimulus attract human attention (Józsa and Hámornik, 2011), it is not surprising that the external environment proved more interesting for all groups than the internal environment.

The change in pupil diameter suggests that as pupil dilation increases when individuals watch internal elements in each group, based on the findings of Varga (2016), we can assume that this environment entails deeper involvement. This result may also prove to be interesting since even though overall, the external environment was given greater attention based on the fixation count and duration in each segment, in terms of the change in pupil diameter, deeper involvement occurred in the case of internal elements. This means that even though the subjects' gaze was fixated on the internal environment for a shorter time, they could still become more engaged while watching these elements. Furthermore, if we assume that the participants experienced the virtual journey as a sort of stress, based on the findings of Sheng et al. (2019), we can say that watching the internal environment proved to be preferable to watching the external environment.

6 Conclusions

Technology acceptance models aim to identify factors influencing behavioral intention. Initially, applied in corporate environments, these models predominantly focus on functional variables (e.g., performance expectancy, effort expectancy) rather than emotional factors. However, when applied to consumer innovations, emotional elements such as perceived risk, hedonistic experience, and trust are often incorporated. In the context of accepting autonomous vehicles, trust becomes notably significant. Comprehending the acceptance of autonomous vehicles arguably requires a thorough examination of trust as a key factor. Models addressing trust, such as the measuring technology acceptance, commonly utilize question-based methods. However, relying solely on such methods is considerably limited in the case of autonomous vehicles. It is crucial to underscore that consumer attitudes toward autonomous vehicles are diverse. Investigating the issue across different consumer segments is practical. The literature reveals substantial differences in consumer attitudes based on factors such as age, household size, education level, sustainability attitudes, and openness to innovation.

Our research aimed to investigate trust as one of the key factors of technology acceptance regarding autonomous vehicles with a neuroscientific method using an attitude-based segmented approach. To address the research question, we conducted eye-tracking tests on a sample of 102 valid items under laboratory conditions, which we complemented with posttest interviews.

Based on the fixation count, total fixation duration, and pupil dilation, it could be verified that the 'traditional rejection' segment' s trust level is the lowest, and based on the direction of gaze and the fixation count, all five segments' trust levels are relatively low. An increase in trust level was indicated when the subjects received extra information about the ride in the form of an interior tablet. Another important finding is that self-reported levels of trust are not always reflected in eye movement results.

Given the acknowledged limitations of the study, it is crucial to note that the trust measured in the video-watching scenario within a laboratory setting may differ from the trust generated through experiences in real vehicles, especially considering the potential risk of accidents associated with real-world automated driving. Although the absence of real-world risk might have influenced the study results, the data still suggest the validity of our methodology for investigating user trust. Another limitation is the short duration of the video, which lasted only 2 min and 55 s, preventing us from making statements about long-term use. Additionally, due to group segmentation, only 17 data points were available for analysis, potentially decreasing the internal validity.

To address these limitations, further studies are necessary. These methods can help overcome the identified shortcomings and contribute to achieving the ultimate goal of this research. Our findings can serve as a foundation for conducting eye-tracking studies in real autonomous vehicles, as opposed to in simulated environments, complemented by other neuroscientific measurement methods such as mobile electroencephalogram (EEG) and galvanic skin response (GSR) sensors.

Our findings have several practical implications for manufacturers in the field of AVs. Based on the results, manufacturers can refine the user interface and experience of autonomous vehicles. They can understand how passengers' trust levels influence the acceptance of the vehicle and accordingly shape the user experience. Additionally, they can fine-tune vehicle safety systems. For instance, if passengers exhibit lower trust levels in a specific situation, the systems can be more proactive in notifications and control. During technology development, special attention should be given to trust factors. For example, enhancing real-time information during travel or introducing technologies that boost user confidence could be considered.

In conclusion, we believe that our research may contribute to understanding trust as a key factor in the acceptance of autonomous vehicles through the application of real-time eye-tracking measurements in addition to traditional assessment methods. The application of eye-tracking measurements of trust on an attitude-based presegmented sample can be considered a methodological novelty that offers insight into the complex interaction of trust, physiological responses, and different consumer groups in the context of the acceptance of AVs.

Replication and data sharing

The data of this study are available at https://doi.org/10.26599/ETSD.2024.9190027.

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Declaration of competing interest

The authors have no competing interests to declare that are relevant to the content of this article.

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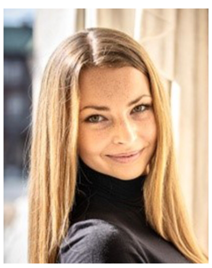

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