What Are the Expectations of Users of an Adaptive Recommendation Service Which Aims to Reduce Driver Distraction?

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Abstract. Adaptive systems are a promising approach to reduce driver distraction caused by using functions of the infotainment system while driving. The number of operation steps can be reduced through proactive recommendations based on the user behavior in the past. We describe the methods and results conducted in the first two iterations of an user-centered design process to develop an interaction concept for an adaptive recommendation service. The result of an extensive requirements analysis is described and how different concepts perform in comparison with each other.

Keywords: Adaptation · Recommendation service · User-centered design process · Heuristic evaluation · User study

1 Introduction

Driver distraction caused by using functions of the infotainment system while driving is an increasing problem. A growing amount of infotainment functions, combined with complex menu structures leads to more driver distraction. The driver must be supported by launching the functions, but not being distracted. An approach to reach accomplishing these issues is the use of adaptive systems. An adaptive system aims to predict what function the driver wants to use and and reduce the number of operational steps involved in selecting that particular function by providing proactive recommendations. Apart from reducing driver distraction the adaptive system must also be accepted by the user. Hence, the following work will focus on how to achieve both these outcomes. This leads to the questions what requirements do users have relating to such a recommendation service in the vehicle and how different approaches perform in comparison with each other. This is answered with the help of a user-centered design process like described in the ISO 9241-210 [11].

2 Adaptive Systems and Driver Distraction

Driver distraction is caused by the conflict between the primary task of driving a vehicle and the operation of the infotainment system, which uses both cognitive

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and visual resources for information processing [25]. Adaptive systems can reduce this load. Jameson [13] described different types of adaptive systems and several of them can be used to reduce driver distraction e.g. by filtering and summarizing information for the driver or taking over operation steps. The last type is used within this work and an interaction concept therefore is developed.

2.1 Adaptive Systems in the Vehicle

There already exist some adaptive solutions for automotive applications e.g. recommendations for driving destinations [6]. These solutions already shorten the number of operation steps within an application. A solution to reduce the number of operational steps also must account for applications that are added to the infotainment system by the user. Only a few approaches to this issue are mentioned in literature. One approach is to support the driver by using a shortcut list for recommendations and executing functions autonomously depending on the situation, developed by Garzon [4]. Results from a study show, that the shortcut list performed better in most points, for example efficiency, reliability or controllability, than the autonomous execution of applications. Another approach is the use of information agents which are designed to take over certain tasks and can be activated by the user or proactively by the system [1]. For both approaches no end-users were involved during the development process. As seen by Garzon [4] and more focused in the work of Lavie and Meyer [14] there is the possibility of different adaptation levels to support the user. Adaptation levels can be mapped to the degree of automation. Lavie and Meyer described four levels. The first level is the manual level where the user operates the infotainmenr system as usual without support. In the level “User Selection” (US) the driver can choose from a choice of recommendations like from a list of shortcuts. The level “User Approval” (UA) recommends a function to the user but needs an approval from him. The last level “Fully Adaptive” (FA) takes over operation steps automatically for the user. Several criteria e.g. the preferences of the user, characteristics of the task or the situation, influence the decision, which adaptation level is most suitable.

2.2 The Project: An Adaptive Recommendation Service for Infotainment Systems

The goal of this project is to develop an adaptive system, which recommends preconfigured functions to the driver. As described in [22] an architecture for context-sensitive warning messages is therefore extended. The interaction concept which decides “how” a recommendation is presented to the driver is one extension. This paper describes the steps taken in development of an interactive concept, utilizing a ‘user-centered’ design process. In our work we follow the approach of Lavie and Meyer [14] and compare different recommendation concepts with different adaptation levels referring to the requirements identified before. This approach is necessary since there can be negative aspects of highly adaptive systems e.g. loss of control or paternalism [13]. It is important to identify the requirements of the potential users and take them into account within the development process.

3 User-Centered Design Process

A user-centered design process as described in the ISO norm 9241-210 is used to develop the interaction concepts. The user should be involved in the development process very early to derive important requirements and gain more user acceptance through incorporating their feedback. With this iterative process a higher quality of the end-product can be reached through a higher usability, higher user experience or reduction of discomfort and stress [11]. Figure 1 shows the user-centered design process according to [11]. The first step is "Specify the context of use" which includes the analysis of whom the product is for and in which environment it should be used. The second step is "Analyze Requirements" wherein requirements are determined through different methods. In this work, literature research and user interviews were conducted (see Chap. 4). "Design Realization" is the third step in the development process to develop a design based on the requirements. Different prototyping methods are suitable e.g. paper prototypes, screen prototypes or functional prototypes [23] (see Chap. 5). The last step of the iteration is the "Evaluation" where it is tested if the design meets the requirements e.g. with the help of a heuristic evaluation or user interview (see Chap. 6). Afterwards a new iteration can be started at any step of the process as required.

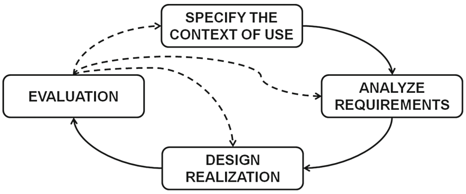


Fig. 1. User-Centered Design Process according to [11]

4 Analyze Requirements

It is very important to know the users' requirements to develop a satisfying interaction concept, especially for adaptive systems. This is due to possible negative impacts associated with adaptive systems with high adaptation levels. Therefore we need to find out what is of great importance for the users in this special case. The requirements are deduced from literature and complemented by the results of a user interview. Both are important since there is no literature especially for a user-adaptive context-sensitive recommendation service in the vehicle, which works across functions.

4.1 Literature

Since there are only few solutions in the research area of adaptive in-vehicle recommendation services like [2] or [4], we need to consider also literature from related fields like adaptive systems [3], [13], interactive systems [21] and recommendation systems [20]. Mainly this literature takes several topics into account [5]. Literature being useful for in-vehicle systems we consider guidelines like the NHTSA visual-manual guidelines [15], JAMA Guideline for In-vehicle Display Systems [12] and the European Statements of Principles on Human Machine Interface for In-Vehicle Information and Communication Systems [24]. Also ISO standards, like the ISO 9241-110 [8], the ISO 9241-11 [9], the ISO 9241-12 [10] and the ISO 15005 [7], are taken into account. The results of this literature research complemented with the results of a user study is shown in Sect. 4.3.

4.2 Interview

A second option to find out needed requirements of users for this special topic is to ask them directly. For this reason we processed a user interview with potential users to determine their requirements towards such a recommendation service in the vehicle. The interview starts with general questions and becomes more concrete in the direction of an adaptive support. An interview guideline was prepared to provide a framework but the aim was having a conversation and not asking questions like in a questionnaire. Starting, the participants need to complete a questionnaire about themselves (age, gender, attitude towards technology, etc.) and the infotainment system they use for statistical reasons. Next, the interviewer started the conversation about the functions they use most of their infotainment system, what they like or dislike, which functions the participants are missing (e.g. functions already known from the smartphone) and what the participants are doing while driving. Thirdly the participants were asked how they are supported to use these functions while driving and how they want to be supported. They were asked to imagine that the vehicle is able to adapt itself to the needs of the participants and how they can profit from this. This was conducted in the car of the participants. Six participants (2 female, 4 male) took part in this interview. Two of the participants being under the age of 30, two between 30 and 50 and two participants older than 60. The participants were regular users of modern infotainment systems with at least media player and navigation system. All of them described themselves as technically orientated and use a smartphone. The interview was recorded on audio and analyzed afterwards to document the requirements.

In a second interview with the same participants, first concepts of an adaptive recommendation service in the vehicle were introduced. This was more effective in getting requirements, since it was difficult for users in the first interview to imagine such an adaptive system on their own. The procedure of the second interview is described in Sect. 6.1, but is mentioned here since these requirements are also described in Sect. 4.3.

4.3 Summary

Requirements from the literature research and the user interviews are combined and described in Table 1. The requirements are categorized in seven categories which are named distraction, configuration, traceability, controllability, user experience, personalization &adaptivity and recommendation. The cate-

Table 1. Requirements for an adaptive recommendation system

Distraction	The operation of the adaptive system should be designed such that it has no adverse impact on the primary driving task
Visual Distraction	The adaptive system operation should be made available while driving
Legal restriction	Functions which are not allowed while driving shouldn't be suggested
Occlusion and Priority	Vehicle controls, displays and warning messages required for the primary driving task should not be obstructed by the adaptive system
Single-Handed	Single-handed operation should be possible
Sound level	No sound should be produced which masks warning from inside or outside the vehicle, or that cause distraction
Traceability	Enable the user to understand the systems status and actions
Transparency	The user should be able to understand the system behavior
Introduction	Tutorial introduction needed to explain the usage of the adaptive system
Device status	The current status and detected malfunction with an impact on safety should be presented
Intuitive and Simplicity	The driver should be able to assimilate relevant information with a few glances
Configuration	The user should have the possibility to configure the adaptive system
Reversibility	User input or configuration should be reversible
Controllability	The user should be able to control particular actions or states of the adaptive system
Freedom of choice	The user should have the possibility to choose to use a adaptation or to decline
Interruptibility	No uninterruptible sequences of visual-manual interactions should be required and an interrupted sequence should be resumable
Speed	Ability to control the speed of interaction, no time-critical response should be necessary

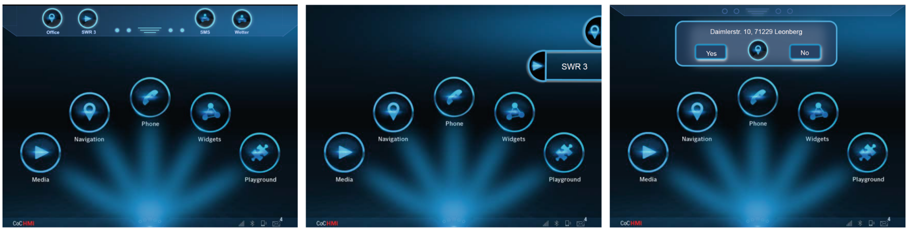
Table 1. *(Continued.)*

Switch off	It should be able to switch off showing non-safety related information to the driver
User Experience	The adaptive system should have a high usability and user experience
Efficiency	The user should be able to perform his tasks quickly
Effectiveness	The user should be able to finish tasks with high accuracy and completeness
Satisfaction	A usage free of impairment and support towards a positive attitude should be provided
Joy-of-Use	The use of the adaptive system should be enjoyable
Accessibility	All relevant information should easily be accessible
Feedback	For every user action, there should be some system feedback
Device Response Time	The response of the system following driver input should be timely and clearly perceptible
Recognizability	The attention of the user is directed to the needed information
Simple error handling	The user should not be able to make serious errors. The system should also offer simple error handling
Consistency	Consistent sequences of actions, identical terminology and consistent commands should be used
Compactness	Only the information which is needed to complete the intended task is shown
Personalization and Adaptivity	The adaptive system must adapt its presentation to different users (user profile), devices and situations
Changing User Behavior	The adaptive system must be able to handle change in user behavior over time
Stability	The user interface should not be modified too much
Locality	A short distance between the location of the collected information and where the adaptation is applied, is expected
Speed of Adaptation	The phase of learning should be short even when only few usage data exists
Breadth of Experience	The user should be able to operate the non-adapted system
Data Privacy	Possibility to control data collection
Recommendation	The user can be supported by giving recommendations
Proactive	The recommendation should be proactive
Scalable	A variety of functions should be supported
Unobtrusiveness	The intelligent support should not distract the user from normal usage of the application
Accuracy	Correct recommendations with a high accuracy are needed

gories represent especially the challenges of adaptive systems and the challenges which gain from the automotive field.

5 Design

Based on the state of the art, described in Sect. 2.1 and the requirements described in Sect. 4.3, several concepts for an interaction concept of an adaptive recommendation service are developed. The adaptation levels described in the work of Lavie and Meyer [14] combined with the realization of Garzon [4] are used as a basis for the concepts. The concepts are realized with different tools and revised after every iteration. Figure 2 shows the concepts which were developed after the first iteration. The adaptation level US is represented as a list of shortcuts (US1) like in the work of Garzon [4], where the user can choose out of up to four recommendations which the adaptive system considers suitable for a specific situation. The second concept (US2) belongs also to the adaptation level US, but is realized in a different way. The recommendations are displayed in form of notification, which are moved into the field of view from the side of the screen. In case the user looks at the recommendation, but is not interested at the moment and looks away again for a certain time, the notifications are minimized. The third adaptation level UA is realized as a pop-up message in which the user needs to approve or disapprove the recommendation. The last adaptation level FA is the automatic execution of a preconfigured function, which can be canceled with a cancel button which is only displayed when the displayed function is started by the adaptive system itself. For the second user interview, described in Sect. 6.1, the concepts were realized as paper prototypes. Figure 3 shows one screen of the paper prototype for the adaptation level US1. For the heuristic evaluation, described in Sect. 6.2, the concepts shown in Fig. 2 are realized as clickthrough prototypes with the tool Balsamiq[1].



(a) User Selection 1 (b) User Selection 2 (c) User Approval

Fig. 2. Different concepts for user interfaces of an adaptive recommendation service realized as screen prototypes

[1] https://balsamiq.com/

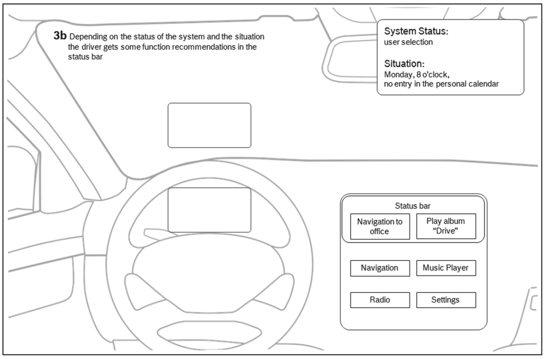


Fig. 3. Paper prototype of the concept US1 for the adaptation level User Selection

6 Evaluation

Step four of the user-centered design process is the evaluation. In this step different methods can be used depending on the stage of development. A possibility to get feedback at a very early stage is an user interview or a heuristic evaluation. For both methods no functional prototype is needed and the prototypes described in Chap. 5 are sufficient.

6.1 User Interview

To get feedback to the idea of an adaptive recommendation service in the vehicle and first ideas of an interaction concept realized as paper prototypes, a user interview was conducted.

Method. Within this interview, three different interaction concepts were introduced for three adaptation levels in form of paper prototypes. The adaptation level US was at this stage represented as a list of shortcuts (US1), UA as a pop up message and FA as the automatic execution of a preconfigured function, but without the cancel button. The concepts were always presented in this order, but additional beginning with the manual operation. First a storyline was presented to the participants to get used to the manual use of the infotainment system. The storyline (drive to the office at Monday morning and start navigating to the office while driving) was maintained through the whole interview and repeated for every concept. After each presentation of the storyline, with help of the different concepts, questions were asked. The questions addressed the general usability of those concepts, the challenges of adaptive systems and driver distraction. For example, the participants were asked if the operation is easy or not and if they perceive the concept useful while driving. At the end the participants had to compare the different concepts and choose the one they liked most. This interview was conducted in dialog form recorded on audio, instead of answering questions of a questionnaire. A total of six participants, the same as in the first user interview, described in Sect. 4.2, were interviewed, following Nielsen's proposal that five to six participants result in the best cost-benefit ratio, still addressing up to 80 percent of the usability problems to be identified [19].

Results. The results of this interview are mainly the contribution to the requirements shown in Sect. 4.3. But there are also some findings related to each concept and the comparison of the concepts. The participants described the operation of the manual infotainment system as distractive due to many operation steps, which are needed. The participants liked the concepts for the adaptation levels US and UA, but did not like the concept for the adaptation level FA. The participants rated the usage of the concept US as simple and could imagine to use it while driving. For comparison, all of them experienced the manual concept as too distractive to use while driving. The concept for UA is assessed nearly equal, but the question of what happens when a recommendation is rejected or not replied, occurred. There should be the possibility of being able to choose the recommendation later again or to configure the behavior for this case. The concept for FA has to be extended with an option to cancel an automatic execution and a one-time approval of a recommendation, hence the user can feel more in control of the adaptive recommendation service. There are different opinions about the FA concept. Some participants noted that they could think about using it when the accuracy is high enough and others would never use it. Some participants mentioned that the system behavior could not be understood e.g. why a function is recommended. The traceability needs to be increased. Based on this results the design was revised and further developed. A second realization (US2) of the adaptation level US was developed and the concepts were realized as clickthrough prototypes with Balsamiq (see Chap. 5).

6.2 Heuristic Evaluation

After the first iteration the concepts have been revised and realized as click-through prototypes. The next evaluation method, which we used within the user-centered design process, is the heuristic evaluation. It is a method to identify usability problems with the help of heuristics. The participants of an heuristic evaluation are experts, who have specialized knowledge and are able to put themselves in the position of the user [17].

Method. A total of six participants took part in this evaluation [19]. Experts from the fields of ergonomics, software development, design and user experience evaluated the four different concepts US1, US2, UA and FA (see Chap. 5). Nine heuristics, which are a mix of the heuristics of Nielsen [16] extended by some heuristics for driver distraction, were introduced to the participants. Afterwards the storyline (enter an address and change the radio station while driving) was presented with the help of the manual infotainment system. Next, the idea of an adaptive recommendation service is explained and the configuration of a potential service, which should be used within this study is shown in form of an explanation menu on a tablet. This enables the participants to understand the system behavior and to comprehend the current configuration. The participants are then requested to perform tasks with the clickthrough prototype for each concept on a tablet and evaluate the concept. The order in which the concepts are presented to the participants is permutated. The participants are asked to say the problems they find out loud and the interviewer write down the findings in form of a protocol. Each finding is assigned to one of the heuristics and weighted with a severity rating.

Results. The findings of the heuristic evaluation were summarized and for each problem a severity rating from 0 to 4 was given within a workshop depending on frequency, impact for the user and persistence of the problem [18]. The total number of problems is different for each concept. Concept US1 and US2 have more problems and several problems with rating 4. Figure 4 shows the distribution of the number of problems for the related severity rating and for each concept. The concepts US1 and US2 include a lot of user interaction compared to the concepts UA and FA. This is the reason why there are more problems and also problems with a higher severity. Several problems were identified for the heuristics related to control and obtrusiveness for the concept FA. The experts mentioned among other things a complete loss of control and that there is no possibility to deactivate recommendations directly. Possible countermeasures could be a menu to enable a deactivation of recommendations or a one-time approval for each recommendation for this adaptation level. Another heuristic that was called very often for the concepts US1 and US2 is the heuristic which concerns showing enough, but only necessary information. Shortcuts are small and it is a challenge to show all needed information to understand a shortcut. The experts asked for example which shortcut is most relevant in the situation. A possible solution is to arrange the shortcuts and start with the most appropriate one. As a conclusion of the heuristic evaluation, it may be stated that for the concepts US1 and US2 several points can be improved. Within the evaluation already some ideas were mentioned. For the concepts UA and FA the method was not that much effective since both concepts involve less user interaction. To improve these concepts other measures must be taken like the ones in [13], e.g. enable settings, combination of the adaptation levels in one interaction concept.

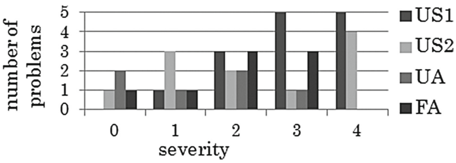


Fig. 4. Results of the heuristic evaluation according to the severity rating for each concept

7 Discussion and Future Work

Two iterations of the user-centered design process have been performed. The results of each step are important and have influenced the next step or iteration. But there are also some things which need to be criticized and discussed. The participants of both user studies could not experience the adaptive system. They had to imagine the system behavior on basis of the paper prototypes or descriptions. This is the reason why most requirements could be derived as the idea was described to the participants with the help of the paper prototypes. They liked both concepts for the intermediate adaptation levels US and UA, but we claim that they could not distinguish between these two on the given basis. The concept for FA was not assessed as good as in the first iteration, but it is a promising concept as it relieves the driver most when it has high accuracy and is accepted. To moderate the negative aspects, several measurements like described in [13] need to be taken. Only people who are described as technology-oriented were interviewed, because we expected that they are more in the position to understand such a future-oriented service. However, especially the non-technology oriented persons need support to operate the complex infotainment system. Their point of view was not considered until now. The results of the different methods are an important step in the development process of an adaptive recommendation service, but to gain reliable results for the evaluation of user acceptance and driver distraction, the adaptive system needs to be experienced by the participants. The next step in the user-centered design process is to build up a prototype to enable experiencing an adaptive recommendation service in a driving simulator environment. This will be the next step towards a prototype in real vehicle.

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