What is the acceptability of the autonomous vehicle for disabled people ? The case of a virtual reality application: test and evaluation.

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ABSTRACT

This study aims to evaluate the acceptability of people with disabilities towards connected and autonomous vehicles (CAV). For this purpose, a virtual reality application, simulating two types of fully autonomous shuttles and a conventional bus, was developed and tested by eleven participants with physical disabilities. The results show that the subjects have a relatively high trust in the autonomous transport system and prefer it to the conventional bus. The premium autonomous shuttle with more services on board was particularly appreciated by the subjects. These results are encouraging and consistent with research conducted on the general population. It seems necessary to confirm these acceptability results by testing larger panels in real life situations.

Author Keywords
Virtual reality; acceptability; autonomous and connected vehicle; disabled people.

ACM Classification Keywords
Human-Centered Computing

General Terms
Human Factors; Design; Measurement.

DOI : 10.37789/rochi.2022.1.1.*

INTRODUCTION

Disabled people have far fewer mobility and transport options for accessing places and living spaces than the general population [1]. Some authors use the term "transport disadvantage" [2, 3, 4] to describe these mobility difficulties faced by disabled people. In a review of the literature on transport disadvantage, Currie and Delbosc [2] note that among the few studies that consider disabled people, the disadvantage is more pronounced among them [6, 7, 8, 9]. This disadvantage compounds the exclusion that disabled people face every day [10, 11], affecting all areas of their lives, including employment, health, education, social participation and leisure [12].

Attitudes towards CAV

The governments of several countries have stated that they want most vehicles on their roads to be driverless by 2040 [13]. Thus, fostering positive public attitudes towards CAV by manufacturers and by public agencies that manage transport infrastructure and systems is an important task. Surveys of public opinion on CAV have produced divergent results. Payre et al [14] and Morris [15], for example, found that majorities in their samples were in favour of CAV. In contrast, a study by Haboucha et al [16] of 721 drivers in the United States and Israel found that there was "significant hesitation about adopting autonomous vehicles" (p. 37), that 44% of their sample strongly preferred regular vehicles, and that 25% were unwilling to travel in CAV even if the rides were free. A survey of 8862 people in 112 countries by Bazilinskyy et al [17] found that 39% of participants were in favour of CAV and 23% were critical. These results show that, in the words of Konig and Neumayr [18], "widespread acceptance and thus adoption of this new technology is far from certain" (p. 42) (a sentiment echoed by Bansal et al. [19]).

Presumed benefits of CAV for disabilities people

One of the main claimed benefits of CAV for disabled people is their ability to provide wider and more convenient transport options for people who cannot currently drive [20, 21, 22, 23]. The adverse consequences of lack of mobility include a reduced ability to socialise [24], to access health care (particularly for older disabled people [25]), to attend hospital appointments, to shop, to obtain employment [26] or to participate in education. These problems can lead to psychological isolation and feelings of confinement resulting in anxiety, stress and possibly depression [22, 27, 28]. Public transport poses significant problems (physical and behavioural) for disabled people, such as inoperable lifts and ramps, inaccessible stations and platforms, long distances to bus stops, and drivers not stopping for disabled passengers, not providing stop announcements or route identification [29, 30]. In principle, CAV should alleviate many of these problems through shuttles that cross bike lanes, roads and pedestrian areas, etc., "intelligent bus stops with sensors" [31] and multiple door-to-door services [32]. With regard to owned or leased personal CAV, Soltani et al [33] noted that accessible parking is an important consideration and that currently parking for disabled people is often unavailable. CAV are able to "self-park" and independently find a parking space after dropping off the passenger. According to Bobillier-Chaumon [34], technological acceptability aims to evaluate and/or predict the conditions and motives that may make a technology acceptable, or not, to future users. It is within this framework that the objectives of the study were established. We wanted to measure the acceptability of CAV to disabilities people. The virtual reality application was evaluated in order to measure its usability and its effect on the participants' attitude.

METHODOLOGY

This study was carried out within the framework of the PAsCAL project, funded by the European Commission, which aims to assess the level of acceptance of European citizens towards future autonomous vehicles, through an interdisciplinary approach combining innovative tools in human sciences and technology.

Virtual reality simulation

The experience was conducted in virtual reality using an Oculus Quest II RV headset. The scenario and the associated simulation of the multimodal travel were completely designed and developed within the framework of the project, by a team composed of experts in ergonomics and computer development. All participants used the same travel and boarded a conventional bus, a conventional autonomous shuttle and a premium autonomous shuttle (Figure 1) for a travel of approximately 15 minutes (5 minutes for each transport used).

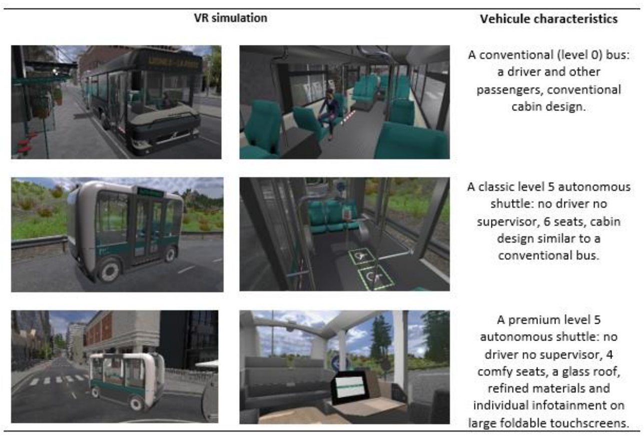

Figure 1. The characteristics of the three vehicles in the virtual reality simulation

Population

Eleven volunteers with physical disabilities were recruited to participate in this study. The population was composed of one woman (52 years old) and 10 men (M=34; min=23, max=45 years old) from differents socio-professional categories. 1 person with tetraplegia (paralysis of all 4 limbs) and 10 people with paraplegia (paralysis of both lower limbs) participated.

Measured variables

Several measures were carried out to study the VR application and to analyse the acceptability of the participants towards the CAV. The RV application was evaluated from two perspectives: through a System Usability Scale (SUS) questionnaire [35] to measure its usability; and through the Attrackdiff questionnaire [36] to measure the user experience. The latter makes it possible to identify 4 components of the user experience: pragmatic quality (PQ; measuring usability), hedonic quality-stimulation (HQ-S; measuring stimulation), hedonic quality-identity (HQ-I; measurement of identification to the user), and overall attractiveness (ATT; measuring overall value). The acceptability of VAS was measured by questionnaires developed in the PAsCAL project [37] and interviews on attitude, trust, perceived risk, willingness to pay and ease of use. The questionnaires were completed 15 days before the experiment and again immediately afterwards, in order to assess the potential effect of the simulation on the participants' opinions.

RESULTS

First of all, the scores of the SUS questionnaire items reflect a good level of usability of the application. According to Brooke [35], the overall score calculated from the 10 SUS items presented is 74.87/100. According to Bankor et al [38], this is a good level of usability of the VR application and a high level of acceptability for the participants. Similarly, the Attrackdiff scores reflect a good overall user experience of the application by participants with disabilities [36]. Specifically, the application would enable users to achieve their travel goal well (PQ= 1.3) and would provide some positive stimulation (HQ-S= 1.2). The overall attractiveness score (ATT= 2) reflects the pragmatic and hedonic qualities of the virtual application. The results of the evaluation of the VR application are therefore in favour of good usability and a satisfactory user experience, which favours the immersion of the participants and therefore the interest in the judgement of the autonomous vehicles evaluated in the following results.

Items	M1 (SD)	M2 (SD)	p value
Using the L5 shuttle makes you more dependent (1), more independent (7)	4,6 (0,88)	5,6 (0,92)	0,076
It is important for me to be independent	6,5 (0,51)	7,0 (0,42)	NS
Stress of using the L5 shuttle	3,5 (1,02)	2,5 (1,14)	NS
Ideas about the L5 shuttle are confusing (1), promising (7)	4,9 (0,74)	6,5 (0,56)	0,018
My attitude towards the L5 shuttle is very negative (1), very positive (7)	5,0 (0,98)	5,7 (0,97)	NS
I would use the L5 shuttle	5,1 (1,01)	5,5 (1,45)	NS
I would be able to use the L5 shuttle	4,9 (0,88)	6,2 (0,32)	0,031
The L5 shuttle would provide access to non-accessible areas	5,5 (1,13)	5,1 (1,22)	NS

Table 1: Participant's attitudes towards the CAV before (M1) and after the experiment (M2). Questions assessed on a Likert scale from 1 (I strongly disagree) to 7 (I strongly agree). N=11

Table 1 presents the results on the effect of the experiment on the acceptability of CAV. It seems that the participants' attitude is partially changed after the simulation. They mention the promising potential of VAS more after the virtual reality experience, and the ANOVA shows a significant difference (6.5 vs. 4.9/7; p= 0.018). Subjects mention in interviews "a nice interest", "a breakthrough for mobility", "an excellent on-demand vehicle" or "an advanced and enjoyable technology". The subjects also thought after the experience that CAV would give them more independence (5.6 vs. 4.6; p= 0.076): "it would allow us to move around more easily", "it is very important for people with motor disabilities who cannot move around as they wish". Also, the participants stated that they were more willing to use the CAV (5.5 vs. 5.1/7) and that they would be more able to use the CAV after the experience (6.2 vs. 4.9/7; p= 0.031). This is evidenced by some very positive statements: the system was "intuitive", "easy to access" or "finally, everything is done by itself".

Items	M 1 (SD)	M 2 (SD)	M 3 (SD)
The transport was pleasant	3,36 (0,86)	4,91 (0,88)	6,64 (1,02)
My travel was stressful	2,42 (0,42)	2,01 (0,21)	1,97 (0,64)
The means of transport was attractive	2,53 (0,42)	5,79 (1,32)	6,47 (1,03)
I was able to use the mode of transport	6,12 (1,11)	6,03 (1,19)	6,08 (1,01)
I felt safe in the transport	4,22 (1,54)	5,44 (0,92)	5,54 (0,88)
I have confidence in the means of transport	6,02 (0,45)	6,08 (1,00)	6,12 (0,99)

Table 2: Participant's attitudes towards the three transport modes conventional bus (M1), conventional CAV (M2) and premium CAV (M3). Questions assessed on a Likert scale from 1 (I strongly disagree) to 7 (I strongly agree). N=11

The participants were also asked to express their attitude and feelings during their travels towards the three modes of transport used (Table 2). Although the differences are not significant, the results show that CAV are more appreciated than the conventional bus. Participants found the travel more pleasant on the classic CAV (M=4.91; SD=0.88) and the premium CAV (M=6.64; SD=1.02) than on the conventional bus (M=3.36; SD=0.86). Respondents said of the CAV premium, "a very comfortable, pleasant vehicle", "perfect for long travels especially", with "simple interactions, it is easy to get on and off". Also, the classic CAV (M=5.79; SD=1.32) and especially the premium CAV (M=6.47; SD=1.03) are considered more attractive than the conventional bus (M=2.53; SD=0.42). Some participants mention an autonomous mode of transport that is "entertaining", "with very useful multimedia features", "much more appealing than conventional buses".

CONCLUSION

The main results seem to show a good level of acceptability of the CAV among participants with disabilities [31, 32]. The virtual reality simulation gave a more concrete idea of how a CAV works and the services it can provide. The experience of the CAV was a positive experience for most of them. Their attitude increased when reassessed afterwards, although they still expressed concerns about a possible technical failure, much more than about accidents or other problems. The results also show that vulnerable disabled participants prefer CAV to conventional buses. They seemed to feel safer in the shuttle than in the conventional bus, and their attitude and acceptability seemed better. Logically, they expressed a clear and enthusiastic preference for the premium shuttle because it offers additional multimedia and infotainment services, combined with superior design and comfort. Participants said they felt better in the L5 premium shuttle. However, their willingness to pay did not really increase when considering this option. These results are encouraging and consistent with research conducted on the general population. It is now necessary to confirm these effects on acceptability by testing larger panels and situations in real autonomous shuttles.

ACKNOWLEDGMENTS

We would like to thank the European Union's Horizon 2020 research and innovation programme and our partners in the PAsCAL project (grant No. 815098) under which the experiment was carried out, as well as the EQUIPEX-CONTINUUM project (Collaborative Digital to Human Continuity)

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