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Icy roads and urban environments. Passenger experiences in autonomous vehicles in Finland

Petri Launonen [a,b,*], Arto O. Salonen [a,c], Heikki Liimatainen [b]

[a] Faculty of Social Sciences and Business Studies, University of Eastern Finland, P.O. Box 1627, FI-70211 Kuopio, Finland
[b] Transport Research Centre Verne, Tampere University, P.O. Box 600, FI-33014, Finland
[c] Smarter Mobility Innovation Hub, Metropolia University of Applied Sciences, Helsinki 00079, Finland

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ABSTRACT

This study focused on identifying customerś real-life experiences, perceptions and feelings about travelling in different autonomous vehicles and in various operating conditions in Finland in 2018. Quantitative convenience sample (n = 141) were collected from passengers travelling on an autonomous shuttle bus in Helsinki. Qualitative data (n = 70) were gathered by interviewing passengers of a driverless shuttle bus in Helsinki and passengers of an autonomous car in winter conditions in Lapland. This research was first one which included passengers' real-life experiences after using autonomous vehicles in winter conditions. We applied the Theory of Planned Behaviour. The research questions were (a) What beliefs about outcomes and evaluation of outcomes do passengers have and carry out when they travel in an autonomous vehicle, irrespective of vehicle type or operating conditions? (b) What key factors influence people's positive or negative attitudes towards autonomous vehicles? (c) What key factors could induce people to use autonomous vehicles? The quantitative data were analysed by nonparametric Kruskal-Wallis H test and qualitative data by inductive content analysis. According to the results, trust, safety and security were the main factors influencing people's positive attitudes towards using autonomous vehicles. Results from passengers travelling in heavy winter conditions indicate that winter conditions do not significantly influence passengers' attitudes towards using autonomous vehicles. There were no significant differences between gender regarding passengers' perceptions of traffic safety, personal security and emergency management. However, younger passengers felt their personal security on board to be significantly better than older and students their possibilities to act in a case of emergency significantly better than employed people.

1. Introduction

Autonomous vehicles represent one of the biggest changes and opportunities in the field of mobility (McKerracher et al., 2016; Fulton et al., 2017; International Transport Forum, 2015; Fagnant, 2014). Predictions regarding the implementation of autonomous vehicles vary greatly, and the technology needs to be developed before totally autonomous vehicles can be brought into everyday use. Some ambitious predictions say that up to 40% of the mileage driven in Europe could be covered

* Corresponding author at: Faculty of Social Sciences and Business Studies, University of Eastern Finland, P.O. Box 1627, FI-70211 Kuopio, Finland.
E-mail address: petri.launonen@tuni.fi (P. Launonen).

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by autonomous vehicles by 2030 (Kuhnert et al., 2018) and after 2040 over 70% of new cars sold in urban areas in the US could be shared driverless cars (Corwin et al., 2016). Sharing in this way redefines mobility as a service without private car ownership (Hensher, 2017).

Autonomous public transport could serve as the backbone of sustainable mobility and new mobility services. Autonomous shuttle buses could be used as a last-mile solution and reduce the cost of travel as drivers are no longer needed. They could also lead to safer roads, less congestion and reduced parking (Fagnant & Kockelman, 2015; Grush & Niles, 2018; OECD 2018). On the other hand, there are psychological barriers preventing the complete implementation of autonomous buses. The most important potential negative factors include increased vehicle and infrastructure costs, safety risks under certain conditions (e.g., system failures etc.), and possible reduction in employment opportunities (Lopez-Lampas & Alonso, 2019). Nevertheless, autonomous buses may come into wide use earlier than other autonomous vehicles because they can be designed to operate on specific routes instead of having to cope with complex traffic manoeuvres across the entire road network.

Passengers' experiences and expectations are one of the key issues in developing autonomous vehicles. A survey of 11 European countries found that more drivers are uncomfortable than comfortable with the prospect of autonomous vehicles, while technological optimism, uptake of driving technology, and lower sociability towards other road users were related to more positive attitudes towards autonomous vehicles (Tennant et al. 2019). 78% of Americans reported that they fear riding in an autonomous vehicle (Power, 2017). Only 10% of people living in the US reported that they would feel safer sharing the roads with driverless vehicles (Brannon, 2017). Over 80% of people across the UK, France, Germany, Norway and Spain are not willing to trust their loved ones to technology (Berland, 2016). However, these results are based on expectations, not on real-life experiences. Real-life experiences show that, for example, in Switzerland passengers of autonomous shuttle buses trust in the safety and reliability of the system (Wicki & Bernauer, 2018).

People hold the key to the success of autonomous vehicles (McKerracher et al., 2016). People's potential to change their behaviour has been studied in many questionnaire surveys (Kaur and Rampersad, 2018; Liljamo et al. 2018; Kyriakidis et al. 2015; Schoettle & Sivak 2014), but only a few previous studies have focused on passengers who have actually used autonomous vehicles (Ainsalu et al. 2018). Results from a trial in Berlin-Schöneberg, Germany, indicate that the acceptance and use of autonomous vehicles in public transport is influenced by their perceived usefulness, ease of use and social influence (Nordhoff et al., 2017). According to the previous research on self-driving shuttles in Vantaa, Finland, passengers assessed traffic safety to be better than the safety of a conventional bus on the same route (Salonen, 2018). One good experience enhances personal feelings of safety considerably, but in contrast to attitudes towards human drivers, no errors by autonomous vehicles are tolerated (Salonen & Haavisto, 2019).

In Finland, passengers are on average ready to test and use autonomous vehicles if their safety and reliability can be guaranteed (Liljamo et al. 2018). In the present study, we identify people's real-life experiences, perceptions and feelings about travelling in two types of autonomous vehicles in various operating conditions in Helsinki, the capital of Finland, and in Muonio, a small town in Lapland, Finland. In Helsinki, passengers used a driverless shuttle bus in two test areas in summer 2018. In Muonio, local residents travelled with an autonomous car in heavy winter conditions on main road 21 (Finnish national road 21, part of European route E8). The results of this study help to understand the logic of behavioural changes in mobility irrespective of the type of autonomous vehicle, weather, or other circumstances.

In this study we are interested in identifying factors of behavioural change linked to autonomous vehicles, irrespective of the vehicle or operating conditions. Especially we are interested in what are key factors in our test pilots influencing people's attitudes towards autonomous vehicles and inducing people to use autonomous vehicles.

2. Theoretical framework: The theory of Planned behaviour

We apply the Theory of Planned Behaviour (TPB) (Ajzen 1985; Ajzen & Madden, 1986; Ajzen 1988; Ajzen 1991). The TPB is an extension of the Theory of Reasoned Action (TRA), a general theory of social behaviour (Fishbein and Ajzen, 1975) based on adjusted expectancy-value theory. People behave according to their beliefs about the outcomes of their behaviour and the values they attach to those outcomes. Beliefs about and evaluation of outcomes lead to an attitude towards the given behaviour, according to Fishbein and Ajzen (1975), and this attitude towards the behaviour is one of the main influences on people's intention to act in a given way. Intention to act, in the Fishbein-Ajzen model, is the immediate antecedent and key determinant of behaviour. A second major influence on intention in TRA is what Fishbein and Ajzen called a person's subjective norm, that is, a person's perception that most people who are important to him think he should or should not perform the behaviour in question (Ajzen & Fishbein, 1980).

The specific modification (Fig. 1) in developing TPB from TRA was to include a new variable known as perceived behavioural control (PBC) as a third major indicator of intention. PBC has also been used to predict action. PBC is defined as 'the person's belief as to how easy or difficult performance of the behaviour is likely to be' (Ajzen & Madden, 1986). Together, these three indicators are key influencing factors in changing the behaviour of people.

The TPB suggests that in order to have behavioural changes, you need to change attitudes, subjective norms and perceived behavioural control. The importance of each of these determinants of intention can vary from behaviour to behaviour and from population to population. As a general rule, the more favourable the attitude and subjective norm and the greater the perceived control, the stronger should be the person's intention to perform the behaviour in question.

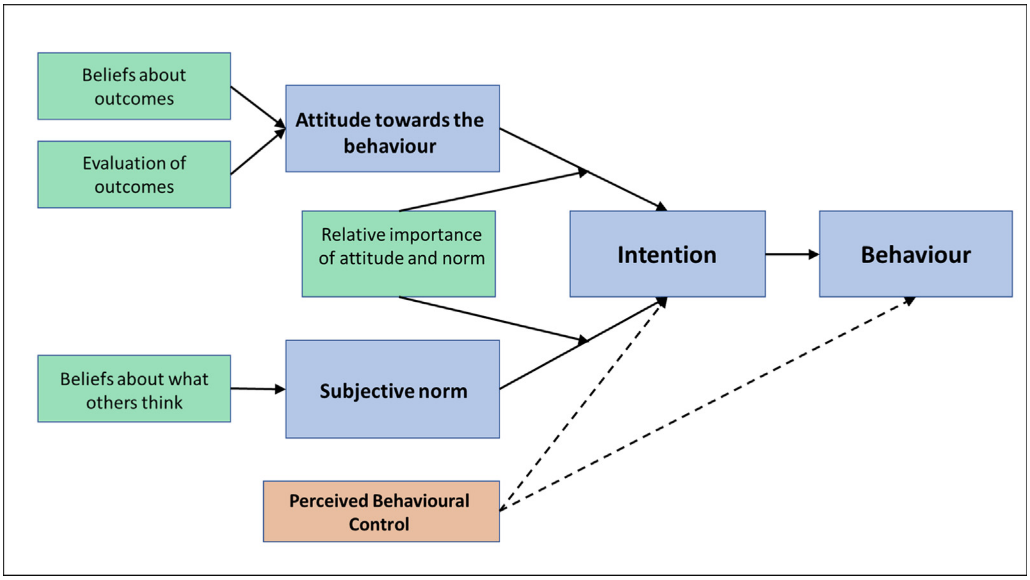


Fig. 1. Theory of Planned Behaviour.

Although TPB has been used in wide range of behaviours, there has been critique to theory's sufficiency. Some new variables have been suggested to be added to the theory to improve its predictive validity. Variables suggested have been for example desire and need, personal and moral norms, past behaviour and self-identity. Also it has been assessed that reasoned action may represent only one mode of operation, the controlled or deliberate mode. A related critique of the TPB's reasoned action assumption relies on that with repeated performance, behaviour becomes routine and no longer requires much conscious control for its execution (Jackson, 2005; psychology.iresearchnet.com/social-psychology/social-psychology-theories).

The TPB has been used successfully to predict and explain a wide range of behaviours and intentions including travel mode choice (Dijst et al. 2013) but has not been applied to autonomous driving, although there are some studies in which the main variables of the theory have been mentioned (Nordhoff et al., 2017). In this study, we apply TPB to autonomous driving because it can be used directly to predict actual behavioural achievement, and the main variables have been mentioned in earlier studies. It can be used to predict deliberate and planned new behaviour. There are not yet any routines in using autonomous vehicles and moral norms about using these vehicles are not yet formed. For these reasons we preferred TRB to other theories, such as the most widely used UTAUT2 (Venkatesh et al., 2012; see also Chng et al. 2018).

In this study we are interested in identifying factors of behavioural change linked to autonomous vehicles. Using the TPB, we examine what are the key factors influencing people's intention to use autonomous vehicles and in what ways their behaviour can be changed. More specifically, we answer the following research questions: (a) What beliefs about outcomes and evaluation of outcomes do passengers have and carry out when they travel in an autonomous vehicle, irrespective of the vehicle or operating conditions? (b) What key factors influence people's positive or negative attitudes towards autonomous vehicles? (c) What key factors could induce people to use autonomous vehicles?

3. Materials and methods

Both quantitative and qualitative data were collected from passengers travelling in autonomous vehicles in various trials in Finland 2018. The vehicles used in the trials were the Navya driverless shuttle bus, the EasyMile EZ-10 driverless shuttle bus, and the Sensible 4 Juto driverless robot car. The vehicles used in the trials represented SAE Level 4 automation (SAE J3016).

Quantitative data (n = 141) were collected from passengers travelling on the Navya autonomous shuttle bus in Kivikko, Helsinki, during May-October 2018. The bus operated among normal traffic. Passengers were selected randomly and access to bus was possible for everyone. This kind of convenience sample was most useful to pilot testing (Given, 2008). The scheduled service of the autonomous shuttle was named line 94R (R for Robot). Line 94R complemented the network of Helsinki's metropolitan public transit authority Helsinki Region Transport (HSL). The line was also incorporated into the Helsinki Region Transport Journey Planner. It offered mobility services from Kivikonlaita to Kivikko Sports Park and back (Fig. 2). The top speed of the vehicle on the route was limited to 18 km/h. The carrying capacity of the bus was eight passengers. There was also a human operator present on board. The operator intervened in driving if the bus stopped due to flying leaves or dust. The autonomous shuttle bus worked well during the trial apart from some incidences of sudden breaking due to

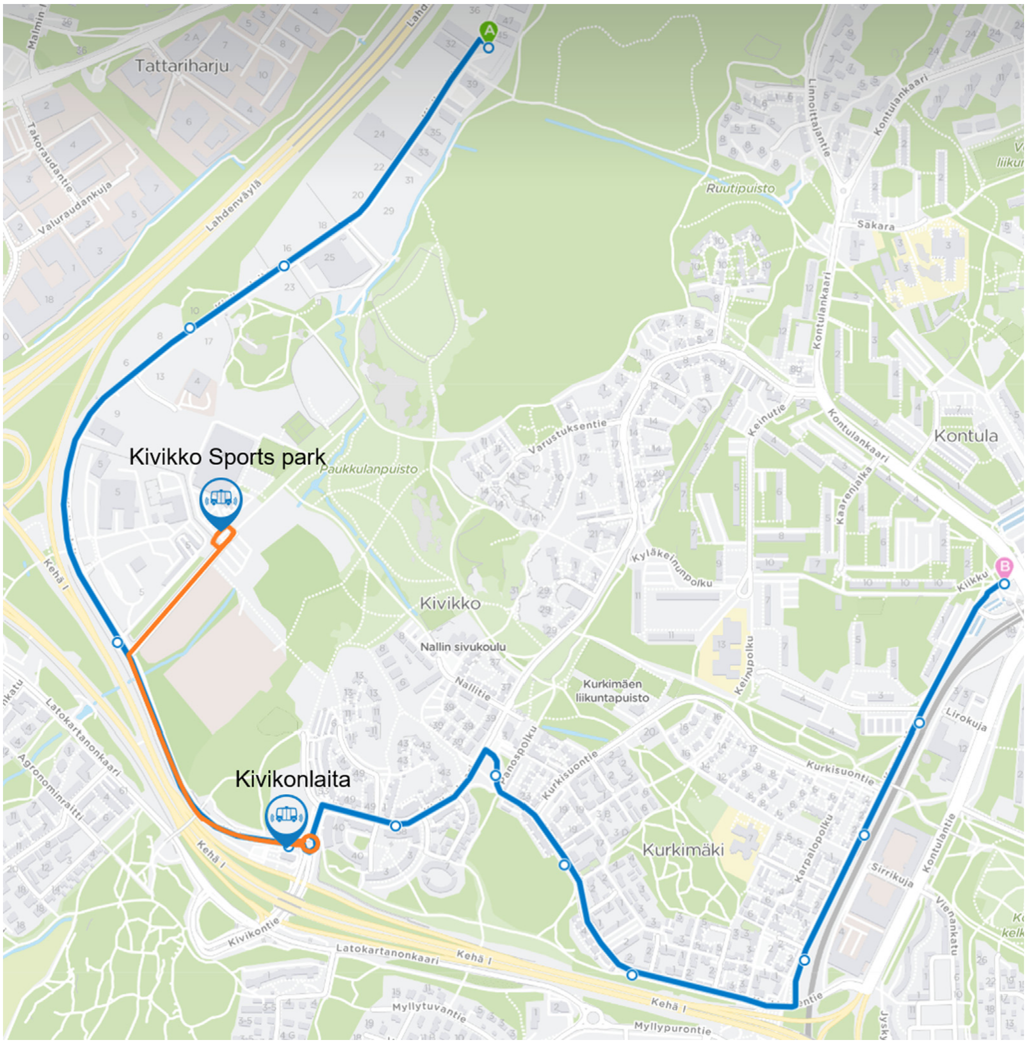


Fig. 2. Route of the driverless shuttle bus in Kivikko, Helsinki (orange), supporting other public transport in the area (blue). Map data: © Open Street Map contributors; Helsinki RobobusLine 2018. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

obstacles or other traffic. The human operator took over operation during these situations but otherwise the vehicle operated autonomously.

Passengers on line 94R were asked to compare their perceptions about traffic safety, personal security, and emergency management (i.e. possibilities to act or get help in an emergency) with a conventional bus on the exact same route on a scale of *much worse* (1) to *much better* (7). The data were analysed by nonparametric Kruskal-Wallis H test to determine any significant differences between passenger groups. The socio-demographic characteristics of the respondents are presented in Table 1.

The qualitative data (n = 70) were gathered during May-June 2018 in Helsinki (Suvilahti) and in October 2018 in Lapland (Muonio) by interviewing passengers of autonomous vehicles who were travelling a predefined route. Passengers were selected randomly and access to vehicles was possible for everyone. Sample was a convenience sample because of small size and sample being drawn from people close to hand in test areas (Given, 2008). Suvilahti is a former industrial area and nowadays regenerated as a cultural centre near the new Kalasatama district, about 4 km from the centre of Helsinki. The weather conditions in Suvilahti were normal summer conditions.

In Suvilahti the route passed through the cultural area between the gates of the Suvilahti cultural centre and the Sörnäisten rantatie road. The route provided transport between locations in the cultural area both in small alleys and more open areas without clear driving lanes. The route was operated by the EasyMile EZ-10 driverless shuttle bus. In the trial, the driverless shuttle bus operated among other traffic. The volume of traffic in the area was low. The one-way length of the route was approximately 700 m. The carrying capacity of the bus was 10 passengers (6 seats and 4 standing passengers).

Table 1
Socio-demographic characteristics of the respondents (n = 141) in the quantitative data for Kivikko (Helsinki).

Socio-demographics		n	%
Gender	male	86	61.0
	female	54	38.3
	no answer	1	0.7
Age	15–24	45	31.9
	25–34	23	16.3
	35–44	27	19.1
	45–54	21	14.9
	55–64	10	7.1
	65–74	12	8.5
	over 74	3	2.1
	no answer		
Employment status	student	54	38.3
	entrepreneur	6	4.3
	employed	51	36.2
	pensioner	18	12.8
	other	12	8.5

The maximum operating speed was 12 km/h during the trial. The passengers were instructed that the driverless shuttle bus was operated autonomously. On board the driverless shuttle bus was a human operator, who was a member of the project team, and the interviewer.

Muonio is a small town in Lapland, near the Swedish border. The trial was run in winter conditions on a snowy and icy road and in hard wind, but with no snowing. The temperature was approximately −2 °C. Main road 21 between Kolari and Muonio serves as a test road for autonomous driving. The route is used by the Aurora Arctic Challenge project. In the trial, the route was operated by the Sensible 4 Juto driverless robot car between the SEO petrol station and Hyvä Pata restaurant for two days. The one-way length of the route was 1.3 km. The carrying capacity of the car was one passenger, also on board the driverless car was a human operator who was a member of the project team. The vehicle drove in slippery lane during the trial in heavy winter conditions. Nevertheless, the vehicle stayed in its lane well, despite the windy and snowy and icy road conditions.

The interviews in the Helsinki and Lapland trials were conducted after the passengers exited the vehicle. The interviews, conducted in Finnish, lasted 10–15 min and were recorded with the permission of the passengers. The interviews were semi-structured and the questions were divided into four themes: (a) immediate reactions, (b) feelings and emotions, (c) attitudes, and (d) social factors. Immediate reactions was a general theme. The other themes were derived from the TPB. According to the TPB, attitude towards behaviour, subjective norms and perceived behavioural control form the intention for behavioural changes. Firstly, we asked the passengers to describe their immediate reactions to the autonomous vehicle. Secondly, we were interested in identifying the passengers' feelings and emotional impressions and reactions. We asked the passengers to tell us which adjectives described their feelings about the autonomous vehicle. We were interested in knowing, for example, whether they felt confident, unsafe, insecure, calm, excited, curious or critical, and whether they were surprised about anything. Thirdly, we asked the passengers about their attitudes towards using autonomous vehicles. According to the TPB, attitudes can be identified by beliefs and evaluations of the outcomes of a new behaviour – in this case riding in an autonomous vehicle. PBC (the person's belief as to how easy or difficult performance of the behaviour is likely to be) was taken also into account in the questions. We asked the passengers to tell us what benefits they can see in using autonomous vehicles, what would make them use autonomous vehicles regularly in the future, and what might hamper the widespread use of autonomous vehicles in their daily life. We asked the passengers to describe what users they imagine would benefit most from autonomous vehicles. We also asked them to tell us what they thought their friends would think about autonomous vehicles and why. In addition, we asked them to reflect on whether they are the type of person who would use autonomous vehicles in the future or not. The last theme of the interview focused on beliefs about what others think. These questions were used to define the subjective norm.

All interviews (n = 70) were transcribed, resulting in 42 pages of Suvilahti data and 9 pages of Muonio data (Arial font, size 11, 1.15 spacing). The socio-demographic characteristics of the respondents in the qualitative survey in Suvilahti (n = 56) and Muonio (n = 14) are presented in Table 2.

As a qualitative research method, we applied inductive content analysis as our aim was to create a significant and broad description of the perceptions of the passengers in autonomous vehicles (Miles, Huberman & Saldaña, 2014; Elo & Kyngäs, 2008; Ajzen & Madden, 1986). This kind of exploratory research method enables the researcher to describe the meaning of qualitative data systematically (Schreier, 2012). It also increases understanding of the phenomena (Krippendorff, 2004) because in inductive content analysis the categories are not predefined. This approach is used to understand the perspective of the respondents and it moves from individual observations towards a general statement (Elo & Kyngäs, 2008). Previous observations, knowledge or theories have very little effect on the outcome of the analysis because the analysis is directed by the content of the data. The inductive process starts with reducing the data, then clustering the data, and, finally, drawing conclusions (Miles, Huberman & Saldaña, 2014).

Table 2
Socio-demographic characteristics of the interviewed passengers (n = 70) in Suvilahti (Helsinki) and Muonio (Lapland).

Socio-demographics		n	%
Gender	male	39	55.5
	female	30	42.9
	no answer	1	1.4
Age	15–24	5	7.1
	25–34	13	18.6
	35–44	15	21.4
	45–54	6	8.6
	55–64	16	22.9
	65–74	11	15.7
	over 74	0	0
	no answer	4	5.7
Employment status	student	10	14.3
	entrepreneur	3	4.3
	employed	30	42.9
	pensioner	19	27.1
	other	8	11.4

Firstly, the data from both trials was read through several times in order to fully internalise it (Elo & Kyngäs, 2008). The data was combined because we were interested in understanding the phenomena both as a whole and as a variety of experiences of travelling in different autonomous vehicles in different operating conditions. In the first phase of analysis, we excluded all irrelevant information, and all relevant parts of the data were then separated out from the text. We considered that relevant parts described the experiences, perceptions and feelings of travelling in an autonomous vehicle and therefore answered the research questions. Irrelevant parts included technically specific speculation or opinions about vehicles' quality and were excluded. When clustering the data, we coded the data by reading it through carefully and forming categories of similar content. The purpose of forming categories is to reduce the data by grouping expressions that have the same meaning into a single category, which is given a name that describes its content (Elo & Kyngäs, 2008). The data were first broken down into subsets and then sorted into different subcategories. These subcategories were then joined to create generic categories where appropriate, from which the main categories were eventually formed (see Table 3). This continued as far as it was feasible, and categories that describe the phenomena were formed (Flick, 2014). After the inductive analysis we compared our results within the theoretical frame of TPB, as presented in the discussion in Chapter 5.

4. Results

The main categories formed by inductive content analysis were: safety and security perceptions, trust perceptions, operating environment, and affordance, of autonomous vehicles. We divided these main categories into generic categories and subcategories. As one of the identified main categories covered safety and security perceptions – the same focus as the quantitative analysis – we included the results of the quantitative analysis in Section 4.1.

Trust and safety refer to the passenger's internal experience. Operating environment and affordance refer to the autonomous vehicles and the possibilities for using them.

4.1. Safety and security perceptions

None of the interview questions directly asked about safety or security. However, the respondents raised issues related to traffic safety and personal security themselves. Overall, they felt that their sense of safety and security as passengers exceeded their prior expectations. The maturity of the applied technology and the quality of the operating environment affect safety. Slow speed, the presence of a human operator on board the vehicle, smooth driving and easy driving conditions without congestion were associated with positive perceptions. *It goes so slow that this vehicle won't go far off the road even if something did happen. (Female, age 55–64, retired)*

Autonomous vehicles were considered to be safer than conventional vehicles with human drivers. The respondents generally considered it fairly evident that autonomous vehicles would make fewer mistakes. The respondents also understood that autonomous vehicle technology is not yet fully developed and further advancements are needed before they can work well in busy urban areas. They seemed to be aware that the trials were carried out on learned routes and discussed how autonomous vehicles would manage on congested roads. *If this one would run and replace a normal bus, I think it would be safer. I trust more in technology than drivers. (Female, age 25–34, student)*

The icy conditions of road 21 in Lapland resulted in the autonomous vehicle sliding sideways on the driving lane. In Suvilahti, Helsinki, there were a number of sudden braking incidents, which startled some respondents. However, due to the slow speed, the presence of a human operator in the vehicle, and other positive experiences during the trip, the passengers nevertheless considered autonomous vehicles to be safe.

Table 3
Categories formed by inductive content analysis.

Main category	Generic categories	Subcategories
Safety and security perceptions	Safety	Technology reduces traffic accidents. Technology level now and in future. Preconceptions. Positive and negative feelings during the trip. Weather conditions.
	Personal security	Security at night in buses. Privacy in buses.
Trust perceptions	Trust in technology	Autonomous vehicle as a future solution. Human error. Automated driving errors. Interested in technology.
	Increased trust after trying autonomous vehicles and getting information about them	Perceptions during the trip. Information from media and friends. Seeing autonomous vehicles in traffic.
	Trust level indicators	Confidence Curiosity Calm Excitement Fear Interest
Operating environment	Range of use	Urban centres Complementing public transport with last-mile solutions Not for small roads Airports.
	Responding to mobility needs	Routes Schedules of buses Speed of autonomous vehicles Needs similar to normal public transport
	Feelings about travelling in autonomous vehicles	Feels like normal bus or tram. Autonomous vehicles as normal vehicles. Driver absence unnoticed in buses. How well autonomous vehicle did work.
Affordance	Suitability for different purposes of travel	Flexible on-demand service. School transport. Demand-responsive transport. Cargo.
	Suitability for different user groups	For all. For older people. For disabled people.

Preconceptions were considered to be a barrier to using autonomous vehicles. Respondents mentioned low trust in technology and perceived lack of safety as the main reasons for possible negative preconceptions. Good experiences from using autonomous vehicles and getting more information from the media and friends seemed to be the best ways to reduce negative preconceptions.

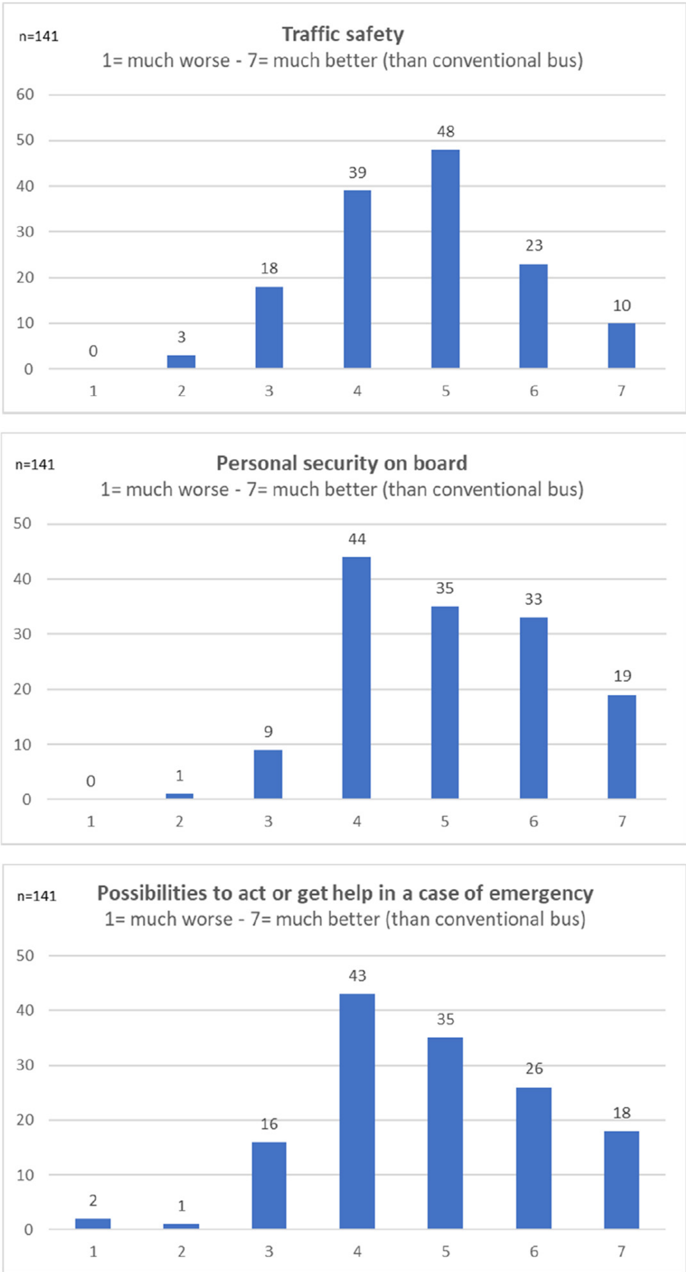
Weather conditions were mentioned more often in Lapland, where the trial was carried out in heavy winter conditions. According to the Muonio respondents, icy roads, cold, and snow present challenges for autonomous driving. *It's these natural elements and snow that make conditions in Finland so variable. You have to take a lot of things into account when developing an autonomous vehicle. (Male, age 35–44, employed)*

In contrast, in the Helsinki trial only few respondents considered weather conditions to be a challenge. Moreover, the Helsinki trials were conducted in summer conditions, enabling the respondents to focus more on their own feelings and impressions during the trip.

Some respondents raise the issue of personal security within the bus. Security while travelling on the bus at night and also protection of privacy while travelling were concerns for some respondents due to the lack of a driver. Who would help or witness if something happens? Should there be a guard on board if there is no driver? These concerns were mentioned especially by older people. *It's the customers that usually cause problems. Who will help and what robot bus will do if for example two customers start to fight? (Male, age 55–64, employed)*

To help examine these safety and security questions we also gathered a quantitative convenience sample from the autonomous vehicle trial in Kivikko, Helsinki (see Tables 4 and 5). The autonomous bus operated among other traffic. Passengers of the scheduled driverless shuttle bus line 94R were selected randomly and the access to the bus was open for everyone. Even if the access was open to everyone, we assumed that the answers described the local interest in the new mode of transport. We asked passengers to compare their perceptions about traffic safety, personal security and emergency management with a conventional bus on the exact same route on a scale of *much worse* (1) to *much better* (7). The data was analysed using non-

Table 4
Answer distributions on scale 1–7 (traffic safety, personal security on board and possibilities to act or get help in case of emergency) in Kivikko, Helsinki (n = 141) compared to a conventional bus on the same route.



parametric Kruskal-Wallis H test (Daniel, 1990) to determine any statistically significant differences between gender, age and employment status (student, entrepreneur, employed, retired or other).

Traffic safety was considered to be slightly higher in the autonomous vehicle than a conventional bus (mean 4.7, standard deviation 1.2). More than 60% of responses were in categories 4 and 5. Personal security in the autonomous vehicle was also considered better (mean 5.0, standard deviation 1.2), although the distribution differed from traffic safety. Regarding possibilities to act or get help in an emergency, the mean was 4.8, the standard deviation 1.3, and the response distribution was similar to personal security.

In this study there were two statistically significant differences between different groups of passengers. There was a significant linear trend, χ^2 (6) = 15.057, p = .020, indicating that younger passengers (age 15–24) felt their personal security on board to be significantly higher than older (age 25-) passengers. Students felt their possibilities to act in a case of emergency significantly better than employed people, χ^2 (4) = 9.801, p = .044. Otherwise, there were no differences in feelings regarding traffic safety between gender, age group or employment status. Moreover, there were no differences in sense of personal security between men and women. Regarding emergency management, men viewed their possibilities to act or get help in an emergency slightly more positively than women but the difference was not statistically significant. The results can't be generalized because we used convenience samples from the test pilot. The results of the qualitative data supported these quantitative results.

4.2. Trust perceptions

Trust in autonomous vehicle technology was widely mentioned by the respondents. Trust in this sense can be defined as the willingness to place oneself in a vulnerable position with respect to a technology based on a positive expectation of an outcome or a positive aspect of future behaviour (Mayer et al., 1995; Kaur & Rampersad, 2018). Two perspectives of trust were raised. Respondents trusted in the technology as an example, or prototype, of a future solution. They mentioned that autonomous vehicles reduce human errors. In contrast, the reliability of the technology and whether it would work in different circumstances were also questioned. Positive experiences of using an autonomous vehicle gained from the trial, being interested in new technologies, and getting information in advance increased trust in the technology. If respondents were not informed in advance about how the technology worked, their responses tended to be more uncertain. *Well, during the trip my confidence increased when I saw that this works well and always stopped when there were obstacles on the road. (Male, age 55–64, retired).*

Isolated moderately negative experiences during the trip did not greatly affect the passenger's intention to use autonomous vehicles in future if their experiences were positive overall. In the Lapland trial, the vehicle slid sideways on the driving lane, yet the respondents still said that they would use autonomous vehicles in the future. In Suvilahti, the bus braked suddenly a number of times, yet this did not affect the passengers' overall intention to use autonomous vehicles in the future, because otherwise their experiences were positive. Many respondents understood that the technology is not yet mature, while some commented on how well the technology functioned. Winter conditions nevertheless raised concerns about the technology. *It's these natural elements and snow that make conditions in Finland so variable. You have to take a lot of things into account. Male, age 35–44, employed)*

The slow speed of the vehicles and relatively easy driving conditions without congestion increased trust in using autonomous vehicles, although the slowness also reduced the attractiveness of using them. Confidence was also increased by the presence of an operator in the vehicle during the trip. However, the respondents did not consider it important for them that there was a driver in the vehicle.

Respondents were asked to describe their perceptions and impressions. From these responses, different feelings and emotional reactions could be identified that also reflect different levels of trust. Almost every respondent had a positive attitude to autonomous vehicles after the trial. Confidence was also mentioned as an overall impression by most respondents. Based on the analysis, we recognised the following indicators of different levels of trust: confidence, curiosity, calm, excitement, fear, and interest.

The respondents' sense of experiencing a new future technology was positively expressed as interest, excitement and curiosity. The trials functioned well overall, and the respondents had positive experiences and a sense that they were trying something new and exciting. They also expressed their willingness to use autonomous vehicles in the future. *I was excited that technology has come so far that autonomous vehicles are becoming a reality. (Male, age 55–64, employed)*

Calm was one manifestation of trust. Trust in technology increased passengers' sense of quietude. Slow speed, smooth driving, and relatively easy traffic conditions increased passengers' feelings of confidence and quietude. When a trial ran well with no surprises, quietude was the first affect on the passengers. However, fear was also mentioned by some respondents. These respondents experienced a negative sense of uncontrolled movement, which was highlighted if they did not know how the autonomous vehicle functioned. Negative attitudes towards technology in general heightened feelings fear and anxiety.

Respondents were also asked what they thought others' attitudes towards autonomous vehicles might be and what feelings or impressions about them they might have. Most respondents answered that they thought their friends would try autonomous vehicles. One reason for this might be that the persons participating in the trials may already have had a level of interest in technology and autonomous vehicles. *I would think that many would want to try these at least once, but I don't think they'd be passionate about them, either positively or negatively. (Female, age 35–44, employed)*

The majority of respondents stated that they thought other people's and friends attitudes would be mostly quite positive and base on trust rather than fear.

4.3. Operating environment

According to the data analysis, three subcategories related to operating environment were identified: range of use, responding to mobility needs, and feelings about travelling (passenger experience).

Table 5
Differences in socio-demographic characteristics of the respondents in Kivikko, Helsinki (n = 141).

Variables	df1	df2	χ^2	Sig.
Gender				
Traffic safety	1	138	0.891	0.345
My personal security on board	1	138	0.385	0.535
Possibilities to act or get help in an emergency	1	138	3.382	0.066
Age				
Traffic safety	6	134	2.327	0.887
My personal security on board	6	134	15.057	0.020
Possibilities to act or get help in an emergency	6	134	8.609	0.197
Employment status				
Traffic safety	4	136	1.393	0.845
My personal security on board	4	136	7.879	0.096
Possibilities to act or get help in an emergency	4	136	9.801	0.044

A number of respondents mentioned city centres as the most suitable area for using autonomous vehicles. Complementing public transport with last-mile solutions arose in many responses in Suvilahti, possibly due to the small size of the shuttle buses and the trial area. Respondents suggested using autonomous vehicles on more flexible customised routes and for demand-responsive traffic. Costs were expected to be lower due to elimination of drivers' salaries. Relatively easily navigated environments such as airports and campus areas were mentioned as possible operation areas. Some respondents mentioned that taxis should be autonomous in the future. *Now that the metro from Helsinki to Espoo has started, these would work perfectly there, from residential areas to metro stations. There should be buses moving all the time, then they don't have to be big buses. (Male, age 55–64, retired)*

Centres of towns and short distances were also mentioned as possible operation areas in the Lapland trial as, according to the respondents, autonomous vehicles would not be suitable for the non-paved minor roads in the area, especially in winter. This was considered to be due to the current level of the technology, which is yet to be highly developed. However, most respondents mentioned that autonomous vehicle managed surprisingly well in winter conditions. Short distances to local supermarkets and the health care centre, for example, were mentioned as possible trips for autonomous vehicles in Muonio. On the other hand, it was also considered that normal main roads might be easier for autonomous vehicles than city centres where traffic situations are more complex. *Of course it's a little bit surprising that it manages so well here in these rough conditions. But it's great that we can try these out here in Finland. It's really a gorgeous thing. (Female, age 35–44, employed).*

Responding to mobility needs (routes, time schedules, good accessibility of the service, speed) was considered by most the respondents to be essential for using autonomous buses, just as in normal public transport. They stated that after using autonomous vehicles for the first few times and gaining experience of them, they would use autonomous vehicles just as they now use conventional public transport. As shown in earlier studies, transport routes were considered a decisive factor for using autonomous shuttle buses. If the routes do not fit your daily mobility needs, you do not use them. *I'd use them like any other means of transport if they go at suitable times from where I need to leave to where I need to go. (Male, age 35–44, student)*

The speed of autonomous vehicles was raised as an important factor. Slow speed was considered by some respondents to reduce the appeal of autonomous vehicles and also to make them better suited to passengers who are not in a hurry, such as retired people. Some respondents recognised that the slow speed was due to the nature of the trial and the level of the technology, and that once the technology develops to maturity the vehicles will be able to drive as fast as normal vehicles. However, some respondents seem not to have grasped the potential of the autonomous vehicles, for example: *This vehicle is so slow. If you're in a hurry it's faster to walk. (Male, age 34–45, employed)*

Passenger feelings about travelling on an autonomous vehicle were raised in Suvilahti when asked about possible operating environments. To a number of respondents, the autonomous shuttle bus felt like a normal bus or tram. Some respondents even mentioned that during the trip they stopped noticing that there was no driver. Based on the Suvilahti responses, if autonomous vehicles become more common and work well, passengers could get used to them, trust the technology and safety, and not notice the differences from conventional vehicles. On the other hand, slow speed, low trust in technology, negative attitudes, lack of personal security in the bus, and unresponsiveness to mobility needs can hamper the use of autonomous vehicles.

In the Lapland trial the vehicle was smaller, i.e. for only one passenger. Therefore, the passengers' feelings were focused more on the technology, the coldness and the small size of the vehicle. However, the trial strengthened the passengers' perceptions that autonomous vehicle technology is coming into wider use.

4.4. Affordance

Autonomous vehicles were recognised to be suitable in principle for all. The purpose of use depends on what kind of vehicle is used. Autonomous shuttle buses were mentioned to be especially suitable for flexible on-demand services and demand-responsive traffic, such as the last-mile solutions mentioned previously. Possibly due to the small size of the trial shuttle bus and the trial area, some respondents considered that the vehicles would be more suitable for short distances. Smaller autonomous vehicles, such as used in the Lapland trial, were mentioned to be suitable for the daily mobility needs of all passenger types, mostly for short distances. The majority of respondents thought that autonomous vehicles could be used like normal vehicles in the future. *I think these suit everyone if they are intended to be used for public transport. (Male, age 35–44, student)*

Demand-responsive traffic was mentioned to be especially suitable for older and disabled passengers. According to respondents, autonomous shuttle buses are not suitable for passengers that require assistance unless an assistant accompanies the passenger, as there is no driver on board to assist.

Some respondents estimated that use of autonomous shuttle buses will increase as the numbers of elderly people increase. In contrast, some older respondents considered the use of autonomous vehicles to be more attractive to younger people. Small autonomous vehicles, as used in the Lapland trial, were seen to be suitable for all users, but especially for old and disabled people for short distance journeys, such as to shops, health services and friends. Autonomous vehicles were considered to help expand the mobility of disabled people. Small vehicles were also considered suitable for normal traffic needs, like normal cars. *Maybe old people in particular could use these for getting to shops and other services. But why not also other people? (Female, age 35–44, employed)*

Autonomous vehicles were also recognised by some respondents to be suitable for school transport: daily routes would be relatively simple and repetitive, and the service could positively assist the daily routine of families with school-age children. Children were considered to be a suitable passenger group if traffic safety and personal security can be fully guaranteed – parents would not let their children use autonomous vehicles if the technology, traffic safety and personal security are uncertain.

Use of autonomous vehicles for carrying light goods was also mentioned. Goods deliveries could be combined with buses, or smaller autonomous vehicles could be used to deliver goods to customers.

5. Discussion

According to the Theory of Planned Behaviour (TPB), peoples' beliefs about and evaluations of an outcome lead to an attitude towards a given behaviour. This attitude towards behaviour is one of the main influences on people's intention to make behavioural changes. A second major influence on intention is a person's subjective norm, that is, a person's perception that most people who are important to them think that he or she should or should not perform the behaviour in question. The third major influence according to the TPB is perceived behavioural control (PBC), which is defined as 'the person's belief as to how easy or difficult performance of the behaviour is likely to be'. Using these three indicators, we aim to understand the changes that are needed to increase the use of autonomous vehicles.

The quantitative (n = 141) and qualitative (n = 70) data used in this study doesn't allow wider generalizations of the results to the other areas in Finland or other countries because of small convenience samples gathered from test pilots. Also, slow speed of the vehicle, operating environment, presence of a human operator in the vehicle, smooth driving, and lack of traffic jams affected the results. However, the data supposed to be the first one which was collected from passengers who have travelled in autonomous vehicles in heavy winter conditions in Lapland. It could be the first data where the analysis combines passengers' feelings in regular summer and heavy winter conditions. The results can be used as an example of passengers' perceptions and feelings after travelling in autonomous vehicles and also when defining the needs of research regarding autonomous vehicles in other countries and different circumstances.

5.1. Attitude towards new behaviour

According to our results, the vast majority of the participants started out with a positive attitude towards autonomous vehicles and had an even more positive attitude after the trials. This may be due to positive passenger experiences resulting from the high quality of the vehicles used and the fact that the trials were overall carried out successfully. Interest in technology seemed to increase trust. If a respondent did not know how the technology worked, their responses were more uncertain and trust was lower. On average, Finns are ready to try and use autonomous vehicles if their safety and reliability can be guaranteed (Liljamo et al., 2018). Compared to other countries, attitudes in Finland seem to be relatively similar to the US, UK and Australia where, according to Liljamo and colleagues' study, approximately 60% of people had a very or mildly positive attitude towards autonomous vehicles. However, many people in Finland are opposed to autonomous vehicles and would not wish autonomous vehicles to become widespread (Liljamo et al. 2018; Schoettle & Sivak 2014).

According to previous studies, the key factors influencing driverless car adoption are performance expectancy, reliability, security, privacy and trust. Operating environment and suitability are also mentioned in previous research. The main barrier to adoption of autonomous vehicles is lack of public trust (Kaur and Rampersad, 2018). Pertinent technology adoption theories include the technology adoption model (TAM) (Davis, 1989) and the unified theory of acceptance and use of technology (UTAUT) (Venkatesh, Morris, & Davis, 2003). According to these theories, the key factors are reliability, performance expectancy, trust, security and privacy. Trust, security and privacy also feature in the driverless cars literature (Kaur and Rampersad, 2018).

In our study, trust in the technology of autonomous vehicles was highlighted. This key aspect was raised from two opposing perspectives: on one hand, respondents trusted in the technology and saw autonomous vehicles as eliminating human error. In contrast, the reliability of the technology and how it would work in different operating conditions were brought into question. The discussions showed that trust in the technology was positively influenced by slow speed, the presence of a human operator in the vehicle, smooth driving, and lack of other traffic. According to the respondents, it is also essential to recognise the challenges that winter conditions pose to the technology. According to our study, passenger trust in autonomous vehicle technology is increased by positive experiences gained from using autonomous vehicles, being interested in new technologies, and being informed about the technology in advance. When people's trust in technology in general is high, attitudes to autonomous vehicles are also more positive.

In agreement with earlier studies based on passenger experiences of using autonomous vehicles (Nordhoff et al. 2017; Merat et al. 2017; Salonen 2018; Salonen and Haavisto, 2019), passengers' sense of traffic safety in autonomous vehicles was found in our study to be relatively high. There were no differences between men and women, between age groups or between employment status groups. It was recognised that there should be more autonomous vehicles on the road in order to achieve significantly positive effects on traffic safety, given that autonomous vehicles are capable to avoid reliably individual pedestrians as well as other in-path objects. As with trust perceptions, the slow speed of the vehicle, operating environment, presence of a human operator in the vehicle, smooth driving, and lack of traffic jams affected passengers' safety perceptions. If the speed of the autonomous cars would have been similar to normal traffic, the results might have been less positive with respect to attitudes towards traffic safety.

As found also in the study by Nordhoff et al. (2017), the presence of a human operator was preferred. This reveals a tendency for people to be cautious towards driverless vehicles. Without the presence of an operator, the results may thus have been less positive. The on board operator does not need to manage the car in any way, but the impression of a human in charge increases the passengers' feelings of safety and trust towards autonomous vehicles (Salonen & Haavisto, 2019). This is a limitation of our study.

Personal security has been mentioned as a key challenge in earlier studies, especially from the perspective of women (Salonen, 2018). In our test pilots, there was no difference in personal security perception between men and women. However, this concern was raised by older passengers: in our study there was a statistically significant difference related to age, as younger passengers (15–24) felt their personal security to be significantly higher than older (25−) passengers. The Salonen study cited above was conducted in the Vantaa area during a big event where the buses were full. In both trials of that study there was an operator present in the bus. In our study trials, the buses operated with relatively few passengers. This might have affected our positive results. However, in order to achieve better personal security in autonomous shuttle buses, remote monitoring with displays and clear information on what to do in emergency situations could be helpful if there is no operator on board the vehicle. At the same time, however, the privacy of passengers should be guaranteed.

In previous studies, the emergency management of the driverless shuttle bus has also been a challenge for passengers but there have not been identified significant differences between men and women, between age groups or between employment status groups (Salonen, 2018). In our study students felt their possibilities to act better than employed. Students are in average younger than employed and results are similar to results in personal security. In order to have better emergency management, remote monitoring and clear information could also be helpful.

5.2. Subjective norm

Understanding the social factors that guide the social conception of automation is critical (Ghazizadeh et al., 2012). Social factors such as norms, roles and self-concept define peoples' behaviour. They have an impact on what should and should not be done (Triandis, 1977). According to our analysis, the passengers of the autonomous vehicles considered that their friends are interested in new technologies, such as autonomous vehicles, and that they would try autonomous vehicles if the opportunity arose. However, some responses indicated that the respondents' friends would be anxious about using autonomous vehicles. The respondents' common perception was that autonomous driving is becoming more acceptable. Increasing interest and curiosity towards autonomous vehicles is expected because people are naturally curious about new things. This may help to change the subjective norm and thus effect behavioural change.

Younger people care less about the opinions of people important to them than older people do when deciding whether or not to use autonomous vehicles (Nordhoff et al., 2017). This was also seen in our study. Older people were more attentive to their peers' opinions about autonomous vehicles than young people.

Human-driven mobility is the norm in society (Salonen & Haavisto, 2019). In our study, the lack of a human driver was mentioned only a few times and it did not affect the passengers' attitudes towards using autonomous vehicles. Preconceptions were considered a challenge and barrier to the use of autonomous vehicles. The respondents considered low trust in technology and perceived lack of safety to be the main reasons for people's possible negative preconceptions about autonomous vehicles.

The sustainability of mobility and new mobility services can be increased by autonomous vehicles because they can be used as a last-mile solution and cost of travel is reduced. The services can be more achievable to everyone and cover more areas. The social sustainability of autonomous shuttle buses is a complex issue because autonomous buses can transform the work relations in transportation system. This can be seen as a part of work revolution which comes with development of new technologies in every field of society. Social sustainability was not in center of the article but can be problematic although the costs of travel can be reduced.

5.3. Perceived behavioural control

The importance of perceived behavioural control is apparent in our research. According to our results, the easiness of the new travel mode is one of the key influencing factors in changing an individual's mobility behaviour. Lack of easiness was not a barrier to perceived behavioural control because the passengers felt that public transport operated by autonomous vehicles is relatively similar to conventional public transport. Similarly, in a trial conducted in Switzerland (Merat et al., 2017) 92% of respondents (n = 181) felt that the driverless shuttle bus was easy to use. Age also correlates with views on how easy driverless shuttle buses are to use, the older the passenger, the more they are considered difficult to use (Nordhoff et al., 2017; Salonen & Haavisto, 2019). In our study, younger people were more interested in using autonomous vehicles and also considered them to be easier to use compared to older people. Older respondents were more likely to consider the benefits of autonomous vehicles in terms of how they could help meet their practical daily needs, for example if they no longer have a driver's license or as helpful when carrying shopping. Notably, many old people felt they would need an on board assistant if the bus has no driver. This may negatively affect the use of autonomous buses.

According to previous research, the affordance of mobility services needs to meet the real mobility needs of people (Salonen & Haavisto, 2019). According to our results, this could be achieved by focusing on routes, schedules, good accessibility of the service, and the speed of vehicles. In practical terms, on-demand autonomous vehicles have been recognised as an effective solution to people's everyday mobility needs (Liljamo et al. 2018). If the routes are well positioned to enable flexible on-demand autonomous bus services, it would be easier to achieve sufficient perceived behavioural control to enable the new mode of mobility.

Our study results show that autonomous shuttle buses are most suitable as last-mile solutions on flexible routes. Complementing public transport with last-mile solutions would give passengers significant benefits by making the public transport system more accessible and easier to use. Smaller autonomous vehicles were recognized in our study to be suitable for the daily mobility needs of all people. Such a service could significantly expand and facilitate the mobility of old or disabled people, for example.

The operating environment has a big influence on the acceptance of autonomous vehicles and their ease of use. Closed areas, public transport with an on board operator, and main roads have been identified good application areas for autonomous vehicles (Kaur and Rampersad, 2018). In the present study, trials were implemented in closed areas as public transport-like traffic (Suvilahti, Helsinki), on a street among normal traffic (bus line 94R, Kivikko, Helsinki), and on Finnish national road 21 as a normal car in normal traffic (Muonio, Lapland). Respondents generally considered city centres the most suitable areas for autonomous vehicles. On the other hand, it was also mentioned that it might be easier for autonomous vehicles to operate on main roads than city centres where traffic situations are more complex.

The speed of autonomous vehicles arose as an important factor. The perceived behavioural control of the passengers of the autonomous vehicles in our study may have been at a good level due to the slow speed and relatively safe, low-congestion operating environments of the trials. In our trials the maximum speed was 18 km/h, which is slow compared to normal public transport. Slow speed could hamper the use autonomous vehicles in the future. On the other hand, there is a current trend in Europe towards slower speed limits in urban areas, and 30 km per hour seems to be more and more common. This trend is closing the gap between different travel modes.

6. Concluding remarks

This study was first one where part of the data was collected from passengers who have travelled in autonomous vehicles in winter conditions. The data used in this research doesn't allow wider generalizations of the results to the situation in Finland and other countries because of small samples. Still the results can be reflected to research of autonomous vehicles and what kind of research is needed.

Trust, safety and security were in our study the main factors influencing people's *positive attitudes* towards using autonomous vehicles. At the same time, it was recognised that people are not prepared to accept any significant errors in the technology although they did understand that the technology is not yet mature. In order to mainstream a new service offered by autonomous vehicles, from the perspective of *perceived behavioural control* the service must be as easy or even easier to use than conventional public transport. Positive real-life experiences on board and relevant information from peers and the media are the best ways to diminish negative preconceptions and change *subjective norms*.

There was no significant differences between gender regarding passengers' perceptions of traffic safety, personal security and emergency management. This is encouraging when developing the autonomous vehicles to different kind of user groups. There were significant differences between groups in personal security and in emergency management. Younger passengers felt their personal security on board to be significantly higher than older and students their possibilities to act in a case of emergency significantly better than employed people. The initial results from passengers travelling in heavy winter conditions indicate that winter conditions do not significantly influence passengers' attitudes towards using autonomous vehicles. However, more research on autonomous driving is needed, especially in complex operating conditions. Based on the insights from the test pilots, key areas for future study both in Finland and other countries are trust, traffic safety, personal security on board, affordance, and the effectiveness of autonomous vehicles. These areas are the ones which have to be developed when getting autonomous driving more acceptable and attractive mode of transport.

CRediT authorship contribution statement

Petri Launonen: Conceptualization, Formal analysis, Investigation, Writing - original draft. **Arto O. Salonen:** Methodology, Writing - review & editing, Supervision. **Heikki Liimatainen:** Writing - review & editing, Supervision.

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.

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