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Travel Behaviour and Society 33 (2023) 100641

Contents lists available at ScienceDirect

Travel Behaviour and Society

journal homepage: www.elsevier.com/locate/tbs

Acceptability of autonomous trains with different grades of automation by potential users: A qualitative approach

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ARTICLE INFO

Keywords:
Acceptability
Acceptance
Public perception
Autonomous train
Interviews

ABSTRACT

While automation in public transport has gained new momentum in recent decades, the Autonomous Train (AT) is still in its infancy. To guide the deployment of the AT, it is necessary to study its acceptability by the public. The aim of this study was to investigate for the first time the factors that influence the acceptability of the AT. This qualitative study comprised interviews divided into 3 parts. The first part was devoted to free evocation of the AT, while the following ones asked participants to express themselves on the definition of the AT without a driver but with on-board staff (GoA3) and then without any staff on board (GoA4). Thirty participants were interviewed. The sample was balanced in age, gender, train usage, and living location. The semi-structured interviews were recorded, transcribed, and analysed according to the method of thematic content analysis. Overall, the results showed a lack of knowledge and an idealized representation of the AT. Participants expressed several concerns inherent in the deployment of ATs. Lastly, the intention to use was more favourable in GoA3 than in GoA4. In fact, the participants expressed rejection of GoA4, due to the absence of on-board staff and lack of trust in remote communication tools and train supervisors. This article is the first to explore the public acceptability of the AT by adopting an interview methodology to avoid priming participants' responses. It thus adds to the field of research on the acceptability of autonomous vehicles the railway world which previously focused on driverless subway and freight trains only and now opens the idea of AT on a regular train service.

1. Introduction

Automation is commonly recognized as one of the likely futures of transportation (see Wang et al., 2016). It involves the use of a combination of technologies to perform tasks previously performed by humans (Parasuraman & Riley, 1997). Automation can be applied to all existing modes of transport. The automobile industry was the first to follow in the footsteps of aeronautics and the subway, quickly followed by the bus or the shuttle. The train has now entered the race for automation. Automating a train involves transferring the responsibility for managing the operation of the train from the driver to a control system (Union Internationale des Transports Publics (UITP). (2012)). The classification of train automation (Grades of Automation (GoA; Union Internationale des Transports Publics (UITP). (2012))) is divided into four levels, which depend on the extent of staff involvement in the basic functions of train operation. GoA2 is already a reality in the railway. In GoA3, Driverless Train Operation (DTO), there is no driver in the cabin but there is a train attendant on board. In the highest grade (GoA4), Unattended Train Operation (UTO), the train is fully automatic, without any staff member on board.

However, this automation, especially at its highest levels (without drivers or staff on board), will only be possible if the users of these modes of transport are taken into account. Many studies have therefore focused on the public perception, opinion, or acceptability of autonomous vehicles. The oldest research focused on autonomous cars (Payre et al., 2014; Schoettle & Sivak, 2014), the mode of transport that has been the most widely studied to date (see reviews by Gkartzonikas & Gkritza, 2019; Lemonnier et al., 2020; Nordhoff et al., 2019a; Sun et al., 2017). In recent years, autonomous road public transport has been more widely studied, in particular due to the increasing number of experiments on real sites (Alessandrini et al., 2016). As far as rail is concerned, no study has targeted the train although some studies have been conducted on automated subways (Fraszczyk et al., 2015; Wahlström, 2017; Fraszczyk & Mulley, 2017). There are currently too few such studies, given the economic, ecological and social issues involved in train automation.

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https://doi.org/10.1016/j.tbs.2023.100641
Received 26 October 2020; Received in revised form 15 March 2023; Accepted 12 July 2023

In designing a study on the perception of Autonomous Trains (ATs), there is much to be learnt from studies that focus on public transport. The following literature review will allow us to present what the existing studies tell us but also to highlight the gaps that we propose to fill.

2. Literature review

Between 2015 and early 2020, we have identified 27 studies that assess the views of potential users on an autonomous public transport mode. Of these 27, only three focus on urban subway-type train transport. Therefore, the need for studies on autonomous long-distance train is considerable. In order to enrich our knowledge of the subject in advance of our study, however, we thought it might be interesting to consult studies on autonomous public transport in general, including buses and shuttles.

The studies consulted show a rather positive perception of autonomous public transport whether they are buses (Wicki & Bernauer, 2018), shuttles (Christie et al., 2016; Hilgarter & Granig, 2020; Nordhoff et al., 2018) or subways (Fraszczyk et al., 2015). However, when participants are offered a choice between a staffed autonomous mode, a traditional mode or a remotely supervised autonomous mode, the majority of studies show a preference for the conventional driver-driven mode (Dong et al., 2019; Nordhoff et al., 2018; Roche-Cerasi, 2019; Wahlström, 2017; Zhu et al., 2020). Only Piao et al. (2016) found that two thirds of people surveyed would consider taking automated buses if both automated and conventional buses were available on a route.

The studies consulted also provide information on the impact of the characteristics of the audiences concerned on the opinion of autonomous public transport modes. In particular, acceptability was found to be lower among certain categories of the population. This is the case for women and older people in many studies (Dong et al., 2019; Hyde et al., 2017; Hilgarter & Granig, 2020; Madigan et al., 2017; Piao et al., 2016; Roche-Cerasi, 2019; Salonen, 2018). Moreover, unfamiliarity and inexperience seem to have a negative influence on the intention to use (Moták et al., 2017) and its factors (Eden et al., 2017; Pakusch & Bossauer, 2017; Xu et al., 2018). Inversely, familiarity positively influence the intention to use. The information received, for instance through the media, has been reported to increase perceived self-efficacy, acting favourably on intention to use (Zhu et al., 2020). In the interviews conducted, participants often compared the autonomous mode of public transport and the public transport they are currently familiar with, emphasizing their proximity (Nordhoff et al., 2019b; Salonen & Haavisto, 2019). Lastly, studies have highlighted the fact that current users of the transport mode studied are more inclined than non-users to use this mode in its autonomous version (Dong et al., 2019; Fraszczyk & Mulley, 2017; Nordhoff et al., 2018).

In general, an interest in autonomous public transport requires a more comprehensive view of the transport service than what is necessary to measure the acceptability of the autonomous car (Eden et al., 2017; Hinderer et al., 2018; Nordhoff et al., 2019b; Salonen & Haavisto, 2019; Stark et al., 2019). In this respect, studies provide us with different insights depending on whether they are conducted on a concept of autonomous transport or following a real experience of autonomous transport. After direct experience of riding in an automated vehicle, users have voiced some reservations about the usefulness of buses and shuttles, particularly because of the speed restrictions linked to the experimental context (Frison et al., 2018; Nordhoff et al., 2018; Nordhoff et al., 2019b) or because the shuttle crossed pedestrian areas where people preferred to walk (Eden et al., 2017). The interview study by Nordhoff et al. (2019b) shows how much importance potential users place on quality of service in relation to the acceptability of an autonomous shuttle (115 quotes over 340). Participants consider it important to moderate the ticket price (Stark et al., 2019), increase the frequency (Nordhoff et al., 2019b), serve larger areas (Eden et al., 2017; Salonen & Haavisto, 2019; Stark et al., 2019) and extend the running periods (Eden et al., 2017).

Regarding safety, studies reported a good level of trust in the technologies used and few concerns about their ability to operate the vehicle (Christie et al., 2016; Hilgarter & Granig, 2020; Piao et al., 2016; Rehrl & Zankl, 2018; Salonen & Haavisto, 2019; Stark et al., 2019). What appears to frighten individuals, especially at night, is the fact of being potentially vulnerable to attack in the absence of on-board staff (López-Lambas and Alonso, 2019; Piao et al., 2016; Portouli et al., 2017; Roche-Cerasi, 2019; Salonen, 2018; Stark et al., 2019). The job losses involved by automation are also a frequently raised concern (Hilgarter & Granig, 2020; López-Lambas and Alonso, 2019; Nordhoff et al., 2019b; Pettigrew et al., 2018; Wicki & Bernauer, 2018).

The majority of published studies used questionnaires to measure the factors affecting the acceptability of autonomous vehicles such as attitudes, concerns, and benefits, exploring the perception of potential or actual users of autonomous public transport modes. Reservations have been expressed, however, about this method of studying imagined vehicles (see Lemonnier et al., 2020, for a summary of potential biases). In their questionnaire study, for instance, Nordhoff et al. (2018) indicated the risk of a "yea-saying" effect whereby participants respond without critically reflecting on the meaning of each question. In another paper, the same research team stressed the weakness of questionnaires in obtaining in-depth information and the effectiveness of qualitative methods in exploring new or unknown phenomena such as automated public transport (Nordhoff et al., 2019b). Generally, there has been extremely little use of interviews to consider the acceptability of autonomous public transport. As far as we know, only 4 studies whose results were published between 2015 and early 2020 carried out an in-depth analysis of interviews on autonomous shuttles (Eden et al., 2017; Hilgarter & Granig, 2020; Nordhoff et al., 2019b; Salonen & Haavisto, 2019). None of them concerned the automated subway or the AT; all of them dealt with participants' opinions after (or before and after) riding in an autonomous shuttle. Interviews have the potential to follow the recommendations of Tennant et al. (2019, p.114), namely: *"pay attention to possible framing effects arising from the naming of the attitude object, description of the technology and the sequencing of questions", "ensure that the attitude object is clearly defined for respondent"*.

This literature review highlighted the following gaps:

- Although perceptions are rather positive, the desire to replace a traditional mode with a driver by an autonomous mode is not in the majority. The reason for this phenomenon remains to be explored further.
- No study has questioned potential users about their perception of the AT, even though this service is currently undergoing technological development. The modes studied are too different from the train to consider that it is possible to apply the results obtained to predict the acceptability of the AT. Long-distance train has almost nothing in common with a shuttle, and is different from the subway because of travel time, speed and open vs. closed environment.
- There are too few in-depth interview studies, even though they avoid framing the participants' discourse.

The present research aimed to contribute to the study of the acceptability of autonomous public transport by focusing especially on ATs at different levels of automation, namely GoA3 (without a driver but with on-board staff) and GoA4 (with distant supervision). Using in-depth semi-structured interviews on a sample of 30 people, the ideas that come to mind when dealing with "autonomous trains" and the factors that may affect citizens' intentions to use ATs were explored. This study seeks to fill a gap in existing knowledge on the perception of automation in transportation, respecting as far as possible the complexity of the subject. The results of this work will make it possible to improve the design and implementation of ATs in the years to come by taking their future users into consideration.

3. Method

The data collected consisted of a corpus of verbatim reports following interviews with a varied sample of inhabitants of Northern France.

3.1. Recruitment procedure and participants

Thirty volunteers (half of each gender) were recruited by e-mail through professional and personal networks. None of the participants had a job related to train operation or research on the AT and none were personal relations of the research team. The e-mail contained no mention of the AT. Participants were invited to talk about their vision of the train. Prior to the interview, participants were e-mailed a consent form to ensure that they were properly informed of their rights regarding the data collected and the purposes of the collection. In accordance with the requirements of the general data protection regulation that applies within the European Union, the personal data protection officer of the research institute registered the database.

The participants were 17 to 73 years (M = 42.87; SD = 15.68). They were chosen to obtain a balanced sample on the following criteria: gender, age, train use vs. non-use, living location: rural, *peri*-urban, and urban (Table 1). They were offered no financial compensation for their participation.

3.2. Interviewing procedures

The individual interviews were semi-structured and based on a grid that consisted of a list of open-ended questions in no specific order to adapt the prompts according to the participants' responses. The interview was, however, structured in four specific parts. First, participants were asked about their train use to confirm their assignment to a group (users vs. non-users); the verbatims concerning this part were not included in the content analysis. The aim of the second part was to let them freely evoke the ideas that came to mind in response to the question, *"If I say autonomous train, what does it evoke for you?"* In the third part, participants listened to a definition of the AT in GoA3 (Table 2) and were asked to react in the same way as before: *"What does it evoke for you?"* The participants were also asked if they could imagine themselves travelling on this train. In the last part, a definition of the AT in GoA4 was given and the participants were asked the same questions as before. The definitions were repeated as many times as necessary.

Within parts 2, 3 and 4, prompts could be made if necessary, to bring up topics not spontaneously addressed (safety, usefulness, advantages, concerns, trust and knowledge). In order to influence the participants as little as possible, the prompts were made, for example, in the form: *"What about safety?"*.

Interviews were conducted by telephone, recorded with the consent of the participant, and then transcribed verbatim. They took place between 19 February and 31 March 2020. They lasted between 23 and 69 min (37 min in average).

Table 1
Sociodemographic characteristics of participants.

Sociodemographic characteristic	Response category	n
Gender	Male	15
	Female	15
Age	17–30	8
	31–50	12
	51–73	10
Use of train	At least once a week	11
	1–3 times a month	4
	Never or almost never	15
Living location	Rural areas	7
	Peri-urban areas	11
	Urban areas	12
Socio-professional category	Employees/workers	7
	Intermediate or higher professions	15
	Pensioners	5
	Students	3

Table 2
Definitions given to the participants.[1]

Grade of Automation	Definition
GoA3	*"There is no longer a driver in the cab in this train. The train itself ensures both the driving and the detection of any external event requiring it to take action (braking, whistle, communication with passengers, etc.). On the other hand, there remains on board staff capable of performing certain safety functions and managing degraded modes such as evacuation of persons, access for emergency services, or modification of the service offered to passengers (removal of certain stops, reduction in speed, etc.)."*
GoA4	*"There are no staff on board in this train. There are staff who remotely manage the degraded modes and, if necessary, ensure remote control. Supervisory staff can interact with passengers via, for example, a terminal, intercom systems or an application."*

[1] These definitions were written by the authors in collaboration with an expert of the railway environment and more specifically of the autonomous train in France.

3.3. Data analysis

Thematic content analysis (Bardin, 1977; Berelson, 1952; Fallery & Rodhain, 2007) was carried out in 5 steps. The first step was the transcription of the interviews. Each interview was transcribed in full, respecting word for word the participants' responses. Second, we reread the corpus of interviews and identified the themes following the principles of inductive category development (Mayring, 2000), which allows for the comprehensibility and verifiability of the study. These themes were based on those highlighted in the literature reviews on the acceptability of autonomous vehicles (Gkartzonikas & Gkritza, 2019; Lemonnier et al., in press; Nordhoff, et al., 2019a). Third, each interview was cut into several dozen extracts. An excerpt corresponds to a passage from the participant's response composed of one or more sentences in which they evoke ATs or express their point of view on this subject. Each excerpt was then classified within one of the themes selected. As the themes were independent of one another and not redundant, each extract was classified within a single theme and could not correspond to several themes. In the fourth step of the analysis, the sub-themes within each main theme were highlighted. For two thirds of the main themes, the excerpts were organized into sub-themes to allow a more precise analysis of the concepts addressed in the responses. Excerpts in which the opinion was expressed in very general terms such as *"There is no benefit"* or *"I have no concerns"* were classified within the corresponding theme, but not within a specific sub-theme. Finally, each interview excerpt was assigned a valence to determine for each sub-theme whether participants expressed a positive, negative, or neutral viewpoint.

The analysis was carried out by the first two authors. After first agreeing with the second author on a definition for each theme to guide the classification of extracts within the themes, the first author carried out each step of the analysis by regularly exchanging with the second author. She then proposed a classification of the extracts within the themes and sub-themes, which was the subject of a counterproposal by the second author after a thorough rereading of the extracts. The first author then adapted the sub-themes according to the suggestions of the second author. Finally, in case of disagreement on the classification of an extract, a discussion was initiated between the two authors until a

consensus was reached.

4. Results

In the thematic content analysis, we distinguished the results on the one hand in terms of the number of times a sub-theme was mentioned, and on the other hand in terms of the number of participants who mentioned the sub-theme. This double reading of our results allowed us to identify the coverage of the themes, i.e. whether a theme was frequently addressed because many participants referred to it or because a small number of participants mentioned it many times (the case in several interviews). Consequently, the number of occurrences per sub-theme was sometimes higher than the number of participants. The data analysis resulted in the identification of 716 occurrences overall.

Table 3
Number of occurrences (Occ.) and participants (Pps) by theme and sub-theme in the parts of the interview dedicated to AT.

Theme	Sub-theme	AT		GoA3		GoA4	
		Occ.	Pps	Occ.	Pps	Occ.	Pps
Safety	Effect of the presence or absence of staff on board	17	13	35	20	27	21
	Change or lack of change with respect to non-ATs	12	11	8	7	8	7
	Risk of Accident	12	6	6	5	9	9
	Safety on board the AT	0	0	3	3	52	24
Usefulness	Accessibility	11	5	8	6	15	8
	Frequency	11	7	4	4	3	2
	Punctuality	27	19	13	12	9	7
	Speed	6	6	2	2	3	3
	Comfort	2	2	6	4	0	0
	Ticket price	0	0	5	5	6	6
Benefits	Savings for the railway operator	7	7	8	5	10	5
	Evolution of railway professions	9	6	5	4	2	2
	Environmental benefit	8	7	9	5	0	0
Concerns	Job loss	19	16	17	11	5	5
	Carbon footprint associated with AT	3	3	0	0	3	3
	Feeling of dehumanization	8	5	0	0	0	0
	Decrease in on-board services	0	0	0	0	10	8
	Concern about remote communication malfunctions	0	0	0	0	25	14
Trust	Trust in technology	39	20	29	14	12	9
	Hacking	3	3	1	1	2	1
	Trust in railway operator	0	0	17	9	8	6
	Trust in AT supervisors	0	0	4	4	32	20
Knowledge	Reference to other autonomous transport modes	24	16	9	8	12	8
	No representation of the AT	4	4	0	0	0	0
Attitudes	Interest	8	5	8	5	6	3
	Rejection	3	1	2	2	14	12

These were assigned to one of the 7 themes highlighted (Table 3). Four main themes were extensively mentioned: safety (189 times), trust (147 times), usefulness (131 times), and concerns (90 times). Three secondary themes were less frequently mentioned: benefits (58 times), level of knowledge (49 times), and attitudes (41 times). Among these themes, we can also distinguish between those that were spontaneously brought up or not. Among the main themes, three were very often spontaneously mentioned: concerns (83% of occurrences were spontaneous), trust (72%), and safety (69%); among the secondary themes, two were almost always spontaneously evoked: level of knowledge (96% spontaneous), and attitudes (88%). In comparison, remarks concerning usefulness and benefits were more frequently made in response to a prompt by the interviewer with 59% and 60% of spontaneous evocations, respectively.

4.1. Safety

4.1.1. Effect of the presence or absence of staff on board

In the free evocations part, 9 participants expressed fears about the absence of staff on board and thus spontaneously projected themselves into an AT in GoA4.

> *"I also think about passenger safety. Because, when you talk to me about autonomous trains, there is no longer a driver, but I imagine there is no longer a ticket inspector either."* (Participant 30)

In the GoA3 part of the interview, participants' comments were much more positive and 17 of them said they would be reassured by the presence of personnel on board the AT, whereas in the GoA4 part of the interview, fears associated with the lack of staff on board were mentioned by 16 participants. Some of them used the term dehumanization and reported feeling a sense of abandonment about being alone in the AT if *"someone gets sick…"* or *"a fight breaks out…"* or *"an assault is made…"*. The participants thus considered that *"without staff on board, the reaction time will be… longer! Well, as a result, that there will be less passenger safety."* (Participant 8).

4.1.2. Change or lack of change with respect to non-autonomous trains

Eight participants in the free evocations part of the interview, 7 in GoA3, and 6 in GoA4 stated that as they did not see the driver today anyway, the absence of a driver would not cause any significant change. This opinion was even more pronounced in level GoA3, where the train attendant on board is perceived by the participants as equivalent to the ticket inspector they are familiar with today.

> *"So, that, basically, it does change a lot of things. But, in, when you put yourself in a user's shoes, once he or she is on the train, the train goes on as usual. There is a ticket inspector as usual. So… That, on the feeling, anyway, I don't see too much change daily."* (Participant 9)

4.1.3. Risk of Accident

The participants did not anticipate more accidents on board the AT. Three participants also mentioned the fact that train accidents seldom occur and that there is no reason why they should become more frequent with AT. This argument is constant throughout all the parts of the interview.

> *"It's like planes. From time to time, there are accidents, but, well, in the end when you look… There are fewer plane accidents than…, domestic accidents! So, it wouldn't scare me, being on this train and all that."* (Participant 15)

4.1.4. Safety on board the AT

The perception of safety on board the AT in terms of assault, degradation, but also discomfort diverges significantly between the two higher levels of automation, GoA3 and GoA4. Participants only very rarely mentioned this theme in GoA3. They were not worried about the risks of mugging or passenger discomfort. In GoA4, 23 participants

(77%) stated that they would feel unsafe in such a train, because no one would help them if they were assaulted. Similarly, if a passenger became ill, participants anticipated a complex and anxiety-provoking management of the situation if no passenger on board the train were trained in first aid.

4.2. Usefulness

Usefulness groups together the characteristics of the AT or the associated service that have a direct impact on the transport and the quality of service offered to the user.

4.2.1. Accessibility

Four participants mentioned better accessibility in terms of territorial coverage with an AT that would serve more stations, small stations that are now closed, or that would even allow the creation of new stations.

4.2.2. Frequency

In an idealized projection of AT, and based on their knowledge of the automated subway, 7 participants imagined an AT as frequent as a subway. The participants thus anticipated that the AT would pass through their station more often.

4.2.3. Punctuality

Punctuality was the sub-theme on which the participants insisted the most, repeating the same arguments throughout the interview. We deduce from this that the social unrest of late 2019 in France had made an impression on the participants, both users and non-users. Thus 17 in the free evocation part and 9 in GoA3 declared that thanks to ATs there would no longer be any problems associated with strikes, due to the reduction or even absence of staff on board the trains.

4.2.4. Speed

Five participants considered that ATs would be faster than current trains. It should be noted that this idea was often put forward by the non-user participants. When they use the train, it is very often the high-speed train; thus, these participants imagined an AT similar to the only train they know, namely high-speed.

4.2.5. Comfort

Four participants anticipated greater travel comfort inside an AT due partly to a more aesthetically pleasing environment and partly to additional travel comfort on several levels (seats and equipment provided, quiet environment, and for GoA3, on-board staff offering multiple services).

4.2.6. Ticket price

Five participants mentioned that the elimination of train drivers would result in financial gain for the transport operator, which could be reflected in the price of the ticket with *"some slightly cheaper tickets."* (Participant 20).

Nevertheless, 6 participants feared an increase in ticket prices to compensate for the scientific and technological investments generated by the design of the AT. This fear was brought up only in the GoA4 part of the interview.

"People they're gonna have to pay twice as much for the ticket." (Participant 12).

4.3. Benefits

The benefits are the positive aspects that do not directly influence the user and their journey. There was an imbalance between the three parts of the interview, with a higher number of positive remarks in the free evocations and GoA3 parts (24 and 22 times respectively) and a low proportion (12 times) in GoA4. This means that participants envisaged more benefits in GoA3 than in GoA4.

4.3.1. Savings for the railway operator

Ten participants stated that an AT in GoA4 would not bring them any advantage; and 5 that only the railway operator would gain from an economic point of view. The participants were therefore aware that ATs will generate investment costs, but they stated that in the long term these costs would be recouped through the gains generated by staff cuts.

> *"There will necessarily be far fewer staff and therefore a colossal reduction in staff costs. And… Well, even if it requires a big investment at the beginning, I think that in the long term, it's a big cost reduction."* (Participant 20)

4.3.2. Evolution of railway professions

The participants stated that the deployment of ATs would allow for an evolution of railway professions through the creation of the supervisory profession, which would gradually replace the train driver profession according to 6 participants. Participants had a positive perception of these career developments for transport operator staff who would be able to acquire new skills.

> *"It's a question of the evolution of the profession in the railway industry, where, indeed, we might need a geek rather than a guy who knows how to drive a train. Yeah, an evolution, because anyway, there will be a need for other jobs. Different, but there will be a need for other jobs."* (Participant 23)

4.3.3. Environmental benefit

Seven participants imagined the AT as a *"greener"* train (Participant 12), some even evoking a *"self-sufficient"* train (Participant 10) that would be able to produce its own energy.

4.4. Concerns

This theme brings together the fears and concerns of participants about the human, economic, environmental, and technical aspects associated with the deployment of ATs. The distribution of responses within the different parts of the interviews was not balanced. Concerns were relatively numerous in the free evocations part of the interview (mentioned 30 times), and much rarer in GoA3 (17 times). Concerns were very numerous and new ones surfaced when participants listened to the definition corresponding to GoA4 (43 times).

4.4.1. Job loss

The main and constant concern throughout the interviews was the loss of jobs among transport operator staff. Participants felt that the evolution of railway professions would not prevent a massive loss of jobs. Thus, 16 participants in the free evocations part, 11 in GoA3 and 5 in GoA4 mentioned or insisted on their fears regarding job losses, for both train drivers and ticket inspectors. The participants stated that there is already a lot of unemployment in France and that job losses among railway employees would aggravate the situation.

> *"There may be problems of employment. Well, I mean, that's more the negative side. […] It's a bit like robotization in many fields… It doesn't necessarily create jobs."* (Participant 14)

4.4.2. Carbon footprint associated with ATs

Some participants raised the issue of the carbon footprint associated with the design of these trains. This concern is related to the criticisms that are now being made of electric cars and by extension automated cars. Participants referred to these examples and stated that even if this type of car pollutes less than others, the carbon footprint is too high to achieve an environmental gain. These participants would be opposed to the deployment of ATs if the same problem arose.

4.4.3. Feeling of dehumanization generated by the absence of staff on board

Participants expressed deep concern about the lack of staff on board. Five participants expressed this concern by evoking a sense of dehumanization. For example, participants indicated a preference for a traditional cash register which allows for human contact, as compared to automatic ones, saying that they feel more confident with a human interlocutor than in front of a machine. Moreover, this also preserves jobs.

> *" Personally, it worries me…, it worries me a little, yes. If it's a robot that does things instead of a person…, well, a robot is a robot! Even if there's a person behind it who has to supervise… I think it's going to…, isolate people more and more… real relationships, you know."* (Participant 19)

4.4.4. Decrease in on-board services

For 7 participants, the absence of staff on board in GoA4 was likely to be accompanied by a reduction in the services offered on board. Without staff to help them in case of problems or answer their questions, participants stated that the services offered on board would be poorer in quality and more difficult to access. According to the participants, a remote supervisor with whom they interact via a terminal would not provide them with the same quality of service as a train inspector present on board. Indeed, the supervisor may have other trains to manage and will therefore not be available as quickly as an agent on the train.

4.4.5. Concern about remote communication malfunctions

The definition of the GoA4 level of automation that was provided to the participants states that a supervisor will be able to interact with passengers via an intercom, a terminal, or an application. This was a source of concern for 12 participants who stated that they were not in favour of remote communication replacing a train attendant on board for three reasons: a risk of technical malfunction, a risk of difficulties in use, a risk of less effective assistance (misunderstanding the context, failure to take account of non-verbal language).

"It's not the same thing via the intercom or the terminal… So, on the other end of the intercom, there are humans, but…, they are not going to experience the situation the way a person might experience it on the train. They won't know if… for example, they'll say, "Go out the door," but if the door doesn't open, they'll keep saying, "Go out the door." And…, well, no, the door doesn't open. They are going to give instructions that don't match up to reality." (Participant 21).

4.5. Trust

This theme covers all the manifestations of trust and mistrust expressed by the participants towards the AT itself, the train operator or the AT supervisors, as well as the fears associated with piracy.

4.5.1. Trust in technology

Participants' views on the issue of trust in technology were not unanimous. Nine participants said they trusted technology and artificial intelligence more than humans, who can fall asleep, be tired and less focused and thus make mistakes.

> *"Finally, by letting machines do it… there is less risk of accidents, than by letting men do it."* (Participant 2)

On the contrary, 10 participants thought that no machine would be able to replace human operators and declared that they were wary. Many of these participants believed that technology should unburden humans and allow them to do their work in better conditions but not replace them.

> *"Even if the train is autonomous, there can still be… a breakdown, an incident on the track. I mean, well, that's… technology can't control everything, so I think we still need…, more staff, you know."* (Participant 14)

4.5.2. Hacking

Hacking was rarely mentioned. The participants who addressed this sub-theme wondered about the consequences that hacking of an AT could cause and raised the notion of digital terrorism.

4.5.3. Trust in the railway operator

Once again, the opinion of the participants about trust in the railway operator was not consensual. Five participants stated that they trusted the railway operator, indicating that if ATs were put into operation, the railway operator would no doubt have carried out all the necessary checks beforehand to ensure passenger safety.

> *"It is still rare that…, something is put in place that doesn't work for sure, in fact. At least things of that magnitude. They are tested and re-tested and re-tested before they are put in place."* (Participant 20)

On the other hand, 4 participants were much more suspicious of the railway operator. These participants had doubts about the definitions provided, especially at the GoA3 level, and stated that when ATs became functional, they would run directly without staff on board.

> *"The problem is that tomorrow when you get on board… Your definition of autonomous train, it will be forgotten. And there will be no one on board."* (Participant 5)

Opinions were therefore divided on this issue: while some participants trusted the railway operator to ensure passenger safety, others mistrusted the discourse and communication around ATs and were convinced that the sole purpose of ATs was to enable the railway operator to economize.

4.5.4. Trust in AT supervisors

The notion of supervision was predominant in the participants' responses in GoA4. Fifteen participants declared a lack of trust in AT supervisors. They feared that supervisors would not be as engaged as a train driver or on-board attendant could be, arguing that in the event of an incident, supervisors would not be able to analyse the situation as easily as they do today because they would not experience it themselves. As a result, the participants were afraid that the supervisors would not be able to help them or would be less effective in solving the problem since they were at a distance. In addition, participants anticipated significant delays in dealing with incidents and that these delays would be even longer if human intervention on site was required, as it would take time for the train controllers to travel to the AT to solve the problem.

"I have the impression that when there's someone on board… they are obliged to take care of us, to take care of the problem. Because they're on the train with us anyway. That's what they're there for. Whereas if it's a person who manages remotely, maybe they're managing other trains that also have problems. Well, obviously, as the person is far away, for me, they feel less concerned by the problem." (Participant 2).

4.6. Level of knowledge

From the participants' remarks on other autonomous vehicles we can infer how much they know about ATs. We found that knowledge about this form of public transport was limited and often based on knowledge acquired with the automated subway (45 comments out of 49).

4.7. Reference to other autonomous transport modes

Throughout the interviews, participants referred to the types of autonomous transport that exist today and that they know better than ATs. More specifically, in the free evocations part, 16 of them referred to other autonomous transport modes, namely automated cars, shuttles, but also, and above all, the automated subway. The latter is the closest to the AT because both run on rails, but it is also the most familiar to the participants as it has been in operation for many years in some French regions.

"For me, it would be, it would be …, the transposition of what there is on the lines, the subway lines already autonomous today, whether in Lille or Paris." (Participant 23)

Participants imagined the AT as a subway, with its advantages (frequency, punctuality, accessibility) and its disadvantages (lack of services on board, insecurity at late hours). However, several participants pointed out the differences between the subway that runs in a closed environment and the train that runs in an open environment, claiming that this makes the design of ATs more difficult.

4.7.1. No representation of the AT

In the free evocations part, in which the participants were not yet familiar with the definitions of ATs, 4 participants stated that they had no idea what an AT is, probably because this type of public transport has not yet been developed, neither in France nor abroad and because there is still little wide-ranging communication about it.

4.8. Attitudes

Attitudes correspond to the expressions of interest and rejection expressed by the participants with respect to ATs. Five participants showed an interest in new technologies, and by extension in ATs. These participants declared that they would feel proud if ATs were developed in France. They were enthusiastic about the definitions provided and were even willing to test the AT as soon as it is put into operation.

"Because it's true that to build, as a result, a completely autonomous train, like that… It would be spectacular, so it's also a good image for France." (Participant 15)

However, in GoA4, 12 participants expressed reservations or even a feeling of rejection, stating that it was premature to consider deploying ATs, and that other issues needed to be addressed beforehand, such as upgrading the railway infrastructure. Participants even expressed a strong rejection of ATs, calling this new technology *"dumb"* (Participant 21). Due to the lack of staff on board the AT, criticism of the AT was even more pronounced in GoA4. The participants rejected this level of automatism even more strongly and indicated that they would no longer take the train if this type of AT were introduced.

"This is a typical definition that I don't like at all. Because it totally evacuates the human… factor. So…, there wouldn't be any more of them inside." (Participant 30)

4.9. Intention to travel in an AT

At the end of the GoA3 and GoA4 parts, we asked the participants if they could imagine travelling in an AT. This measure, which can be likened to behavioural intention, does not represent a determining factor, but is rather the result of all the psychological factors mentioned above. In GoA3, 26 participants expressed a positive view and declared that they were willing to travel in an AT. One participant expressed a neutral point of view, and 3 a negative point of view, refusing to travel in this type of train. Overall, the attitude towards this level of automation was positive.

"Yeah, yeah. Oh yeah, honestly, I would see myself…, traveling in it without any worries." (Participant 15)

The opposite trend was observed in GoA4, where only 4 participants declared that they would agree to travel on such a train, while 15 would refuse to board it.

"No. No, no, no! The train of the second definition, I…, I wouldn't travel in it anymore, no." (Participant 30)

Finally, 11 participants offered a more neutral view by saying that they would travel in it because they would have no other choice than to continue taking the train. Although more nuanced, this type of response remains relatively negative.

"Yeah, if I'm forced to! Or if it's imposed, that's all there'll be in two, three, ten, twenty years, I don't know, well…, yes!" (Participant 23)

4.10. Effect of socio-demographic variables

We investigated the effect of each socio-demographic variable on the 7 factors affecting the acceptability of ATs identified through the thematic content analysis. In our analysis, we assigned a valence to everyone's opinion on a theme: positive, negative, or neutral. Participants who did not mention the topic were included in the neutral valence. For each socio-demographic variable, the distributions did not allow us to carry out a Chi2 test.

4.10.1. Gender

We found the same pattern of results regardless of gender in terms of safety, benefits, concerns, trust, and knowledge. Regarding the usefulness of AT, 67% of women expressed a positive opinion about it compared to 47% of men. Men were more neutral in their views (53% vs. 33%). Also, although 40% of women perceived benefits from the deployment of ATs, 27% perceived no benefits at all. In comparison, only 7% of men said there was no benefit to deploying the AT. The majority (53%) did not comment on the issue. Finally, 40% of men and only 14% of women expressed a clear-cut attitude towards ATs.

4.10.2. Age

We observed the same pattern of results regardless of age in terms of benefits, concerns, trust, attitudes, and knowledge. For safety, 50% of older participants had a negative view of safety on-board the AT (compared to 37.5% and 33% for younger and middle-aged participants respectively). Concerning usefulness, many young and middle-aged participants perceived the deployment of the AT as useful (62.5% and 67% respectively), while only 40% of older participants held this opinion. In conclusion, we found that older participants were more concerned about safety on board the AT and perceived the usefulness of deploying such trains less than other groups.

4.10.3. Living location

Results showed that the usefulness of ATs was mostly noted by inhabitants of *peri*-urban areas, 67% of whom perceived ATs as useful, while 55% of urban residents had a neutral point of view. Also, participants living in *peri*-urban areas tended to have a neutral point of view regarding trust in ATs or did not express themselves on this subject. On the contrary, many urban residents did not trust ATs (54%) and rural residents were as likely to say they trusted ATs as to say they did not (43%). In conclusion, we note that residents of *peri*-urban areas were more likely to perceive the usefulness of ATs while urban residents were less likely than other participants to express trust in ATs.

4.10.4. Train usage

The same pattern of results was observed regardless of the frequency of train use for all the factors influencing AT acceptability highlighted in the thematic content analysis. No difference was found for this variable.

5. Discussion

5.1. Factors influencing the acceptability and intention to use according to the thematic content analysis

The thematic content analysis provides details about 7 factors affecting the acceptability of ATs; all are mentioned in the literature: safety, usefulness, benefits, concerns, trust, knowledge, and attitudes. The analysis also allows assessment of the behavioural intention to travel in an AT. The results show a high intention to use ATs in GoA3 and

a low intention to use ATs in GoA4. Participants were easily able to imagine themselves travelling inside an AT in GoA3, whereas many of them refused to board an AT in GoA4 or expressed strong reservations.

In general, our study provides results that are fairly close to those obtained by existing studies. As also reported by other studies (Christie, et al., 2016; Hilgarter & Granig, 2020; Piao, et al., 2016; Rehrl & Zankl, 2018; Salonen & Haavisto, 2019; Stark, et al., 2019), our participants did not appear to be worried about the potential risk of accidents even though some of them did not have much trust in the ability of an artificial intelligence to drive a train. Rather, they had some concerns. First, they were concerned by the need for an increase in the quality of the service provided as a guarantee of the usefulness of the AT, as has already been reported by Hinderer et al. (2018), Nordhoff et al. (2018, 2019b), and Salonen and Haavisto (2019). Second, they expressed concerns about the risks associated with the absence of staff on board. These findings correspond to those observed by López-Lambas and Alonso (2019) (see also Piao et al., 2016; Roche-Cerasi, 2019). They underline the proximity between the AT and the automated subway they are familiar with (Nordhoff et al., 2019; Salonen & Haavisto, 2019). Third, as already reported by Pettigrew et al. (2018), the participants consistently mentioned job losses as a major drawback of the introduction of this type of train even if a scenario for the evolution of railway professions was also evoked (see also Hilgarter & Granig, 2020; López-Lambas and Alonso, 2019; Wicki & Bernauer, 2018). Some advantages mentioned in the literature, whether environmental or economic (Fraszczyk et al., 2015; Fraszczyk & Mulley, 2017), were also mentioned by our participants.

Despite these similarities, our study goes beyond what has already been studied on several points. First, comparing the free evocation of the AT and more clearly defined ATs of different levels of automation sheds significant new light on a subject that has not yet been decided. While potential users of the AT have few fears about the absence of a driver, the total absence of staff gives rise to many fears and even rejection, in contradiction to the positive opinions frequently identified in the literature (Christie et al., 2016; Fraszczyk et al., 2015; Hilgarter & Granig, 2020; Nordhoff et al., 2018; Wicki & Bernauer, 2018). The use of interviews makes it possible not to constrain the expression of the participants' ideas. On the one hand, they show an idealized vision of the service associated with the AT in terms of territorial coverage, frequency, punctuality, speed and, to a lesser extent, comfort. On the other hand, they evoke a feeling of abandonment and loss of social ties. The points of view are complex and paradoxical. Remarkably, this is the first time that utility criteria are based on the participants' discourse. In many other studies, researchers ask participants to evaluate the usefulness of automated vehicles by a questionnaire. This method can prime the participants' responses and does not reveal the utility criteria that first come to participants' minds, and which are thus a priority for them. Finally, the study has shown the low level of knowledge of our participants concerning the AT. When no definition is given, more than 1 in 7 participants are unable to answer our questions. Although this dimension has been relatively little investigated in studies on autonomous public transport since almost all of them are based on experiments in real conditions, it has been widely explored in studies on the autonomous car, showing a good self-assessed level of knowledge (Regan et al., 2017). In our study, we also see that attitudes vary according to the level of knowledge. Indeed, half of the participants do not express any attitude towards ATs. The other half have a more clearly defined attitude, which varies according to the level of automation. The majority of opinions are positive for GoA3 and negative for GoA4.

Finally, our study proposes some elements that have never been identified to our knowledge. Our participants seem to project themselves into the reality of what they encounter during their usual journeys and have specific fears related to distance supervision and communication. They think of common situations of damage to equipment that could affect remote communications equipment, situations of malaise, various breakdowns, and imagine talking to someone who does not understand them and whom they do not understand. They imagine the difficulties linked to the lack of a common framework for the discussion and those linked to the failure to take account of non-verbal language. Also, they imagine that the supervisor will be less concerned or too busy elsewhere to take an effective interest in their problem.

5.2. Socio-demographic variables

The last stage of our analysis concerned the effect of socio-demographic variables on the different factors influencing AT acceptability. We studied the effect of 4 socio-demographic variables: gender, age, living location, and train usage.

For gender, the results showed that women were more likely than men to perceive ATs as useful. This result is the opposite of those observed in the literature (Dong et al., 2019; Hilgarter & Graning, 2020; Piao et al., 2016). A possible explanation for this discrepancy is that among our 15 women participants, 9 are occasional or frequent train users, and the literature has shown that users perceive more usefulness from autonomous public transport than non-users (Dong et al., 2019; Fraszczyk & Mulley, 2017; Nordhoff et al., 2018).

In terms of age, the main difference observed was between older people and younger and middle-aged participants. Corroborating the literature on automated cars (Lemonnier et al., 2020), older participants were more concerned about safety within the AT than the other two age groups. Similarly, with respect to usefulness, older participants had a mostly neutral point of view, unlike younger and middle-aged people, who perceived the usefulness of deploying ATs. Rather, these findings appear to be consistent with existing studies that have shown that older participants are less accepting of automated vehicles than younger ones. It should be noted, however, that we did not find the effects observed in the literature in terms of benefits and attitudes.

With respect to living location, a higher proportion of *peri*-urban than rural and urban residents considered the deployment of ATs to be useful. Furthermore, many urban residents said they did not trust ATs, the majority of *peri*-urban residents did not express an opinion on the issue and were mostly neutral in their views, and rural residents were as likely to say they trusted ATs as they were to say they did not. These results contrast with those in the literature, which show that urban residents have a higher acceptability of automated vehicles than rural residents (Hilgarter & Granig, 2020).

Finally, the last socio-demographic variable we studied was train usage. No difference was observed between train users and non-users. These results are at odds with those showing that current users of public transport are more likely than non-users to use an autonomous public transport (Dong et al., 2019; Fraszczyk & Mulley, 2017; Nordhoff et al., 2018).

5.3. Study strengths and limitations

The first strength of our study is its methodology. The semi-directive interview method allowed us to have access to a greater depth of discourse and thus to information that is impossible to obtain from a questionnaire. Secondly, this study is the first to investigate the acceptability of ATs among the public. Several industrial projects are already in the design phase of ATs worldwide, but no study has investigated the acceptability of this new means of transport among the population. However, we perceive a definite interest in studying this mode of transport specifically, on the one hand because it is public transport, whereas most studies to date have concerned cars, and on the other hand because it differs from other forms of autonomous public transport since it operates on rails and not on roads like the bus or shuttle. Thus, apart from studies on the automated subway (Fraszczyk et al., 2015; Fraszczyk & Mulley, 2017; Wahlström, 2017), no studies have specifically addressed the acceptability of ATs or, more broadly, of a rail mode. Thirdly, the literature shows that the factors influencing the acceptability of autonomous vehicles are generally identical from one

type of vehicle to another (see Lemonnier et al., 2020 for a review). However, by analysing in depth the sub-themes of each factor, the results of this study sometimes differ from those found in the literature on autonomous public transport, but also on driverless cars. Each transport mode has its own specificities that influence its acceptability, which makes it impossible to transpose the results from one mode of autonomous transport to another.

Finally, there are some limitations and perspectives to this study. Firstly, the size of our sample hinders the generalization of our results. In fact, the application conditions necessary to carry out inferential tests were not met. A larger sample would have allowed us to obtain statistical results. Our results are therefore exploratory in nature and represent the starting point for experimental studies involving more participants. Secondly, while our sample is well balanced on several dimensions – gender, age, living location and train use – this is not the case for the level of education with an over-representation of participants with an advanced level of education. This may have an influence on the sub-themes highlighted in the content analysis as the level of education may influence the perception of individuals, particularly in terms of the benefits and concerns related to autonomous transport. Thirdly, the participants' answers are only the result of projections. This study is thus decontextualized from the real daily mobility of the participants even if they seem to project themselves in real use. To counter this bias, we took care to provide them with precise definitions of the different levels of automation of ATs, but none of the participants had any concrete experience with it. However, this was impossible since no AT is currently running in France.

5.4. Recommendations and perspectives

Before concluding this paper, we would like to propose a number of recommendations for research and for the deployment of ATs.

First for research, our results allow to identify some topics to be further explored. This is particularly the case for trust in the operator of autonomous transport. Our study shows the importance, in order to understand the acceptability of ATs, of taking into account the level of trust in the ability of the operator of the AT and/or the supervisory authorities to guarantee the full safety of these trains. As far as we know, this dimension has never been studied yet, but seems important for our participants. We think that it would also be interesting to multiply studies including populations from different housing areas as this socio-demographic variable has been less often studied than the others in the literature. In the same perspective, it would be important to continue to compare current users and non-users of the public transport concerned, including larger samples of participants. In the future, it would thus be interesting to compare the acceptability of different autonomous modes of transport: individual road, collective road, and collective rail within the same sample of participants. It would allow measuring the impact of the service itself vs. the automation in the acceptability of an autonomous transport mode. From a methodological point of view, we encourage researchers to favour the spontaneous expression about innovations such as autonomous vehicles. This is of particular interest for the utility criteria associated with autonomous vehicles. Secondly, we advocate that the level of knowledge should be measured using spontaneous comments or objective evaluations as done by Sanbonmatsu et al. (2018) for automated cars, rather than with self-assessment scales. We also insist on the importance for the participant to project himself in the use to answer questions about an autonomous transport mode. As soon as prototypes are functional, it will be relevant to study the acceptability of ATs through simulations that would make it easier for the participants to project themselves into the use of an AT. This would make it possible to study practical acceptability with the objective of improving the user's travel experience in accordance with their needs and expectations.

Lastly, our study offers a multitude of avenues to follow for designers of ATs. We recommend that designers pay attention to the service associated with the AT. It is also important to take into account the issue of the customer relationships, either by leaving staff on board or by offering a means of remote communication that promotes dialogue and trust. We also stress the importance of communicating about the AT. Communication campaigns are of paramount importance to improve the level of knowledge and promote the intention to use autonomous public transports (Moták et al., 2017; Zhu et al., 2020).

6. Conclusion

This interview study analysed people's views concerning the acceptability of ATs both in general and at two different grades of automation in terms of safety, usefulness, benefits, concerns, trust, knowledge, attitudes and intention to use. People seemed to have little knowledge of this mode of transport and used the comparison with the automated subway to project themselves. They also had an idealized vision of the service offered by the AT. Finally, the study showed a high intention to use GoA3 trains but a widespread refusal to board GoA4 trains. Most of this rejection seems to be linked to the lack of staff on board, which is not compensated for by remote means of communication. People feared being abandoned by supervisors who were too far away or too busy to be interested in their problems or because of technical malfunctions. The results of this study, carried out with great care to avoid influencing participants' opinions, are a first sobering look at the acceptability of the AT.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors thank all the participants and the participants' providers for giving their time disinterestedly. They also express their gratitude to Elizabeth Rowley-Jolivet for English language editing of this article.

Funding

This research work was carried out in the framework of IRT (Technological Research Institute) Railenium, Valenciennes, France, and therefore was granted public funds within the scope of the French Program "Investissements d'Avenir".

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