master's thesis

Conversational Interface for Secondary Tasks While Driving a Car

Bc. Lukáš Chvátal

January 2020

supervisor: doc. Ing. Zdeněk Míkovec, Ph.D.

Czech Technical University in Prague
Faculty of Electrical Engineering, Department of Computer Graphics and Interaction

MASTER'S THESIS ASSIGNMENT

I. Personal and study details

Student's name:	**Chvátal Lukáš**
Personal ID number:	**420068**
Faculty / Institute:	**Faculty of Electrical Engineering**
Department / Institute:	**Department of Computer Graphics and Interaction**
Study program:	**Open Informatics**
Branch of study:	**Human-Computer Interaction**

II. Master's thesis details

Master's thesis title in English:

Conversational interface for secondary tasks while driving a car

Master's thesis title in Czech:

Konverzační rozhraní pro sekundární úlohy během řízení vozidla

Guidelines:

Analyze scientific literature about interaction with car infotainment with an emphasis on multimodal and conversational interfaces. As part of the analysis, focus on situations arising in the performance of secondary tasks while driving (e.g. interaction with navigation, messaging) with respect to the target group of older drivers. Design conversational interface for controlling selected secondary tasks. According to User-Centered Design principles create a prototype and conduct at least 2 iterations of experiment with target user group which will check the validity of the design and help to get insights into the target group behavior.

Bibliography / sources:

1. Collet, C., Clarion, A., Morel, M., Chapon, A., & Petit, C. (2009). Physiological and behavioural changes associated to the management of secondary tasks while driving. Applied ergonomics, 40(6), 1041-1046.
2. Maciej, J., & Vollrath, M. (2009). Comparison of manual vs. speech-based interaction with in-vehicle information systems. Accident Analysis & Prevention, 41(5), 924-930.
3. Fofanova, J., & Vollrath, M. (2011). Distraction while driving: The case of older drivers. Transportation research part F: traffic psychology and behaviour, 14(6), 638-648.
4. Bruyas, M. P., Brusque, C., Debailleux, S., Duraz, M., & Aillerie, I. (2009). Does making a conversation asynchronous reduce the negative impact of phone call on driving?. Transportation research part F: traffic psychology and behaviour, 12(1), 12-20.
5. Bjelkemyr, Anna & Dukic, Tania & Owens, Rachel & Falkmer, Torbjorn & Lee, Hoe. (2013). Support Systems Designed for Older Drivers to Achieve Safe and Comfortable Driving. Journal of Transportation Technologies. 03. 233-240. 10.4236/jtts.2013.34024.
6. Pfleging, B., Schneegass, S., & Schmidt, A. (2012, October). Multimodal interaction in the car: combining speech and gestures on the steering wheel. In Proceedings of the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (pp. 155-162). ACM.
7. Mattes, S., 2003. The lane-change-task as a tool for driver distraction evaluation. In: Strasser, H., Kluth, K., Rausch, H., Bubb, H. (Eds.), Quality of Work and Products in Enterprises of the Future. Ergonomia Verlag, Stuttgart, pp. 57–60.

Name and workplace of master's thesis supervisor:

doc. Ing. Zdeněk Míkovec, Ph.D., Department of Computer Graphics and Interaction

Name and workplace of second master's thesis supervisor or consultant:

Date of master's thesis assignment: **18.09.2019** Deadline for master's thesis submission: ______

Assignment valid until: **19.02.2021**

[redacted] [redacted] [redacted]

doc. Ing. Zdeněk Míkovec, Ph.D. Supervisor's signature	Head of department's signature	prof. Mgr. Petr Páta, Ph.D. Dean's signature

Acknowledgement

I would like to thank my supervisor doc. Ing. Zdeněk Míkovec, Ph.D. for his guidance, assistance and valuable comments. Further, I would like to thank people of Czech Technical University in Prague at the Faculty of Transportation for technical support and all participants of conducted experiments for their participation. Finally, I would like to express my deep gratitude to my family, girlfriend and Ms Žaneta Blažená for their support and encouragement throughout my study.

Declaration

I declare that I worked out the presented thesis independently and I quoted all used sources of information in accord with Methodical instructions about ethical principles for writing academic thesis.

Prague, January 6, 2020 ....

Abstract

Tato práce se zabývá interakcí s palubním počítačem automobilu pomocí konverzačního rozhraní s ohledem na cílovou skupinu seniorů. Hlavním cílem této práce je analyzovat chování seniorů při plnění sekundárních úkolů pomocí konverzačního rozhraní při řízení a navrhnout toto rozhraní podle jejich potřeb. Tyto sekundární úkoly byly specifikovány v případech použití navigace a odesílání zpráv. Pro evaluaci navrženého low-fidelity prototypu konverzačního rozhraní byly provedeny dva experimenty v kvalitativní studii. Výsledkem byl finální návrh konverzačního rozhraní pro sekundární úlohy přizpůsobený starším řidičům a také poznatky ohledně jejich chování ve zkoumaných situacích.

Klíčová slova

konverzační rozhraní, navigace, posílání zpráv, řízení auta, senioři

Abstract

This thesis deals with interaction with car infotainment using a conversational interface with respect to the target group of older drivers. The main objective of this work is to analyse the behaviour of older drivers while performing secondary tasks using a conversational interface while driving and to design this interface according to their needs. These secondary tasks were specified in use-cases of navigation and message-sending. For evaluation of designed low-fidelity prototype of a conversational interface, two experiments in qualitative studies were conducted. The outcome was a final design of a conversational interface used to control secondary tasks by older drivers and also insights about their behaviour in these situations.

Keywords

conversational interface, navigation, message-sending, car driving, older adults

Contents

Abbreviations

List of abbreviations used in this thesis:

LCT	Lane Change Task
POI	Points of Interest
SUS	System Usability Scale
DALI	Driving Activity Load Index
HTA	Hierarchical Task Analysis

1 Introduction

Car transportation is the most popular and common mean of transport for passengers nowadays [1] and this seems unlikely to change in the near future. Car manufacturers come with improvements to make driving safer, more comfortable and enjoyable by adding new functions and possibilities to adjust car behaviour. On the other hand, these additional systems, controlled by a driver, could cause an increase in distraction while driving. The number of these systems and their functions is growing,[2] thus the right design of interaction interface becomes more challenging. Moreover, using a mobile phone while driving is one of the bad habits of nowadays drivers. According to the study by Hallet, Lambert, and Regan (2012), [3] 66 % of respondents use mobile phone for reading messages and 52 % for texting at least once a week while driving. It is hard to change a habit but would it be possible to make it safer?

Controlling car's infotainment could be difficult, especially when the situation on the road is not easy. It becomes more complicated for older adults who are more likely to have some physical, sensory or cognitive limitations such as lower body mobility, impaired vision and hearing, prolonged reaction time etc. [4] The number of older adults is increasing and they expect to maintain a high quality of life, including driving a car.

This thesis examines interaction with car infotainment with an emphasis on multimodal and conversational interfaces. The study focuses on situations arising in the performance of secondary tasks while driving with respect to the target group of older drivers to help them feel more comfortable when using a car. The examined secondary tasks are related to the car navigation, which is common and affordable these days, and message-sending, which is also a current topic and in the context of the target group could have potential in helping with related issues.

1.1 Main objectives

The main objective of this thesis is to examine use-cases related to navigation and message-sending while driving and propose the way how the interaction between driver and system should be done while performing these secondary tasks. The analysis and design should be done with respect to older drivers to help them feel more comfortable and confident while driving. Voice conversation will be considered as it has the potential to be more natural and less distracting.

The goal is to design a conversational interface for controlling selected secondary tasks and according to User-Centered Design principles create a prototype and conduct two iterations of experiment with target user group which will check the validity of the design and help to get insights into the target group behaviour.

2 Analysis

This chapter examines existing studies and concepts related to performing secondary tasks while driving, distraction while driving, speech-based interaction and behaviour of the target group – older drivers. Insights of these studies may be valuable for designing a conversational interface for controlling selected secondary tasks in the car.

2.1 Conversation asynchronicity

Described in the study: *'Does making a conversation asynchronous reduce the negative impact of phone call on driving?'.* [5]

The objective of this study was to assess whether asynchronous communications will have specific characteristics that may reduce the impairment of driving performance in comparison with regular real-time call. The main idea is in dividing the whole action of communication into separate phases so the driver can control the pace of communication asynchronously. This helps to reduce pressure on the driver since regular phone call cannot be naturally suppressed according to the situation on the road as in-car conversation (authors called it conversation suppression hypothesis). Asynchronous communication is divided into three phases: interaction with the voice interface, listening to the message, answering message. It depends on the driver when the specific phase will be processed.

2.1.1 Environment

The experiment was conducted on a driving simulator. Sound system reproduced the sound ambience both inside the vehicle (engine, rolling noise, starter) and outside the vehicle (traffic). The car body was a Renault Espace with a manual gearbox and all the standard passenger compartment features, displays and controls.

2.1.2 Tasks

Driving (primary) task
Primary driving task was to follow a car and react to the two stimuli represented by brake lights and the flashing right indicator on the leader car. In the case of the brake light, a participant had to take their foot off the accelerator pedal as quickly as possible, in order to simulate slowing down. When right indicator was activated, the subjects had to push a button on the wheel as quickly as possible to simulate the turn signal.

Designed (secondary) task
The secondary task, performed during the driving task, was to lead phone conversation on topics related to everyday life. Two sets of conversation topics involved mainly two types of cognitive processes: retrieval of information from episodic memory and route planning. Each set was tested with a regular phone conversation and an asynchronous approach.

Surrounding scenario
There was no special background for the tasks. Participants drove on a fairly straight and easy to drive two-way secondary rural road 18 km long by 90 km/h speed. During this journey, they went through twelve realistic and friendly phone conversations.

2.1.3 Target group

The concept was tested on 15 males and 15 females aged from 18 to 50 years. All of the participants had a driving licence and reported driving at least 5000 km per year. Most of them stated that they drove every day and all of them use a mobile phone in everyday life, occasionally while driving.

2.1.4 Method

Driving performance was evaluated by analysing the proportion of stimuli (brake lights and flashing light) to which the subject responded correctly. This ratio was calculated by dividing the number of correct responses by the total number of stimuli. Mean response time for each driver was then computed for the stimuli that received a correct response.

2.1.5 Results

The results of this study show that the proportion of stimuli with correct responses is higher in the asynchronous approach condition than in the regular phone condition. On the other hand, response time in both communication conditions increased by the same amount compared with the control condition. This could be affected by the fact that the driving route was fairly straight and very monotonous so the trajectory control task was quite straightforward. It was mentioned that asynchronous approach brings the communication under driver's control because it is easy to suspend communication when necessary and the driver is free to listen to the message again and prepare his or her recorded reply. Moreover, the other insight was that voice interface interactions and message listening cause a less cognitive load of a driver than answering phase.

2.2 In-vehicle speech-based interaction

Described in the study: *'Comparison of manual vs. speech-based interaction with in-vehicle information systems'.* [6]

The aim of this study was to examine whether speech-based interfaces for different in-vehicle-information-systems reduce the distraction caused by these systems. It was done by comparing the driver's distraction while using these systems with speech-based interfaces and with a touch screen. Both of these conditions were compared to driving without any secondary task. Test cases were performed for three frequently used in-car systems - audio, telephone with name selection, navigation system with address entry and point of interest selection.

2.2.1 Environment

Lane Change Task (LCT) [7] was used for the evaluation of distraction caused by the different in-vehicle information systems. LCT was set up by PC equipped with a joystick steering wheel, gas and brake pedal. The audio system was represented by MP3-player in manual condition testing and laptop-based prototype music selection system was applied in the speech condition.

2.2.2 Tasks

Driving (primary) task
Main driving task was represented by LCT simulation. In this simulation, the driver sees a straight section of a three-lane road on the screen and his/her goal is to drive with constant speed and keep the current lane. During the journey, the driver is instructed by signs to change the current lane for a specified one. The lane change request was induced approximately every 10 seconds of a three minutes ride. This was not a typical case, in which a driver will execute a secondary task in real word driving situation. However, the main goal of the authors was to create a well-defined level of the driving task difficulty which requires frequent attention of the driver.

Designed (secondary) task
As mentioned above, secondary tasks were situated in the most common interactions with in-car systems. The first task was controlling the audio system, which consisted of selecting an artist, album or title. The second task was making a hands-free phone call and the last one was interaction with two types of navigation systems, which required visual affirmation even in the cases using speech input. These two navigation systems differed on how many visual steps they demanded. The objectives were selecting points of interest (POI) in several cities and entering an address. Secondary tasks were compared in cases when it's system was operated by a touch screen or a speech interface. To give a meaningful estimation of the effect size, both conditions were compared to a baseline.

Surrounding scenario
This experiment background was situated on the straight three-lane road (possibly highway) where the driver was obliged to follow some rules and react to the actual driving situation. While driving, the driver was requested to deal with common in-car secondary tasks (audio, phone call, navigation).

2.2.3 Target group

Participants in this study were 29 drivers (16 male, 13 female) who had normal or corrected to normal vision. All had a valid driver's license and were aged from 19 to 59.

2.2.4 Method

Rate of distraction caused by executing secondary tasks was evaluated according to monitoring driver's behaviour and car reactions, which were recorded with 62 Hz corresponding to a precision of 16 ms. The task was divided into separate lane-keeping and lane-changing phases, which were measured. For the lane-keeping phases, the standard deviation of the lateral position (SDLP) of the car was computed. For the lane changes, reaction time was measured and additionally, for the whole trial a mean deviation to an 'ideal' behaviour was computed. For this simplified ideal behaviour it was assumed that during lane-keeping the car should stay in the middle of the lane. Also, gaze behaviour was monitored and conducted. Moreover, subjective distraction was evaluated.

2.2.5 Results

This study very well demonstrates the strong distraction effect caused by the manual control of the different systems. Quality of driving control decreased and the reaction time needed to change the lane increased, which was mainly caused due to visual distraction. In the case of speech control of in-car system interaction, reaction time decrease was noted in comparison with manual control. According to the study, speech enables the drivers to focus more on the road and that improves driving performance. However, these improvements were not strong enough to reach the baseline performance level in all parts of the driving task and proved that secondary tasks substantially increased the risk of a critical situation or an accident. [8] In addition, it was shown that the distracting effect of the secondary task using voice control is minimal when the driving situation is easy, but the traffic situation may change very fast.

2.3 Multimodal interaction

Described in the study: *'Multimodal Interaction in the Car – Combining Speech and Gestures on the Steering Wheel'*. [2]

This study dealt with the impact of using multimodal interaction on driving performance against a baseline using only physical buttons. Speech commands were used for identification of functions and gestures for manipulation (e.g., left/right), which provided fine-grained control with immediate feedback and easy undo of actions.

2.3.1 Environment

The experiment was taken in a lab environment. For the simulation a steering wheel with integrated Android-based tablet was used. On this tablet a voice and gesture recording app was running. In the standby state (waiting for gesture input) tablet displayed only white background on the screen. A driving simulation was running on PC and visual output was presented by 24" screen.

2.3.2 Tasks

Driving (primary) task
The driving task for this experiment was to drive along a 2-lane infinite highway where blocking obstacles indicated necessary lane changes.

Designed (secondary) task
The secondary task was aimed at interaction with a build-in tablet in the steering wheel. Participants went through 26 tasks, each of them was divided into three parts. In the first one, one or two augmented photographs of an object in the car were presented to the driver. Images represented the initial state and the final state of the object and the driver was asked to verbally address the object/function. In the case when addressing was not precise enough driver was asked for refinement. In the second phase, the driver was given voice instruction by the tablet to suggest gesture to set parameters to the chosen object (e.g. moving the window up or down). No auditive or visual feedback was given for both voice commands and touch gestures. The last phase was feedback from a participant about the difficulty of conducting the command and gesture.

Surrounding scenario
No special scenario was presented for the tasks. Drivers had to drive on the 2-lane infinite highway and change lanes according to obstacles. While driving, the task of controlling in-car systems and setting the environment such as seats and mirrors were done using the voice commands and gestures on the touch screen of the steering wheel.

2.3.3 Target group

All the participants had a driving licence and were aged from 20 to 39. The group consisted of 10 men and 2 women. Their average driving experience was 10,6 years car usage ranged from once a month to every day.

2.3.4 Method

For the evaluation, the 5-point Likert scale was used, which indicated how comfortable participants were with adjusting car systems using the multimodal approach. Influence of secondary task to driving performance was measured by mean distance to the baseline of both interaction approaches - classical and multimodal. Moreover, feedback of the participants was measured with SUS [9] and DALI [10] questionnaires to extract perceived usability and perceived task load.

2.3.5 Results

The key conclusion of this study was that multimodal interaction is comparable to current interaction approach but offers better flexibility. One of the insights was that visual demand is higher for the traditional approach than for the multimodal approach, which is important for safe driving. On the other hand, the multimodal approach can invoke a higher workload of a driver.

2.4 Error recovery

Described in the study: *'Error Recovery in Multitasking While Driving'*. [11]

This study examined how errors in interacting with infotainment systems influence driving performance and how drivers recover from these errors. This experiment was focused on the input of the words using a touch-screen. Four different error recovery strategies were identified.

2.4.1 Environment

The study used for its experiment car simulator, which consists of one 65” screen placed at a distance of about 54” from the driver and includes standard steering and pedal setup.

2.4.2 Tasks

Driving (primary) task
Participants were instructed to drive at a speed of 80 km/h in the right lane of the undivided, four-lane highway with a shoulder on each side. After a lead vehicle appeared, they had to follow it with the fixed following distance of 70 meters.

Designed (secondary) task
The secondary task was performed on 7" touchscreen located in the centre position, where control systems are usually placed in real cars. The display had text block on the top, that showed entered text, and a virtual keyboard on the bottom. The participant went through 12 trials, 6 of them focused on short words (4 letters) and the other 6 on long words (12 letters). Words for the tasks were selected from the text reading and text input assessment study conducted by Boyle et al. [12] All trials were done in two system conditions - with a delay and the other without a delay. In the case with the delay, the input result of each letter shown on display after 500-1200 ms. This did not affect the input of the letters, so the participants could type letters ahead. The participants could use the backspace key to delete a letter.

Surrounding scenario
Driving scenario was defined by the NHTSA [13] visual-manual guidelines and as written above, participants drove on the four-lane highway at a speed of 80 km/h and followed a lead car. While driving, they performed the secondary task of typing words into the touch-screen system.

2.4.3 Target group

The total number of 48 participants were divided into age groups per 12 participants in each (18-24, 25-39, 40-54, and 55+ years old). The number of men and women in groups was equal.

2.4.4 Method

Driving performance was measured by the standard deviation of lane position and the standard deviation of headway distance. Eye glance data were manually coded and logged. The level of distraction associated with secondary tasks was evaluated by measuring the total visual demand of the task.

2.4.5 Results

Errors detection of this study was defined as a case when the participant found out that he/she inputs the wrong letter and corrects it using backspace and entering the correct character. Each of 46 participants completed 24 trials and the mean number of errors was 1.21 per trial. An error occurred at least once in 22.6 % of all trials and for each letter, the probability of being typed wrong was 2.9 %.

It was observed that drivers adopt four different error recovery strategies based on the task-switching decisions that drivers make at two points: the first is after perceiving and before correcting the error, and the second is after correcting the error and before resuming the secondary task. The fourth strategy was the most represented one.

Common insight for all strategies was that when attention is more often moved back to the road, it samples visual information more frequently, but it requires time to relocate attention repeatedly. In the condition with system delay, participants switched more often and used the fourth strategy more. The final statement was that error in a word typing task was fairly common and it increased the total task time, which means that the drivers are not fully engaged in the driving task for a longer period, and longer individual glances away from the road imply a higher probability of missing unexpected events on the roadway.

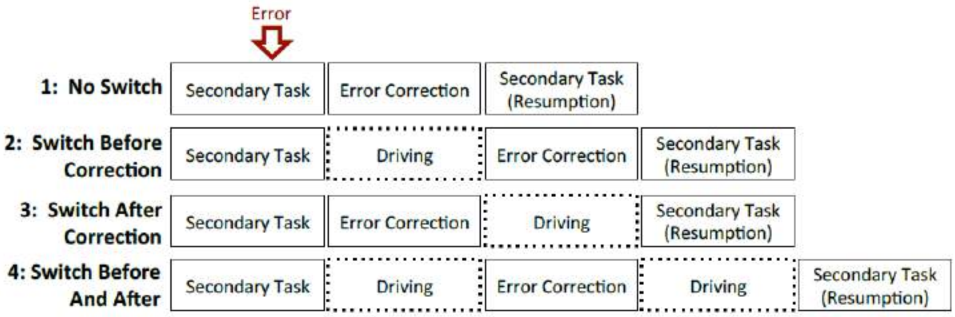


Figure 1 Four error recovery strategies defined according to the task switching decisions before and after correcting the error. [11]

Authors observed that people adapted the behaviour to system design and switched more often when there was a delay in the letter entry system interface. Authors also recommend that "to prevent extensive engagement in the secondary task, sufficient but not greater than necessary visual information should be provided to let the drivers focus on driving for the rest of the time."

2.5 Older drivers and distraction

Described in the study: *'Distraction while driving: The case of older drivers'*. [14]

The aim of the study was to examine the effect of age on driving performance as well as the compensation strategies of older drivers under distraction. To assess driving performance the LCT [7] was used. This method aims at estimating driver demand while a secondary task is being performed, by measuring performance degradation on a primary driving-like task in a standardized manner. The study also deals with the effects of time pressure within the secondary task.

2.5.1 Environment

For the simulation was used a standard PC equipped with a joystick steering wheel, a gas and a brake pedal. As a displaying device 17" monitor was used and the audio system with noises of engine illustrated the real situation complemented the simulation.

2.5.2 Tasks

Driving (primary) task
The primary driving task was simulated by Lane Change Task. A driver was instructed to drive along a straight three-lane road at a constant speed of 60 km/h and according to sign is required to change the lanes. The track is about 3000 meters long and it takes approximately three minutes to finish it.

Designed (secondary) task
The secondary task was in the form of a computer-based version of 'd2 Test of Attention' [15] and can be comparable to visual-manual operating of in-car devices according to authors. D2-task was running on the computer monitor positioned on the participant's right-hand side. During the d2-task participant was required to press the key '1' when the target letter 'd' (marked with two dashes) was displayed on the monitor. For all

distractors, the key '2' had to be pressed. Distractors were made up of combinations of the letters 'd' and 'p' with none or one to four dashes arranged either above or below the letter. Time pressure case was achieved by changing items on the screen every 1500 ms. In the other case, the presentation was self-paced by the driver.

Surrounding scenario
The background of tasks was given by above mentioned LCT method, which means that participants were driving on a straight three-lane road and had to change lanes according to signs. During this ride, they interacted with the secondary in-car system.

2.5.3 Target group

Group of participants consisted of 10 older drivers aged 60-73 and 10 middle-aged drivers aged 31–44. Each group included 2 female and 8 male participants. All of them had a driving licence. Older drivers had more driving experience when measured in years of active driving.

2.5.4 Method

In the primary driving task, driving performance was measured using mean deviation, which refers to the deviation between a normative model and the actual driving course of the participant along the track. In lane-keeping phases, the standard deviation of the lateral position (measured in meters) was computed. During the lane-change phases, the reaction time was measured. Moreover, the subjective rating of the participants was taken into account.

2.5.5 Results

The study brings the following insights. The overall driving performance (mean deviation from the optimal trajectory) of the older drivers was worse in all conditions as compared to the younger ones. Lane-change reaction time was comparable for both groups. The difference showed in lane-keeping phases where the older participants were more affected than the younger ones. This may be explained by finding that older drivers focused more on the most relevant part of the driving task, which was the lane change manoeuvres. The driving performance of the older drivers was not additionally impaired when the secondary task imposed time pressure, but the accuracy in secondary task decreased. According to the study, older drivers took significantly more time to respond to items of secondary tasks in the condition without time pressure than the mid-aged participants. However, despite the fact that older drivers tried to concentrate more on driving while executing the secondary task, their driving performance was still affected.

2.6 Support systems designed for older drivers

Described in the study: *'Support Systems Designed for Older Drivers to Achieve Safe and Comfortable Driving'*. [4]

The aim of this study was to investigate the mechanisms behind self-regulation and driving cessation in order to suggest the development of support systems to prolong older drivers safe mobility. A content analysis revealed broad self-regulatory behaviour as already reported in the literature, e.g., avoiding driving at rush hour and at night. The participants also reported difficulty in finding the way to their final destination and an increasing need to plan their travelling. Co-piloting was a behaviour applied by couples to cope with the difficulties encountered in traffic.

2.6.1 Environment

This study used focus group method, which helps collect data for qualitative research by making interviews in groups of participants.

2.6.2 Focus group

Participants were divided into three focus groups, in which they discussed four main themes: 1) mobility patterns, 2) self-regulation, 3) driving cessation, and 4) vehicle support systems. The interview was organized into two parts. The first part aimed to cover the participants' mobility pattern, their perceived driving self-regulation in the last year and the question of when and why they would stop driving in the future. In the second part, three video-clips of city, main road and highway were shown and the aim of this interview was to investigate participants' perception of limitations as well as their use of support systems.

2.6.3 Target group

A total of 19 participants were recruited according to a few criteria. They had to be older than 65, being retired, having a driving license and being an active driver.

2.6.4 Method

The interviews were recorded using a digital voice recorder and all of them were transcribed. On the transcribed material a content analysis was performed. The data were categorized into themes and a total of 34 subthemes.

2.6.5 Results

Mobility patterns
According to Musselwhite's classification, [16] travelling can be classified into three categories: travelling to fulfil practical needs (e.g. shopping), travelling to fulfil social needs (e.g. visiting family and friends), and travelling for aesthetic needs (e.g. to see the ocean). The result was that practical and social travelling was performed by means of a car and practical travelling was in most cases once a week for a purpose to shop in a mall. In addition, the difference between men and women was reported when the couple was travelling together in the car. In this situation, men are usually drivers and women passengers.

Self-regulation
Participants in all groups reported self-regulating while driving to avoid physical or mental discomfort. Self-regulation was in a form of reducing speed, avoiding motorways, avoiding big cities, avoiding long, distance travels, avoiding unknown cities, avoiding driving in darkness, avoiding overtaking, avoiding poor weather, planning journeys and avoiding rush hours. Few of these regulations are possible because older drivers are more time flexible. Participants reported that the consequences of self-regulations make them

calmer and more relaxed on the road. An interesting insight was that a large number of signs (especially in the cities) causes problems in orienting of participants and finding their destination in unknown cities. It was also mentioned that stress during driving has a negative impact on participant mood after arrival to a final destination. When some couple travels, they handled specific situations on a road as a team. It means that passenger is 'co-pilot' and for example informs the driver about cars on intersections.

Driving Cessation
By the topic of Driving Cessation, participants were asked when they planned to cease driving and for what reasons. One reason was their health condition, mainly visual problems. Participants claimed that they expected to realise by themselves when their health conditions were too bad to continue driving or their partner or family would stop them. Another reason to stop driving is increase of participants' stress level on the road.

Support System
Participants' experiences with support systems depend on what car they drove. Most of them were used to compensate physical limitations and increase driver comfort. For example, electric gear mirrors, parking assistance and having automatic transmission was likewise highly valued.

2.7 Summary

According to the analysis of mentioned studies, several valuable insights were found out, which can help with designing a conversational interface with respect to the target group of older drivers. First of all, it is important to say that none of the concepts keeps driving performance, while dealing with secondary tasks, on the same level as when the attention is focused only on driving. On the other hand, some of the approaches helped effectively reduce distraction. Disturbance can be often caused by other persons - passengers or someone on the phone, but the effect is not usually the same in both cases. Passenger is a direct participant in traffic so the conversation can be modified according to the situation on the road. In opposite, a phone call cannot be naturally suppressed (conversation suppression hypothesis). Making these real-time tasks asynchronous can help reduce pressure on the driver because the suitable pace can be chosen in respect of traffic situation.[5] Another most common problem is controlling infotainment systems manually which leads to long or frequent off-road glances which pose a big danger. Although voice control has also some negative impact on the driver's workload, it still has better results than displays and manual controls.[6] One possible approach can be multimodal interaction, which may provide fine-grained control with immediate feedback and easy undo of actions.[2] It is obvious that older drivers have special demands. Besides some physical impairments (visual, motion etc.), they are more sensitive to time pressure and complexity of the tasks. On the other hand, older drivers are calmer, less reckless and less daring drivers than earlier in life and there are many aspects from which older drivers can profit. For example from their life-long driving experience, maturity and flexibility to drive at times and places that they perceive as being safer.[14] This flexibility closely relates to a phenomenon of self-regulation, which can manifest as avoiding certain conditions (e.g. driving at night or during rush hour) or difficult traffic situations (e.g. driving through specific intersections), next reducing speed, avoiding motorways, avoiding big cities, avoiding long-distance travels etc.[4]

3 Design – first iteration

This chapter deals with the first design of conversational assistant, which should help older drivers solve specific situations in selected use-cases – Navigation and Message-sending.

3.1 Navigation use-case

For the navigation use-case there are several insights and notes that should be taken into account:

- navigation should be a complex one,
- navigation should be not so deeply branched menu system, [17]
- keep in mind cognitive distance, [18]
- road signs recognition problem for older people,
- mental states during driving can influence mood after arrival,
- older people reported being calmer, less reckless and less daring drivers than earlier in life,
- self-regulation of older drivers,
- passenger often plays a part as co-pilot, [4]
- time flexibility of older drivers,
- older people are more sensitive to time pressure. [14]

According to the analyzed literature, three possible problems related to the navigation and older drivers were selected:

- Dealing with error stressful situation,
- Adapting the route to a driving purpose,
- Traffic signs noticing.

Each of the problems is described by scenario for better illustration of problematics and how conversational assistant could be helpful.

3.1.1 Scenario 1 – Dealing with error stressful situation

It is a weekday afternoon, the rush hour in traffic, and Carl, the retired older gentleman, is driving to the large capital city, where his daughter Alice lives with her husband Thomas and children. Alice and Thomas have tickets for tonight's show at the National theatre and asked Carl if he could take care of children during the evening. He was not happy about driving to the capital, because there are a lot of cars on the roads nowadays and he does not drive so often, so he is a little bit stressed while driving. But Carl wants to help Alice and looks forward to seeing his grandchildren, he likes them a lot. Before the ride, Carl set up his navigation system in the car to the final destination, to be more confident about the way. Everything went fine until he has reached the city and the big intersection with many lanes. He knows, according to navigation, that he has to turn left but unfortunately he is in the most right lane and the traffic is so heavy. He is starting to be nervous and more stressed, but then the navigation system asked that if it is hard to get into the left lane. Carl immediately responds 'yes' and get feedback from *the system that everything is okay and he can continue in this lane, because there is another chance to turn left at the next intersection ahead, so he will have time to change the lane. The delay will be insignificant. That calmed Carl down and he successfully arrived at his daughter's house without being unnecessarily stressed.*

3.1.2 Scenario 2 – Adapting the route to a driving purpose

Maria and Steven are a retired couple, but they are fans of an active lifestyle and their favourite activity is sightseeing. Every week they make at least one trip somewhere by car because Maria loves to drive and they are not dependent on the timetables of public transport. It is Wednesday and Maria with Steven planned a trip to a beautiful castle. Maria is used to driving with the navigation system, so she entered the address and selected driving purpose. This is a feature of this navigation she knows she can rely on. Everything is prepared, a snack is packed in a trunk, so they start their journey. The navigation system suggested the road according to the selected driving purpose. The estimated total time of the journey will be 25 minutes longer than the fastest route, but they will avoid heavy traffic on a highway. Moreover, they will see some interesting places along the road as the navigation system informed them. And that is what they really want because they are making a trip and want to be relaxed.

3.1.3 Scenario 3 – Traffic signs noticing

Robert is a retired 68-year-old man, who lives in a small village in a house, where he has several domestic animals. He really likes this peaceful countryside lifestyle. The village has only several dozen inhabitants, so there are not any shops. Because of this, once a week Robert takes his car and goes shopping in a city 30 kilometres far from his home. It is no big issue for him, thanks to the almost 50 years of driving experience. But the times are changing – everything is faster, there are more cars on the roads and also more traffic signs. Especially reading of signs has become more difficult for Robert, sometimes he feels overwhelmed by signs and billboards in the surroundings of the road. He tries to focus mainly on driving, not on finding the one useful sign in a bunch of information. But sometimes it happens that he misses the information which he needs to know, e.g. the speed limit sign. In these cases, he uses a car conversational assistant, which can help him. Robert just asks 'what is the speed limit' and he gets an immediate answer, the same way he can ask if parking is allowed on the side of the road or other useful information.

From these three problems, described by scenarios, **Dealing with error stressful situation** topic was selected to be more deeply examined and interaction of conversational assistant to be designed.

3.1.4 Hierarchical Task Analysis (HTA)

Hierarchical Task Analysis (HTA) is used to decompose a task into subtask to analyze single steps. HTA of *Dealing with error stressful situation* see in Fig. 2.

Plans define the execution of the task, respectively the plan is a sequence of steps from HTA to be performed. For one HTA, multiple plans are possible.

Plans for the HTA of *Dealing with error stressful situation*:
Plan 1: 1.1 – 1.1.1 – 2 – 4

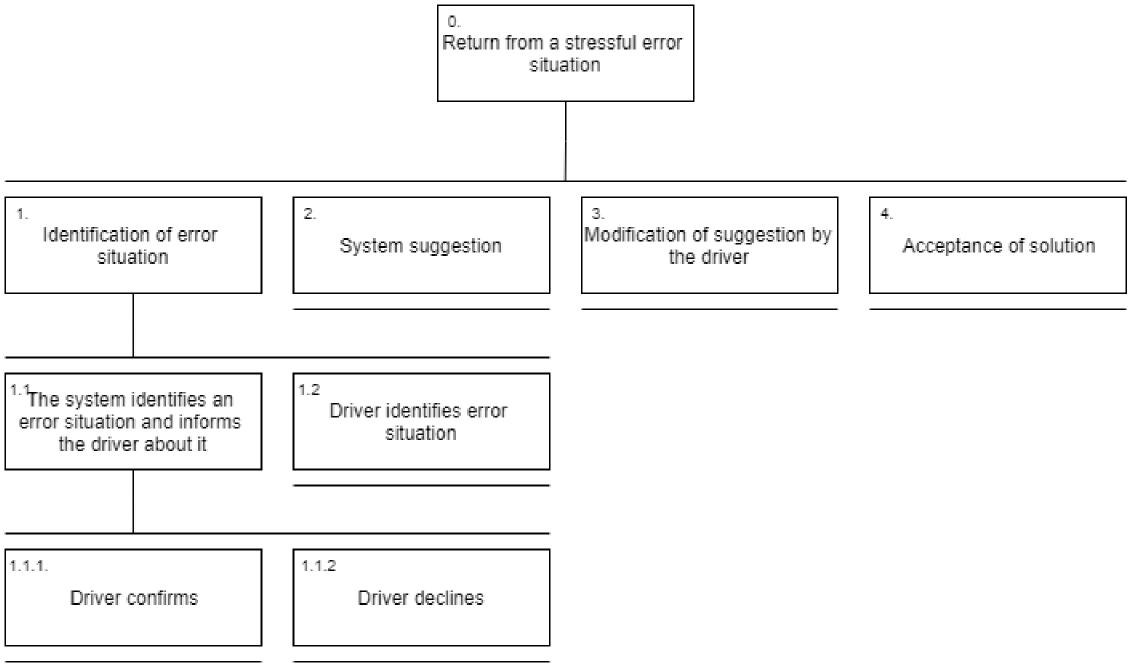


Figure 2 HTA of *Dealing with error stressful situation*

Plan 2: 1.1 – 1.1.1 – (2 – 3) can be repeated multiple times – 4
Plan 3: 1.1 – 1.1.2
Plan 4: 1.2 – 2 – 4
Plan 5: 1.2 – (2 – 3) can be repeated multiple times – 4

3.1.5 Sketching

Sketching of the conversational assistant interaction was done for the two specific situations:

1. Wrong turning lane at an intersection
2. Lack of fuel

Wrong turning lane at an intersection

The driver is arriving at the intersection with three lanes. Traffic is heavy, he is in the most right lane but according to the navigation, he should be in the most left to turn left. The system evaluated that he is too close to the intersection to change the lane safely.

System:	It seems that it is hard to go left now, is it true?
Driver:	Yes, I can't make it.
System:	That is no problem, you can continue straight in this lane, there is another way and the delay will be only one minute.
Driver:	Okay, that's good.
System:	Behind the intersection, try to get to the left lane when it is possible. You will be informed about the next steps, don't worry.

Table 1 Plan 1 dialogue

System:	It seems that it is hard to go left now, is it true?
Driver:	Yes, I can't make it.
System:	That is no problem, you can continue straight in this lane, there is another way and the delay will be only one minute.
Driver:	I'd rather go right, the situation in front me looks complicated.
System:	Okay, go right. There is a better way, which is more peaceful and the delay is insignificant - only 4 minutes more. You have plenty of time to get to your final destination.

Table 2 Plan 2 dialogue

System:	It seems that it is hard to go left now, is this true?
Driver:	No, I just want to go right to the fast-food restaurant on the corner.
System:	Okay, do you mean 'Krusty Krab' restaurant?
Driver:	Yes.
System:	Perfect, go ahead, the parking lot is in 200 meters. The entrance to the drive-thru is a few meters further.

Table 3 Plan 3 dialogue

Lack of fuel

The driver noticed that a fuel indicator shows that there is not much fuel left in the tank. The driver feels insecure and starts a conversation with the system.

Driver:	I have low amount of fuel, is it enough to get home?

System:	It should be enough to get home, but I recommend to stop at a gas station due to the traffic situation. Do you want to find gas stations?
Driver:	Yes, find gas stations.
System:	There is a gas station Benzina twelve kilometres ahead on the road you are going. Do you want to stop there?
Driver:	Nah, is there any Shell station, I have their VIP card.
System:	Yes, there is a Shell station in 20 kilometres, but it is along another route, which is 6 kilometres and 10 minutes longer. Do you want to go to this gas station and use this new route?
Driver:	No, this is too far for me. How much fuel will be in the tank after my arrival?
System:	Approximately for 30 kilometres.
Driver:	Ok, I'd rather stop at that Benzina station.
System:	Got it. I will navigate you to the Benzina station twelve kilometres ahead on this road.

Table 4 Plan 5 dialogue

3.2 Message-sending use-case

For the message-sending use-case there are several insights and notes that should be taken into account:

- message-sending should be simplified,
- more emotional phone conversations tend to cause more dangerous driving behaviours, [19]
- older people are more sensitive to time pressure, [14]
- with the increase in age, the percentage of those who considered mobile phone use while driving an unsafe activity, also grew. [20]

In the scenarios below, a different type of behaviour of a conversational assistant, helping with message-sending, is described.

3.2.1 Scenario 1 – Message-sending assistant

Mark is the owner of a construction company and it is common that during the day he receives many informative text messages from his employees about the projects they are working on. Mark uses a car a lot for his business and he knows that sometimes clients communicate with him via text messages, too. He does not want to leave these messages without a quick response when he drives. On the other hand, Mark is a responsible driver and knows that texting on the road is dangerous. Fortunately, conversational assistant in his car has a feature that perfectly fits him. When he sits into his car, the assistant asks if he wants to turn on "do not disturb mode" and he confirms it. From this moment *the system automatically replies to all the messages that Mark is driving now and he will contact the sender as soon as possible. When the system assesses that the driving conditions are suitable (e.g. long straight route, low level of traffic), it informs Mark about received messages and offers him to read them for him. Mark usually listens to the messages to know what is going on and by voice command sets a reminder at the ones he wants to reply. After his arrival at final destination, the system will remind him not to forget to answer the selected messages.*

3.2.2 Scenario 2 – Semi-autonomous message-sending

It is Thursday morning and in a town's swimming pool regular lecture for older people ends. One of the participants is 70-year-old Maria, who is an enthusiastic swimmer and she never misses a lecture. She lives with her husband in a nearby city, but the connection by public transport is not good, so she uses a car for transportation. Her husband is not happy with this, because he worries about her and knows that she could be more tired after an hour of swimming, but there is no other option. Thankfully, they have a conversational assistant installed in their car. This assistant can send text messages automatically, so Maria's husband can be calmer when he gets messages about the journey of his wife. When the engine has started, Maria has been asked by the assistant if she wants to send a message to her husband that she is about to go. The system reads a prepared message and asks for confirmation. She replies 'yes' quickly and the pre-prepared message has been sent. During the way home, Maria got into the rush hour of the city and got stuck in a traffic jam. At that moment the system asks if she wants to inform her husband about the traffic situation and delay. She replied 'of course' and the system sent a text message to Maria's husband about the situation and estimated delay. Then it informs her that the message has been sent. Both Maria and her husband can be relaxed because they know that everything is alright.

Possible events for sending a message:

- start of driving
- traffic jam
- break during driving (lunch, petrol station)
- car defect (e.g. flat tire)
- end of driving

For further study and designing conversational assistant, **Semi-autonomous message-sending** behaviour described in Scenario 2 was selected.

3.2.3 HTA

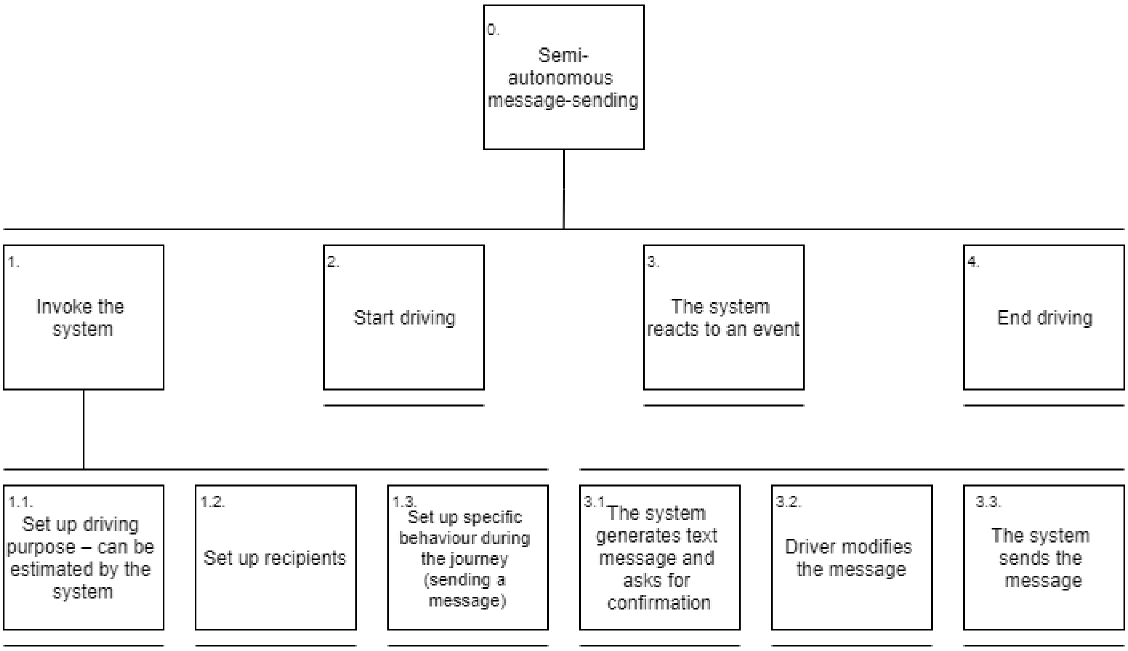


Figure 3 HTA of *Semi-autonomous message-sending*

Plan for the HTA: 1.1 – 1.2 – (1.3) – 2 – 3.1 can repeat multiple times – (3.2) when the message is confirmed, then 3.3 – 4

3.2.4 Sketching

Sketching is done for a situation when the driver wants to inform someone (relatives / friends etc.) about the progress and state of the journey.

Informing someone about the journey

The situation described in Scenario 2. Maria (the driver) is going home from the swimming lesson.

Driver:	I want to send a message.
System:	I see that you are driving home, do you want to set Peter (husband) as a recipient or someone else?
Driver:	Peter, please.
System:	Got it. Should I text him that you are about to go home?
Driver:	Yes.
System:	Do you want to add something to the message?
Driver:	No.
System:	Okay. I have sent the message to Peter.

	Maria had started driving but after a few kilometres, she got stuck in a traffic jam.
System:	It seems that there will be a little delay due to this traffic jam. Should I send a message to Peter about it?
Driver:	Yes, please.
System:	I will send him this text: 'Hi Peter, I am in a traffic jam on Neibolt street, it seems that I will arrive ten minutes later, around 6:45. Maria.' Should I add something?
Driver:	Yes, add that he could start boiling the water before my arrival, we will have spaghetti for dinner.
System:	Okay, I added to the end of message this text: 'You could start boiling the water before my arrival, we will have spaghetti for dinner.' Should I send it now?
Driver:	Yes.
System:	Okay. I have sent the message to Peter.
	Maria arrived in front of her house.
System:	You have arrived at your final destination, should I send a message about it to Peter?
Driver:	No, call him. I will need help with my bags.
System:	Sure. **Dialing**

Table 5 Message-sending plan dialogue

4 Qualitative study – first iteration

This chapter deals with the experiment conducted to evaluate the first design of the conversational assistant.

4.1 Target group

The target group for the experiment were people over 60 years old. Having a currently valid driving licence was not required but the participants should have driving experience. For this qualitative testing, 7 participants were recruited.

4.2 Environment

The experiment was done in a lab environment. A personal computer with a screen (see Fig. 4) was used for running a script (written in JavaScript programming language) which simulated primary task (driving). A participant had to react to the actions performed in the simulation script while making a conversation with the designed conversational assistant. The conversational assistant was controlled from the laptop by the moderator who led the session (see Fig. 5).

Figure 4 Primary task setup

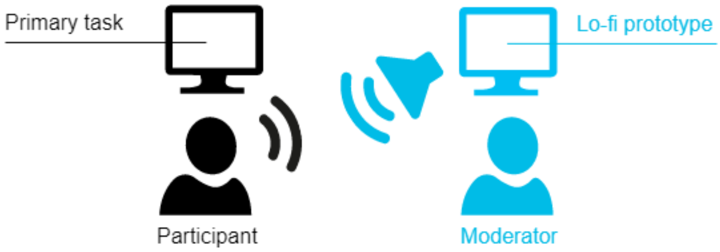
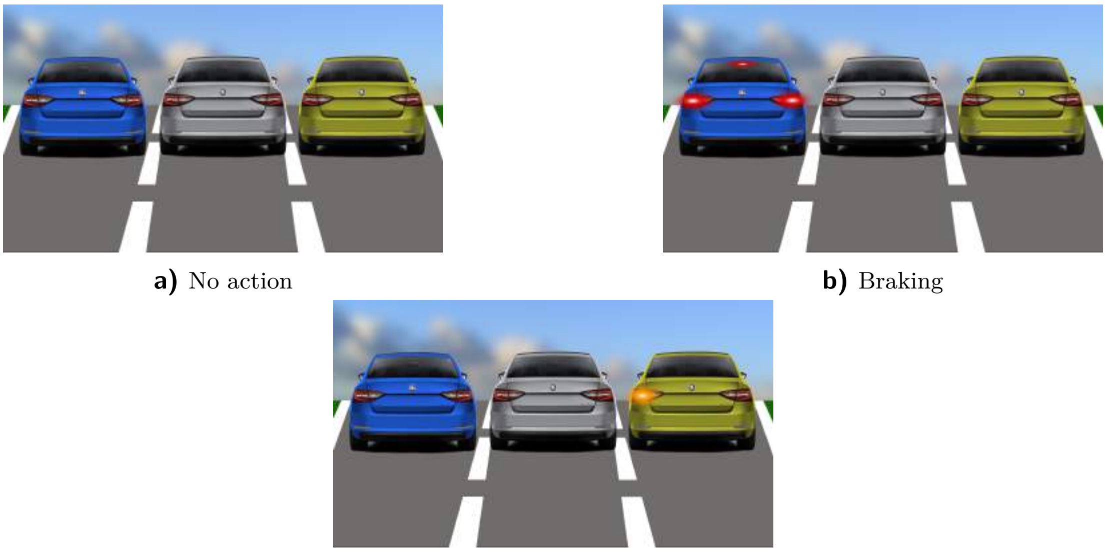


Figure 5 Setup overview

4.3 Primary task simulation

The primary task was designed as a simulation of paying attention while driving. It was handled by a script, which shows a static picture of three cars from the back view on the computer screen. After a time period between 6 to 10 seconds (randomly selected), one of the cars performs an action of braking, signals turning right or left (illustrated by turning on back brake lights or flashing of indicator lights). All of these parameters are chosen randomly. The participant had to react to these actions by pressing the correct key on the keyboard when the action was spotted immediately. This interaction was repeated during the use-case testing. The reaction time and correctness of a pressed key could be measured. However, the number of participants was not relevant for making conclusions from these values.



a) No action

b) Braking

c) Turning indication

Figure 6 Screens of primary task script in three different states

4.4 Secondary task

The secondary task for the participant was the interaction with the conversational assistant while he/she was doing the primary task (simulation of paying attention to driving). The purpose of interaction with the conversational assistant was given by a surrounding scenario. Behaviour and feedback of the assistant were handled by the moderator using the Wizard of Oz technique.

4.5 Dialogue management (Wizard of Oz)

Wizard of Oz technique is method congruent for testing low-fidelity prototypes. This technique was used for simulation of interaction with the designed conversational assistant (dialogue system) for each use-case. In the Wizard of Oz technique, the tested system has not to be implemented, because the moderator can act as the system. In this experiment, the moderator was playing pre-recorded phrases according to the participant's responses and the current state of dialogue (see Fig. 7). For the uncovered states (unexpected participant's answer or request), universal recovery phrases were prepared. Furthermore, the participant could ask for repetition of question/answer if it seemed unclear.

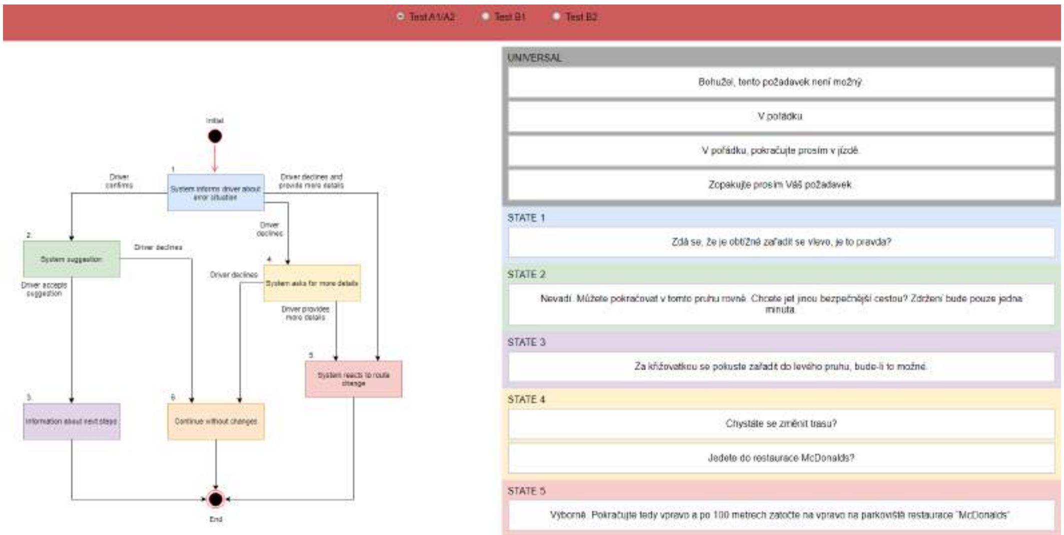


Figure 7 Web application for controlling dialogue system

4.6 Method

The experiment was qualitatively evaluated by observation during the session and using pre-test and post-test interviews with participants. The pre-test and post-test interview structure can be seen in appendix A.

4.7 Navigation use-case

The examined problematics of *Dealing with error stressful situation* can be generally divided into two cases. First, when the error is identified by the system, second, when the driver feels insecure and induces an error by himself/herself. For each of these cases, special surrounding scenarios were created.

4.7.1 Error identification by the system

This case is further categorized according to the evaluation of the reported situation by the driver. The situation can be recognized as false-negative – driver wants to solve it, or false-positive – the driver has the situation under control. Following surrounding scenarios are complemented by a sketch of a map with traffic situation at the intersection for a better illustration (see Fig. 8).

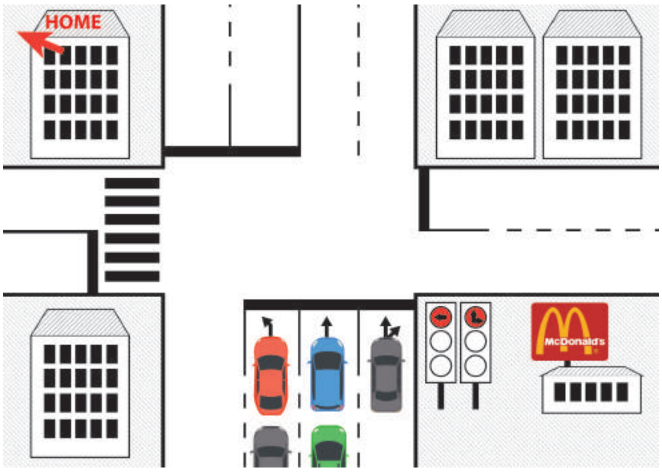


Figure 8 Map for the surrounding scenario

Surrounding scenario – false-negative

(Related to navigation Scenario 1 – Plan 1 in the Design section.)

The driver is arriving at the intersection with three lanes. Traffic is heavy, he is in the most right lane but according to the navigation, he should be in the most left lane to turn left. The system evaluated that he is too close to the intersection to change the lane safely. The driver really wants to go left, but the situation seems to be too risky.

Surrounding scenario – false-positive

(Related to Scenario 1 – Plan 3 in the Design section.)

The driver is arriving at the intersection with three lanes. Traffic is heavy, he is in the most right lane but according to the navigation, he should be in the most left lane to turn left. The system evaluated that he is too close to the intersection to change the lane safely. But the driver changed his/her plans and decided to turn right because he/she wants to go to the fast-food restaurant 100 meters from the crossroad.

Dialogue state diagram

The dialogue state diagram is used to describe the possible states of the designed conversation (see Fig. 9).

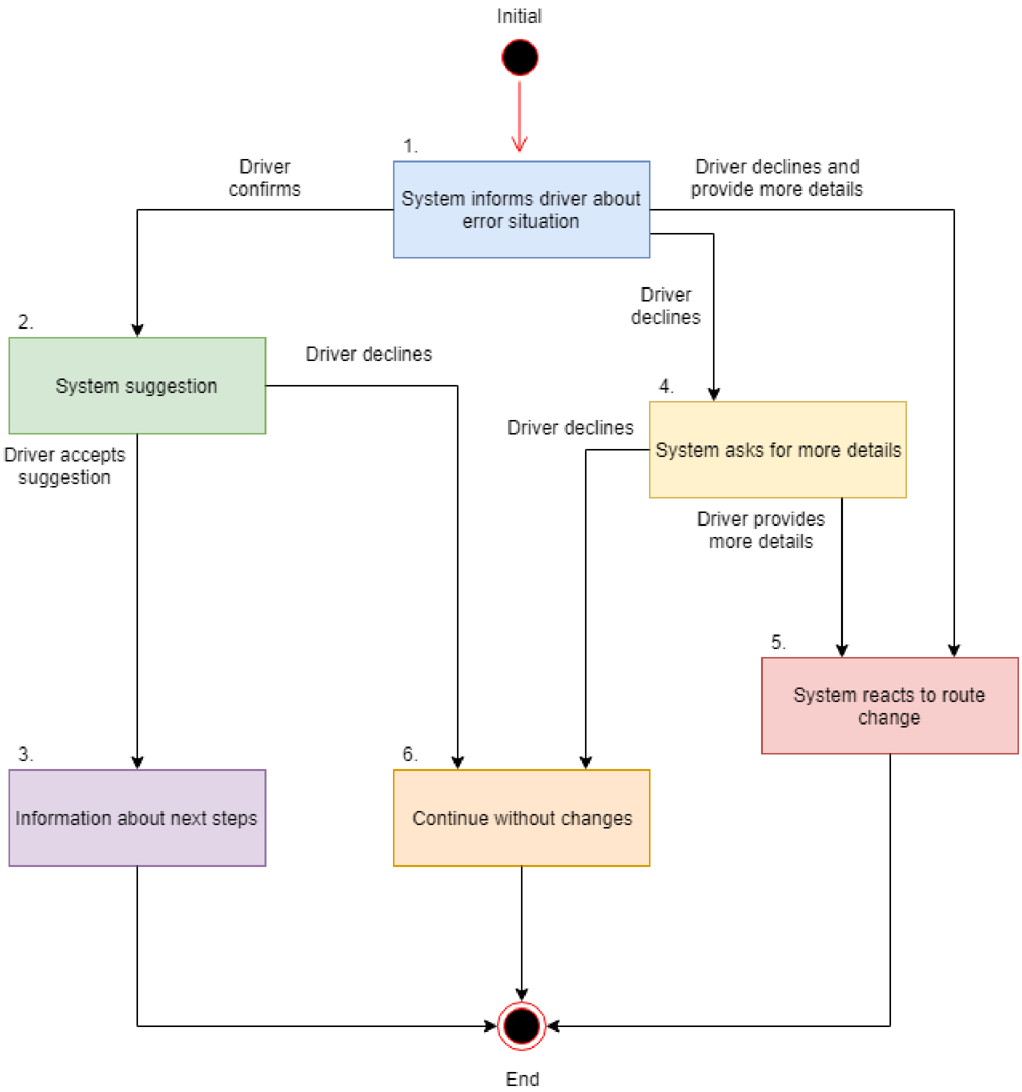


Figure 9 Dealing with error stressful situation (identification by the system) - dialogue state diagram

System phrases for the states

State 1	It seems that it is difficult to turn left, is it true?
State 2	It's okay. You can continue going straight here. Do you want to use another safer route? The delay will be only one minute.
State 3	After you've driven through the intersection, try to shift into the left lane if possible.
State 4	Are you going to change the route?
State 5	Are you going to McDonald's?
State 6	Great. Continue going right here and then after 100 meters turn right onto the restaurant parking lot.
State 7	All right, please continue driving.

Table 6 System phrases for states when system identifies the problem

4.7.2 Error identification by the driver

This case simulates a situation when a driver feels insecure about something while driving and asks the system for help. The surrounding scenario is complemented by a sketch of a map for a better illustration (see Fig. 10).

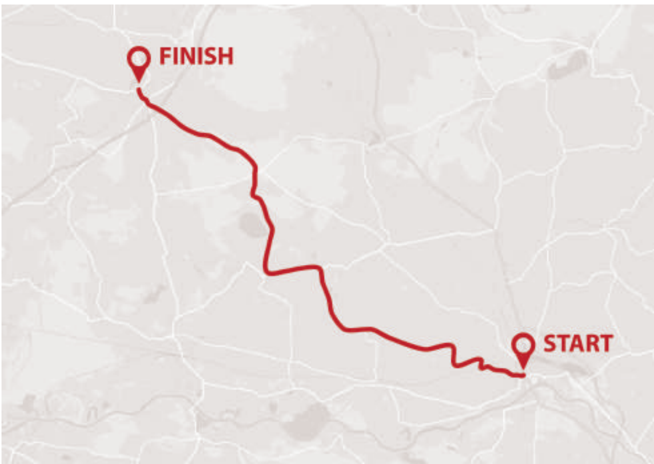


Figure 10 Map for the surrounding scenario

Surrounding scenario

(Related to navigation Scenario 1 – Plan 5 in the Design section.)

The driver is on the way home but noticed that there is not much fuel left in the tank, feels insecure if he/she can get home and starts a conversation with the system. Driver owns Shell's VIP card and thanks to it he/she can have cheaper fuel per litre by this company. It is expected that the driver would try to stop at these specific gas stations.

Dialogue state diagram

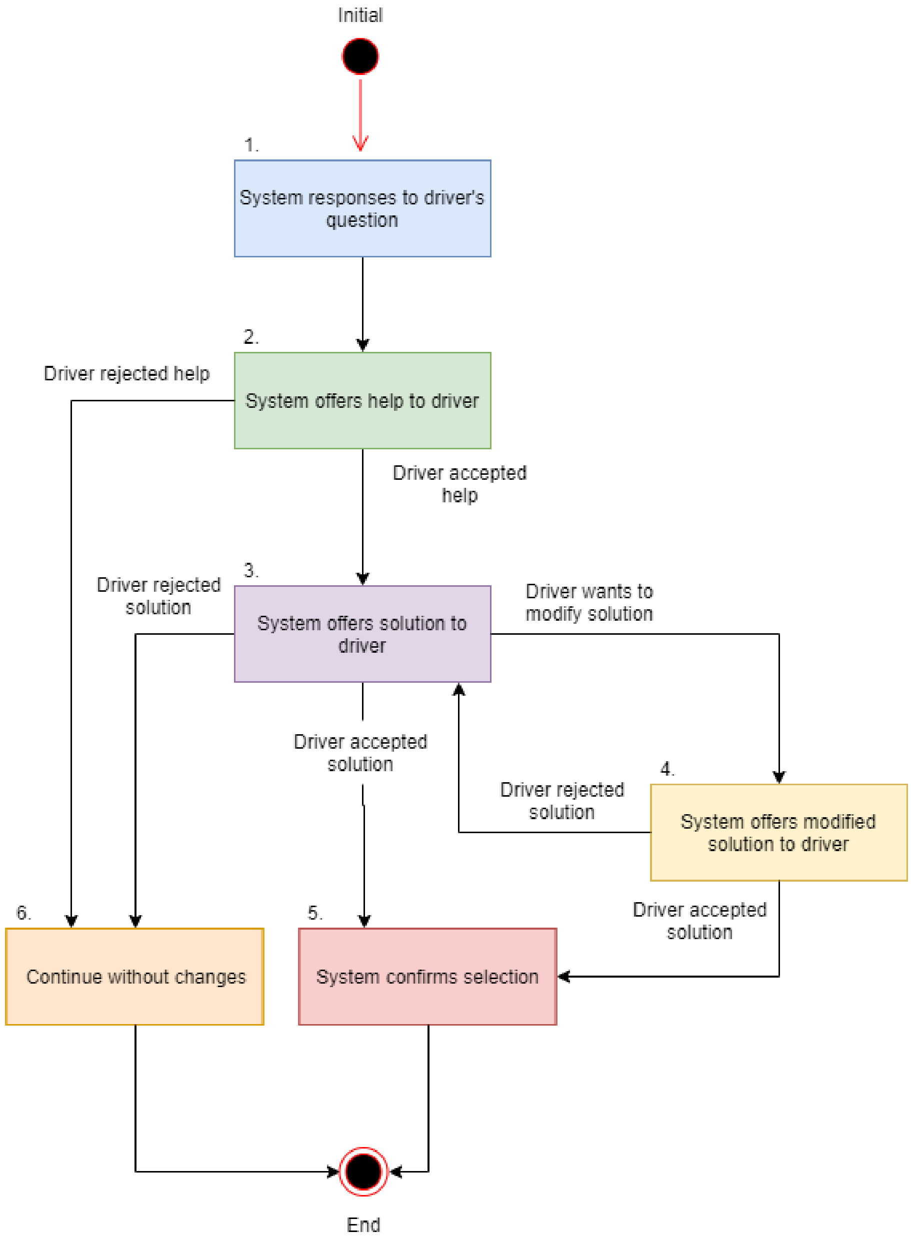


Figure 11 Dealing with error stressful situation (identification by the driver) - dialogue state diagram

System phrases for states

State 1	There should be enough fuel to reach the destination. However, it would be appropriate to refuel due to the traffic situation.
State 2	Do you want to find gas stations nearby?
State 3	Twenty kilometres along your route is the Benzina gas station. Do you want to stop there?
State 3 *Driver refuses modified option*	Would you like to stop at Benzina gas station? The route will remain unchanged.
State 4	There is also Shell gas station 30 km far from here, but the route would be modified. The new route would be 6 kilometres longer, the delay would be 8 minutes. Do you want to navigate to this gas station?
State 5	You will be navigated to the chosen gas station.
State 6	All right, please continue driving.

Table 7 System phrases for states when driver identifies the problem

4.8 Message-sending use-case

The surrounding scenario for message-sending use-case is supported by a sketched map for better illustration of the situation, see Fig. 10.

4.8.1 Surrounding scenario

(Related to message-sending Scenario 2 in the Design section.)

The driver is at the beginning of his/her way home. He/she wants to activate the conversational assistant with semi-autonomous message-sending function to let know his/her son David about the journey.

4.8.2 Dialogue state diagram

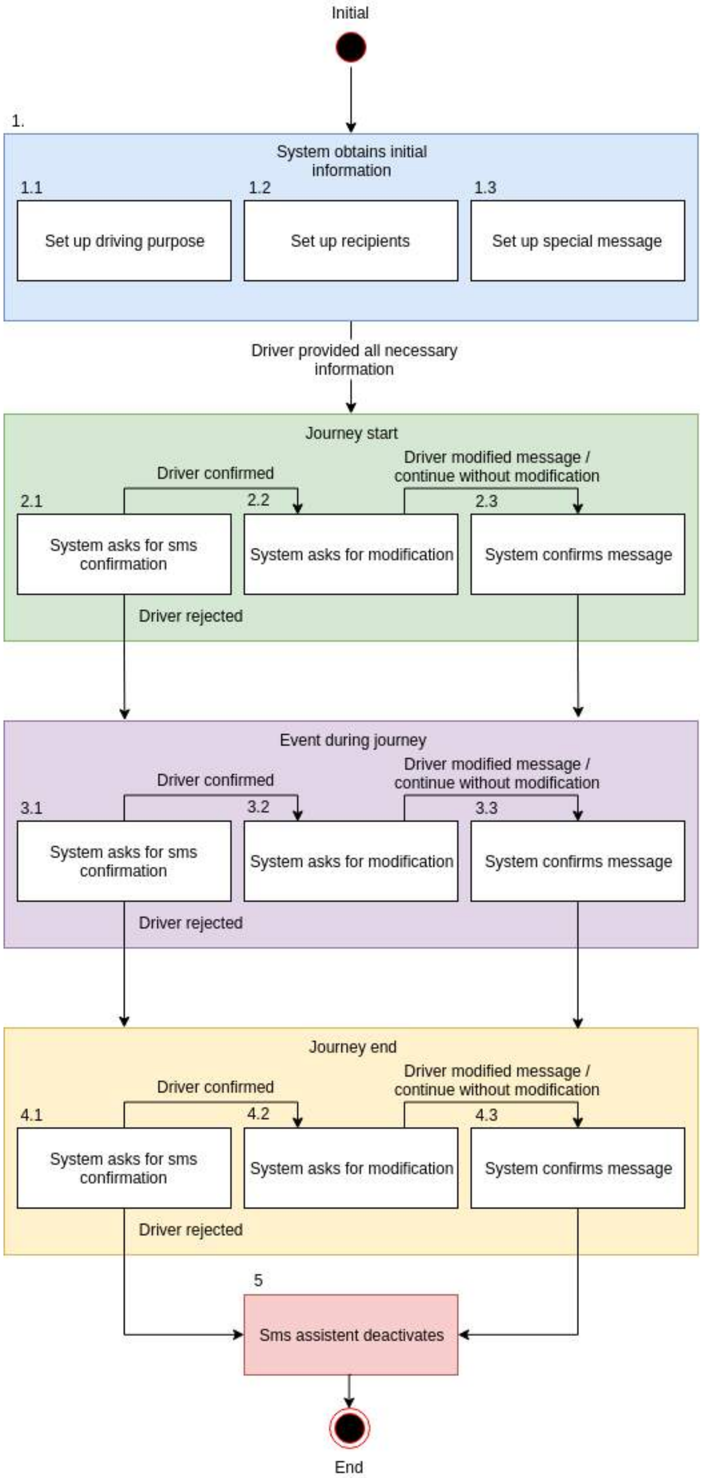


Figure 12 Semi-autonomous sms assistant - dialogue state diagram

4.8.3 System phrases for states

State 1.1	What is the destination and purpose of your trip?

State 1.2	Would you like to set up your favourite contact 'son David' as the recipient for messages?
State 1.3	Do you want to prepare a text message that will be automatically sent during your trip according to your requirements?
State 1.3	Please dictate the text of the message and specify when to send the message.
State 1.3	The message will be sent according to your requirements.
State 2.1	Do you want to send a canned message to David that you are about to go?
State 2.1 *Driver declines*	Okay, please continue driving.
State 2.2	Do you want to add something besides departure information to the message?
State 2.2 *The driver wants to add something to the message*	Please dictate the text you want to add.
State 2.2	The message has been modified.
State 2.3	The message about your departure has been sent to David.
State 3.1	It looks like there will be a delay because of the traffic jam ahead. Would you like to inform David via text message?
State 3.1 *Driver declines*	Okay, please continue driving.
State 3.2	A message will be sent as follows: 'Hi David, I'm in a traffic jam, I'll be there ten minutes later. Around 9:45.' Do you want to add anything to the message?
State 3.2 *The driver wants to add something to the message*	Please dictate the text you want to add.
State 3.2	The message has been modified.

State 3.3	The message about the delay has been sent to David.
State 3.4	Your preset message has just been sent to David.
State 4.1	You just arrived at your destination. Do you want to inform David about it?
State 4.2	Do you want to add something to the message besides that you have arrived at your destination?
State 4.2 *The driver wants to add something to the message*	Please dictate the text you want to add.
State 4.2	The message has been modified.
State 4.3	The message about your arrival has been sent to David.
State 5	The assistant is now deactivated.

Table 8 System phrases for states in message-sending scenario

4.9 Evaluation

4.9.1 Participants overview

Participant ID	Balancing	Age	Gender	Active driver	Infotainment exp.	Voice interface exp.	Visual Impairment
P01	AB	61	male	yes	yes	yes	reading and distance eyeglasses (5-6 dioptre)
P02	BA	62	female	yes	yes (not using navigation)	no	distance eyeglasses (2 dioptre)
P03	AB	74	male	no	no	no	uses eyeglasses only when the light conditions are not good
P04	BA	74	male	yes	no	no	reading eyeglasses
P05	AB	67	male	yes	yes	no	no
P06	BA	72	male	yes	yes	no	distance eyeglasses (2 dioptre)
P07	AB	71	female	yes	no	no	uses eyeglasses for reading and driving

Table 9 Information about participants

4.9.2 Insights

Wrong turning lane at an intersection

This situation was for most of the participants hard to imagine. They often used short and brief answers which were not sufficient for going through dialogue states even when using the Wizard of Oz technique, for a real system it would be hard or impossible to recognize driver's intent. Moreover, it was obvious that the dialogue would be too long for the designed situation. In general, driving through the intersection usually takes only a few seconds, the dialogue would be possible only when drivers stop at traffic lights for a longer period of time.

Lack of fuel

Participants did not initiate the conversation by themselves because they were not sure how to do it. That could be caused by no experience with voice control and the fact they had to start speaking to something which is not physically present. A few participants did not know if it is possible to ask the assistant about their favourite gas station or they mentioned they would expect that the assistant would know the context and their preferences. In general, the participants appreciated the discussion, they do not like driving in a risky situation having low fuel.

Semi-autonomous message-sending

Some participants would expect more autonomous behaviour of the conversational assistant, the dialogue was too long for them. Nevertheless, all participants appreciated the message-sending by the assistant and found it useful. They would imagine using this function in real life while driving.

4.9.3 Summary

The findings gained by the observation or interviews with participants show that they often did not know how to start the conversation or in which state the assistant is (if it is listening, processing, standing by etc.). The first reason was that older drivers have mostly no voice control experience. Second, the tasks were hard to imagine for the participants. It was intended not to tell them how they should start the conversation to see how they will behave without previous experience with the system. The complexity of the participants' utterances to the conversational assistant varied widely across the participants. Some of them were talking to the assistant in complex sentences. On the other hand, there were users who used very brief and austere commands. The message-sending function was perceived with a predominantly positive attitude among all the participants. They would find it useful and could imagine using it in their car. Some participants would expect the message-sending to be even more autonomous and found it unnecessary verbose. Here arises an opportunity to personalize the conversational assistant, for example, based on verbosity and level of automation – not even for the message-sending function but for the conversational assistant itself. Subjective judgements about the level of comfort, comprehension, intuitive conversation and acceptance in traffic were done using 5-Likert scale during the post-test interviews (see Fig. 13).

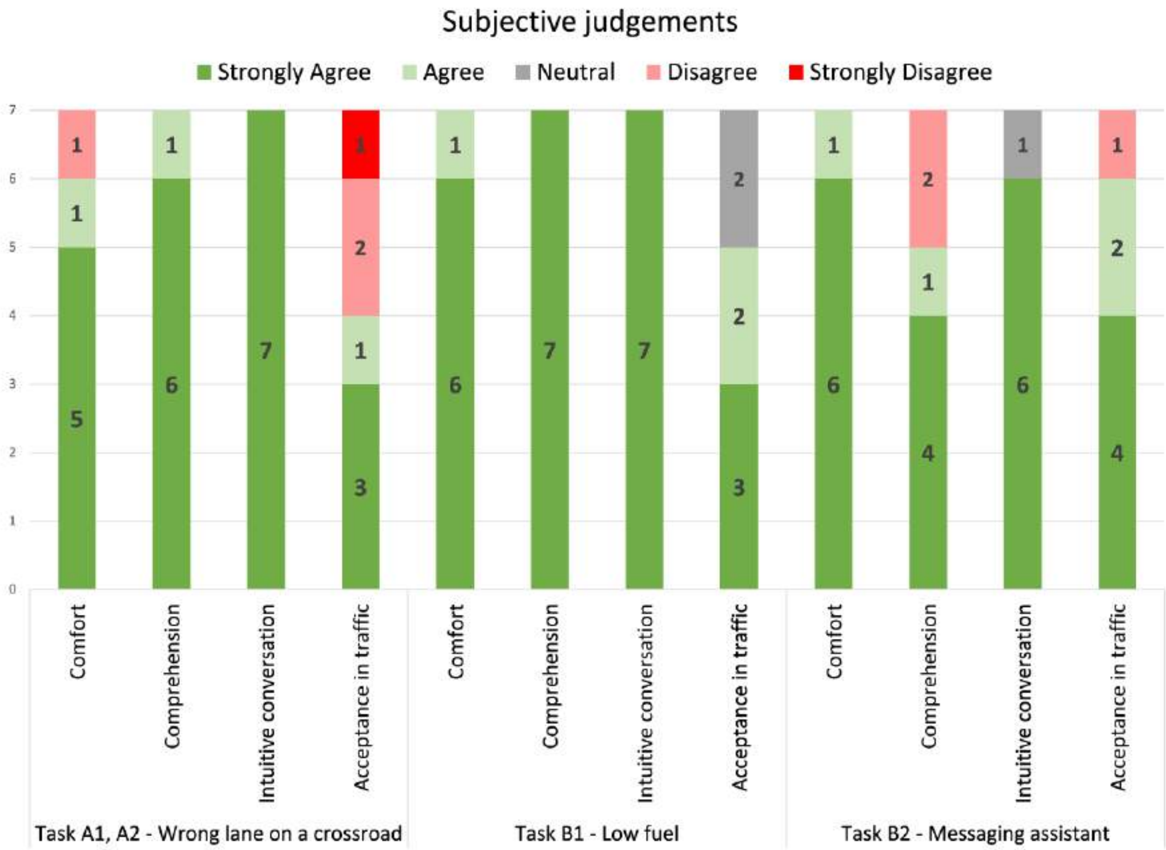


Figure 13 Subjective judgements about level of comfort, comprehension, intuitive conversation and acceptance in traffic (N = 7)

5 Design – second iteration

Based on the results and findings of the previous experiment this chapter examines and extends the use-case related to the conversational assistant with message-sending. This functionality of the conversational assistant was perceived positively among all participants of the experiment and also gives an opportunity to observe and study the interaction with the assistant in various decision-making situations. These decision-making, especially stressful situations were examined in Navigation use-case (4.7) but evaluation of its scenarios showed that the set up is not very well designed for further study. Scenario describing the situation when the driver is standing in a wrong turning lane on a crossroad and trying to solve this error state by using the conversational assistant was too specific and for many participants hard to imagine. Furthermore, this situation in the real world would last only a few seconds and according to observation and feedback from participants, it would be difficult to perceive longer voice advice or make any conversation with the system. Next, in the second navigation scenario related to finding the right gas station was complicated to simulate real stress caused by having a lack of gas in laboratory conditions. Therefore, a new simulated messaging use-case was extended by suggesting route change in cases like a traffic jam or other problems on the road. Changing route according to traffic is a common feature in nowadays navigation apps, hence it should be more natural and easy for participants to imagine the situation.

Moreover, an interesting question can be asked. Do people want to be only puppets of navigation app or do they want actively control route changes? Here arises the possibility for a dialogue with the conversational assistant and decision making. Making a decision in these situations can be influenced by messaging or messaging can supplement the decision. It is important to remind that messaging is not meant using a mobile phone but using the conversational assistant to process and send a message or let the assistant proceed it fully autonomously.

5.1 Insights from the previous experiment and the following challenges

The past experiment brought several insights and challenges related to the use-case of route changing and messaging. For message-sending, the driving purpose was required but for participants, it was not natural to define it. This information is not important to be known in advance and dependent parameters such as recipients and context of the journey can be obtained during the conversation in case they are needed. This is followed by how much verbose or austere system should be. To make the system universal, it is important to find the right balance between these two states. Another insight is that the driver should control how much automatic message-sending is. Furthermore, valuable feedback to the driver could be confirmation of message delivery. Very noticeable problem was that participants did not know how to start a conversation with the assistant and felt insecure about it. Besides the fact they had almost no previous experience with voice control, they were forced to speak to 'no one'. This could be solved by adding some keyword in commands (e.g. system name) or placing a physical element in the car which would represent the conversational assistant. The element/object could also provide information about the system state which has been requested by the participants. The element could signalize system states such as 'listening', 'speaking', 'processing' or 'standing by' using different lights or symbols. How exactly this should be represented could be part of another study. For the following examination, it is sufficient to find out if this element could help drivers feel more comfortable when speaking to the assistant.

Some noticeable findings related to creating phrases used in conversation should be taken into account. Questions should not be asked in a way of possible yes or no answer when the system needs more detailed information. The question should be built in the most possible straightforward form and should be at the end of the utterance to avoid driver forgetting the question.

The focus on a discussion about route change is also supported by the fact the for some participants a little detour sometimes does not matter.

For a better illustration of how the conversational assistant may work in a designed situation, scenarios are used.

5.2 Scenario without using a conversational assistant (current situation)

Michael is a 63-year old owner of an electro-technics company. Every day he commutes by car to his office which is 30 kilometres far from his home. Although he knows the route very well, he uses car navigation with actual traffic information to avoid traffic jams because he usually goes back home during the rush hour. It is Thursday evening and Michael with his wife Anna has tickets to the evening show in a theatre. Michael is on the way back home but suddenly he noticed that car navigation is leading him to a different route than usual probably because of heavy traffic on the highway. The original estimated arrival time has been increased by ten minutes. Michael followed navigation but also the detour route was already full of cars and the estimated arrival time was increasing more and more. Michael began to doubt the efficiency of the detour route and started being nervous about reaching the evening show on time. Moreover, he wanted to let Anna know about the delay. Despite knowing that using a cellphone while driving is risky, he took his phone and dialled her number.

5.3 HTA without a conversational assistant

Plan 1: 1 – 2 – 3 – 4 – 4.1 – 4.2 – 4.3 – 4.5
Plan 2: 1 – 2 – 3 – 4 – 4.1 – 4.2 – 4.4 – 4.5
Plan 3: 1 – 2 – 3 – 4 – 4.1 – 4.6

All plans of HTA (see Fig. 14) show that driver does not control route change and follows a new direction of the navigation. When there is a delay, communication about it to someone else is done through a cell phone. The safest way is by using hands-free equipment, but the cellphone still has to be controlled to dial the number (Plan 1). Driving becomes more dangerous if hands-free equipment is not used (Plan 2) and the worst case for safety occurs when a driver writes a message during driving (Plan 3).

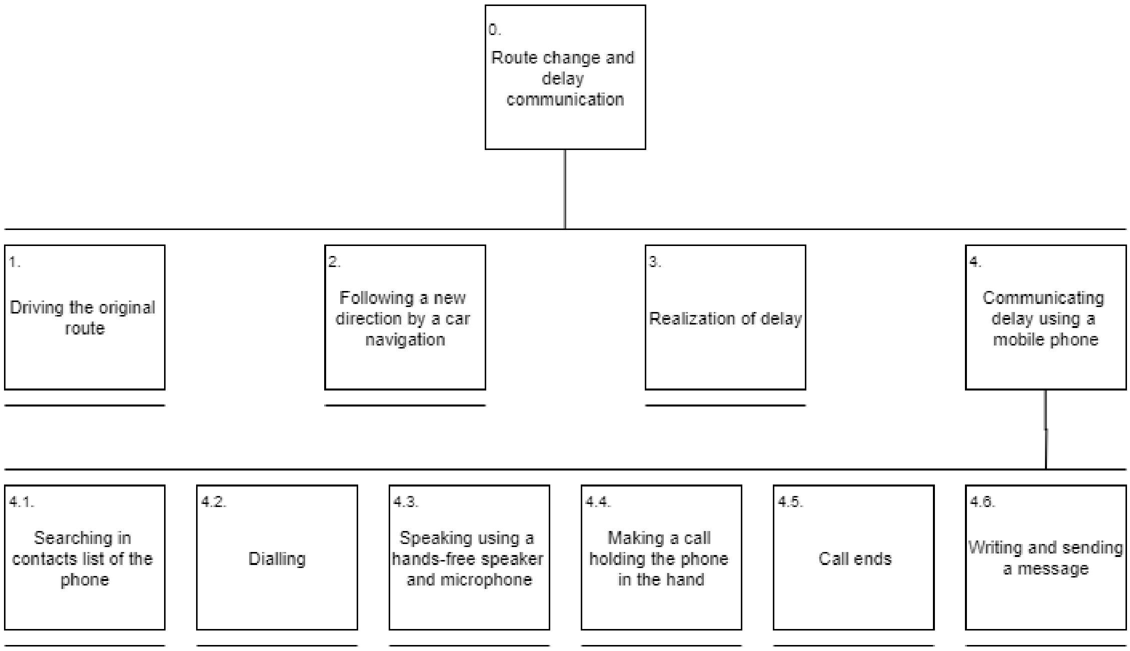


Figure 14 HTA without using a conversational assistant

5.4 Scenario 1 with using a conversational assistant

Emma is a 70-years old retired accountant. Despite the fact that she no longer works, she still lives very active and social life. Moreover, every year she attends a big reunion of her relatives and friends which is organized by her sister Alice. Emma is always excited about going there and seeing beloved people. The only inconvenience is that her sister lives around 100 kilometres far from Emma's hometown and the fastest way how to get there is going by car. That's not a big problem, Emma has got a car and used to drive a lot when she was younger but nowadays the traffic is heavier and faster than before so she is not that self-confident especially during this long ride. Luckily she is using navigation and conversational assistant in her car, which is convenient and easy to use. So when she is ready to go she sits in her car and tells the assistant her final destination, which is Alice's house. Emma also asks the assistant to inform her sister that she is about to go. The assistant said that the message to Alice was send and a few seconds later that it has been delivered. The assistant also asked if Emma wants to automatically inform Alice about the progress of the journey. 'Why not,' said Emma to herself and confirmed that to the assistant. Everything is ready, Emma sees the direction on the screen and starts driving. But after half an hour of driving the assistant announced that there is a traffic jam ahead due to the car accident. It suggested route change which is ten minutes slower than the original estimated arrival time but still faster than going through the traffic jam. Emma trusts the assistant and rather drives than stands in a traffic jam so she confirmed this change. The assistant also informed her that her sister received a message about the delay. A few minutes after the assistant informed Emma that Alice sent her a message: 'Everything is okay, we will wait for you with the cake. Drive safely! Alice.' Emma has become even more relaxed and enjoyed the rest of the journey to her sister and friends.

5.5 Scenario 2 with using a conversational assistant

Bob and his son Dan have a common hobby - fishing. Bob is retired and even though Dan is often busy with his job, every first Saturday of a month they manage to go fishing together and enjoy a peaceful time by the river. Bob uses his car to get to their place by the river. He used to be a good driver but he is not that active today and uses a car usually only for this trip. Before Bob starts driving he sets up his final destination to the navigation system. His car is also equipped by the conversational assistant. It asked him if he wanted to inform someone with a message that he is ready to go. Bob did not think it is necessary now so he rejected it and started driving. When he was driving on a highway, the assistant informed him that there is heavy traffic ahead which will cause a delay. At the same time, the assistant suggested another two routes with details such as names of cities and villages which will be passed by. Bob knows that these routes are zigzag and he does not like it. He will rather stay in a traffic jam for a while. So he rejected these detours and asked the assistant to inform his son about the delay.

5.6 HTA with a conversational assistant

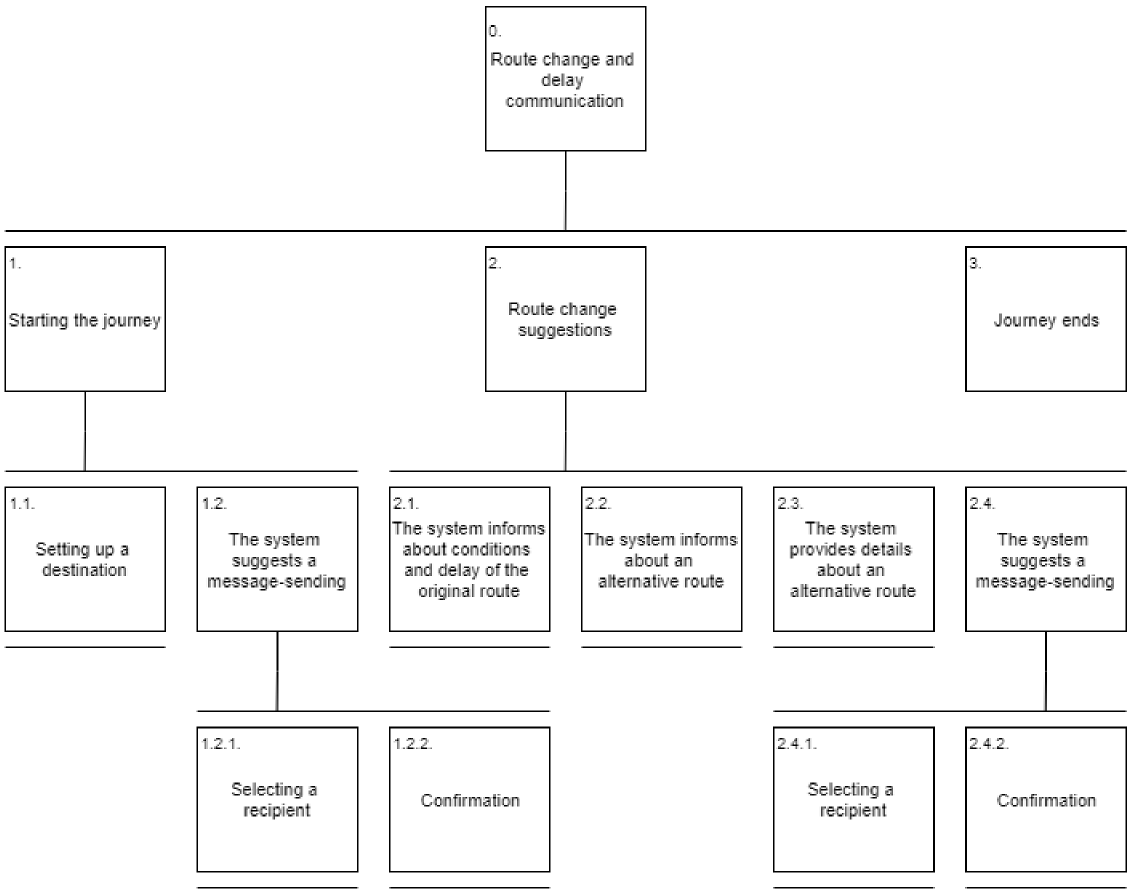


Figure 15 HTA with using a conversational assistant

Plan 1: 1. – 1.1 – 1.2 – 2 – 2.1 – 2.2 – 2.2.1 – 2.3 – 3
Plan 2: 1. – 1.1 – 1.2 – 1.2.1 – 1.2.2 – 2 – 2.1 – 2.2 – 2.2.1 – 2.3 – 3
Plan 3: 1. – 1.1 – 1.2 – 2 – 2.1 – 2.2 – 2.2.1 – 2.3 – 2.3.1 – 2.3.2 – 3
Plan 4: 1. – 1.1 – 1.2 – 1.2.1 – 1.2.2 – 2 – 2.1 – 2.2 – 2.2.1 – 2.3 – 2.3.1 – 2.3.2 – 3

5.7 Sketching

Following sketches of conversation try to make communication flow straightforward. Questions should be asked in a simple form with yes or no answer if it is possible to cover cases of the reticent driver. The system should not provide much information at one utterance to reduce the driver's workload and prevent forgetting parts of the information. When there would be a longer pause between interaction with the system, the system should announce its intent of speaking by playing a short sound to prepare the driver for listening.

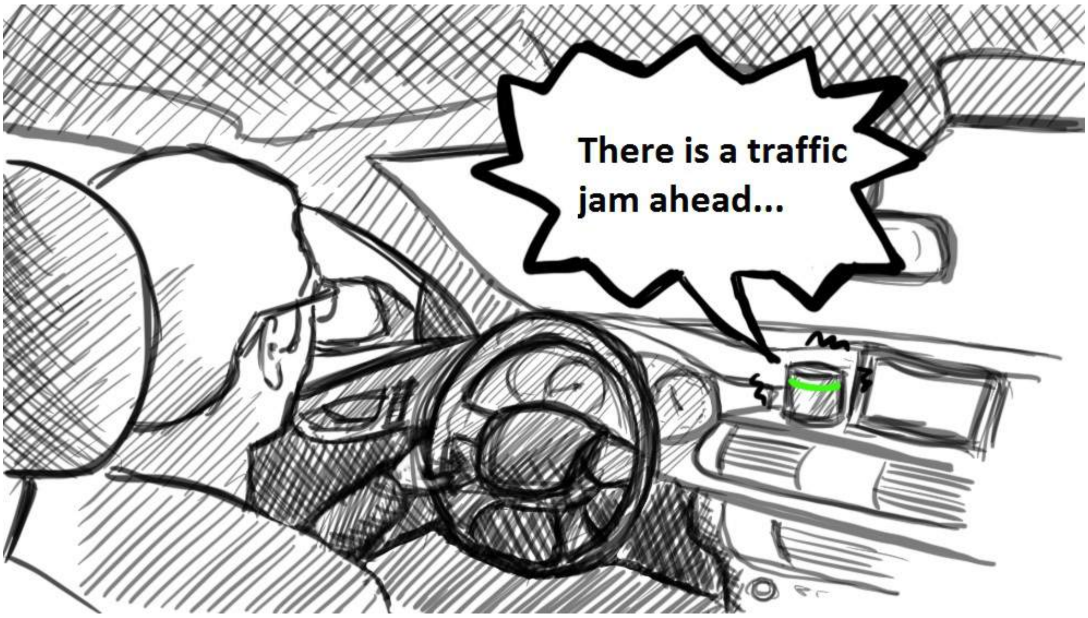


Figure 16 Sketch of communication between a driver and the conversational assistant

5.7.1 Use-case flow diagram

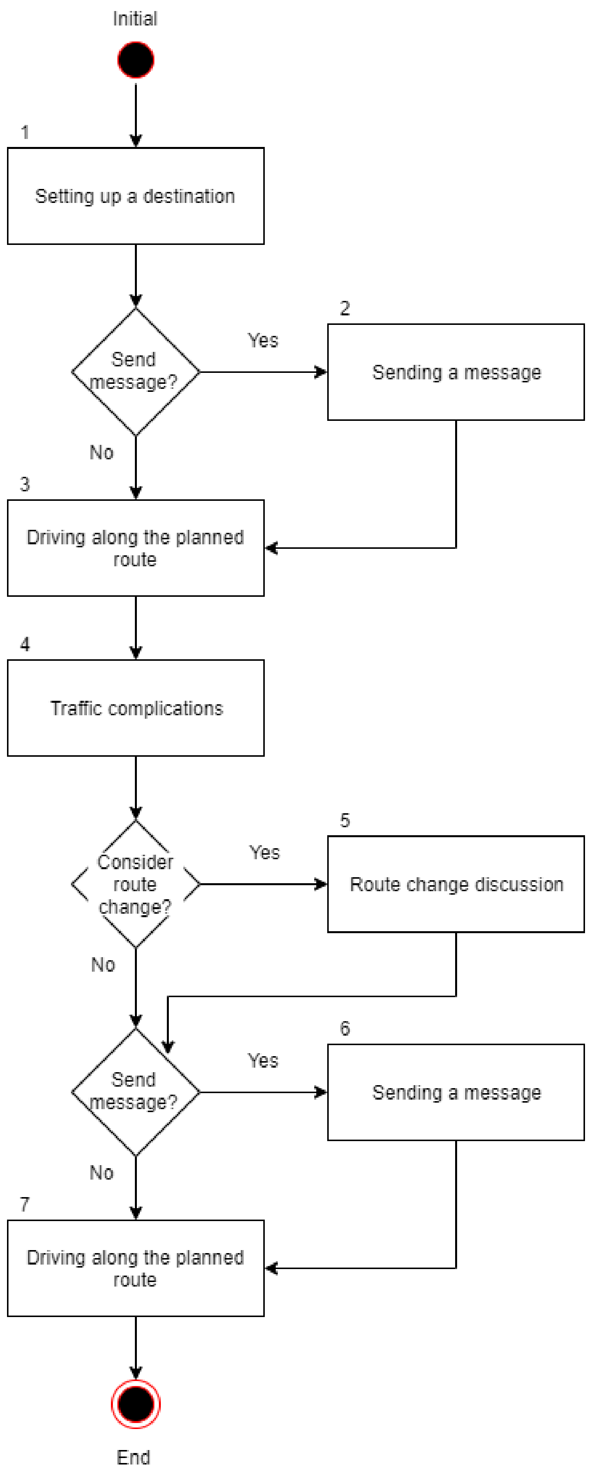


Figure 17 Diagram of the use-case flow

5.7.2 Initialization

The driver is sitting in a car, starting up car systems and navigation app. He/she is getting ready to start a journey.

5.7.3 Setting up a destination (1)

System:	Good morning. Please tell me your destination.
Driver:	Prague, Vinohradská 20.
System:	Okay. The destination is set to Vinohradská 20, Prague. Please follow the instruction on the screen
Driver:	Do you want to let someone know that you are ready to go?
System:	Yes.*

Table 10 Setting up a destination dialogue

* *if the answer is negative, the use-case will continue directly to 'Driving along the planned route (3)'*

5.7.4 Sending a message (2)

System:	Please tell me the name of the person you want to send a message.
Driver:	John.
System:	Do you mean John Snow, John Wick or someone else?
Driver:	John Wick.
System:	Okay. I'm sending a message to John Wick that you are ready to go
System:	The message about your departure was delivered to John Wick.

Table 11 Sending a message dialogue

5.7.5 Driving along the planned route (3)

The driver is driving according to instructions of the navigation app.

5.7.6 Traffic complications (4)

System:	There is a traffic jam ahead on a highway. Estimated delay is 15 minutes. Do you want to hear about alternative routes?
Driver:	Yes.*

Table 12 Traffic complications dialogue

* *if the answer is negative, the use-case will continue directly to 'Send message'*

5.7.7 Route change discussion (5)

System:	There are two alternative routes. First is with 8 minutes delay, second with 10 minutes delay. The continuing original route is with 15 minutes delay. Would you like to know more details about the routes?
Driver:	Tell me more details.
System:	The first alternative route has an estimated average speed of 70 km/h. The second alternative route has an estimated average speed of 60 km/h. Do you want to hear more details?
Driver:	Tell me more.
System:	The first alternative route has semi-heavy traffic. The second alternative route has low-traffic. Do you want to hear more details?
Driver:	Yes.
System:	The first alternative route is A-road. The second alternative route is B-road. Do you want to hear more details?
Driver:	Yes.
System:	The first alternative route goes through 4 towns, mostly countryside area. The second alternative route goes through 7 towns, mostly countryside area. Do you want to hear more details?
Driver:	Yes.
System:	The first alternative route has one gas station. The second alternative route has no gas station. Do you want to hear more details?
Driver:	No.
System:	Please tell me which route do you want to use. The first alternative route, second alternative route or continue the original route.
Driver:	I want to go along the first alternative route.
System:	Okay, the route will be changed to the first alternative route. Please follow the instruction on the screen.

Table 13 Route change discussion

The whole description of each alternative route is divided into smaller pieces of information to reduce the driver's workload. Moreover, it depends on the driver how much additional information he/she needs and will request to make a decision of selecting the route to continue. By sequentially giving only one property for each route at once, it should be easier for driver step by step compares the options.

This sketch shows a situation when the information is given to the driver according to his/her yes or no answers to straightforward questions. But the system would be also able to react to more complex answers such as ’Yes, tell me if there is any restaurant along the route’ instead of a simple ’Yes’.

5.7.8 Message-sending suggestion

System:	Do you want to send information about the delay to John Wick?
Driver:	Yes.*

Table 14 Message-sending suggestion dialogue

* *if the answer is negative, the use-case will continue directly to ’Driving along the planned route (7)’*

5.7.9 Sending a message (6)

System:	Okay. I’m sending a message to John Wick about the route change and delay.
System:	The message about the delay was delivered to John Wick.

Table 15 Sending a message dialogue

5.7.10 Driving along the planned route (7)

System:	You have received the following text message from John Wick. ’It’s okay. Don’t be in a hurry, I’ll wait for you.’

Table 16 Driving along the planned route

6 Qualitative study – second iteration

This chapter deals with the experiment conducted to evaluate the second design of the conversational assistant related to the use-case described in the previous chapter.

6.1 Target group

The target group was the same as for the first experiment – former or active drivers over 60 years old. Therefore it was not necessary to have a currently valid driving licence but the driving experience was required. For this qualitative testing, 10 participants were recruited according to a screener. The screener is a questionnaire used for choosing suitable participants who meet the criteria for the target group. The screener can be found in appendix B.

6.2 Environment

The study was conducted in a lab environment of Czech Technical University in Prague at the Faculty of Transportation. The room was equipped with car skeleton with front seats, functional dashboard, steering wheel and pedals, see Fig. 18b. Skeleton was surrounded by three screens to display front and both side views to the driver. While the participant was driving, the moderator was sitting in the back of the room. Therefore participant was not disturbed by the moderator presence and the moderator could easily see simulation visualisation and control conversational assistant interface according to the participant's interaction. In the same room pre-test and post-test interviews were conducted, see Fig. 18a.

6.3 Driving simulation

Visualization of driving simulation allows showing directional arrows on the screen at each intersection. For this experiment, the cyclic route was designed in one of the default maps, see Fig. 19. Therefore, there was not a big need to control or synchronize progress of driving with the conversational assistant and moderator's full attention could be paid to the interaction with the driver through the conversational assistant.

a) The lab

b) Vehicle interior

c) Front view with the conversational assistant device on central dashboard

Figure 18 Vehicle simulator lab

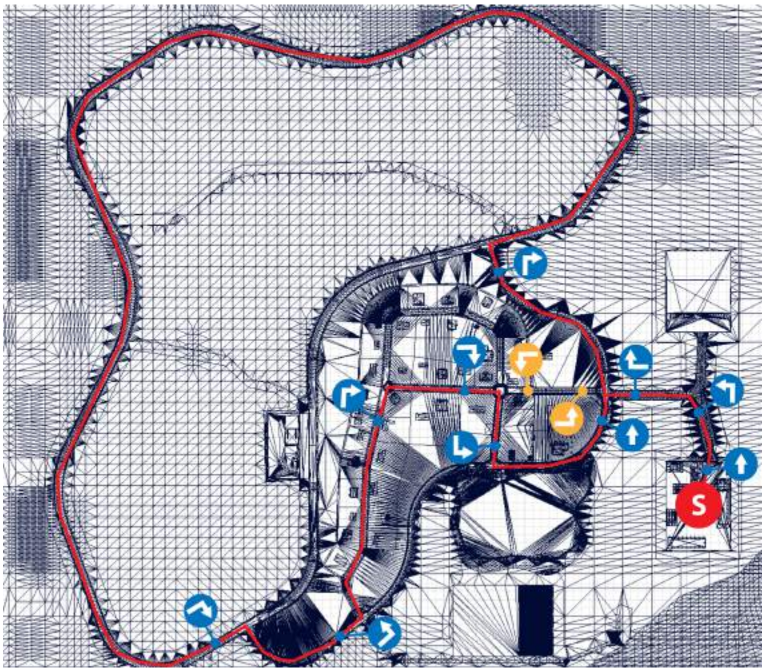


Figure 19 Designed route

Figure 20 Simulation environment

6.4 Secondary task

The secondary task was controlling navigation, especially route change, and message-sending using the conversational assistant. The conversational assistant was represented by a Bluetooth speaker placed on the central part of the dashboard, see Fig. 18c. This should help the driver to feel more comfortable when listening to something from a specific position and speaking to a specific direction instead of communicating with ambient voice. Simulation of assistant communication was performed using the Wizard of Oz technique as in the previous experiment (section 4.5). Moderator was reacting to the participant's interaction and played pre-recorded phrases using a previously prepared web interface, see Fig 21.

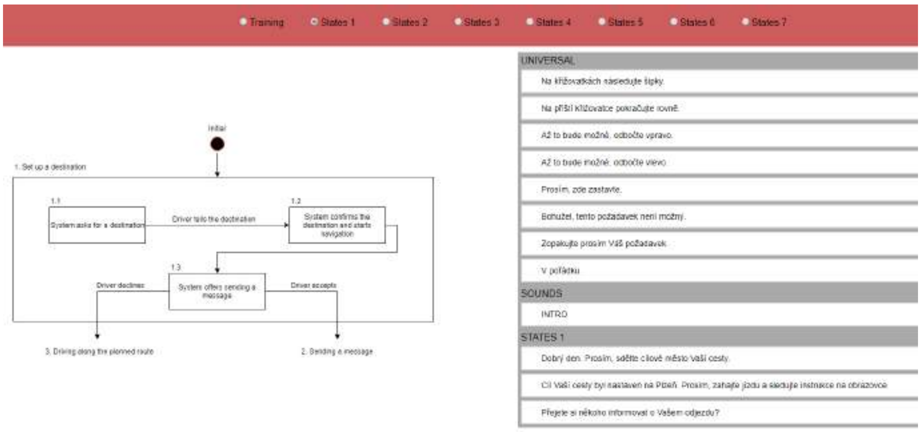


Figure 21 Created web application for dialogue management

6.5 Method

For the experiment executing, the qualitative method was used. This method provides insight and the detailed description which allows the formulation of the hypothesis for the future qualitative testing and evaluation. Qualitative evaluation of this experiment was done by observation and post-interviews with participants after testing sessions. Moreover, the System Usability Scale (SUS) questionnaire for measuring perceptions of the usability was used which allows comparing the usability to other designs evaluated with this method. The SUS was created by John Brooke in 1986 and since then it has become an industry standard with references in over 600 publications. The SUS questionnaire consists of 10 statements, participant expresses consent rate using the Likert scale (1 - Strongly disagree, 2 - Disagree, 3 - Do not know, 4 - Agree, 5 - Strongly agree). These responses are evaluated and the SUS score is determined. [9]

6.6 Use-case

6.6.1 Subject of study

The main purpose of examining the following use-case was to find out if participants will be able to adjust navigation to their needs and wishes in situations when a navigation app is reacting to unforeseen traffic density or trouble. In addition, question if it is even worth it for drivers to manage this situation could be asked. The suggestion is that drivers maybe want to manage the route change but they do not know how to do it. Therefore, they blindly follow the instructions given by the navigation app with uncomfortable feelings such as not knowing where exactly the road leads, its conditions etc.

The ability to discuss the route change was tested in the scenario, where the system actively informed the driver about the possibility of alternative routes and providing details. Using the proactive approach of a conversational assistant is supported by the results of the study [21] where authors examined proactive personal assistant's behaviour which was favoured by the participants and rated as a good added value.

Messaging task in this experiment was present but fulfilled a complementary role. There was not much space to control the message-sending process, the driver only decided if an informative message about a specific event should be sent and to whom it may concern. The driver did not know how the message is exactly formulated and there was not a possibility to modify the text of the message. In the previous experiment reactions to the message-sending feature was highly positive and feedback also brought the suggestion to make it more autonomous. Therefore, the goal for the message-sending case was to find out how it will be perceived by other participants and if the provided information and the lower level of interaction is sufficient for them.

Last but not least, an important observation was how much are drivers distracted by the conversation with the system, if they feel comfortable using it and if they find it helpful.

To sum up, in relation to the designed system, the following questions should be answered:
Do the drivers appreciate a discussion about the route change?
Will the drivers be able to adjust navigation to their needs and satisfaction?
Do the drivers appreciate the level of autonomous behaviour of the message-sending feature?
How much are drivers distracted by the conversation with the system?
Do the drivers feel more comfortable using the conversational assistant in these situations?

6.6.2 Surrounding scenario

The driver is going to visit his/her relatives at the family reunion. It takes part in a city which is approximately 100 km far from the driver's home. He/she is starting the journey with setting up the navigation app using the conversational assistant which is active during the whole trip. The assistant offers to send messages regarding the progress of the journey. The assistant also informs about traffic jam and the driver should solve the situation of route changing with the assistant according to the driver's specific preferences for the driving (a favourite type of the road, average speed etc.)

6.6.3 Dialogue state diagram

The dialogue state diagram shows the states of the conversational assistant during the journey related to use-case flow, see Fig. 17.

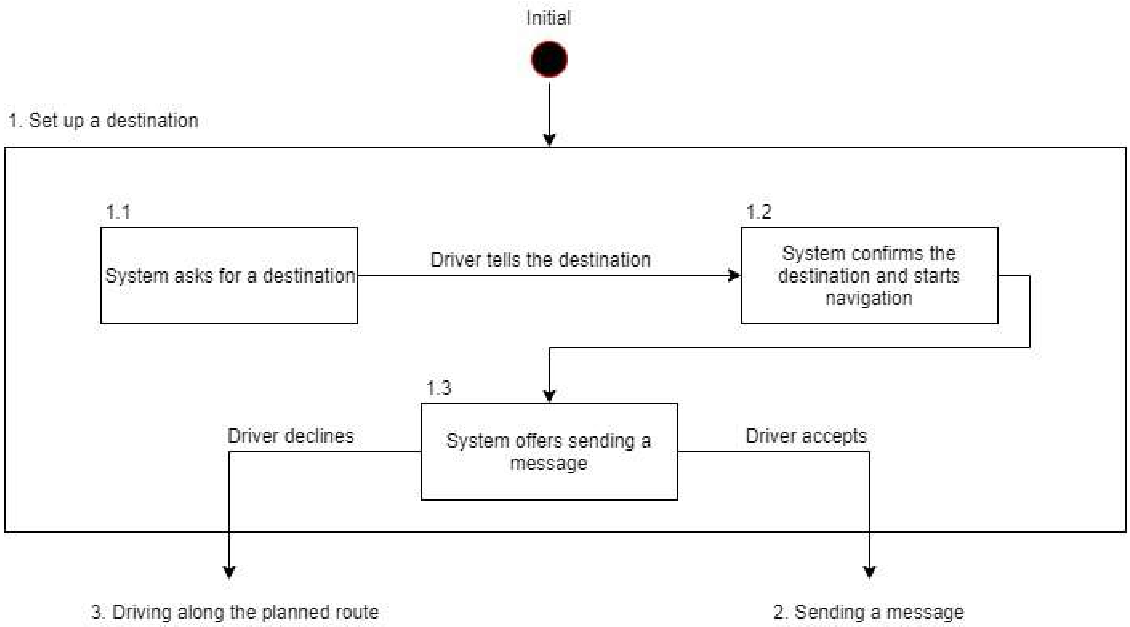


Figure 22 Dialogue state 1: *Set up a destination*

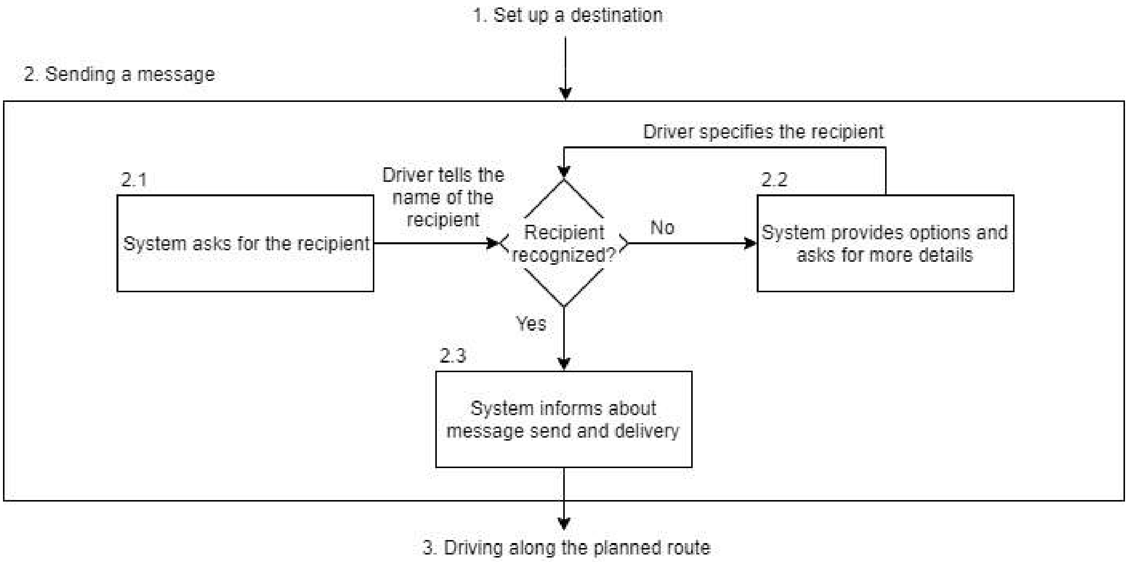


Figure 23 Dialogue state 2: *Sending a message*

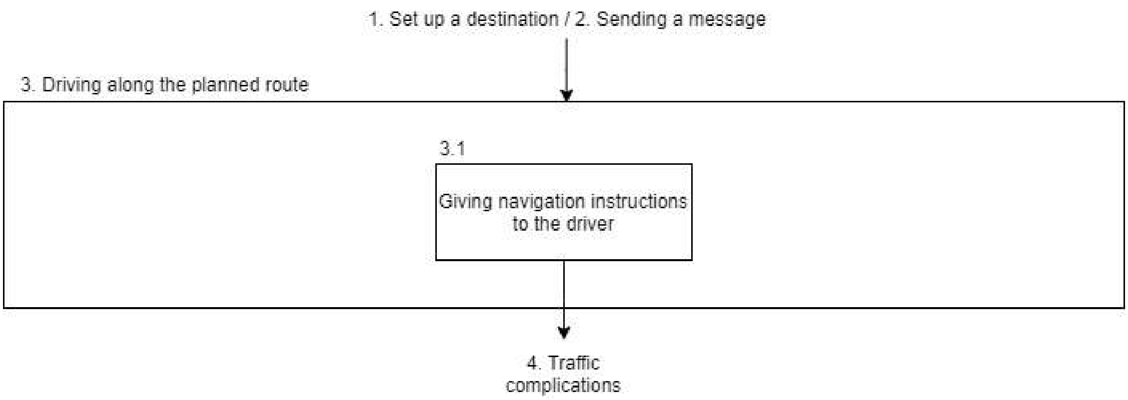


Figure 24 Dialogue state 3: *Driving along the planned route*

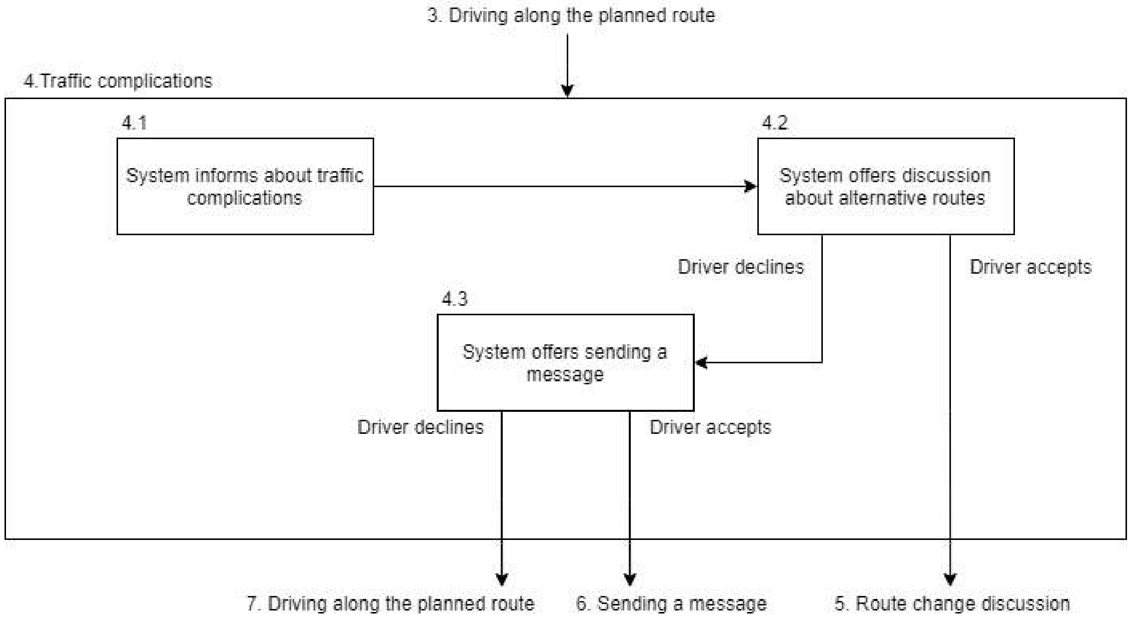


Figure 25 Dialogue state 4: *Traffic complications*

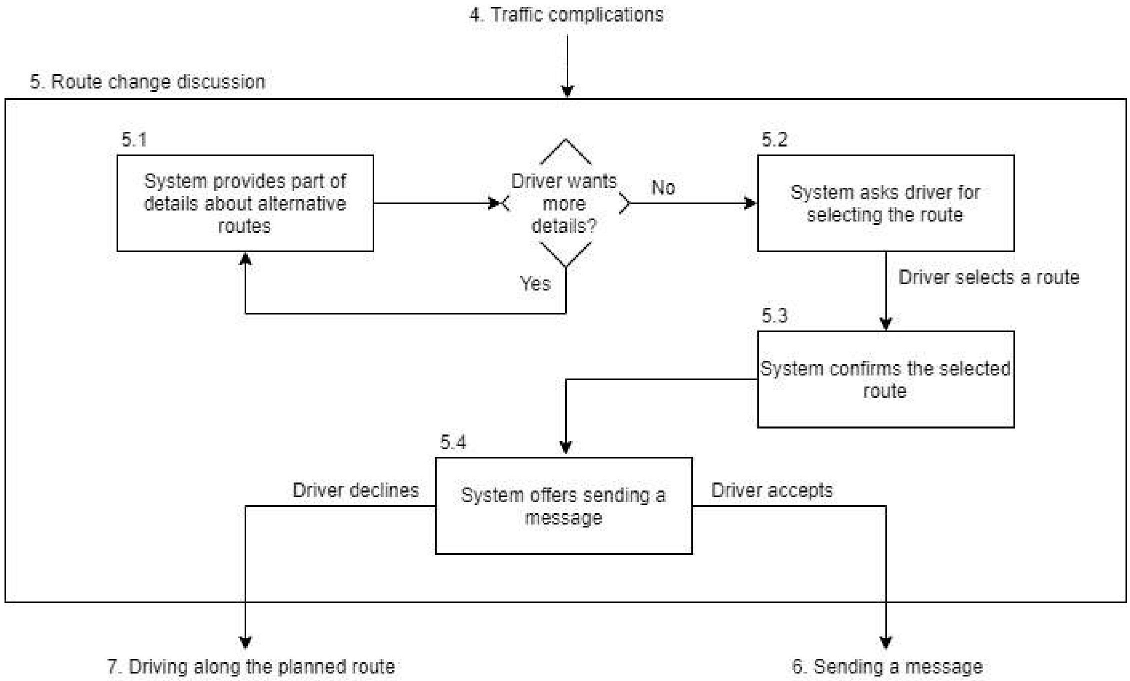


Figure 26 Dialogue state 5: *Route change discussion*

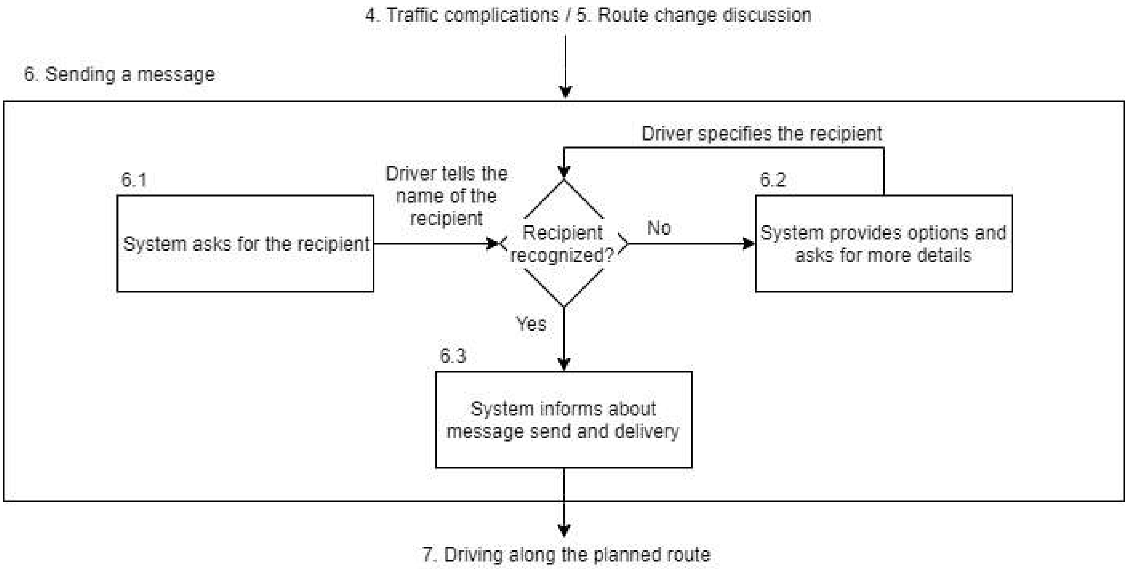


Figure 27 Dialogue state 6: *Sending a message*

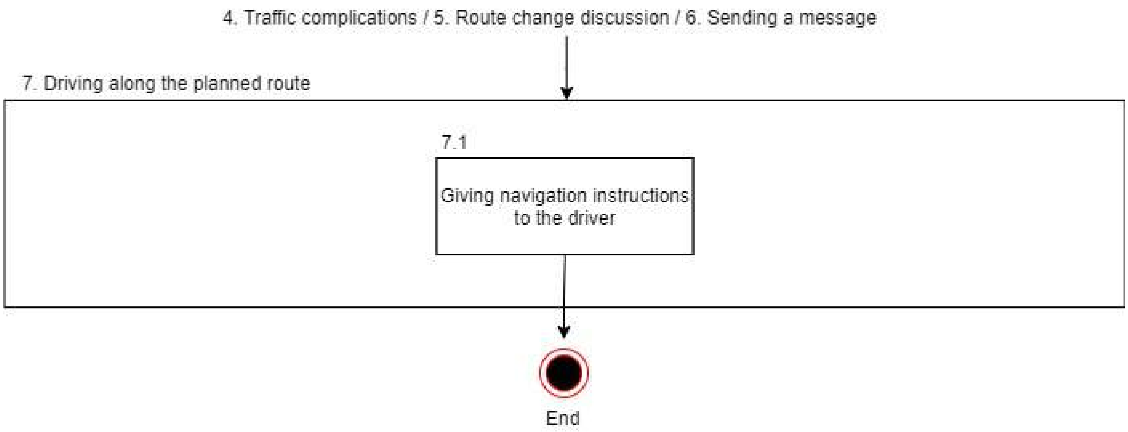


Figure 28 Dialogue state 7: *Driving along the planned route*

6.6.4 Assistant's phrases

Each state of the conversational assistant had prepared phrases for the dialogue in the examined use-case.

State 1.1	Good morning. Please tell me your destination.
State 1.2	Okay. The destination has been set to [destination]. Please follow the instructions on the screen.
State 1.3	Do you want to let someone know that you are ready to go?

Table 17 State 1: *Set up a destination*

State 2.1	Please tell me the name of the person you want to send a message.
State 2.2	Do you mean John Snow, John Wick* or someone else? **system offers most used or first contacts related to a given name*
State 2.3a	Okay. I'm sending a message to John Wick that you are ready to go.
State 2.3b	The message about your departure was delivered to John Wick.

Table 18 State 2: *Sending a message*

State 3.1	The driver is following instructions on the screen.

Table 19 State 3: *Driving along the planned route*

State 4.1	There is a traffic jam ahead on a highway. The route has been recalculated. The new estimated arrival time is with 8 minutes delay.
State 4.2	Do you want to hear about alternative routes?
State 4.3	Do you want to send information about the delay to someone?

Table 20 State 4: *Traffic complications*

State 5.1a	There are two alternative routes. First is with 8 minutes delay, second with 10 minutes delay. The continuing original route is with 15 minutes delay. Would you like to know more details about the routes?
State 5.1b	The first alternative route has an estimated average speed of 70 km/h. The second alternative route has an estimated average speed of 60 km/h. Do you want to hear more details?
State 5.1c	The first alternative route has semi-heavy traffic. The second alternative route has low-traffic. Do you want to hear more details?
State 5.1d	The first alternative route is A-road. The second alternative route is B-road. Do you want to hear more details?
State 5.1e	The first alternative route goes through 4 towns, mostly countryside area. The second alternative route goes through 7 towns, mostly countryside area. Do you want to hear more details?
State 5.1f	The first alternative route has one gas station. The second alternative route has no gas station. Do you want to hear more details?
State 5.2	Please tell me which route do you want to use. The first alternative route, second alternative route or continue the original route.

State 5.3a	Okay, the route will be changed to the first alternative route. Please follow the instruction on the screen.
State 5.3b	Okay, the route will be changed to the second alternative route. Please follow the instruction on the screen.
State 5.3c	Okay, the route will not be changed and you will continue the original route. Please follow the instruction on the screen.
State 5.4	Do you want to send information about the delay to someone?

Table 21 State 5: *Route change discussion*

State 6.1	Do you want to send information about the delay to John Wick or someone else?
State 6.2	Do you mean John Snow, John Wick* or someone else? **system offers most used or first contacts related to a given name*
State 6.3a	Okay. I'm sending a message about the delay to John Wick.
State 6.3b	The message about the delay was delivered to John Wick.
	State 6.3b can be followed by a received message from John Wick. 'It's okay. Don't be in a hurry, We'll wait for you.'

Table 22 State 6: *Sending a message*

State 7.1	The driver is following instructions on the screen.

Table 23 State 7: *Driving along the planned route*

As mentioned earlier, when the assistant is going to start speaking after a long pause, it is announced by playing a short tone to prepare the driver for listening.

6.7 Experiment setup and procedure

6.7.1 Equipment

1. PC/laptop for the moderator to control the conversational assistant interaction
2. Bluetooth speaker for playing conversational assistant phrases and simulating physical modulo on a dashboard
3. Audio-recording device to record the session

6.7.2 Before test

The participant was notified that the session is being recorded and he or she has been asked to agree with informed consent. Informed consent describes the rights of the participant and how his or her personal data will be handled. The participant was acquainted with the purpose of research, interaction with the conversational assistant and the driving simulation.

6.7.3 Pre-test interview

Before every session, pre-test interview was done to get the basic knowledge about the participant. It supplements demographic information about participant obtained using the Screener which is a short questionnaire distributed to potential participants during the recruitment (can be found in appendix B). The following questions in the pre-test interview were considered.

Q1: How often participant drives?
Q2: Does the participant have any visual impairment?
Q3: Does the participant have any experience with infotainment?
Q4: Does the participant have any experience with a voice interface?

6.7.4 Simulation

The simulation itself was done in the following way. The participant was sitting in the car simulator, drove along the route and followed navigation arrows in the visualization. The moderator was sitting outside the car skeleton and controlled conversational assistant's behaviour through the web app according to the participant communication with the assistant (see the Wizard of Oz section 4.5). The assistant's utterances were played from a Bluetooth speaker placed on a dashboard in the car.

6.7.5 Training

Prior to testing conversational assistant in a designed scenario, the participant had ten to fifteen minutes to get to use to driving in the car simulator at the training route. During this training conversational assistant interaction was presented to the participant so he or she could get more familiar with it. When the participant was confident with car simulation and understood how conversational assistant works, the session moved to testing the assistant in the surrounding scenario.

Here is an example of a training conversation with the assistant:

System:	**intro sound** Good morning. Please follow the navigation arrows on the screen when arriving at a crossroad.
	**pause in the interaction, the driver is driving and following instructions on the screen*
System:	**intro sound** Would you like to listen to the radio?
Driver:	Yes.
System:	**plays radio**
	**pause in the interaction, the driver is driving and following instructions on the screen*

System:	**intro sound** Do you feel tired?
Driver:	No.
	**pause in the interaction, the driver is driving and following instructions on the screen*
System:	**intro sound** Please, stop the car here.

Table 24 An example of a training conversation with the assistant

6.7.6 Executing scenario

Before the main testing of the prototype of the conversational assistant in the designed scenario, moderator described the situation of the scenario to the participant and asked if he/she could get into this situation:

The participant is going by his/her car to a family reunion in Pilsen (city). This reunion is organized by Jan Svoboda who is very caring for the participant because there is a long journey ahead of him/her. Therefore, Jan would appreciate if the participant could let him know about the progress of the journey.

The moderator also informed the participant that conversational assistant could help with some traffic complications during the journey. The participant was asked to behave in the same way he or she does in the real world in the case of some decision-making point. The scenario has begun with the interaction of the conversational assistant.

After passing through the dialogue system states, the moderator prompted the participant to stop.

6.7.7 Post-test interview

When the simulation was ended, the moderator conducted a post-test interview with the participant. The following questions in the post-test interview were considered:

Q1: What is your first impression?
Q2: Is there something you like or dislike in the dialogue?
Q3: How do you rate the discussion about changing the route? (Was the information provided sufficient for you? Did you finally choose the way you wanted?)
Q4: Is it important for you to decide which route will you use?
Q5: How do you rate the sending of informational messages? (Was the information provided sufficient for you?)
Q6: How was it for you to drive and communicate with the assistant at the same time?
Q7: Can you imagine using the assistant this way in your car?

6.7.8 System Usability Scale (SUS)

The post-test interview was followed by the System Usability Scale questionnaire consisting of ten statements. The participant had to decide how much he/she agree or disagree with each of these statements:

1. I think that I would like to use this system frequently.

2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

For the expression of acceptance the statement, the Likert scale was used (1 - Strongly disagree, 2 - Disagree, 3 - Do not know, 4 - Agree, 5 - Strongly agree).

6.7.9 After test

After the session, the moderator thanked the participant for his/her participation and in an informal interview asked for any observations, comments and suggestions of the participant.

6.8 Evaluation

6.8.1 Participants overview

Ten participants were recruited. They were aged from 62 to 79 (mean = 72, SD = 4.52), five women, five men.

Participant ID	Age	Gender	Active driver	Infotainment experience	Voice control experi-ence
P01	75	male	no	no	no
P02	79	female	no	yes	no
P03	72	female	yes	no	no
P04	75	male	yes	no	no
P05	74	male	yes	yes	no
P06	70	female	yes	yes	no
P07	62	female	yes	yes	no
P08	70	female	no	yes	no
P09	73	male	yes	yes	no
P10	70	male	yes	yes	yes

Table 25 Information about participants

6.8.2 Insights

Participant 01

The participant was a 75-year-old man without any experience with advanced infotainment systems or voice control. He was not used to talking during driving but appreciate the voice control because he did not have to look off the road to any display at the central panel. It was not hard for him to communicate because the dialogue was brief and he did not feel distracted from driving. In the discussion about the route change, he chose the detour immediately when the first information about the time delay was spoken. The reason behind was that the participant did not want to talk too much and could not imagine which other information he could get. Therefore, this was the easiest way how to deal with the situation. He was a little bit confused with the possibility of 'inform someone' that he is about to start the journey, he did not associate it with message-sending. The participant did not use message-sending when the delay had occurred because 15-minutes delay is not that serious for him. But he would use it in case the delay was longer. It is not so important for him to decide which route he should use, especially when he is not in a familiar area he would appreciate straightforward help including information about traffic signs, so he could fully focus on driving. The most important thing for him is system reliability.

Participant 02

The participant was a 79-year-old woman. She stopped driving a car a few years ago. She used to use car navigation for the trips she went for the first time. She had no voice control experience. The participant did not have problems with communicating during driving and did not feel distracted. She fully trusted the navigation app and did not have a need to discuss the route change if the system/co-driver told her where to go. On the other hand, if the delay caused by traffic jam would not be so long, she would rather continue the original route instead of using any detour. As well as she would use message-sending possibility according to a length of delay and purpose of her journey (the difference between going to a business meeting and trip).

Participant 03

The participant was a 72-year-old woman without any experience with advanced infotainment systems (including car navigation) or voice control. She felt a little bit distracted at the beginning with the conversation because she was not used to it. She appreciated that the dialogue was brief. When there was a discussion about the route change due to the traffic jam, she only used information about the time delay and average speed because she estimated the other parameters the detour could have and she was satisfied with this option. She expected B-road which is road type she was used to. She prefered the fastest route and rather decided where to go by herself. She could imagine using the conversational assistant on the routes she already knows, only for help in cases something unexpected happened. The participant rated message-sending positively and the provided information were sufficient for her. Sending a message about the delay was not necessary for her because she did not consider the delay significant.

Participant 04

The participant was a 75-year-old man without any experience with advanced infotainment systems (including car navigation) or voice control. He found the dialogue easy to follow. In the route change discussion, he was interested in the cities the detours went through. He would choose the one he knew. It is important for him to decide which route he would use but he could also accept advice from someone else (system/co-driver). The participant found the message-sending useful but he did not consider delay significant for letting someone know about it.

Participant 05

The participant was a 74-year-old man who drives every day. He uses an external navigation device or smartphone with a navigation app. He did not have any experience with voice control, but he knew about this possibility of control in his navigation device. He found the communication and utterances of conversational assistant very clear and intelligible. The participant emphasized the importance of voice colour, intonation and volume. Information about route change was sufficient for him, the time of delay was more important than extra distance for him. The quality of the road was another parameter for him to make a decision. He does not like when the system is too verbose and a driver is overwhelmed with information. The participant perceived message-sending positively and found it safe thanks to the voice control and almost fully automatic process. He did not find the delay significant to inform someone. It depends on the ratio between the total time of the journey and the time of a delay. The participant found the conversational assistant useful and could imagine using it in his own car. He mostly follows the instruction given by the navigation device/app.

Participant 06

The participant was a 70-year-old woman who is an experienced driver. She uses car navigation and because she needs to be fully concentrated on driving, she only listens to voice commands of the navigation device. However, she does not have any experience in conversation with an artificial system. She found interaction with the designed conversational assistant pleasant and did not feel distracted because the utterances were brief. Nevertheless, she would like to communicate with the assistant more but did not feel it was possible. In the route change discussion, time of delay and route quality was most important for her. She also mentioned that the purpose of the journey takes part in decision making. She would not mind being late if she is not in a hurry (e.g. trip to somewhere). The participant appreciated sending informative messages because she is a caring person and found it useful. The amount of information provided was sufficient for her but she would be glad if she could send the message by her own intent, too. The conversation with the system was not disturbing for her, she is used to talking in a car and she could imagine using the conversational assistant in her own car. The participant usually drives according to commands of a navigation app.

Participant 07

The participant was a 62-year-old woman who drives for ten years but not very often. She uses a navigation app only when she is not familiar with the route but she feels safer when she can drive with more experienced co-driver when going somewhere for the first time. She perceived conversational assistant positively, she did not mind talking while driving and did not feel disturbed. She thought that dialogue was easy to understand. In the alternative route discussion, she was curious about what information she could get. She chose the route, she perceived being ideal for her - better road and fewer cities. However, she admitted that it depends on the purpose of the journey. She would not mind going through the villages if she was making a trip. The participant would also appreciate information about interesting places along the route. She was excited about the message-sending because the assistant asked her so she did not have to think about it. Moreover, she liked that she did not have to write the message on her own because the assistant did it automatically. The participant could imagine using the conversational assistant in her car, especially when something is wrong to calm her down and help her solve the situation. Choosing the route she wants is important for her, she would prefer a longer but more comfortable route for her when she is not in a hurry.

Participant 08

The participant was a 70-year old woman, she had experience with navigation device but only as a co-driver (setting up for her husband), she never used it while driving. She had no experience with voice control. In the discussion, the participant needed only two information (delay time and average speed) to make a decision. She deduced that the traffic on selected detour would be smooth. She also admitted that she thought it is necessary to make the decision quickly to not to miss a turning on the road. The participant also mentioned that the purpose of the journey is important for making a decision. It was important for her to use the route where she would feel comfortable and she also felt more confident when she knew the route's characteristics in advance. She appreciated message-sending, especially that she did not have to do it manually. System feedback and the reply she received were very important for her. She also suggested making a direct call because she is familiar with using a hands-free headset. The participant found the conversational assistant useful, not disturbing and she could imagine using it in her car giving her some advice.

Participant 09

The participant was a 73-year-old man who drives every day. He has been using a navigation device since the beginning of this technology. He uses navigation only for unknown routes, his wife usually helps with setting up the destination on the device. The participant had no experience with voice control. The participant appreciated help from the conversational assistant and message-sending functionality. In the discussion about alternative routes, he chose the one with a lower average speed because he wanted to feel safer and drive slower. He liked that the information provided was specific so he could easily imagine the route characteristics and did not have to stop to check it on the map. He also mentioned that the purpose of the journey takes part in his decision. When he is in a hurry, he would choose a highway, when making a trip, he would choose a comfortable route with interesting places around. In case of informing someone about the delay, it depends on how big the delay is. He could imagine making a direct call in this situation, too. The participant found the conversational assistant easy to use and not disturbing. It is important for him to know details about the routes and have the possibility to choose. He could imagine using the conversational assistant in his car, especially during long trips. He would also appreciate if the assistant could help him to stay alert or notice new or special traffic signs.

Participant 10

The participant was a 70-year-old man, an active driver who drives almost every day. He uses a hands-free headset in his car and navigation device also when he knows the route because he wants to know the arrival time to the destination. The participant tried voice control previously in his life but he did not find it reliable. He appreciated the information provided during the alternative routes discussion because he usually wants to know the details about the route. He often checks the route characteristics before he starts driving. The participant liked the message-sending possibility because he also informs relatives in real life. He suggested making a direct call or message dictation, too. In case of delay it depends on the purpose of the journey, he would like to know if there is a delay time in the automatic message. The participant could imagine using the conversational assistant in his own car, he did not feel distracted and liked the reliability of the assistant - he did not have to repeat the commands. He found assistant easy to use and saw potential in controlling complex things with easy commands if the assistant would work in the context of the whole situation.

6.8.3 SUS evaluation

The SUS questionnaire for each participant was evaluated in the following way. Numeric values of answers for odd items in the questionnaire were subtracted by one. For even-numbered items, user responses were subtracted from 5. This scaled all values from 0 to 4 (4 is the most positive response). The sum of this value was multiplied by 2,5 to get a score at range 0-100. [9]

Participant ID	01	02	03	04	05	06	07	08	09	10
SUS score	80	80	85	80	70	92,5	100	95	85	82,5

Table 26 SUS score

According to Jeff Sauro, who reviewed the existing research on SUS and analyzed data from over 5000 users across 500 different evaluations, the average SUS score is 68. [22] The resulting SUS scores were min = 70, max = 100, mean = 85, SD = 8,74. The SUS scores indicate that overall usability for the conversational assistant was high, according to the study [22] the raw mean score 85 converts to a percentile rank of 90 % which means that the assistant has higher perceived usability than 90 % of all products tested with this method.

6.8.4 Summary

In the experiment design, key questions were asked. Following answers are based on observation during the experiment and interviews with participants.

Do the drivers appreciate a discussion about route change?

For most of the participants, it is natural to follow the navigation instructions given by co-driver or a navigation device, especially when they are not familiar with the route. On the other hand, they feel more comfortable if they know the details about the route in advance (delay, road quality, traffic level, cities etc.) and if they can adjust the navigation to their needs. Therefore, the discussion about route change was perceived positively.

Will the drivers be able to adjust navigation to their needs and satisfaction?

In general, participants were able to adjust the navigation to their needs. Typically, they only asked for two kinds of details which they used to make a decision. It was enough for them or they estimated the overall characteristic of the route according to the given details. The reason why participants did not ask more was that they were thinking there was not much time to make a decision. Participants often mentioned that the purpose of the journey is important when choosing the route.

Do the drivers appreciate the level of autonomous behaviour of the message-sending feature?

The message-sending feature was highly appreciated among all participants. They liked the pro-active approach and autonomous behaviour which was not distracting for driving. Some of them would also appreciate initiate message-sending by themselves (and dictating the text of a message).

How much are drivers distracted by the conversation with the system?

Participants did not feel distracted when communicating with the assistant. They consider dialogue brief, intelligible and easy to follow.

Do the drivers feel more comfortable using the conversational assistant in these situations?

All the participants found the conversational assistant useful and most of them could imagine using it in presented situations. Most of the participants appreciate the brief and austere conversation. However, the attention should be paid to a personalization of the conversational assistant because the preferred level of verbosity could differ for each driver.

7 Final design

This chapter deals with the final design determined from the two conducted experiments, findings and insights they have brought. The design describes an abstract implementation, behaviour of the conversational interface and properties it should have.

7.1 Implementation

The overview of how conversational interface would work is described by Fig. 29. The key feature is knowledge of the User's Preferences (UP) which allows personalization of the conversational assistant and also affects the Route Context (RC). These two properties (UP and RC) are used by abilities provided by the Conversational Assistant (CA), see Fig. 31. The main program procedure and examined abilities are described by pseudo-code, see Listing 1, 2, 3.

7.2 Properties

The speech of conversational assistant should be intelligible and easy to understand. Sufficient volume is important, too. The state of the conversational assistant (listening, processing, standing by etc.) should be shown (for example by using colour lights). Furthermore, speaking of the conversational assistant is announced by playing a short tone to prepare the user for listening.

Two beneficial abilities of conversational assistant were derived and examined in this study – Route adjustment in Navigation and Message-sending. As mentioned earlier, the behaviour and abilities of the conversational assistant are strongly affected by the user preferences and context of the route. The User's Preferences, especially personalization, is a complex problem and it was not subject examined in this study. However, the necessity of personalization was a key finding of this study. Route Context includes data obtained from the user, journey details, car state and external information. Attributes of Route Context are used as parameters for the functionality of abilities in the conversational assistant. Especially the driving purpose is the essential attribute for the route adjustment in Navigation ability and as well as in the Message-sending ability. Moreover, each ability handles its own context for more precise and specific behaviour and to save its state for being easily resumed after interrupted.

7.3 Physical appearance

The target group having mostly no voice control experience hence the physical representation of the conversational assistant is important so the users do not have to talk to something ambient. There is no necessity to have a complex physical device with the functionality of the conversational assistant, the representation is only for the psychological need but the implementation could be done somewhere else. The fact that all interaction with the interface could be done only by voice commands was highly appreciated during the study. Safer driving behaviour was emphasized. Therefore, there is no need of physical interaction in the examined use-cases.

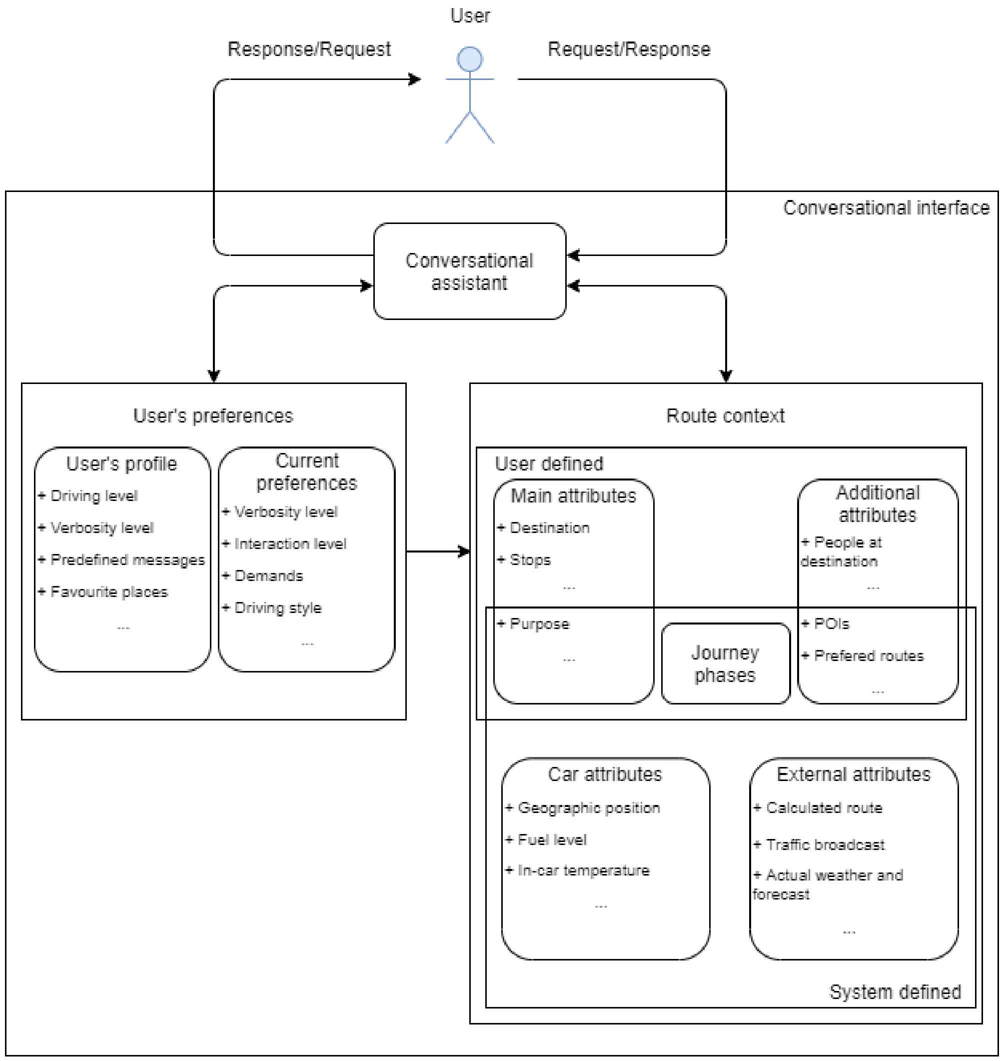


Figure 29 Overview of the conversational interface

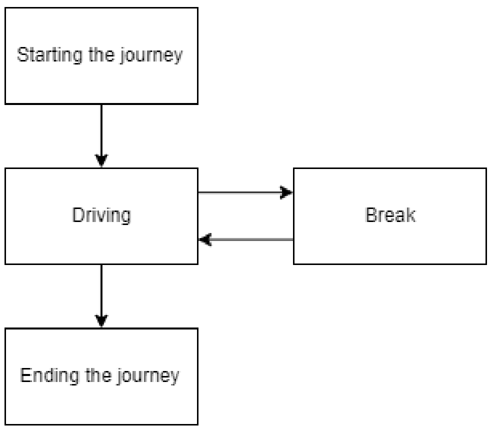


Figure 30 Diagram of Journey phases in Route Context

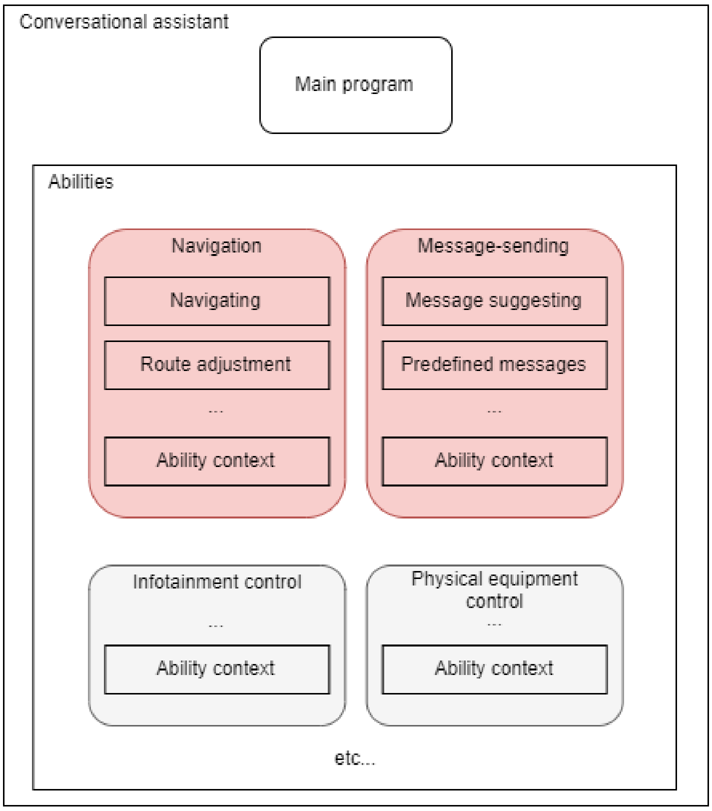


Figure 31 Structure of the Conversational Assistant

```
CA is Conversational Assistant
UP is User Preferences
RC is Route Context

while(CA is running)
  if (CA is activated by the user or user is responding) then
    process the utterance
    if (CA obtained UP attributes) then
      update UP
    if (CA obtained RC attributes) then
      update RC
    if (CA ability is requested) then
      if (ability is running) then
        update ability
      else
        run ability

  if (RC or UP has changed) then
    run or update related abilities

  if (an attribute is required and the user did not stop conversation)
    then
    ask for the required attribute
```

Listing 1 Main program pseudo-code

```
while (Navigation ability is running)
  if (voice navigation is enabled in UP) then
    navigate
  if (RC has changed) then
```

```
    inform user
  if (user requests information) then
    provide information
```

Listing 2 Navigation ability pseudo-code

```
while (Message−sending ability is running)
  if (related attribute in RC has changed) then
    suggest sending a message

  if (user requests sending a message) then
    case (user intent) is
      send a predefined message:
        if (system has required attributes) then
          send the message[now / at scheduled time]
        else
          ask for the required attribute

      create own message:
        ask for the message details
        if (system has required attributes) then
          send the message[now / at scheduled time]
        else
          ask for the required attribute
```

Listing 3 Message-sending ability pseudo-code

8 Conclusion

In this work literature related to a conversational interface, secondary tasks while driving and older drivers has been analyzed. Two use-cases of secondary tasks while driving were specified to be examined in case of using conversational interface controlling. The conversational interface, which should play a part as a driver's assistant, was designed according to the gained knowledge from analysis and with respect to the target group of older drivers. First iteration low-fidelity prototype of this conversational assistant was examined using the Wizard of Oz technique (section 4.5) in the conducted experiment with 7 participants. Gained insights and findings from the experiment was used for better specification of use-cases and in the second iteration of designing the conversational assistant. The defined use-case dealt with navigation, especially route adjustment, and semi-autonomous message sending which should help older drivers feel calmer while driving.

The second prototype of the conversational assistant was examined in the qualitative study experiment conducted in a lab environment with car simulator. Ten participants were recruited and according to findings from their interaction with the conversational assistant, behaviour and notes combined with results of the first experiment, final design of the conversational interface was derived. That includes the functional structure and key properties of the conversational interface.

Moreover, studies brought insights into the behaviour of older drivers and their acceptance of the conversational interface. The most noticeable information is that the route details and adjustment is a significant aspect of their driving habits strongly affected by the purpose of the journey. The conversational assistant's feature of autonomous message-sending was positively perceived among all participants and they would appreciate this function in their own car.

The voice-interface interaction and secondary tasks while driving are wide and complex topics. This work does not come with a whole finished product to equip a car tomorrow. But it brings useful insights into how older drivers would interact with the conversational interface in a car, what are their expectations and which functions they perceive being useful for them. The key properties and structure of conversational assistant were described. This information can be used in other related studies or in the implementation of a functional product.

Appendix A

First iteration

A.1 Pre-test interview

Before every session, a pre-test interview was done to get the basic knowledge about the participant. The following questions were considered.

Q1: What is the age of the participant?
Q2: Which gender is the participant?
Q3: Is participant an active driver?
Q4: Does the participant have any visual impairment?
Q5: Does the participant have any experience with infotainment?
Q6: Does the participant have any experience with a voice interface?

A.2 Post-test interview

After every tested scenario, a post-test interview was done to get feedback from a participant about the subject of testing. The following questions were posed to the participant.

Q1: What are your first impressions?
Q2: Is there anything you liked or disliked in the dialogue?

Following claims were evaluated using Likert scale.
Q1: I felt comfortable when using the system.
Q2: I think that the system spoke intelligibly.
Q3: I think that the conversation was intuitive.
Q4: I can imagine that I would use the system in traffic.

Likert scale:
1 - Strongly agree
2 - Agree
3 - Neither agree nor disagree
4 - Disagree
5 - Strongly disagree

At the end of the session, an informal interview was held to get more impression and insight from the participant.

Appendix B

Second iteration

B.1 Screener

1. How old are you?
    - >= 60
    - < 60 *
2. Do you have or did you have a driving licence?
    - Yes
    - No *

Participants who will answer one or more questions marked with * are not suitable for this experiment.

Bibliography

[1] Directorate-General for Energy European Commission and Transport in co-operation with Eurostat. *EU Transport in Figures, Statistical pocket book.* [online]. [January 2000]. URL: https://www2.uni-mannheim.de/edz/pdf/2000/transstat.pdf.

[2] B. Pfleging, S. Schneegass, and A. Schmidt. “Multimodal interaction in the car: combining speech and gestures on the steering wheel”. In: *4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications.* Oct. 2012, pp. 155–162.

[3] C. Hallet, A. Lambert, and M. A. Regan. “Text messaging amongst New Zealand drivers: Prevalence and risk perception”. In: *Transportation Research, Part F* (15 2012), pp. 261–271. DOI: http://dx.doi.org/10.1016/j.trf.2011.12.002.

[4] A. Bjelkemyr et al. “Support Systems Designed for Older Drivers to Achieve Safe and Comfortable Driving”. In: *Journal of Transportation Technologies* (03 2013), pp. 233–240.

[5] M. P. Bruyas et al. “Does making a conversation asynchronous reduce the negative impact of phone call on driving?” In: *Transportation research part F: traffic psychology and behaviour* (12(1) 2009), pp. 12–20.

[6] J. Maciej and M. Vollrath. “Comparison of manual vs. speech-based interaction with in-vehicle information systems”. In: *Accident Analysis and Prevention* (41(5) 2009), pp. 924–930.

[7] S. Mattes. “The lane-change-task as a tool for driver distraction evaluation”. In: *Quality of Work and Products in Enterprises of the Future* (2003), pp. 57–60.

[8] S.G. Klauer et al. “The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data (National Highway Traffic Safety Administration, Eds.)” In: (2006).

[9] J. Brooke. “Sus: A quick and dirty usability scale.” In: *Usability evaluation in industry* (1996).

[10] A. Pauzie. “A method to assess the driver mental workload: The driving activity load index (dali)”. In: *Humanist* (2(4) 2008), pp. 315–322.

[11] J.Y. Lee, M.C. Gibson, and J.D. Lee. “Error Recovery in Multitasking While Driving”. In: *2016 CHI Conference on Human Factors in Computing Systems (CHI ’16).* 2016, pp. 5104–5113. DOI: https://doi.org/10.1145/2858036.2858238.

[12] L.N Boyle et al. “Text Reading and Text Input Assessment in Support of the NHTSA Visual-Manual Driver Distraction Guidelines”. In: (2013).

[13] National Highway Traffic Safety Administration. *Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices (Docket No. NHTSA-2010-0053).* [online]. [23.4.2013]. URL: http://www.nhtsa.gov/.

[14] J. Fofanova and M. Vollrath. “Distraction while driving: The case of older drivers”. In: *Transportation research part F: traffic psychology and behaviour* (14(6) 2011), pp. 638–648.

[15] R. Brickenkamp. “Test d2 Aufmerksamkeits-Belastungs-Test”. In: *Manual. 9., überarbeitete und neu normierte Auflage* (2002).

[16] C. Musselwhite and H. Haddad. “Prolonging the Safe Driving of Older People through Technology”. In: *University of West England, Final Report* (2007).

[17] I. Tashev et al. “Commute UX: Voice enabled in-car infotainment system”. In: (2009).

[18] S. Kim and A.K. Dey. “Simulated augmented reality windshield display as a cognitive mapping aid for elder driver navigation”. In: *CHI* (2009).

[19] C. S. Dula et al. “Differing types of cellular phone conversations and dangerous driving”. In: *Accident Analysis & Prevention* (43(1) 2011), pp. 187–193.

[20] K. Lipovac et al. “Mobile phone use while driving-literary review”. In: *Transportation research part F: traffic psychology and behaviour* (47) 2017), pp. 132–142.

[21] Maria Schmidt et al. “Assessing Objective Indicators of Users’ Cognitive Load During Proactive In-Car Dialogs”. In: *Adjunct Publication of the 27th Conference on User Modeling, Adaptation and Personalization*. UMAP’19 Adjunct. Larnaca, Cyprus: Association for Computing Machinery, 2019, pp. 87–91. ISBN: 9781450367110. DOI: `10.1145/3314183.3324985`. URL: `https://doi.org/10.1145/3314183.3324985`.

[22] Jeff Sauro. *Measuring Usability with the System Usability Scale (SUS)*. [online]. [02. 02. 2011]. URL: `https://measuringu.com/sus/`.