SUpporting acceptance of automated VEhicle

Deliverable 1.6. Guidelines on mitigation strategies and interventions to effectively stimulate people towards a higher acceptance of CAV, in general, and ALFRED specifically

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Legal disclaimer

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Terminology and Acronyms

CAV	Connected Automated Vehicle
CI	Confidence Interval
D	Deliverable
df	degrees of freedom
EU	European Commission
KPI	Key Performance Indicator
M	Mean
SD	Standard Deviation
WP	Work Package

EXECUTIVE SUMMARY

In this final deliverable of WP1 we formulate the possible mitigation strategies and interventions to stimulate the public acceptance of CAV, in general, and of ALFRED in specific. To define these strategies we draw upon all the acceptance research conducted within the SUaaVE project. First, we provide an overview of the studies and experiments that have been conducted and where the full reports can be found. Then we report our recent study in which we compared CAV and ALFRED.

In our new study we described the "human-like" ALFRED and the "technology-inspired" CAV to participants using text, videos, and storyboards. Participants rated the vehicles from both the perspective of a potential user and of a pedestrian. We found that although ALFRED was not rated higher on acceptability than CAV for potential users, most participants preferred ALFRED when having to choose between the vehicles. Moreover, we found that specifically for pedestrians ALFRED was rated as more acceptable than CAV, and participants had greater trust in ALFRED's technology than in CAV's technology. This highlights the importance of an eHMI to support other road users.

We replicated our psychological model for both CAV and ALFRED, and found that the most important attributes for acceptability were perceived convenience, pleasure, and safety / trust in the vehicle's technology. We also found that if the expected adoption norm was low, perceived status-enhancement became more important for acceptability. In other words, when few close others are expected to adopt the vehicle, the vehicle is only acceptable when it is seen as a status product.

The results of the new CAV & ALFRED study and the second loop driving simulator experiments are used to confirm the KPIs related to WP1. We show that our acceptance model can explain a high percentage (over 80% in the CAV & ALFRED study) of the variance in acceptability of CAV and ALFRED. We also show that ALFRED is rated at least slightly positively on acceptability by more than 60% of participants, and that many participants prefer ALFRED over CAV.

Based on the results of the second loop driving simulator experiments and the ALFRED & CAV study, we extend the preliminary list of suggestions (included in D1.5) to improve the acceptance of CAV and ALFRED. We include suggestions for both potential users and other road users, so the vehicles can be acceptable for different user groups. We conclude that the acceptance research of WP1 has been a success, and that we were able to provide several options to stimulate people towards a higher public acceptance of CAV and ALFRED.

1. INTRODUCTION AND OBJECTIVES

One of the goals of the SUaaVE project is to enhance public acceptance of connected automated vehicles (CAVs), in general, and the acceptance of ALFRED specifically within the EU.

In work package 1 (WP 1), we examine the acceptance of connected automated vehicles (CAV) and ALFRED among both potential users and other road users. During the project, several studies and experiments have been conducted to determine which factors influence the acceptability and acceptance of CAV (please refer to Deliverables 1.2, 1.3, 1.7, 6.3, and 6.4). In the present deliverable we will report the results of a large European survey to assess and compare the acceptability both a “technology inspired” CAV and ALFRED from both the perspective of a potential user and the perspective of a pedestrian interacting with the vehicle.

The key objective of the present deliverable is to define mitigation strategies and interventions to effectively stimulate people towards a higher acceptance of CAV in general, and of ALFRED specifically.

We have first formulated the acceptance requirements for CAV and ALFRED in D1.3. Then, a preliminary version of mitigation strategies and interventions for enhancing acceptance of CAV was reported in D1.5. We will now expand the suggestions made in D1.5 by including the results of the second loop driving simulator experiments, the Wizard of Oz on-road experiment, and the CAV & ALFRED study. Based on these results we will provide additional suggestions for mitigation strategies and interventions to enhance the acceptance of CAV, and also include specific suggestions for ALFRED. First, we will provide a short overview of the acceptance research done within SUaaVE. Then, we will report the results of the CAV & ALFRED study, which has not been reported elsewhere. Lastly, we will list the suggested mitigation strategies and interventions.

1.1. Related Key Performance Indicators

There are two Key Performance Indicators (KPIs) related to the present deliverable. KPI 1 asserts that the psychological model will predict up to 70% of CAV acceptance among different user groups. KPI 6 asserts that for 75% of end-users the acceptance of the ALFRED concept as compared to a “technology inspired” CAV will increase up to 25%. Both KPI’s will be confirmed in section 4 of this deliverable.

2. PREVIOUS ACCEPTANCE RESEARCH WITHIN SUAAVE

Many studies and experiments have been conducted within the SUaaVE project relating to the acceptance and acceptability of both CAV and ALFRED. Table 1 gives an overview of studies and experiments that have included measures of acceptance and where the full report of each study can be found.

Table 1. Overview of all studies and experiments including measures of acceptance

Study / Experiment	Full report in
Focus Groups	D1.2
Large Scale Survey	D1.2
First Loop Driving Simulator Experiments	D6.3
Scenario Study with Cyclists	D1.5
Anthropomorphism Study	D1.5
Wizard of Oz On-Road Experiment	D1.7
Second Loop Driving Simulator Experiments	D6.4
CAV & ALFRED Study	D1.6 (present)

3. CAV & ALFRED STUDY

We conducted a large European study to assess the acceptability of both a "technology inspired CAV" and "human-like" ALFRED. Our goal was threefold. First, we wanted to replicate the psychological model to assess the predictive power to confirm KPI 1. Second, we wanted to compare the perspectives of a potential user with the perspectives of a pedestrian interacting with the vehicle, to confirm that ALFRED is acceptable among different user groups. Third, we wanted to compare the acceptability of the "technology inspired" CAV with the "human-centred" ALFRED to confirm KPI 6.

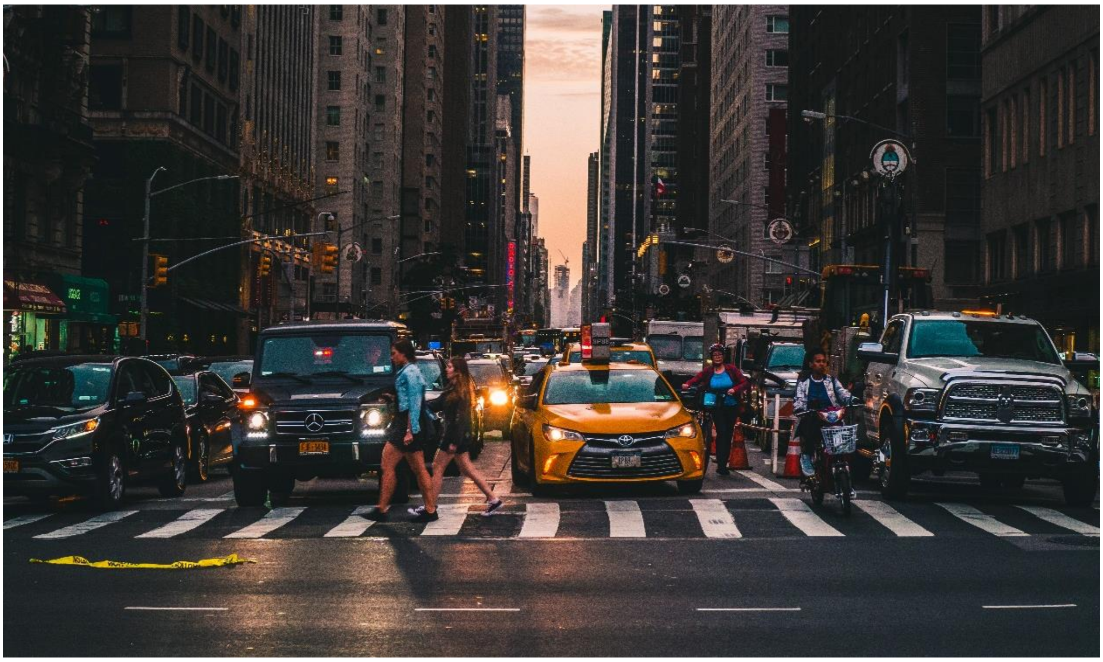


Figure 1 Different types of road users. Photo by Jp Valery on Unsplash.

3.1. Method

Ethical approval to conduct the study was obtained beforehand from the ethical committee of the psychology department of the RuG. The study was conducted as an online survey and participants were recruited by a panel company (Dynata). Participants first selected their country and preferred language. We provided the survey in English, Dutch, German, French, Spanish, and Italian. Then, participants read the information and consent form and provided active consent to participate.

The study had a mixed-subjects design with the type of vehicle (CAV or ALFRED) as a between groups factor, and with perspective (potential user or pedestrian) as a within groups factor. Participants were randomly split into one of two conditions: CAV or ALFRED. They started from the perspective of a potential user. Participants first read a textual description of the vehicle, which included an explanation and the core functions of the vehicle. In the CAV condition, participants read about a "technology inspired" CAV, which was described as a machine with several functions that the passenger could access. In the ALFRED condition, participants read about a "human-centred" ALFRED, which was described as more human-like and which reacted to the passenger's needs. In essence the functions for both vehicles were the same. The full texts can be read in the Appendix in section 8. Once they had carefully read the vehicle's description, participants viewed a short video from the viewpoint of inside the vehicle showing how the vehicle would react to a pedestrian waiting to cross. In the CAV condition the vehicle only stopped to allow the pedestrian to cross. In the ALFRED condition the vehicle stopped and projected the eHMI as developed and used by Université Gustave Eiffel (UGE) to show the pedestrian they could cross. After the video participants indicated how human-like the vehicle was, and rated the vehicle on all attributes (safety, convenience, pleasure, control, trust in the vehicle's technology, status-enhancement, and environmental sustainability), acceptability, perceived behavioural control (the extent to which one feels able to use the vehicle) and perceived adoption norm (the extent to which one believes close others will adopt the vehicle). In short, the full psychological model was measured. For a more detailed description of the constructs, please refer to D1.2.

After taking the perspective of a potential user, participants were asked to take the perspective of a pedestrian. They were shown a video to demonstrate how the vehicle would react to them as a pedestrian. In the CAV condition the vehicle only stopped for the participant. In the ALFRED condition the vehicle stopped and projected the eHMI to indicate to the participant it was safe to cross. After viewing the video, participants rated the vehicle as a pedestrian on perceived safety, trust in the vehicle, and acceptability.

Next, all participants were asked to compare both vehicles. As they had only read about and seen one of the vehicles, a storyboard was used to illustrate them both. The storyboard was about Megan, who often travels alone for work. She is shown using both CAV and ALFRED. When she uses CAV, she can adjust the vehicle's settings, such as the seating position, to make her ride comfortable. When she uses ALFRED, ALFRED will suggest changing the settings for her to make her ride comfortable. For the full storyboards, please refer to the Appendix in section 8. When participants understood how both vehicles functioned, they were asked to indicate with a slider which vehicle they would prefer. After choosing their preferred vehicle, they were asked to pick the two main reasons for their choice. The reasons they could pick were related to all the attributes individually, perceived behavioural control, and the perceived adoption norm.

Finally, participants were asked to answer questions about their demographics. This included their age, gender, nationality, whether they had a valid driving license, and if they did, for how many years they had it. It took approximately 15-20 minutes to participate in the study. Participants were then thanked for their participation and could leave comments if they had any. Participants received payment as compensation for their time.

3.2. Sample

In order to get a representative European sample, the survey was opened to people from several European countries, namely Ireland, the Netherlands, Belgium, Germany, France, Spain, and Italy. With the provided translations, all participants should have been able to complete the survey in their native or second language. Aside from selecting participants from certain countries, we also only allowed participants who were over 18 years old, and aimed for a sample that was balanced in gender. A total of 849 people completed the survey. We used three criteria to filter out data of poor quality. These were (1) participants used continuous straight lining in their answers, (2) participants completed the full survey in less than 4 minutes, and (3) participants spent less

Figure 2. Overview of sampled countries

than 12 seconds reading the vehicle's description.

The final sample consisted of 485 participants. The mean age was 49.0 (SD = 15.3, range = 18 to 81). The majority of participants was female (53.2%), and most participants had a valid driving license (90.9%), which they on average obtained 27.9 years ago (SD = 15.4, range = less than a year ago to 60 years ago). The majority of the participants lived in Spain (16.7%) or Italy (16.5%), followed by France (15.7%), the Netherlands (13.8%), Germany (12.8%), Ireland (12.4%), or Belgium (12.2%).

Participants were randomly and evenly spread over the conditions, with 217 participants in the CAV condition, and 268 participants in the ALFRED condition.

3.3. Results

We analysed the data in several different ways. The result section is structured in the following manner:

1. Descriptives and internal reliability of scales; we report the means, standard deviations, ranges, and Cronbach's Alpha of all scales to give an overview of the data in 3.3.1.
2. We compare CAV and ALFRED from the perspective of potential users on acceptability, attributes, perceived adoption norm, and perceived behavioural control in 3.3.2.
3. We compare CAV and ALFRED from the perspective of pedestrians on acceptability, perceived safety, and trust in the vehicle's technology in 3.3.3.
4. Specifically for CAV we compare the perspective of potential users to the perspective of pedestrians on acceptability, perceived safety, and trust in the vehicle's technology in 3.3.4.
5. Specifically for ALFRED we compare the perspective of potential users to the perspective of pedestrians on acceptability, perceived safety, and trust in the vehicle's technology in 3.3.5.
6. Preference for CAV or ALFRED; we compare which vehicle participants preferred after the storyboards and the reasons for their preference in 3.3.6.
7. We conducted an exploratory analysis of cultural differences in 3.3.7.
8. We replicate the full acceptability model in 3.3.8.

3.3.1. Descriptives and reliability of scales

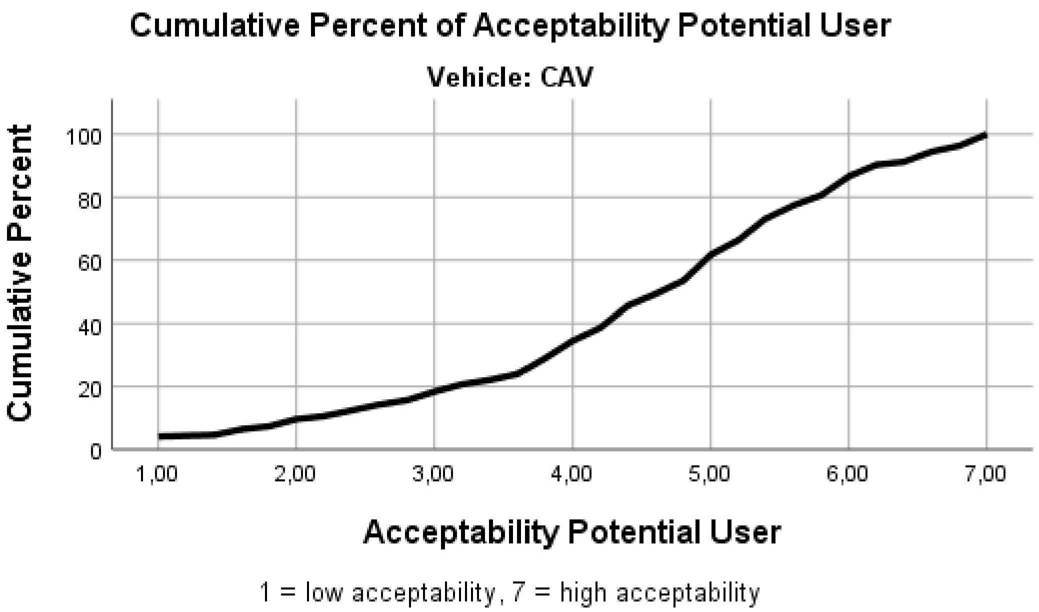
We calculated the scales by adding all items of a scale and then taking the average score. To assess internal validity of the scales, we calculated Cronbach's Alpha. The scales showed good (<.7) to excellent (<.9) internal reliability. Please refer to Table 2 below for a full overview of the means, standard deviations, ranges, and Cronbach's Alpha of each scale or construct.

Table 2. Means, standard deviations, ranges, number of items, and reliability of all scales

Scale	Mean	SD	Range	Number of items	Cronbach's Alpha
Acceptability CAV	4.51	1.51	1.00-7.00	5	.942
Acceptability ALFRED	4.62	1.57	1.00-7.00	5	.947
Anthropomorphism CAV	3.73	1.36	1.00-7.00	5	.844
Perceived safety CAV potential user	4.47	1.44	1.00-7.00	3	.929
Perceived safety ALFRED potential user	4.59	1.51	1.00-7.00	3	.927
Perceived convenience CAV	4.63	1.48	1.00-7.00	3	.869
Perceived convenience ALFRED	4.73	1.61	1.00-7.00	3	.896
Trust in CAV technology potential user	4.24	1.53	1.00-7.00	3	.894
Trust in ALFRED technology potential user	4.41	1.59	1.00-7.00	3	.899
Perceived pleasure CAV	4.39	1.57	1.00-7.00	3	.927
Perceived pleasure ALFRED	4.51	1.63	1.00-7.00	3	.922
Perceived control CAV	4.36	1.36	1.00-7.00	3	.775
Perceived control ALFRED	4.26	1.48	1.00-7.00	3	.818
Perceived status-enhancement CAV	3.50	1.62	1.00-7.00	3	.919
Perceived status-enhancement ALFRED	3.69	1.71	1.00-7.00	3	.913
Perceived environmental sustainability CAV	4.56	1.59	1.00-7.00	3	.961
Perceived environmental sustainability ALFRED	4.51	1.52	1.00-7.00	3	.939
Perceived behavioural control CAV	4.40	1.63	1.00-7.00	3	.914
Perceived behavioural control ALFRED	4.38	1.62	1.00-7.00	3	.897
Perceived adoption norm CAV	38.62	27.78	0.00-100.00	1	n.a.
Perceived adoption norm ALFRED	39.51	29.57	1.00-7.00	1	n.a.
Acceptability CAV pedestrian	4.23	1.57	1.00-7.00	3	.893
Acceptability ALFRED pedestrian	4.65	1.59	1.00-7.00	3	.907
Perceived safety CAV pedestrian	4.43	1.60	1.00-7.00	2	.929
Perceived safety ALFRED pedestrian	4.64	1.65	1.00-7.00	2	.929
Trust in CAV technology pedestrian	4.23	1.58	1.00-7.00	3	.910
Trust in ALFRED technology pedestrian	4.52	1.63	1.00-7.00	3	.909
Vehicle preference (0 = fully prefer CAV, 100 = fully prefer ALFRED)	56.53	32.16	0.00-100.00	1	n.a.

Note. For scales with a single item Cronbach's Alpha cannot be calculated.

Acceptability of both CAV and ALFRED was slightly skewed to the positive side. Figure 3 below shows the distribution of acceptability with a cumulative percentage for both CAV and ALFRED. A higher acceptability score indicates a more positive view of the vehicle. Inspection of the figure reveals that more than 60% of the participants had at least a slightly positive view of CAV or ALFRED as a potential user.



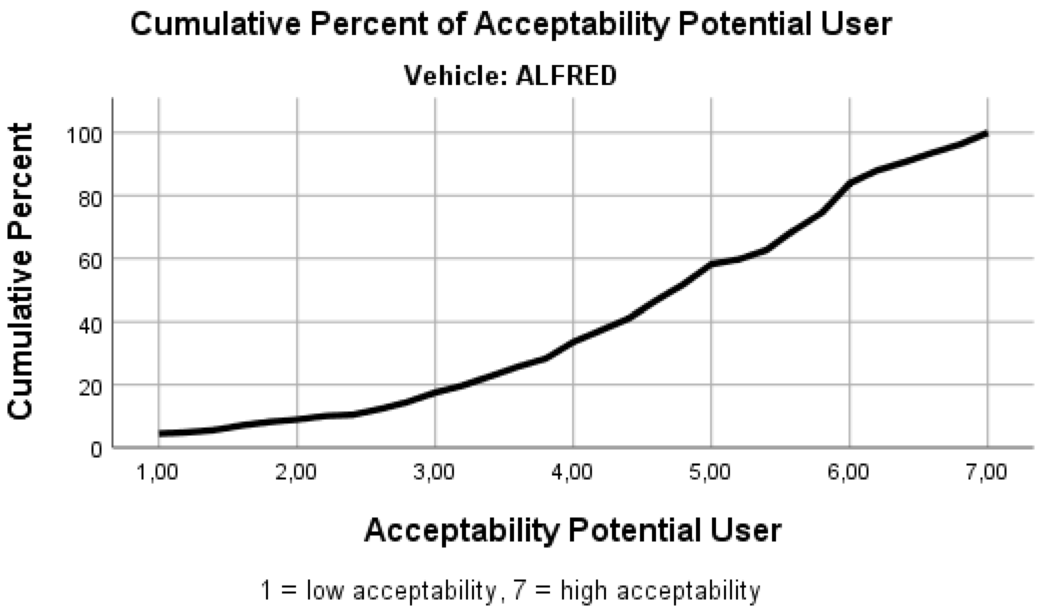


Figure 3 Cumulative percentages of acceptability of CAV and ALFRED

3.3.2. CAV and ALFRED from the potential user's perspective

First, we examined the results from the perspective of potential users of the vehicles. We compared CAV and ALFRED on acceptability, all attributes, perceived behavioural control, perceived adoption norm, and anthropomorphism. To determine if there were significant differences between CAV and ALFRED, we performed a multiple linear regression with vehicle type (CAV or ALFRED) as the predictor. The full results can be found in Table 3 below.

Table 3. Regression analyses comparing CAV and ALFRED from the potential user's perspective

Dependent variable	CAV M	ALFRED M	SD	F	df	p	R^2
Acceptability	4.51	4.62	0.14	0.62	1,483	.430	.001
Perceived safety	4.48	4.59	0.14	0.76	1,483	.385	.002
Perceived control	4.36	4.26	0.13	0.67	1,483	.415	.001
Perceived pleasure	4.39	4.51	0.15	0.70	1,483	.403	.001
Perceived convenience	4.63	4.73	0.14	0.45	1,483	.503	.001
Trust in the vehicle's technology	4.24	4.41	0.14	1.36	1,483	.245	.003
Perceived status-enhancement	3.50	3.69	0.15	1.54	1,483	.216	.003
Perceived environmental sustainability	4.56	4.51	0.14	0.14	1,483	.718	.000
Perceived behavioural control	4.40	4.38	0.15	0.02	1,483	.902	.000
Perceived adoption norm	38.62	39.51	2.63	0.11	1,483	.736	.000

The results show that there are no significant differences in the evaluations of CAV and ALFRED. There are some non-significant minor trends of ALFRED being rated higher on trust in the vehicle's technology and perceived status-enhancement.

3.3.3. CAV and ALFRED from the pedestrian's perspective

Figure 4 Pedestrians crossing a street. Photo by Chris Barbalis on Unsplash.

Next, we examined the differences between CAV and ALFRED from the pedestrian's perspective. We performed a multiple linear regression to predict acceptability, perceived safety, and trust in the vehicle's technology after viewing the video from the pedestrian's perspective, with vehicle type (CAV or ALFRED) as the predictor. The results of this analysis can be found in Table 4 below.

Table 4. Regression analyses comparing CAV and ALFRED from the pedestrian perspective

Dependent variable	CAV M	ALFRED M	SD	F	df	p	R^2
Acceptability	4.23	4.65	0.15	8.34	1,483	.004**	.017
Perceived safety	4.43	4.64	0.15	1.97	1,483	.161	.004
Trust in the vehicle's technology	4.23	4.52	0.15	3.85	1,483	.050*	.008

Note. * = significant at the .05 level, ** = significant at the .01 level.

The results show that pedestrians evaluate ALFRED more positively on trust in the vehicle's technology and acceptability than CAV. It seems ALFRED's eHMI has a positive effect on the vehicle's evaluations by pedestrians.

3.3.4. CAV compared on perspective of potential user and pedestrian

After comparing CAV and ALFRED, we took a closer look at the vehicles individually. First we compared for CAV specifically if there were differences between the perspectives of a potential users and of a pedestrian. For this analysis we selected only the participants who were in the CAV condition. We ran a paired samples t-test comparing acceptability, perceived safety, and trust in the vehicle's technology between the perspectives of a potential user or pedestrian. The results can be found in Table 5 below.

Table 5. Regression analyses comparing CAV from the potential user perspective to the pedestrian perspective

Dependent variable	Potential user M	Pedestrian M	SD	t	df	p
Acceptability	4.51	4.23	1.05	-4.00	216	<.001***
Perceived safety	4.47	4.43	0.94	-0.56	216	.581
Trust in the vehicle's technology	4.23	4.24	0.76	0.21	216	.835

Note. *** = significant at the .001 level.

The results show that CAV is significantly more acceptable for potential users than for pedestrians. However, CAV's safety and trust in the CAV's technology do not differ between potential users and pedestrians.

3.3.5. ALFRED compared on perspective of potential user and pedestrian

Then, we examined the results of ALFRED more closely. We wanted to know if there were any differences between the perspectives of a potential user and a pedestrian for ALFRED. For this analysis we only selected the participants who were in the ALFRED condition. We ran a paired samples t-test comparing acceptability, perceived safety, and trust in the vehicle's technology between the perspective of a potential user or a pedestrian. The results of the analysis can be seen in Table 6 below.

Table 6. Regression analyses comparing ALFRED from the potential user perspective to the pedestrian perspective

Dependent variable	Potential user M	Pedestrian M	SD	t	df	p
Acceptability	4.62	4.65	0.84	0.42	268	.674
Perceived safety	4.59	4.64	0.86	1.06	268	.289
Trust in the vehicle's technology	4.41	4.52	0.74	2.47	268	.014*

Note. * = significant at the .05 level.

The results show that ALFRED is evaluated significantly higher on trust in ALFRED's technology by pedestrians compared to potential users. However, there were no effects on the acceptability of ALFRED.

3.3.6. Preference for CAV or ALFRED

After participants read the storyboards of CAV and ALFRED, they were asked for their preference of either vehicle and the reason why. Preference for CAV or ALFRED (as a potential user) could be indicated with a slider, ranging from 1 (fully prefer CAV) to 100 (fully prefer ALFRED). We created three groups based on this question, as it was possible for people to have no clear preference for one vehicle over the other. The first group preferred CAV (score between 0 and 49.5), the second group had no clear preference (score between 49.6 and 50.4), the third group preferred ALFRED (score between 50.5 and 100). The group that preferred CAV contained 29.1% of the participants, the no clear preference group contained 20.6%, and the group that preferred ALFRED contained 50.3%. We first wanted to know if perhaps participants' preference was influenced by which vehicle they first read and watched a video about. In other words, we wanted to know if participants were more positive towards the vehicle of which condition they were in. This could be important, as it could be an indicator that early exposure to the vehicle is related to a more positive response to it. To test this, we conducted a chi-squared test entering participants' preference group and their condition as variables. The test was significant (χ^2 (df = 2) = 17.70, p = <.001). Inspection of the standardized residuals showed that, as expected, people who first read and saw videos about CAV were more likely to prefer CAV. This indicates that the order in which information is presented is important for people's preferences. As such, it may be important to introduce ALFRED to the public as soon as possible.

Our next question was which reasons people had, explaining their preference for one vehicle over the other. Overall, the most mentioned reasons for their preference were the control over the vehicle (32.0%), the vehicle's safety (31.8%), and the driving pleasure (30.9%). The least mentioned reasons were the vehicle's environmental sustainability (17.3%), status-enhancement of the vehicle (4.7%), and the expected adoption norm (1.4%). We wanted to examine if people who preferred CAV or who preferred ALFRED had different reasons for their preference. To test this, we performed chi-square tests entering preference reasons and preference group as variables. We inspected the standardized residuals to draw conclusions. The results showed that people who preferred ALFRED as a potential user were more likely to mention ALFRED's safety as a reason for their preference. People who preferred CAV as a potential user were more likely to mention control over CAV's behaviour for their preference. People who had no clear preference were more likely to indicate environmental sustainability as a reason for having no preference (which may indicate both CAV and ALFRED are seen as equally environmentally friendly).

3.3.7. Exploratory analysis of cultural differences

Figure 5 People with different cultural backgrounds. Picture by coffeebeanworks on Pixabay.

Although the number of participants for each country was too low to conduct analyses between the countries, we still tried to do some analysis of cultural differences. The sample was roughly evenly spread between the more northern European countries (Ireland, the Netherlands, Belgium, and Germany; N = 248) and the more southern European countries (France, Spain, and Italy; N = 237). Research from Hofstede (Hofstede Insights, 2022) shows, for example, that some cultural differences between northern and southern European countries exist. Northern European countries tend to score lower on power distance, and uncertainty avoidance than southern European countries, while on the other hand the northern European countries tend to score higher on individualism, and long term orientation. To conduct an exploratory analysis of cultural differences, we split the data based on the participant's country (northern or southern). From this point on we will refer to the group of Ireland, the Netherlands, Belgium and Germany as the "northern countries" and to the group of France, Spain, and Italy as the "southern countries".

After splitting the data, we conducted all analyses comparing CAV, ALFRED, and the perspectives of potential users and pedestrians again. As these analyses are exploratory in nature, we will refrain from reporting any statistics. However, we will discuss the greatest trends we found.

First, there was a trend of participants from the southern countries to evaluate ALFRED slightly higher on perceived status-enhancement than CAV. This trend was absent among participants from the northern countries.

The exposure effect of participants being more likely to prefer CAV when they first read about CAV was far stronger among participants from the southern countries than among participants from the northern countries.

The effect of mentioning safety as the main reason for preferring ALFRED over CAV was far stronger among participants from the northern countries. Similarly, the effect of mentioning environmental sustainability as a reason for having no clear preference was far more common among participants from the northern countries.

3.3.8. Testing the psychological model of acceptance

Aside from comparing differences between ALFRED and CAV and the perspectives of potential users and pedestrians, we also conducted the present research to replicate the psychological model of acceptance. Our psychological model was introduced in D1.2 and is explained in great detail there. Essentially, our model proposes that the acceptability of CAV can be predicted by its attributes (perceived characteristics), the perceived adoption norm, and the perceived behavioural control (see Figure 6). Additionally, we proposed a moderation effect of perceived adoption norm on the effect of perceived status-enhancement on acceptability. More specifically, we proposed that when people think few close others will adopt CAV, the effect of perceived status-enhancement on acceptability becomes stronger. This means that when few people are expected to adopt CAV, CAV is only acceptable when it is seen as a status-product.

Figure 6 Psychological model of acceptability of CAV

In the Large Scale Survey (D1.2), our model explained 60% of the variance of acceptability. In D1.2 we also examined the relative importance of the different attributes, and found that perceived safety, convenience, and environmental sustainability were the strongest predictors of acceptability.

We first replicated our acceptance model for the full sample of the present study. We ran a two-step linear regression to replicate it. In the first step we included acceptability as the outcome variable, and attributes, perceived adoption norm, and perceived behavioural control as the predictors. In the second step we added the moderation effect of perceived adoption norm. The model including the moderation effect was significant, F (df = 1, 480) = 649.12, p = <.001, R^2 = .843. We will report the standardized coefficients of the model that included the moderation effect. Attributes had the strongest positive effect on acceptability (β = 0.56, SD = 0.04, t = 16.44, p = <.001), followed by perceived behavioural control (β = 0.42, SD = 0.03, t = 12.71, p = <.001), and the perceived adoption norm (β = 0.19, SD = <0.01, t = 4.55, p = <.001).

The moderation effect of perceived adoption norm on the effect of perceived status-enhancement on acceptability was also significant, (β = -0.20, SD = <0.01, t = -4.66, p = <.001). The moderation effect explained an additional 0.7% of variance in acceptability on top of the direct effects of attributes, perceived adoption norm, and perceived behavioural control. For a schematic overview of the moderation effect, please refer to Figure 7 below. Inspection of the Figure reveals that when the people expect few close others to adopt CAV or ALFRED, perceived status-enhancement has a stronger effect on acceptability.

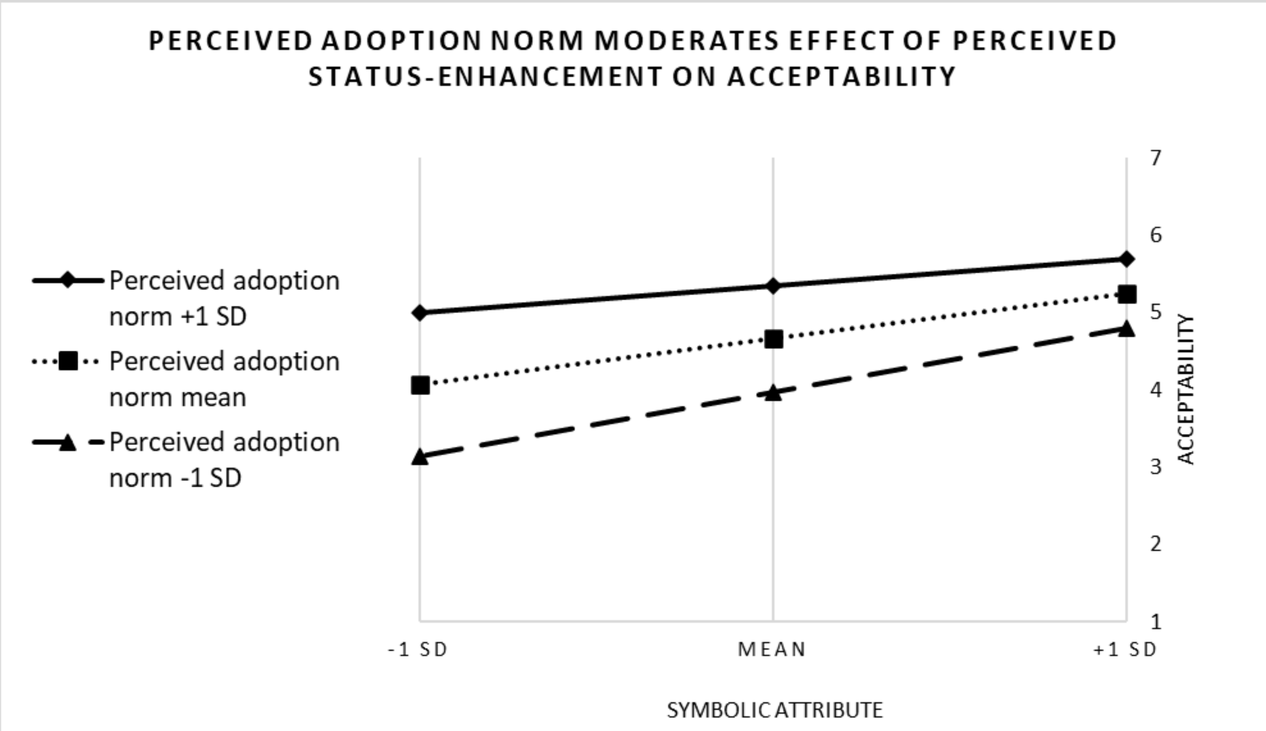


Figure 7 Moderation effect of perceived adoption norm on the effect of perceived status-enhancement on acceptability

Next, we looked at the relative importance of the attributes. We ran a linear regression in which acceptability was the outcome variable, and all the separate attributes were the predictors. We found that the most important attributes for acceptability were trust in the vehicle's technology, perceived convenience, and perceived pleasure. The direct effects of perceived control and status-enhancement were not significant when controlling for the other attributes. This is an interesting result, as perceived control was given as the main reason for preferring CAV over ALFRED in the present study. Another noteworthy point is that perceived safety and trust in the vehicle's technology overlapped to a great extent (Pearson's r = .76). This may be the reason why the effect of perceived safety on acceptability was relatively small. In the Large Scale Survey (D1.2) perceived environmental sustainability had a stronger effect on acceptability than perceived pleasure; in the present study they swapped places in the order of importance. Please refer to Table 7 below for the full results.

Table 7. Regression analysis comparing the relative importance of the separate attributes for acceptability

Attribute	β	SD	t	p	95% CI	η
Perceived safety	0.11	0.04	2.91	.004**	[0.04 – 0.19]	.06
Perceived convenience	0.24	0.04	5.62	<.001***	[0.16 – 0.33]	.11
Perceived control	-0.01	0.02	-0.37	.710	[-0.06 – 0.04]	.00
Perceived pleasure	0.22	0.04	6.11	<.001***	[0.15 – 0.30]	.12
Trust in the vehicle's technology	0.26	0.04	7.48	<.001***	[0.19 – 0.33]	.15
Perceived status-enhancement	0.05	0.03	1.86	.064	[0.00 – 0.10]	.04
Perceived environmental sustainability	0.13	0.03	4.37	<.001***	[0.07 – 0.19]	.09

Note. Reported beta coefficients are unstandardized, as all variables were measured on the same scale; ** = significant at the .01 level, *** = significant at the .001 level.

After confirming our acceptability model for the full sample, we split the data based on vehicle (CAV and ALFRED). We then reran the analyses to examine if there were differences between CAV and ALFRED on what drives their acceptability. We will discuss the greatest differences. First, the model with the moderation effect was replicated for both ALFRED and CAV, with no notable differences. There were some differences in importance of the separate attributes based on vehicle type. For CAV the direct effect of perceived safety on acceptance became non-significant, most likely due to its overlap with trust in the vehicle's technology. For ALFRED the direct effect of perceived status-enhancement became significantly positive, while the effect of perceived environmental sustainability became non-significant. For CAV, perceived environmental sustainability was about as important as convenience and pleasure for acceptability. For ALFRED, we found that perceived environmental sustainability correlated highly with all other attributes except perceived control. This may be a halo effect, just as reported in our study with cyclists (D1.5).

Finally, we did an exploratory analysis of differences between participants from the northern and southern countries. We repeated the analyses of our model and the importance of the separate attributes for acceptability, while splitting the data based on country (northern or southern). The model including the moderation effect of perceived adoption norm on the effect of perceived status-enhancement on acceptability was supported for both participants from southern and northern countries. We did find some differences in the importance of the separate attributes. Participants from the southern countries valued perceived environmental sustainability more for acceptability, while participants from the northern countries valued perceived pleasure more. For ALFRED specifically, perceived convenience was of the utmost importance for acceptability among participants from the southern countries.

3.4. Conclusion

Although we did not find differences between CAV and ALFRED on the evaluations of the vehicle's attributes or the acceptability for potential users, pedestrians did prefer ALFRED. Pedestrians rated ALFRED both as more acceptable than CAV and had greater trust in ALFRED's technology than in CAV's technology. Moreover, when presented with a choice between CAV and ALFRED as a potential user, the majority of participants preferred ALFRED.

We have replicated our psychological model and found that in the present study it explained more than 84% of all variance in acceptability, which was even more than in the Large Scale Survey (D1.2). The most important attributes for acceptability were trust in the vehicle's technology / safety, perceived convenience, and perceived pleasure.

Noticeable was that participants are not sure of why they prefer CAV or ALFRED. Participants preferring CAV indicated control over the vehicle as the main reason for their preference, but perceived control had no significant direct effect on the acceptability of CAV. Likewise, participants preferring ALFRED indicated safety of the vehicle as the main reason for their preference, but perceived safety overlapped with trust in ALFRED’s technology, leading to only a positive direct effect of trust on ALFRED’s acceptability. Perceived environmental sustainability was among the least mentioned reasons for preferring one vehicle over the other, but was relatively important for the acceptability of CAV. These results show that people are poor at determining what drives their preference (Noppers et al., 2014).

4. KEY PERFORMANCE INDICATORS RELATED TO WP 1

Two KPI's are related to WP1, namely KPI 1 and KPI 6. To confirm both KPI's, we will draw upon the recent acceptance research conducted in SUaaVE. First, we will briefly summarize the results of the acceptance of ALFRED research in the second loop driving simulator experiments. Then, we will discuss both KPI's.

4.1. Summary of ALFRED acceptance research of the second loop

4.1.1. IBV

IBV tested the acceptance of ALFRED's emotional module in the second loop of the driving simulator experiments. In this experiment, acceptance of ALFRED was not significantly higher after experiencing ALFRED ($M = 5.77$, $SD = 12.30$) compared to before experiencing it ($M = 5.53$, $SD = 11.97$), t ($df = 25$) = 0.88, $p = .386$. The 75% of participants who evaluated the acceptance afterwards the highest, evaluated ALFRED's acceptance on average as 6.33, on a scale from 1 (low acceptance) to 7 (high acceptance). This means that for 75% of participants there was a 14% increase in acceptance of ALFRED. Please note that acceptance of ALFRED on average among the 75% most positive participants is extremely high.

4.1.2. UGE

UGE tested the acceptance of ALFRED's eHMI with both users and pedestrians in the second loop. In this experiment, the acceptance of ALFRED was significantly higher after experiencing ALFRED for both users ($M = 5.78$, $SD = 1.59$) and pedestrians ($M = 6.02$, $SD = 1.35$) compared to before experiencing it ($M = 4.55$, $SD = 1.18$), t_{users} ($df = 39$) = 3.86, $p_{users} = <.001$; $t_{pedestrians}$ ($df = 39$) = 6.51, $p_{pedestrians} = <.001$. The 75% of participants who evaluated the acceptance afterwards the highest, evaluated ALFRED's acceptance on average as 6.49 for users, and 6.53 for pedestrians on a scale from 1 (low acceptance) to 7 (high acceptance). This means that for 75% of participants there was a 43% increase in acceptance of ALFRED for users, and a 44% increase in acceptance for pedestrians. Please note that the acceptance of ALFRED was extremely high in the sample.

4.1.3. CRF

CRF tested the acceptance of ALFRED's HMI in the second loop. In this experiment, the acceptance of ALFRED was significantly higher after experiencing ALFRED ($M = 6.23$, $SD = 1.07$), compared to before experiencing it ($M = 5.91$, $SD = 1.03$), t ($df = 29$) = 2.14, $p = .041$. The 75% of participants who evaluated the acceptance afterwards the highest, evaluated ALFRED's acceptance on average as 6.82, on a scale from 1 (low acceptance) to 7 (high acceptance). This means that for 75% of participants there was a 15% increase in acceptance of ALFRED. Please note that the acceptance of ALFRED was extremely high in the sample.

4.1.4. IDIADA

IDIADA tested the acceptance of ALFRED's comfort modules in two experiments. In the ambient comfort experiment, the acceptance of CAV with ALFRED was significantly higher after experiencing the vehicle ($M = 6.28$, $SD = 0.80$) than before experiencing it ($M = 5.81$, $SD = 0.92$), t ($df = 23$) = 3.82, $p = .001$. The 75% of participants who evaluated the acceptance afterwards the highest, evaluated ALFRED's acceptance on average as 6.63 on a scale from 1 (low acceptance) to 7 (high acceptance). This means that for 75% of participants there was a 14% increase in acceptance of ALFRED.

In the ride comfort experiment, a different acceptance scale was used ranging from 1 to 9. We recoded it for comparability to the same scale as used in all other experiments ranging from 1 (low acceptance) to 7 (high acceptance). Acceptance was measured after experiencing

CAV in slow mode and in fast mode, and after experiencing ALFRED with dynamic mode. We combined the measures of CAV's acceptance in slow and fast mode to construct a CAV acceptance scale and then conducted a paired samples t-test. The acceptance of CAV (M = 5.29, SD = 1.11) was not significantly higher than the acceptance of ALFRED (M = 5.46, SD = 1.20), although it neared significance, t (df = 29) = 1.91, p = .066. The 75% of participants who evaluated ALFRED's acceptance the highest, evaluated it on average as 5.99. This means that for 75% of participants there was a 13% increase in acceptance of ALFRED compared to CAV.

4.2. KPI 1

KPI 1 asserts that the psychological model developed within WP1 of SUaaVE will predict up to 70% of CAV acceptance among different user groups. In our first test of the model in the Large Scale Survey (D1.2), we found that the model predicted 60% of variance of acceptability of CAV in a large sample consisting of both drivers and non-drivers from the United Kingdom, the Netherlands, Germany, France, Spain, and Italy. We replicated the psychological model in the CAV & ALFRED Study (section 3.3.8. of present deliverable) among drivers and non-drivers from Ireland, the Netherlands, Belgium, Germany, France, Spain, and Italy. In this study, the model explained even more than the 70% as asserted by KPI 1. To be precise, the model explained 84% of variance of acceptability of both CAV and ALFRED. With these results we can fully confirm KPI 1.

4.3. KPI 6

KPI 6 asserts that for 75% of end-users the acceptance of the ALFRED concept as compared to a "technology inspired CAV" will increase up to 25%. To confirm this KPI, we looked at both the results of the second loop driving simulator experiments, and the results of the CAV & ALFRED study.

In the CAV & ALFRED study (sections 3.3.3) we found that ALFRED was rated significantly higher on acceptability than CAV for pedestrians. To confirm a part of KPI 6, we selected the 75% most positive evaluations of ALFRED by pedestrians. On average, the acceptability of ALFRED of these 75% most positive participants was 5.59 on a scale from 1 (low acceptability) to 7 (high acceptability), while the acceptability of CAV was 4.23. This means a 32% increase of acceptability of ALFRED among 75% of pedestrians.

Additionally, in the CAV & ALFRED study (section 3.3.2) we examined the acceptability of ALFRED among potential users. Potential users did not rate ALFRED significantly higher on acceptability than CAV. To confirm KPI 6, we selected the 75% most positive evaluations of ALFRED by potential users. On average, the 75% most positive participants rated ALFRED as 5.37 on acceptability on a scale from 1 (low acceptability) to 7 (high acceptability), while the acceptability of CAV was rated 4.51. This means a 19% increase of acceptability of ALFRED among 75% of potential users.

Lastly, in the CAV & ALFRED study (section 3.3.6.) we found that only 29% of participants preferred CAV over ALFRED if given the choice between them.

Next, we will discuss the driving simulator experiments from loop 2 assessing acceptance of ALFRED (fully reported in D6.4). Our partners found, that for the 75% most positive participants, there were increases in ALFRED's acceptance ranging from 13% to 43%. Please also note that acceptance of ALFRED among the 75% most positive participants was very high, ranging from 5.99 to 6.82 on a scale of 1 = low acceptance to 7 = high acceptance. This confirms KPI 6.

5. MITIGATION STRATEGIES AND INTERVENTIONS TO ENHANCE PUBLIC ACCEPTANCE OF CAV, IN GENERAL, AND ALFRED SPECIFICALLY

In D1.5 we provided a list of a first version of mitigation strategies and interventions to enhance the public acceptance of CAV. We finalize this list based on the results from the acceptance research conducted in the final phase of SUaaVE. Please refer to Table 8 below for our suggestions, whether these apply to CAV, ALFRED, or both, and whether they apply to potential users, other road users, or both.

Table 8. Mitigation strategies and interventions to enhance public acceptance of CAV and ALFRED

Strategy	For vehicle	For user group
Focus on increasing perceived safety / trust, perceived convenience, perceived pleasure and perceived environmental sustainability.	CAV	All
Focus on increasing perceived safety / trust, perceived convenience, and perceived pleasure.	ALFRED	All
The vehicle needs a user-friendly interface on the inside.	Both	Potential users
ALFRED should have the developed eHMI to increase acceptability of pedestrians.	ALFRED	Pedestrians
Make the vehicle drive electrically, or show how fuel- efficiently the vehicle drives.	Both	All
Present the vehicle as a luxurious status product at deployment.	Both	Potential users
Allow users to personalize the vehicle's driving style (for example sporty or cautious).	Both	Potential users
Make the vehicle appealing for all types of users, including vulnerable road users, by giving the option to increase the font size on the display, or have a spoken menu.	Both	Potential users
Let potential users experience the vehicle to increase perceived safety and trust in the vehicle's technology.	Both	Potential users
Demonstrate the vehicle in a complex traffic environment first (instead of a low traffic complexity environment) in order to increase perceived pleasure.	Both	Potential users
Make the driving experience of the vehicle pleasurable to enhance acceptance.	Both	Potential users
The vehicle should avoid crashes or damage (even minor) at all costs.	Both	All
The first experience with the vehicle should be positive at all costs.	Both	All
The vehicle should have medium to low speed and acceleration levels, and should not have a fast vehicle motion.	Both	All
In southern European countries perceived environmental sustainability of the vehicle is more important for acceptability among potential users (than for northern European countries). In marketing in southern European countries there could be a greater emphasis on this.	Both	Potential users: southern Europe
In northern European countries perceived pleasure of ALFRED is more important for acceptability among potential users (than for southern European countries). In marketing in northern European countries there could be a greater emphasis on this.	Both	Potential users: northern Europe

Strategy	For vehicle	For user group
Add a sustainability logo to the vehicle as it enhances trust in the vehicle's technology for other road users	Both	Other road users
In the marketing, emphasize the environmental sustainability of the vehicle (for example mentioning its fuel efficiency). Higher perceived environmental sustainability of the vehicle is related to a higher acceptability, perceived safety, and greater trust in the vehicle's technology for other road users.	Both	Other road users
Present ALFRED as more human-like (i.e. anthropomorphise ALFRED), as it increases perceived status-enhancement, environmental sustainability, and trust in the vehicle's technology, especially among people with a high need for control.	ALFRED	Potential users
Develop ALFRED with the possibility to drive manually, with a steering wheel and pedals accessible inside the vehicle, as this is preferred for current drivers.	ALFRED	Potential users: current drivers
Develop ALFRED without a steering wheel and pedals inside the vehicle, as this is preferred for current non-drivers.	ALFRED	Potential users: current non-drivers

6. TECHNICAL & SCIENTIFIC IMPACTS

In the present deliverable we have reported the final acceptance study of the SUaaVE project. Together with the results of all previous acceptance research conducted within the project, we were able to provide several mitigation strategies and interventions to enhance the public acceptance of CAV and ALFRED. The contents of this deliverable can be used to develop CAV and ALFRED in such a way that the human side of acceptability for both potential users and other road users is taken into account. Additionally, the deliverable provides an overview of what marketing could focus on to increase the public acceptability of the vehicles.

A key scientific impact is our comparison of the perspective of potential users and pedestrians in one study. We found that ALFRED is more acceptable than CAV for pedestrians, and that pedestrians have greater trust in ALFRED's technology than in CAV's technology. This highlights the importance of an eHMI to support other road users and to make the vehicle more acceptable for them.

The technological impact of our findings is that the "human-like" ALFRED, compared to the "technology-inspired" CAV is not necessarily evaluated more positively, but is preferred by the majority (only 29% preferred CAV). Both CAV and ALFRED are evaluated quite positively on acceptability by over 60% of participants. This indicates that the public is already quite accepting of fully self-driving and connected vehicles. We have listed an overview of how the acceptability may be boosted even further.

Lastly, a key impact is the replication of our psychological model to predict acceptability of CAV and ALFRED. The model explained a very large proportion of variation in acceptability in both the Large Scale Survey (over 60%; D1.2), as well as in our study comparing CAV & ALFRED (over 80%; section 3.3.6. of present deliverable). We conclude that our psychological model is a good tool for assessing acceptability of both CAV and ALFRED.

7. CONCLUSION

The key objective of the present deliverable was to formulate the possible mitigation strategies and interventions that could enhance the public acceptance of CAV, in general, and of ALFRED in specific. This objective has been achieved. After reporting a new study comparing CAV and ALFRED, and after including the results from the second loop driving simulator experiments, we have completed the list with suggestions to enhance the public acceptance of both vehicles. We included suggestions for both enhancing the acceptance of potential users, as well as the acceptance of other road users. Thus, the list should provide several options for enhancing the public acceptance of the vehicles among different user groups.

In our study comparing CAV and ALFRED we found that both vehicles were evaluated rather positively on acceptability. More than 60% of the participants rated the vehicles at least slightly positively. If given a choice between CAV and ALFRED, the majority of participants preferred ALFRED as a potential user, with only 29% preferring CAV. Pedestrians preferred ALFRED, as it was rated more positively than CAV on both acceptability and trust in the vehicle's technology. This highlights the need for an eHMI to support other road users. The most important factors for acceptability of both CAV and ALFRED were the attributes of the vehicle, followed by perceived behavioural control, and the perceived adoption norm. Out of the seven attributes, perceived convenience, pleasure, and safety, and trust in the vehicle's technology were the most important for acceptability. For CAV specifically, perceived environmental sustainability was about as important for acceptability as perceived pleasure and convenience. We also found for both vehicles that when participants expect few close others will adopt the vehicle, perceived status-enhancement becomes more important for acceptability. In other words, when few people are expected to adopt the vehicle, it is only acceptable when it is seen as a status-product.

In this deliverable we have confirmed the KPIs related to WP1. Namely, we show that our psychological model can explain 84% of variance in acceptability. We also show that the 75% most positive participants rate ALFRED 13% to 43% higher on acceptance after experiencing ALFRED. Lastly, we found that only 29% of participants preferred CAV over ALFRED.

We conclude that the acceptance research of WP1 has been a success. Our suggestions on how to enhance the public acceptance of CAV and ALFRED should provide an overview of which aspects need to be taken into account in the development of CAV, and of ALFRED specifically.

8. REFERENCES

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9. APPENDIX

Full textual descriptions of CAV and ALFRED as used in the CAV & ALFRED Study.

CAV:

> *A Connected Automated Vehicle (CAV) is a fully automated car. You, the passenger, only have to enter your destination and CAV's computer system will calculate the most efficient route. CAV is equipped with Internet access, which allows sharing data with other cars and transportation systems. This way, CAV is always updated with the current traffic situation to avoid busy streets and traffic jams. With CAV you can reach your destination safely, as it can detect and avoid obstacles, other road users, and other vehicles.*
>
> *While driving to your destination in CAV, you can spend your time on other things than driving, such as reading or watching a movie. It is possible to adjust the seating position in CAV to one that is best suited for whatever activity you would like to do while driving. In case of harsh sunlight, you can blind CAV's windows. If you are in a hurry, you can enter sporty driving mode, which prioritizes speed over comfort without compromising safety. Overall, CAV is designed to make your journey safe and enjoyable.*

ALFRED:

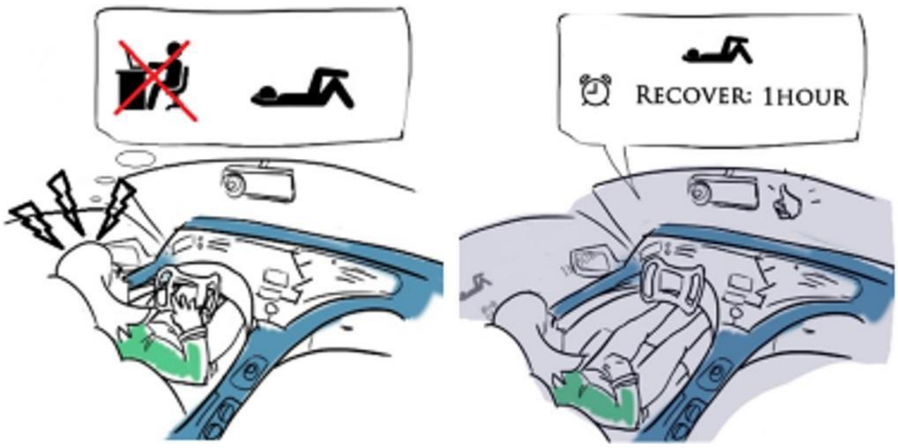
> *ALFRED is a fully self-driving car. You, the passenger, only have to tell ALFRED what your destination is and ALFRED will consider the most efficient route. ALFRED has Internet access and can share data with other cars and transportation systems. This way, ALFRED is always informed of the current traffic situation so he can avoid busy streets and traffic jams. ALFRED can drive you to your destination safely, as he can see and avoid obstacles, other road users, and other vehicles.*
>
> *While ALFRED drives you to your destination, you can spend your time on other things, such as reading or watching a movie. ALFRED can automatically adjust the seating position for you to one that is best suited for whatever activity you would like to do while driving. In case of harsh sunlight, ALFRED will blind the windows. If you are in a hurry, ALFRED can switch to sporty driving, during which he will prioritize speed over comfort without compromising safety. Overall, ALFRED's goal is to make your journey safe and enjoyable.*

Full storyboards used in CAV & ALFRED Study:

CAV

Megan often travels alone for work in CAV, a fully self-driving car. Once she's seated, she sets her route to work. On the highway she starts the fully automated driving mode. Megan is feeling stressed, and wants to use her trip to take some time off to relax.

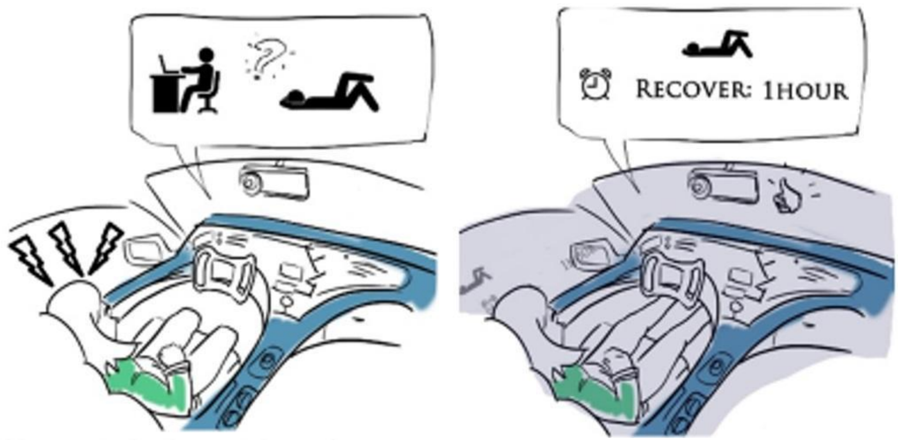
Megan dims the interior lighting, blinds the windows, and changes the seating position to a more relaxing position. She selects a driving mode that is more comfortable, with a slower constant speed. Megan arrives at her office relaxed, fresh, and ready to work.



ALFRED

Megan often travels alone for work with ALFRED, a fully self-driving car. On the highway, ALFRED detects that Megan is feeling stressed and asks her if she prefers to work while ALFRED is driving, or if she prefers to relax for a while. This time she prefers to relax.

ALFRED dims the interior lighting for her, blinds the windows, and places her seat in a relaxing seating position. ALFRED slows down to a constant speed that maximizes comfort, which makes her feel relaxed immediately. Megan arrives at her office relaxed, fresh, and ready to work.



Consortium:

Project Title:
SUpporting acceptance of automated VEhicle

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