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Teenagers and Automated Vehicles: Are They Ready to Use Them?

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Abstract: Mobility needs, expectations, and concerns vary across age groups and are closely linked to users' views on the future of the road transport system. Automated vehicles are expected to have a significant impact on the future of the road transport system, and pilot deployments are increasingly being tested in Europe and beyond, which is also thanks to the evolving regulatory landscape. As a result, several studies have started to analyse citizens' attitudes towards this technology. However, very few studies have focused on teenagers' views on automated vehicles, although today's children and teenagers could be among the first users of such vehicles. Studying teenagers and the way they envisage automated vehicles in the future is of particular significance in defining transport planning strategies and supporting upcoming policy orientations. To cover this gap, the present study aims to explore teenagers' views about automated vehicles and whether and how they could fit into their future transport setting. A series of on-line and face-to-face focus groups, a demonstration of an automated vehicle prototype, supporting engagement activities, and a post-pre survey were used to collect their views on the topic. The results show that even though the teenagers acknowledged the potential advantages, they also expressed concerns in relation to the interactions with other road users, to automated driving systems' reliability, to safety, and to data privacy. In particular, these safety concerns revealed an unwillingness on the part of the teenagers to be among the first users of automated vehicles.

Keywords: automated vehicles; teenagers; expectations; transportation

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1. Introduction

Children and the young generations are the future of our society, representing 31.5% (15.1% children, aged 0–14 years, and 16.4% young people, aged 15–29 years) of the total EU-27 population in 2021 [1]. The importance of taking care of the needs, views, expectations, and opinions of the youth has recently been reflected in the European Youth Strategy, which defined the framework for the EU youth policy cooperation for the period of 2019–2027 [2]. The policy's strategy is based on the concept of youth cooperation and fosters their participation in democratic life, supports social and civic engagement, and aims to ensure that all young people have the necessary resources to take part in the society. The policy focuses on three concepts: *engagement* in all societal activities; the *connectivity* to participate in different ways; and *empowerment* through the possibility to take control of their lives. With a list of 11 youth goals to achieve by 2027, the EU has committed to ensuring a better quality of life for young generations, including their mobility freedom. Previous European youth transport mobility policies are rather scarce, with the exception of the work conducted in 2002 on youth and mobility [3], which led to the need to pay more attention to the topic and to its research and policy implications.

Understanding the mobility and transport needs of children and teenagers and the relevant influencing factors could support the deployment of adapted transport services that can suit these needs better and reduce the concerns teenagers and parents have regarding the mobility to school and other destinations. While children are fully dependent on their families for mobility, teenagers normally become more and more familiar with the transport system, increasing their independent mobility and starting to develop their own travel patterns and mobility habits, which are influenced by their family habits, socio-economic conditions, geographical location, and other variables. Previous work on the topic has identified that the use and ownership of a private vehicle would fit into teenagers' future transport and mobility habits [4,5], while other studies demonstrate a change in tendency, where young generations would not be so eager to use a private vehicle, buy one, or obtain a driving license [6–8]; moreover, other studies have reported a possible decrease in the time dedicated to the driving activity [9]. These tendencies could be influenced by many factors, such as increasing environmental concerns, new forms of mobility, (e.g., shared mobility), and the introduction of new technologies, such as electric and automated vehicles (AVs).

The future of road transport systems will be shaped by the influences of four general trends, namely automation, connectivity, decarbonisation, and sharing, and these will trigger multiple changes at the societal level. The development and deployment of AVs plays a key role in the automation of the driving task [10]. AVs can be referred to as vehicles in which the role of a human driver is limited and will in the future be, possibly, non-existent, which can heavily impact the travel behaviour of their users [11]. The current paper studies the views of teenagers regarding Level 5 automation (full automation with no human intervention under all conditions), as defined by the SAE International [12]. Nevertheless, during the activities the teenagers could refer to their experiences with any level of automation. As with all new technologies, AVs also raise many questions related to their actual use, safety implications, etc. Some studies have already looked at parents' views when faced with AVs [13,14]. However, only a few studies investigate the views of teenagers towards AVs. In addition, these studies do not focus only on teenagers but on broader age ranges (e.g., young minors together with teenagers or teenagers with young adults), usually putting little emphasis on the variation in mobility patterns among the different age categories.

In this context, the current paper investigates the views of teenagers aged 14–17 years in relation to AVs. This specific age group has continuously evolving and transforming travel patterns, and they make trips more independently compared to younger children. The data of this study were collected through focus groups (FG) and various engagement activities (namely, a real-life demonstration of an AV, a mood board activity, and an inspirational space activity), where the students involved could freely express their views on the topic. The engagement activities were then followed by a post-pre survey.

This paper aims to capture teenagers' opinions, perceptions, and concerns about AVs and their possible future use based on their mobility needs. The study is particularly timely because according to the World Health Organisation (WHO), "Road traffic injuries are the leading cause of death for children and young adults aged 5–29 years" [15], and automated vehicles, especially in Europe, are considered one of the main technological tools to achieve Vision Zero, namely the reduction in road deaths to zero by 2050 [16].

The paper is structured in the following manner. Section 2 illustrates previous works supporting the present analysis. Based on the summary of the state of knowledge, we refine in this section our research questions. Section 3 defines the methodological approach undertaken. The results and their discussion are included in Section 4. Finally, the conclusions and possible further research steps are described in Section 5.

2. Literature Review

Teenagers have a relatively set travel pattern—commuting to school and to diverse destinations to attend afterschool activities, sports, and other learning or recreational

activities and returning home. The behaviour of children and teenagers in travelling to school and the modes used were investigated in the literature, particularly the studies focused on transport and urban planning, transport, and public health.

Mitra [17] proposed the behavioural model of school transportation (BMST), a framework developed to guide the research focused on analysing the characteristics of the mobility from home to school among children and teenagers. This model identifies various factors of influence for choosing the mode of travel used in home–school commuting and whether such travel is conducted independently or not. The main factors influencing the school travel presented in the study were the social and built environment (in terms of infrastructure), the household characteristics, the child/youth personal traits, the attitudes and level of physical and cognitive development, and other external factors, such as existing policies and social context.

Two major focus areas were identified in the literature review process. On the one side was the type of mobility (independent or accompanied) the children and teenagers have, and on the other side was the mode of transportation used for commuting to school or other destinations.

2.1. Independent or Accompanied Mobility

The literature identifies a so-called 'age effect' [17,18], which is characterised by an increase in independent mobility related to the physical/cognitive development of children as they grow older and which represents an influencing factor on the travel behaviour of teenagers.

The fact that teenagers travel to school or other destinations more independently was observed in other studies as well [19–23]. When the household income was high, an increase in travelling accompanied to school or with non-family members (e.g., friends or colleagues) was also noticed, especially among teenage girls [24]. The influence of age and gender on the mobility to school was observed by Mitra and Buliung [18] and Carver et al. [25], while Bjerkan and Nordtømm [19] found an influence on the mobility used for leisure activities. He and Giuliano [26] distinguished the role played by the parents' (especially the mother's) employment schedule and workplace location on the independent or accompanied travel patterns of students in primary and secondary education. Ermagun and Levinson [22], in their study covering students aged 12–18 years old, identified a positive correlation of independent mobility with the distance from home to school and a negative one with the distance between school and the parents' workplace. With the desire to feel independent, convenient and comfortable travel experiences and environmental aspects were remarked as important factors for the mobility and travel behaviour of young people in Johansson's study [27].

The meta-analysis review of Sharmin and Kamruzzaman [28] highlighted the differences between the impacts of specific factors on the independent mobility of children and youth in developing and developed countries. It was observed that the distance to the destination, together with the mixed land use and the intersection density, has a strong impact on the independent mobility of children and teenagers ($\leq$18 years old) in developing countries and a limited or no effect in developed ones.

The FG script that guided the discussions of the present study did not include questions to assess the independent or accompanied mobility of the participants; however, information about these patterns of travel appeared spontaneously during the discussions and is presented in the results section.

2.2. Travel Mode–Active or Passive Modes of Transport

The literature remarked on a decline in the use of active modes of travelling (e.g., walking or cycling), especially in commuting to school [29–31]. Some of the reasons for this decline and the corresponding increase in commuting to school by car and by other motorised vehicles or public transport were identified in [32,33].

Yang et al. [30] presented a list of factors with an influence on the decrease in active travel to school, such as the distance to school, the availability of private vehicles in the household, traffic-related aspects, crime, the family time budget, the social norms regarding active travel to school, and parents' attitudes towards active travel modes. The study concluded that countries with economic development and urban sprawl have a bigger role in the reduction in active travel to school compared to that of the influence of urban design or crime and that the increase in the distance between home and school represents a major dissuasive factor against walking or cycling to school.

The influencing role of the distance to school on the mode of travel used was observed by Mitra and Buliung [18]: long travel distances to schools make walking/cycling less attractive for high school students. Similar results were also published by Mandic et al. [31] in a study covering teenagers aged 13–19 years old; by Carver et al. [34]; by Pizzaro et al. [35]; and by van Goeverden and de Boer [36]. A similar finding was also observed by Barnett et al. [37], where the actual or perceived proximity to the destination (school or other) was strongly positively associated with the use of active modes of transport. Broberg and Sarjala [38] identified the negative impacts of both the distance to school and the higher incidence of major roads near the route to school on active commuting. Curtis et al. [39] observed an average distance of 2 km from home to school for the active travellers, and a similar value was reported by Pizzaro et al. [35].

Shengxiao and Pengjun [40] identified an acceptable walking distance to school of around 3 km, while they also remarked on a shift to public transport for those that needed to commute more than 2 km. Moreover, they pointed out that children from low-income households travel more actively by walking than by cycling, and those living in households with a private car have higher chances of travelling to school by car. In [37], similarly, teenagers from households with a high educational attainment and with more access to vehicles were less likely to walk or cycle to school.

The research of Kamargianni et al. [41] on 11–18-year-old teenagers revealed the role of the transport infrastructure (e.g., the availability of a separate path or parking spaces for bicycles and the width of sidewalks) as a factor significantly influencing the choice of the active transport mode. The study also presented the impact of other factors on the mode chosen by teenagers in their mobility: a green lifestyle is related to travelling with public transport; the physical activity propensity of teenagers is linked with the choice to walk and cycle; and safety consciousness leads to choosing the car mode accompanied by an adult. In addition to the above, the built environment and road infrastructure represent factors influencing the active commuting behaviour among adolescents, as observed in Tewahade et al. [42] and Chen et al. [43].

The parents' decisions, attitudes, concerns, and travel availability at the requested time [18] play a significant role in the travel mode choice and behaviour of teenagers in their daily mobility. Ermagun and Samimi [44] noted that parents concerned about the safety of their children do not allow them to walk or take public transport when travelling to school, and those worried about the duration of their children's travel are more willing to use a personal car for that. Carver et al. [25] identified a high level of concern among parents, especially those with children in primary school, about the risk of their children being injured in a traffic accident and that a highly perceived level of road safety and social trust by parents could be linked with a lower mobility by car. Mandic et al. [31] observed that children and teenagers actively commuting to school expressed lower parental concerns about their safety, valued the journey to school as a good opportunity to socialize with friends or colleagues, and did not perceive this mobility as time-consuming. Similarly, children and teenagers travelled more actively to school when they were encouraged by their parents and were accompanied by friends or colleagues [45].

Other aspects remarked on in the literature as influencing the choice of mode used by children and teenagers for commuting to school or to other destinations were seasonal variations, especially in the areas where there were significant temperature differences between winter and summer [46], access to reliable and timely public transport, and

differences between residence areas (e.g., urban, rural, or insular contexts), as presented by Kamargianni et al. [47].

2.3. Teenagers and Automation

Two categories of research emerged in the literature review process in relation to teenagers and automation. Some of the studies focused on the views of minors towards AVs, while others investigated the parents' opinions. To the best of our knowledge, the only study looking into the views of teenagers regarding AVs is that of Ngwu [48], which explored the views of those aged from 13 to 17 years old. In this study, the teenagers stated that AVs would make the roads safer and that they would also trust riding their bicycles alongside AVs during the night or in poor weather conditions.

The acceptance of young people towards the use of AVs varied greatly in the literature. Fortunati et al. [49], in their study investigating different age groups (i.e., 13–15, 16–17, and 18–25 years old), demonstrated that the participants' trust towards the use of AVs was slightly positive and that acceptance did not differ among the different age categories. Tremoulet et al. [50] found that only a minority of young people from 8 to 16 years old would feel comfortable riding an AV alone. However, they would feel more comfortable in an AV than in a conventional taxi or on public transport. Johansson [27] showed that young people from 16 to 23 years old would enjoy riding AVs, but they were concerned about the safety and ethical aspects, especially in situations where the vehicle would have to take decisions that risked injuring humans.

A limited number of studies investigated situations in which taking over the vehicle control was requested. Molnar [51] showed that young novice drivers from 16 to 19 years old were more likely to take control from the automation once a takeover request had been given, as compared to the older drivers who tended to wait for the system to disengage before receiving control from the automation. The results also showed that younger drivers were significantly quicker to take back the control of the vehicle in comparison to the older drivers. The young people interviewed by Tremoulet et al. [50] declared that they would be willing to use the brake pedal, press an emergency button similar to those within school buses, or talk to the vehicle in order to stop the AV in case of emergency.

Studies focusing on parents' opinions of minors from 0 up to 17 years old, remarked that parents were not ready to let their children travel alone in an AV. Tremoulet et al. [50] showed that the majority of parents were more willing to let their children travel with conventional public transport than with an AV. In addition, the parents had higher concerns towards young children not behaving or interacting appropriately in AVs. Somer and Lee [52] showed that parents were significantly either strongly against or very hesitant to place children unaccompanied in AVs compared to people without children. In addition, the study demonstrated that this effect was amplified by the number of children in the household. Koppel et al. [53] found that parents were mostly unwilling to let their children travel in an AV unless various reassurance features were embedded in the vehicle (i.e., microphones, camera, and the ability to summon assistance if the vehicle broke down). However, the possibility of letting their child travel alone was considered differently by parents according to the age of their children, the parents' gender identity, their living place, their level of knowledge towards AVs, or their level of concerns towards the safety of their children [13,52,54–56]. The current study aims to fill the gap observed in the literature regarding teenagers and AVs, to explore teenagers' willingness to use these vehicles to satisfy their mobility needs, and to enhance the knowledge on teenagers' perspectives vis-à-vis AVs.

3. Materials and Methods

3.1. Structure of the Study, Recruitment, and Sample Characteristics

For the data collection, the data were gained from a combined physical presence and online setting (Figure 1).

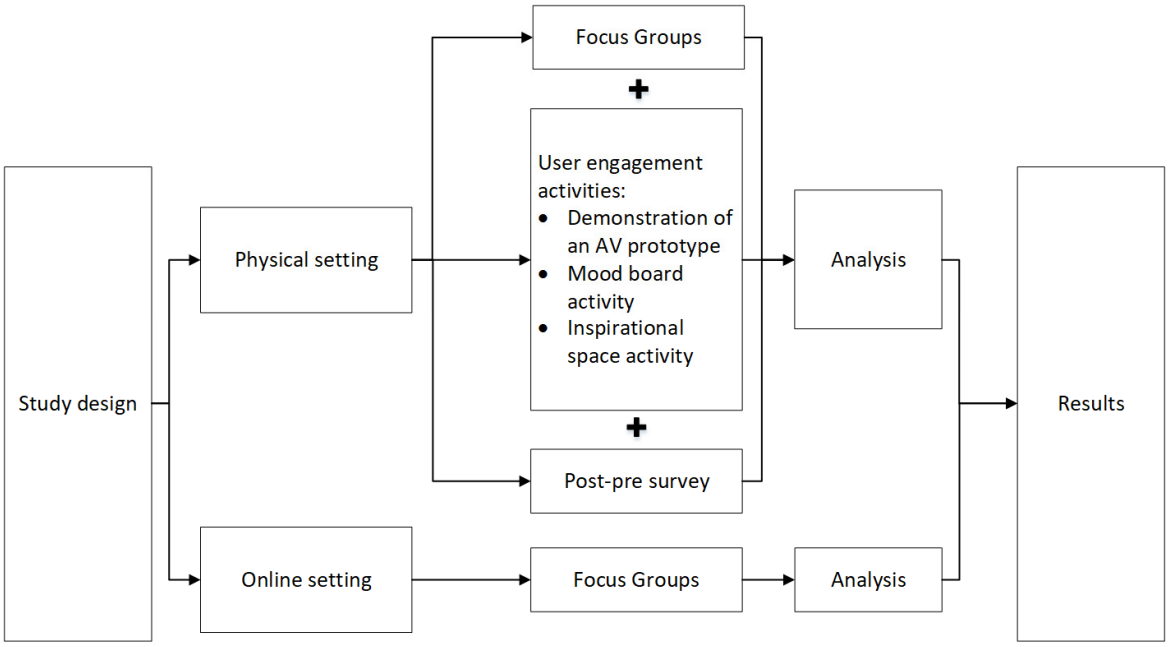

Figure 1. Structure of the study.

The teenagers were recruited through open calls published in all 13 European Schools. (European Schools are a type of international school applying a multilingual and multicultural pedagogical approach to the teaching of nursery, primary, and secondary students. More information can be found here: https://www.eursc.eu/en/European-Schools/mission, accessed on 6 November 2022). The schools are located in Belgium, Germany, Italy, Luxembourg, the Netherlands, and Spain. The teenagers participated in our study with the consent of their parents. Their participation was completely voluntary. Given the travel restrictions imposed during the COVID-19 pandemic and the proximity to the Joint Research Centre (Ispra site), only the participants from the European School of Varese in Italy were involved in the face-to-face FGs and in other engaging activities aimed at increasing the knowledge of participants towards AVs. Thus, a real-life demonstration of an AV prototype, a mood board activity where the participants could share their emotions towards the demonstrated technology, and an inspirational space activity using their knowledge and imagination were organised. All the preliminary activities were conducted in the framework of the Future Mobility Solutions Living Lab (FMS-Lab) located at the JRC Ispra site. At the end of the whole set of activities, the teenagers who had explicitly participated face-to-face were asked to fill in a post-pre survey. The post-pre survey aimed to assess whether and how a hands-on experience with such a technology and the engaging activities could affect teenagers' views on AVs. The rest of the students participated online (divided into groups) only in a two-hour FG.

From September to December 2021, five FGs were organised: three face-to-face with 15 participants and two online with 16 participants, for a total of 31 teenagers (18 girls and 13 boys), with an average age of 15.9 years old and a range from 14 to 17 years old. The face-to-face FGs were then followed by the engagement activities. During the discussions, and in order to establish a common level of understanding, the teenagers were provided with the definitions of automated vehicles, the connected vehicles, and the five levels of automation as defined by the Society of Automotive Engineers [12].

3.2. Focus Group Methodology

The focus group methodology, which is one of the types of the generative design research [57], was used in this study to explore the teenagers' perspectives on the issues related to the acceptance of AVs. The FG research technique "collects data through group

interaction on a topic determined by the researcher" [58], mainly by building upon and contrasting each other's ideas [59,60], which, according to Stewart and Shamdasani [61], represents an "exercise in group dynamics". Krueger [62] described the FG as a small group of people with certain characteristics who provide qualitative data in a focused discussion that helps to better understand a topic of interest. The main difference between FGs and other methods is the collection of attitudes, feelings, beliefs, experiences, and reactions that would not have been possible through other research methods, such as observation, one-to-one interviews, or questionnaire surveys [63].

Moreover, this method has been successfully used in various research fields, including transport, to gain insights and a deeper understanding of transport themes in general [64–67] or of new transport solutions [68–70]. Cyr [71] identified three interrelated characteristics that are grounded using FGs: their *social* character, the *emic* processes (meaning an approach to studying a culture from inside the culture, which focuses on the internal elements and is known as an insider's perspective), and the provided *three levels of analysis* (individual, group, and interactive).

During the semi-structured FGs, the teenagers, among others, were invited to share their current mobility habits and to reflect upon whether using AVs could satisfy their future mobility needs. They were also asked to discuss any possible advantages and disadvantages that this innovative technology might bring with its deployment; to describe any worrying factors related to Avs; to touch upon some related ethical aspects; and, at the very end; to mention any change in their overall considerations regarding AVs resulting from the discussion. The FGs lasted approximately 2 h each and were video and/or audio recorded, followed by a verbatim transcription. Through pseudo-anonymisation, all the names were replaced with fictive ones in the transcripts, and the collected data were coded with the qualitative data analysis software, MAXQDA [72]. A top-level coding was implemented for all the transcripts using a hybrid inductive–deductive approach in which some codes were derived from the FG script while others emerged inductively during the analysis of the transcripts.

The script used during both the face-to-face and the online FGs was in line with the research questions, and the purposes were described beforehand. At the beginning of each discussion, the moderator set the scene by explaining the research aims and the importance of an open, dynamic, and honest dialogue between the participants. Then, audio and video-recorded details were provided anew to the participants who had already given their consent before their participation, ensuring data privacy compliance with the current data protection regulation.

3.3. Demonstration of an AV Prototype and Mood Board Activity

In order to broaden the interaction and gather additional views from the teenagers involved in the face-to-face FGs, they were invited to participate in the real-life demonstration of an AV prototype. The prototype, called Rob.Y, is currently being tested at the FMS-Lab. Rob.Y is being developed by an Italian small and medium-sized enterprise (SME), e-Shock, which is part of the e-Novia group; it was granted access to the JRC LL through an application to an open call for expressions of interest. The demonstration was organised on a dedicated open-air urban test track, closed to traffic at the FMS-Lab. Members of e-Shock and the FMS-Lab research team gave a short introduction and mentioned the technical characteristics of the vehicle. Then, the real-life demonstration followed, where the teenagers could see Rob.Y driving autonomously along the road and reacting to different scenarios and obstacles (pedestrian dummies). At the end of the demonstration, they had the opportunity to express their views in an open discussion and ask questions.

Right after the demonstration, the participants were also involved in a mood board activity. Mood boards, according to Endrissat et al. [73], are collaborative and creative activities, commonly used as visual expressions of intangible qualities (such as an idea or a vision for a new product). In this way, the participants can better express their thoughts,

emotions, and abstract concepts by focusing more on the different meanings of the picture rather than on the picture itself [74].

Each participant received a folder with 16 cards showing one picture each. The pictures were pre-selected to express eight emotions, each represented twice: one through a facial expression or a human interaction and another showing natural elements, animals, etc. The emotions were based on Robert's Plutchik categorisation (known as the wheel of emotions) [75]. This categorisation is based on eight bipolar emotions: joy versus sadness, anger versus fear, trust versus disgust, and anticipation versus surprise; each one was also linked with a colour. Other studies have used emotions as psychological indicators aiming to explore emotion-driven design scenarios [76]. After the distribution of the cards, the teenagers were asked to pick up as many cards as needed to represent the emotions they felt during the AV demonstration. They were also asked to write a few words or short sentences on the back of each selected card to explain how these emotions were linked to the demonstration. At the end, each participant had to orally elaborate on the choices made, and then, all the cards were put on a board divided into three main sections: positive, negative, and mixed. The division into these three categories resulted from their elaborations and aimed to create a map of emotions. The activity aimed particularly at capturing the emotions derived directly after participating in a real-life AV demonstration.

3.4. Inspirational Space Activity

The final event organised with the teenagers from the European School of Varese was a workshop called "inspirational space", where they had the opportunity to present an artefact (with no restriction in material or method; it could be a construction, a drawing, a presentation, etc.) that expressed the way they imagined their future mobility and the future transport system. These 'art tokens' are currently displayed in a dedicated place at the European Commission's JRC Ispra site and are accessible to the researchers working on the Living Lab activities on mobility and other fields of activity.

3.5. Post-Pre Survey Methodology

The survey followed the post-pre survey methodology, a method usually employed to assess the impact of a learning activity (e.g., a course, a workshop) on a given population (e.g., students or workers of a company). This survey method assesses the perceptions of the changes in post- and pre-knowledge at a unique point in time when the activities are over [77]. The most important advantages of the method are the time saved by the gathering data during a single session and the usage of one consistent measuring scale for both assessments. This allows the avoidance, for example, of participants rating their knowledge too high during the first session [78].

The survey had a dual purpose: to raise the understanding of teenagers' opinions towards AVs in a quantitative way and to assess the impact of the different engagement activities on the acceptance of AVs. The survey gathered information on the socio-demographic characteristics of the participants, their transport modes used for commuting to school, their knowledge about AVs, and their opinions and expectations towards AVs (i.e., willingness to use, agreement with data sharing, beliefs, and riding AVs with human supervision). The different opinions were assessed using a Likert-type scale with five items: strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4), and strongly agree (5).

This method allows the estimation of the initial perceptions of the teenagers towards AVs as well as how these perceptions evolved due to the conducted activities. To estimate these changes, the Wilcoxon signed-rank test was used to understand whether the corresponding pre- and post-data distributions were identical or significantly different (p-value ≤ 0.05). The Wilcoxon signed-rank test is a non-parametric alternative to the t-test that is recommended when the population observed is small and not normally distributed, the data are ordinal, and the two datasets compared are dependent. To perform the tests, the R function wilcox.test included in the package dplyr [79] was used.

4. Results and Discussion

4.1. Focus Group Results

The results reported below follow the structure of the script used during the discussions. In Section 4.1.1, the teenagers' current mobility needs are presented, followed in Section 4.1.2 by the positive and negative aspects in their mobility and the changes due to the pandemic in Section 4.1.3. Previous knowledge and experiences with AVs are reported in Section 4.1.4, followed by their beliefs on whether using AVs could satisfy their mobility needs in Section 4.1.5 and the main advantages and disadvantages of using AVs in Section 4.1.6. In Section 4.1.7, their main worries in relation to AVs are presented; in Section 4.1.8, the information that teenagers would like to know before they use AVs is presented. The last two sub-sections, Sections 4.1.9 and 4.1.10, are dedicated to their opinions on sharing mobility data and on the changes in opinions on AVs that might have happened due to the discussions, respectively.

4.1.1. Which Are Your Mobility Habits and Needs?

In the beginning of the FGs, to better understand their current mobility, the teenagers were asked to describe the transport modes usually chosen in their daily mobility to school and other activities. The teenagers mainly indicated passive modes of transport, such as the school bus, public transport, private car driven by parents, or carpooling with friends. Among the least mentioned modes of transport, the active modes were listed, and more specifically bicycling and walking. The bicycle was mentioned only once as a main travel mode and more often as an alternative to passive modes of travel when the weather conditions allowed it. Walking was generally preferred due to the residence's proximity to the school, as an alternative to the school bus or when chained with other transport modes to reach the final destinations.

> "*I live really near by the school; I mostly walk there*". Sandrine, 17 y/o

These findings of the reduced use of active modes of transport in teenagers' daily commuting to school are in line with the observations presented in the literature [30,32,33,36].

An important aspect that was emphasised during their descriptions was the combined use of transport modes to reach school or other destinations. Some explained that they were driven by parents or walked to bus/train stops, others that they combined public transport (PT) with public shared/private bicycle, or that they used multiple PT modes (bus, train, and tram).

> "*I take the school bus and to go to a bus stop my parents bring me there by car or I walk there*". Igor, 17 y/o

> "*I have to take the train early morning and then bicycle from the train station*". Lena, 15 y/o

We consider important the finding related to the combination of different transport modes resulting in complex mobility patterns to reach school or other destinations since, to the best of our knowledge, similar patterns were not identified in the literature.

Exploring the reasons behind these travel mode choices, the FG participants flagged the proximity to school as an enabler to walking and biking. The findings are in line with the aspects pointed out in the literature regarding the influence of distance to school on the use of active modes of transport [18,31,34–37]. On the other hand, the lack of reliable PT options in terms of frequency, arrival times, and proximity to their residence pushes teenagers to depend on their parents who drive them either to the closest station or to their final destination.

The participants were also asked to provide details on their mobility for leisure activities (e.g., sports, meetings with friends, and shopping). All of them mentioned the use of PT as the main or secondary transport mode or combined with rides offered by the parents, the use of a bike, and walking.

4.1.2. What Are the Positive and Negative Aspects in Your Mobility?

Next, the participants were requested to provide details about the positive and negative aspects they identified regarding their mobility (Table 1). As all the teenagers mentioned the use of PT (exclusively or combined with other modes of transport), a large number of comments received were about this travel mode. Some teenagers expressed their preference for PT due to the availability of a unified and intuitive application that provides details about itineraries and waiting times. Others highlighted the proximity of their residence/destination point to the PT stations, the free use of PT in their city (e.g., Luxembourg), the frequency, the reliability, and the offer of many different travel options as positive elements. Among the other travel modes mentioned, flexibility and gains in travel time were highly appreciated when using a private car, while the school bus was seen as an opportunity to socialize with other students. Biking and walking were perceived as more environmentally friendly options to reach a destination with health benefits and to avoid traffic.

Table 1. Positive and negative aspects of teenagers' mobility.

	Positive Aspects	**Negative Aspects**
PT	-convenience -independent travel -perform other activities while commuting -low/reduced ticket cost -unified/intuitive app -residence proximity to PT -free use of PT -frequency -reliability -PT variety	-limited frequency -limited evening/late-night itineraries -delays due to strikes, accidents, traffic, and cancelled itineraries -high ticket cost -lack of ticket sale points -no money change in the sale machines -interaction with strangers -safety concerns -harassment and thefts -applications too complicated/not updated -many applications/not unified -overcrowded PT -lack of privacy
Private car	-reduced travel time -flexibility	-inadequate road infrastructure -lack of parking lots -lack of driving licence -lack of independence
School bus	-opportunity to socialise	-
Bike	-enjoy the physical activity -enjoy the fresh air	-inadequate road infrastructure/bike lanes -interaction with other road users
Walking	-traffic avoidance -cost free -easily accessible -environmentally friendly	-
Combined means of transport	-value of time	-long commuting times

As negative aspects, those using PT pointed out the frequency and reliability problems resulting in delays or even in the incapability to reach the destination point. The non-existence or the limited number of late-night itineraries seem to restrict teenagers' leisure choices, while others required their parents' assistance. Ticketing was presented as another deterrent effect of using PT. Apart from the high cost, the teenagers mentioned struggles in finding ticket sale points close to the stops and that the sale machines inside the vehicles did not give change. Other emphasised negative aspects were safety concerns in relation to the risk of harassment and possible theft fostered in overcrowded PT; overcrowding in PT was also linked to a lack of privacy. Lastly, the participants pointed out being overwhelmed with

the existence of many applications that in most cases are not updated in real time and are difficult to use; instead, they would prefer one unified application with information about all the available modes of transport. Those using private cars or bicycles highlighted, as negative aspects in both cases, the bad road infrastructure coupled with the lack of parking lots and the risky interaction with other road users. When considering the private car use mode, the lack of a driving license makes teenagers depend on their parents, affecting their sense of independence.

4.1.3. Did Your Mobility Change Because of the COVID-19 Pandemic?

In the FGs, we also explored the impact of the COVID-19 pandemic on the teenagers' mobility. About half of the participants mentioned that the pandemic did not affect their mobility patterns and modes used, while the rest indicated both modifications to the travel mode and changes in their travel behaviour. Those indicating changes preferred to reduce the use of PT and switch to different travel modes, mainly private car, private or shared bicycles, carpooling with friends, and the school bus. In this way, they managed to control whom they were in contact with and downscale the possibility to be infected. In addition, four of the teenagers postponed trips and chose closer destinations for their leisure activities.

Additionally, some of the teenagers indicated changes in their travel behaviour and modes used, but these were attributed to the fact that they had become older and more independent and not to the pandemic's impact. The increase in independent mobility reported by the FG participants is in line with and reconfirms the patterns found in the literature [17–24,39].

4.1.4. First Ideas, Knowledge, Opinions, and Experiences with AVs

After sharing their mobility habits and the modes used, the participants were asked to mention what came to mind when they heard about AVs. The majority pointed out the positive aspects related to the environment due to the lower emissions, the reliability, the safety due to less human intervention in the driving tasks, the independence, as the driving license would not be necessary anymore, and the improved driving experience and comfort. Additionally, some of the participants associated AVs with words such as "revolutionary technology", "futuristic", "electric", "self-driving", and "artificial intelligence" (AI), but also with a specific vehicle manufacturer ("Tesla").

> *"I think there are going to be automated vehicles that children or younger people who are not old enough to get a driver's license could use to move around and they might win independency by using them"*. Maya, 15 y/o

The negative aspects linked to AVs were related to ethics, mainly regarding the decision the car would take in the case of an accident; they provided examples that the teenagers had read or seen in social media.

Going further on the potential use of such vehicles and on the way that they will drive around, about one-third of the teenagers considered AVs to always need the possibility of human intervention. This was expressed through safety concerns, mainly with regard to Level 5 automation, which could fail for various reasons, whereas a human operator onboard could intervene in particular situations. According to the teenagers, human supervision is not only meaningful in assisting in the technology breakdowns that might arise but also in determining liability in the case of accidents. Conversely, opposite opinions were expressed by those that imagined AVs without human intervention, as they considered humans to be more prone to errors compared to machines. Some participants defined AVs as private vehicles, accessible to all (like the conventional vehicles of nowadays), customised to personal preferences, with lower pollutant emissions, and comfortable. The private use was supported by the need to avoid the interactions with strangers that they currently face when using PT. Others described AVs as being shared or used in PT as such scenarios would better support environmental sustainability and lower the number of vehicles on the road. Moreover, some participants perceived AVs as vehicles for freight

transport that would drive at night, with the potential to increase efficiency and drive more hours compared to human drivers, overcoming some current legal limitations.

When asked if they already had any kind of real-life experience with AVs or if they had heard/read about them, all the FG participants responded positively. Some had experienced partial automated public transport means (e.g., metro, train) and described these encounters as safe and nice experiences. Others talked about their experiences with partial automated cars as being "interesting", or they talked about experiences with prototype vehicles used for tests and reported 'fear' or a 'strange' feeling due to the absence of the steering wheel. Few mentioned that they only heard about AVs from books or media.

Overall, the ideas and opinions presented by the teenagers are in line with the limited literature available and confirm the findings of Johansson [23], who observed positive attitudes towards AVs among teenagers and young people.

4.1.5. Will You Use AVs to Satisfy Your Mobility Needs?

The majority of the teenagers mentioned that they would use AVs or, in some cases, that they would use them under certain conditions to satisfy their mobility needs; these were followed by those not willing to use them, whereas only a few seemed to be neutral or undecided.

The ones willing to consider AVs for their daily commuting emphasised that these vehicles could reach a comparable or even a lower error rate than human drivers, while others would use them for long distance trips in a transport system where all the vehicles were connected and automated.

Those that were willing to use AVs under certain conditions mentioned that they would be in favour of a solution that enabled the person to choose between automated and non-automated modes. They also mentioned that the first time they might feel 'scared' or 'nervous' using such vehicles and that gaining trust in the technology would help to overcome these feelings and to convince them to use AVs more frequently. More safety tests in place and compliance with high safety standards were mentioned as enablers that could encourage them to use these vehicles.

On the other hand, the teenagers who did not consider AVs as a means to fulfil their daily mobility needs mentioned that they would be eager to drive conventional vehicles by themselves once obtaining their driving license, considering driving as a 'fun' experience that AVs could not provide.

> "*I think the whole "hands off the wheel" takes away the fun of driving*". Amelia, 16 y/o

> "*It's always kind of my dream to get my driver license and actually drive a car*". Emma, 14 y/o

Some of the teenagers linked their reluctance towards AVs with safety concerns related to a lack of control in cases of terrorist attacks or hacking attempts. Safety concerns were also pointed out by teenagers who were undecided whether using AVs could satisfy their mobility needs, but these concerns were not only related to the vehicle itself but also to the interaction with pedestrians and other vulnerable users and to the currently inadequate infrastructure (e.g., narrow roads in specific areas).

It is important to remark that teenagers emphasised in this sub-section some of the challenges AVs must overcome to accelerate deployment and use among the younger population. Reluctance and the need to gain trust in AV technology was also observed among other potential user groups in the literature, such as women [80] or the general population [81,82]. Additionally, the discussions revealed a group of teenagers not yet convinced by the benefits of AVs who desired to obtain their driving licence and experience driving by themselves. This is a finding that is in contrast with the advantage of AVs, which can used by minors without a driving licence.

4.1.6. What Are the Advantages and Disadvantages of Using Avs?

Next, the teenagers were asked to provide details about the advantages and disadvantages they could anticipate with regard to the deployment and use of AVs. In order to structure the information gathered, the inputs were classified in two categories: societal and individual.

Some of the societal advantages identified were related to an improved road system due to the AVs deployment in terms of traffic, travel time, and public transport efficiency.

> "*With these vehicles on the roads, there would be less traffic because they communicate one to another*". Victor, 17 y/o

AVs were also identified as solutions that could potentially reduce the number of car accidents since machines are less accident-prone compared to human beings. Accessibility could be improved for certain passenger categories (e.g., older people, people with disabilities, minors, or people without a driving license), given that a driving license and driving limitations would not be in place anymore. Some participants added that the deployment of AVs will contribute to the reduction in pollutant emissions and improve labour market conditions with the creation of new jobs.

The advantages at the individual level mentioned by the teenagers included the possibility to perform other activities while driving (e.g., reading, doing homework, and sleeping) that, together with the partial or non-existent concentration on driving, could offer an improved travel experience, as well as improved comfort and safety compared to conventional vehicles.

The disadvantages identified at societal level were related to the teenagers' strong belief that part of the population will not be convinced by the relevant stakeholders and scientists to use AVs. Their potential high price at the beginning of their deployment could also increase inequality since low-income households could not afford such a purchase. Environmental concerns were associated with the increased energy consumption that AVs might require for their production and their function, as well as with the adaptation of the current infrastructure needed in order to accommodate such vehicles. According to teenagers, a large number of electric AVs will be produced simultaneously, requiring an important amount of energy, and many electric chargers would have to be installed in order to accommodate those vehicles' energy needs. In addition, negative impacts on the environment and people's health could result from the overuse of AVs. The teenagers expressed concerns that the ease of access to these vehicles (when shared) would be highly appreciated by users who would use them even for short distance trips instead of walking.

> "*You would use resources that you actually wouldn't need because you would maybe use the car to just drive two streets even though you could walk or take your bike*". Maya, 15 y/o

The impact on the labour market was again mentioned by an FG participant, this time from a different perspective, anticipating that AVs would eliminate some of the current driving jobs of professional drivers.

The disadvantages at the individual level were associated with safety concerns, such as the lack of control over the vehicle compared to conventional vehicles, and with unforeseen software bugs, which could be mainly experienced in the beginning of their deployment. Safety concerns were associated with children's curiosity that might make them willing to explore the interior control panel of the vehicle, randomly activating or deactivating different functions. Together with safety, trust concerns towards the AI software arose during the FGs. The teenagers pointed out that humans are able to take better and more ethical decisions in critical situations compared to AI software.

> "*If you had to make a sharp turn and hit a wall, for example, or hit a person walking on the side of a narrow street what would the AI choose versus what would the human choose?*" Claire, 17 y/o

Lastly, according to the participants, AVs will diminish or contribute to the complete loss of driving skills. This risk was perceived as dangerous, especially in the beginning of AV deployment when drivers would probably switch from AVs to conventional ones and vice versa.

The advantages and disadvantages pointed out by teenagers during the FGs are similar to many of the positive and negative aspects observed in the literature related to AV deployment in the transport system [83–85]. These findings indicate a high level of awareness among the FG participants regarding the anticipated impacts of AVs in the future.

4.1.7. Is There Anything That You Are Worried in Relation to AVs?

A large number of worries collected through this question were related to the vehicle's behaviour, particularly in the case of unexpected obstacles in urban areas that are crowded, in highway contexts where the vehicles' speed is higher, and towards other road users. Some participants pointed out that AVs will be vulnerable to hackers that will cripple the transport system by misusing them for their profit. The teenagers also pointed out the vulnerability of their personal data, believing that sensitive information (e.g., location data, and home address) would be shared with unknown persons/entities. Opposite voices highlighted that such information is already shared with the given user's consent on various mobile applications.

> "*Everyone will know what you are doing, where you are going, who you are talking with*".
> Emma, 14 y/o

Trustworthiness worries were raised regarding the software. Thus, the participants mentioned that even a small malfunction could bring serious damages and hurt many people. At the same time, being in a car without a steering wheel and not being able to take back the control in an emergency seems to considerably increase their worries.

Finally, the teenagers were worried about an increase in inequality considering the anticipated high prices of AVs.

The concerns about the safety of AVs emphasised by the teenagers during the discussions are similar and confirm the perceived importance of safety noticed by Johansson [27] among teenagers and by Kim et al. [86] among experts working on AVs and the general public representing the future users. In addition, Piao et al. [87] identified safety as a crucial factor influencing public attitudes towards these vehicles. Thus, overcoming the safety concerns expressed by many groups of potential users will be key to facilitating the large-scale deployment and use of AVs.

Additionally, the worries expressed by the teenagers, which were determined by the lack of control over the vehicle in an emergency, could be alleviated by equipping AVs with features that make the drivers and passengers aware of the actions and operating status of the AV. Such features were observed to significantly reduce anxiety, increase alertness, and give back the sense of control to drivers [88].

Another interesting aspect is the teenagers' strong belief that AVs could increase inequality in society as these vehicles would prove accessible only to wealthy individuals. This observation is in line with the literature that sees the cost of AV technology as a major barrier for market adoption [89].

Conversely, the concerns raised in the literature, which were mainly expressed by older adults, such as learning how to use an AV [90,91] or the commercial use of AVs (e.g., heavy trucks or semi-trailer trucks) [91], were not reported as worrying aspects by the teenagers in our study.

4.1.8. What Information about AVs Would You like to Know before You Use Them?

For this question, the participants mainly emphasised the need for information about the safety of AVs. Some would like to know the details about the prioritisation algorithms that the vehicle will be set to follow in critical situations or when interacting with vulnerable road users. The teenagers would like to know in advance the emergency plan and

where the emergency button that manually deactivates the car in case of malfunction is. Moreover, they would be interested in knowing more details about the functions and the equipment inside the vehicle. Safety certificates and performance testing results were listed among the things they would wish to know before using AVs. During their responses, the teenagers expressed their fear that these tests might not be rigorous enough or would be farmed out to non-trustworthy companies because governments usually lack the relevant technical knowhow.

Moreover, some of the teenagers were not keen to be among the first users of AVs. They preferred to wait to take advantage of the information and the experiences shared by early adopters. In this way, possible malfunctions of the systems could be improved and ways to deal with them would be known to the public. On this occasion, the teenagers highly recommended the need for training before the actual use of the vehicles so that the users would become familiar with AVs and only a successful completion would give them permission to use and avoid awkward situations.

Additionally, the teenagers (considering that AVs will be electric) mentioned that, before each ride, they would like to be informed about the state of charge and whether it was adequate to reach their destination without intermediate stops for charging, which would increase the travel time. Some others, less concerned about the charging stops, mentioned that all the charging stations would need to be mapped and kept in an updated file so that they could be easily reached without wasting time. It is important to remark that although electrification of transport was not among the main areas of interest of the current research, several teenagers identified AVs as being electric.

Lastly, some of the teenagers would like to know beforehand which personal data would be kept, for how long, and how they would be treated if they declared their unwillingness to share their location data with strangers.

The safety aspects, the AV's reaction in an emergency, and the trustworthiness certifications remained some of the important issues reiterated by teenagers in this section. This confirms once again the findings in the literature [92] that the perceived level of safety and solving the ethical dilemma and challenges related to the programming of the vehicle, as well as the liability and regulations, remain some of the most important aspects influencing people's acceptance of AVs.

4.1.9. Would You Agree to Share Your Mobility Data and with Whom?

When it comes to sharing mobility data, a large majority of the teenagers answered positively or would agree under specific requirements; instead, only a few would refuse or were undecided. For those willing to share mobility data, the main justification was that they already share this information through social media and other applications. In addition, the teenagers see it as being linked to the geolocation feature used in mobile phones, a set of geographic coordinates that could be helpful in quickly locating a car involved in a crash and in being reached by emergency services.

> "*I think that it's not really different from the geolocation of mobile phones, so it would not change much. And also, it would be beneficial, when there is a crash, to understand how it happened and everything*". Victor, 17 y/o

The teenagers further elaborated on the value added by the geolocation feature to track criminals and stolen vehicles. Others mentioned that this could relieve parents' concerns when allowing their kids to ride in an AV unaccompanied since this would enable them to remain aware of their children's location at any time. In addition, traffic jams could be anticipated and vehicles could adapt their route to roads with less traffic.

On the other hand, those expressing a reserved willingness to share data mentioned a set of constraints that could be applied to freely share them. Worries were highlighted regarding how their data would be kept and processed and how long they would remain stored. For this reason, some participants were ready to share any relevant information if anonymous or encrypted, collected by trusted entities, stored for a clearly specified retention period, and collected for purposes that were transparently communicated.

Some participants were opposed to the idea of sharing their data and mentioned that a possible share would compromise their safety since their privacy would be violated. Others also started wondering whether it was essential and who would benefit from collecting their information.

> "*I would not like to share, [...]. I do not want like others see all my private data. Not because I've got something to hide, but like it's part of my privacy and I would feel unsafe and probably like not comfortable in my own space*". Ava, 17 y/o

Concerning the entity that they would like to share this information with, teenagers mentioned that they would trust the European Commission and the research institutions which do not aim to make profit on the data collected. They believe that these entities would keep only the important part of these data that were useful for the progress of science and would delete the unnecessary information. The teenagers mentioned that they would agree to share this information with their insurance and maintenance companies and with their close social circle with whom they often travelled together.

> "*I would share it with people in my close circle and people with whom I travel quite often. If I meet a random hitchhiker in the middle of the road, I will not share any data with them. I would keep it to a very private bubble*". Claire, 17 y/o

At this point, the teenagers mentioned that they would like to share data with private or public entities if these were useful in stopping infractions. Conversely, opposite views were raised by those who see with suspicion the data sharing and translate it into money that flows among companies. To better support their views, some of them mentioned examples of visiting places and then automatically receiving requests to review such places on their mobiles. In addition, the teenagers would not be willing to share information that could be used by employers to better monitor their employees.

The willingness to share their mobility data was expressed by the majority of the teenagers; this contradicts many of the findings in the literature where various groups raised privacy concerns when assuming AVs would come into use [86,90,91].

4.1.10. Did You Change Your Opinion after the Discussion and If Yes in Which Way?

This question aimed to collect details and to notice any possible changes in the teenagers' views about AVs that the FG discussions might have influenced. Surprisingly, most of them declared that after the discussion their views had changed and that there were different reasons supporting these changes. The teenagers mentioned that during the discussions, and having interacted with other participants, they heard about issues such as the disadvantages related to privacy, safety, and trust that until then they had not taken into consideration.

> "*But now that we've had this discussion, I'm sitting back and thinking, 'Are we going to allow technology to take over this aspect of our life as well? And are we going to give it our full trust? And are we going to make sure that no one else is harmed in the process of us using automated vehicles?*" Amelia, 16 y/o

Others were positively affected, mentioning that the FGs raised their awareness of a technology concept that would be soon deployed on the roads, while their curiosity about the topic was significantly increased, and they were looking forward to using them. Moreover, a great majority of students acknowledged the learning outcomes of these FGs. The teenagers highlighted the fact that before the discussions they thought that AVs could be only private cars, ignoring the potential of shared or freight transport use. They also highlighted that the information provided about the specific levels of automation and connectivity was among the most important insights gained during the discussion.

> "*I just thought it would be automated vehicles, but I think it's really interesting that they could be also connected and share information*". Matteo, 16 y/o

The engaging character of the FGs and the exchange of opinions with others was highly appreciated by all the participants as they became aware of what their teenage peers

across Europe thought about AVs, while at the same time they enriched their knowledge and arguments on the topic.

> "*I've learned some basic information–which is always good because when, the next time I get into a conversation with my parents, my friends about this stuff, I can actually come up with arguments, which is pretty good*". Frank, 16 y/o

At the end, one participant concluded that the full deployment of AVs might not be so close, considering all the concerns raised during the discussion.

4.2. Mood Board Activity Results

The teenagers participating in this activity chosen all of the eight emotions depicted on the cards, commenting on a total of 40 cards. The most selected and commented cards were those representing the emotions of anger, trust, surprise, and anticipation.

Anger, contrary to our estimations, was perceived differently by the teenagers, and the cards were used to describe anxiety about the impact such technology could have on society and potential climate change. The lack of experience with AVs in terms of human interaction made them also feel overwhelmed. The emotion of *trust* was explained by the fact that AVs (when connected) would connect people and facilitate their daily mobility habits. Moreover, the participants linked their emotion of trust with the research community that works on AV development. The cards depicting the emotion of *surprise* represented the most common choice as 11 out of 15 students picked them up. Their surprise was linked to the advancement of technology they could observe in the showcased prototype and the AI technology in it, its reaction to different scenarios with and without pedestrians, and its size, as many were expecting a smaller vehicle. Some of the teenagers coupled their surprise with hopefulness for the technological progress and with confusion, considering the amount of information received and their lack of knowledge about AI. It is important to mention that none of the participants was negatively surprised.

Anticipation was related to the expected improvement of the prototype in the near future. According to their elaborations, the participants anticipated that similar vehicles than the prototype would be the basis for a more sustainable solution that would contribute to the environment's protection by reducing emissions, while increasing road space efficiency. A participant who picked up a card depicting anticipation was surprised that the AV technology has already reached Europe, thinking that it was only developed and tested in the United States.

The least chosen cards represented the emotions of *disgust*, *fear*, *joy*, and *sadness*. The participants who chose some of the cards representing *disgust* perceived the illustrated emotion differently than what the researchers anticipated and mentioned it as a terror of seeing a vehicle driving by itself and disappointment because such a vehicle was not as advanced as they expected. The card related to *fear* was picked by two participants who explained that this emotion was based on the lack of readiness of the prototype to travel on a real road. The cards of *joy* were chosen in two cases by the participants because this innovation is close to being accessible in the near future, and they were excited about this progress. Finally, one participant selected a card representing *sadness* to describe the emotions evoked during the demonstration. According to this participant's explanations, AVs are often presented as risky and dangerous, while during the demonstration neither of these was experienced. The participant concluded that the scientists and relevant stakeholders needed to work hard on the rehabilitation of the AV's reputation and a more user-friendly appearance.

The research team, based on the indications provided by the teenagers, placed the cards chosen by participants on a whiteboard divided into three categories, according to their descriptions: positive, neutral, and negative. Twenty-seven cards were placed as evoking a positive emotion, eight as neutral, and five as negative. This mapping revealed overall the positive emotions and attitudes of the participants towards the AV prototype demonstration.

4.3. Inspirational Space Results

During this imaginative and engaging activity, the teenagers produced 13 projects, out of which three constructions, six drawings, and four presentations that aimed to capture the anticipated changes that could be observed in mobility and the transport system with the full-scale deployment of AVs.

When describing their creations, the teenagers pointed out a diverse range of topics and changes that could become a reality in the near future with the support of AVs or other innovations and the services that could be deployed.

The transition to a transport system that relies on the use of EVs (both private and public transport) was reflected in the views expressed by many of the teenagers. The increased use of EVs was associated with positive outcomes, such as a reduction in emissions, energy use, and a much greener transport, but also with negative ones such the impact on the environment from EV batteries.

Some of the improvements in the mobility and transport system anticipated by the teenagers, along with an increase in the use of AVs, were: (a) accessibility of AVs for all since such vehicles could be managed through an app or be public transport options; (b) the deployment of community AVs, which could enhance the mobility of the elders and persons with special needs; and (c) cities being made more accessible for walking or biking. On the other hand, some of the challenges foreseen by teenagers with the increased use of AVs were related to safety concerns and accidents, the fact that not all people will be convinced to use AVs, and the fact that this could create further problems in mixed traffic scenarios.

Some of the teenagers considered the future of long-distance travelling to be reliant on high-speed trains and the use of tunnels and high-speed ground-level transport systems such as hyperloop technology. For goods transport, this could be conducted by automated trucks and by smaller delivery vehicles that have access to a special road infrastructure.

The inspirational space activity was a consistent and rich interaction with teenagers from the European School of Varese to further understand their views regarding the improvements and challenges for the future of mobility and the transport system. It helped to gather a diverse range of opinions, concerns, and anticipated changes that could be used to guide some of the research efforts in the short and medium term.

4.4. Post-Pre Survey Results

The parallel design of the quantitative and qualitative method allowed the comparison of both types of results. While the quantitative method provided objective information about people's opinions, the qualitative one offered an additional level of information to our research and knowledge related to the different issues raised in the discussions.

Table 2 presents the results of the survey filled in by the participants and the means of the variables before and after the FG and engagement activities. The difference between the means shows how the opinions of the participants evolved throughout the different activities. In the table, the statistically significant variables are indicated with asterisks according to their level of significance.

When considering the knowledge on AVs, the teenagers surveyed showed a limited knowledge before the activities, while this knowledge significantly increased after the activities. This result is in line with the aspects mentioned in the FGs, where the participants stated an increase in their knowledge after the discussions.

The willingness to use AVs increased significantly for all the related variables after the activities. More specifically, the participants disagreeing before the activities on the use AVs with known people, unknown people, and alone were fairly willing to use them after the end of the activities. Interestingly, while the participants in the FGs anticipated that using AVs would satisfy their mobility needs, the respondents to the survey showed unwillingness to use them, although their opinion evolved positively at the end of the activities. This result can be linked to the need to trust the technology first in order to use it as mentioned during the discussions. Indeed, a person may think that AVs will fit their

mobility needs, while expressing at the same time a need to be reassured in order to accept using them.

Table 2. Item means and Wilcoxon signed-rank test for post-pre survey.

Items of the Questionnaire	Pre-Mean	Post-Mean	Difference in Means
Knowledge about AVs			
I know what an AV is (***)	3.1	4.4	1.3
Willingness to use AVs—Imagining that AVs will be soon available on the roads . . .			
In general, I am willing to use them (*)	3.2	3.9	0.7
I am willing to use an AV with my friends and family (**)	2.9	3.7	0.8
I am willing to use an AV alone in the vehicle (**)	2.4	3.4	1
I am willing to use an AV with people that I do not know (like today with public transport) (**)	2.4	3.7	1.3
Privacy—would you agree to share (anonymously) your mobility and transport information (e.g., data about destination, etc.) with . . .			
public authorities (European, national, local) (*)	3.1	3.7	0.7
other users (*)	2.0	2.5	0.5
private companies	2.1	2.6	0.5
international organisations (UN, OECD, etc.) (**)	3.0	3.9	0.9
Feeling comfortable in an AV—As a passenger of an AV, I would feel comfortable . . .			
with the presence of a human operator in the vehicle (e.g., a bus driver)	4.3	4.3	0.0
with the remote supervision of a human operator (a person assisting the vehicle from an external computer) (*)	3.3	3.9	0.5
without the supervision of a human operator (*)	2.5	3.2	0.7
Beliefs towards AVs—The deployment of AVs will . . .			
reduce accidents	3.4	3.9	0.5
increase accidents	2.0	2.1	0.1
be a new target of cyber-attacks	3.2	3.3	0.1
be a threat to privacy	2.9	3.0	0.1
increase the accessibility for different categories of users (e.g., older people, people with disabilities) (**)	3.4	4.1	0.7
allow the use of travel time for non-driving activities (e.g., working, reading, sleeping)	3.6	4	0.4
decrease travel costs	2.3	2.5	0.2
be safe sharing the road with non-automated vehicles (e.g., cars, trucks)	2.3	2.8	0.5
be safe for vulnerable road users (e.g., pedestrians, cyclists, scooter users, motorcyclists)	2.3	2.8	0.5

(*) p-value ≤ 0.05; (**) p-value ≤ 0.01; (***) p-value ≤ 0.001.

Concerning the mobility and transport data sharing to improve traffic management, the participants showed a fair agreement before the activities with the statements presented to them. They would agree to share data with public authorities and international organisations, while they would disagree with other users and private companies. This reluctance towards sharing data with private companies is aligned with the FG findings and the worries expressed that are linked to their commercial use. At the same time, after the activities the level of agreement significantly increased for data sharing with public authorities, other users, and international organisations.

When considering the setting in which the participants would feel comfortable in an AV, it appears that before the activities, and in line with the FGs, the participants highly agreed with the presence of a human operator inside the vehicle. They also generally agreed with the remote supervision of a human operator and disagreed with using an AV without the supervision of a human operator. However, after the whole set of activities, the attitudes towards riding with a remote supervision and without supervision increased significantly. In particular, the participants showed a slight agreement with the possibility to ride without supervision.

In general, the participants showed disagreement with most of the beliefs presented in the survey and a slight agreement with four of them. Thus, the slight agreements were found for the beliefs that AVs would reduce accidents, increase the accessibility for different user categories, allow the use of travel time for non-driving activities, and be a target of cyber-attack. Interestingly, while the teenagers agree that AVs will reduce accidents, they do not consider them safe for vulnerable road users or non-automated vehicles. After the activities, the opinions did not evolve significantly, apart from the belief on accessibility, where participants showed a high agreement (3.4 to 4.1). These results are aligned with the different opinions expressed by the participants during the FGs on the question related to the advantages and disadvantages of using AVs.

The observed significant changes between before the activities and after the activities shed light on the areas where people may have a higher propensity to change after the introduction of the technology in the future on one side and where they may have more resistance to the acceptance of AVs on the other side. Thus, from the results of the analysis, it appears that people will have more difficulty in changing their beliefs towards the technology and that particular attention should be given to the beliefs related to safety, which are some of the strongest barriers to the acceptance of AVs [93]. It also appears that the different organised activities impacted positively on the willingness to use the technology even without any human supervision, while the literature is generally conservative on this subject [94]. The latter result shows that people may trust the technology after receiving the adequate information about it, as described in Section 4 and in the previous studies [85]. Finally, the finding on the accessibility for different categories of users should be carefully interpreted since studies on the opinions of older people and people with disabilities have not been carried out yet.

5. Conclusions, Limitations, and Future Research

This study focused on teenagers' current mobility preferences and their willingness to use AVs, while it also sheds light on their worries and the information they wish to know before using these vehicles and their level of agreement on the sharing of personal data. Given that the existing research on teenagers' perceptions and views about AVs is scarce [14], the present paper provides insights to cover this research gap using empirical evidence based on FGs and a post-pre survey.

The focus groups proved to be an effective qualitative method, serving as a mechanism for helping teenagers to generate and share their ideas and provide deeper insights instead of being limited to single-word or short-phrase multiple choice responses. As not all the participants had had a real-life experience with an AV and because this topic might have been intangible for them, the FGs succeeded in engaging teenagers in a meaningful dialogue with peers, which resulted in a rich data collection.

The results indicate the generally positive views of teenagers regarding AVs, although there are some acceptance barriers. The participants acknowledged that AV deployment could bring several benefits to society, such as reduced car accidents, increased accessibility for certain user groups, lower transport emissions, and the possibility to perform other activities while on board. At the same time, they also expressed safety concerns about AV interactions with pedestrians and other road users. Such safety concerns could explain the stated reluctance of teenagers to be among the first users, contrasting with the advantage of AVs, which is that they can be used by minors without a driving licence. In addition, the teenagers emphasised that these vehicles could reduce manual driving, depriving them of the pleasure of driving. Particular concerns were raised regarding the overall behaviour of the vehicle in emergency situations, a lack of trust in the software, data privacy, and mistrust of the safety test transparency. Concerning the sharing of personal data, the participants seemed to be familiar with the subject as they use digital technologies in their daily life, but in some cases, they do not feel comfortable in allowing access to their personal information. For this reason, AV-based services will need to pay more attention to properly clarifying what type of data will be needed from users and how they will be treated.

Moreover, the teenagers anticipated that AVs would come with both advantages and disadvantages for the environment. They noted that pollutant emissions could be minimised, but energy consumption and EV batteries production might increase. The transport infrastructure would also be adapted in a prejudicial manner for the environment. However, this does not apply exclusively to AVs but is an issue of electromobility in general. For this reason, we plan to perform a dedicated study on people's views on EVs. Some of the above-mentioned disadvantages could be alleviated by renewable energy strategies, battery recycling, and fewer intervening infrastructure adjustments.

These concerns can provide policy makers and AV developers with indications about areas that need to be further improved and adequately explained in order to build trust and ensure a smooth transition and deployment of AVs. This smooth transition can consequently eliminate the risk of technology aversion and accelerate the market deployment AVs.

Additionally, the mood board activity showed that the most commented on cards represented positive emotions (*trust*, *surprise*, *anticipation*) compared to the least commented on ones that mainly evoked negative emotions (*disgust*, *fear*, *sadness*), but also included a positive one (*joy*). This outcome, even coming from a small-scale activity, showed an overall positive tendency of teenagers towards AVs that is in line with the FG findings. The cards associated with *surprise*, most frequently chosen by the participants and meant as a positive emotion, makes us consider the importance of showcasing the technology and its advancement to the young generations who will be the future users.

The results of the post-pre survey indicate that positive changes of opinions are possible if people are encouraged to talk about the technology, seek information about it, and participate in real-life demonstrations. Particularly during the real-life demonstrations, the potential users' views and opinions can be supported by multiple and more consistent arguments deriving from hands-on experience with the AV technology. These experiences offer a meaningful, complete, and clear idea of the technology, while they present its features and functionalities in an engaging way that leads to the longer retention of the knowledge [95–97]. Such real-life experiences can be enabled in Living Lab environments, which represent open innovation ecosystems that integrate the research and innovation process into real-life settings and apply a systematic user co-creation approach [98]. In this way, future users can gain first experiences with the innovation and provide their views in discussions about the innovation's potential use and impact, as well as actively contribute to the development of the innovation. Knowledge sharing and the distribution of research findings are critical for making diverse transport stakeholders aware of the societal perspectives, expectations, and concerns, as well as for limiting the risk of technology aversion.

Although the findings of this research provide relevant insights into teenagers' opinions about AVs, the following limitations of the study should be taken into consideration when interpreting the results. The number of teenagers participating in the post-pre survey was small due to the geographical reasons linked to the necessary presence at the engagement activities and cannot be considered as representative of the whole teenage population. Consequently, the results of the survey cannot be extrapolated to the entire teenage population, and further research replicating the method employed should be carried out to validate them. Despite the small sample size, the non-parametric test undertaken on the post-pre survey successfully showed differences in opinions over time and was a suitable complement to the qualitative outputs. In addition, the online setting of the FGs could be seen as a limitation as it decreases the level of interaction between participants compared to a face-to-face discussion. Nevertheless, the online setting proved to be useful as it allowed the researchers to reach students dispersed in different geographical areas, such as urban/rural areas or different countries.

Future work should extend this study to the additional topics which were not exhaustively covered here and which emerged spontaneously during the FGs. The complex mobility patterns reported by some participants were neither discussed nor analysed in the

previous research. We consider that a more in-depth analysis is necessary in future research to identify whether such patterns are a general characteristic of teenagers' mobility and to distinguish the factors that play a role in the combined use of multiple transport modes. Further research may also gather and compare the views on AVs of teenagers living in rural and urban areas or with different household incomes or of other user groups, such as women, older people, or disabled people whose needs and mobility patterns differ from the general population. Given that this work considers teenagers from western Europe, it would be interesting to assess the views of participants from other geographical areas and cultures in the future. In addition, an interesting future line of work could focus on exploring the acceptance of AVs through LLs and specific citizen engagement activities, while the LLs could be used as a way to increase public awareness and public participation in AV deployment and development.

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