Understanding the Usefulness and Acceptance of Adaptivity in Smart Public Transport

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Abstract. Adaptive passenger information for enhanced mobility experience may be the next step towards a smart public transport. In our research project, we explored adaptive passenger information and investigated options to increase the intelligibility of adaptive features. We set up an online questionnaire to study the acceptance of adaptivity in public transport information systems. In this paper, we describe our approach to adaptivity in public transport, the design of the questionnaire and we discuss results of our study.

Keywords: Smart public transport · Passenger information · Adaptive systems

1 Introduction

The public transport domain has been significantly transformed by digitization. Smartphones have created a personal access to public transport information and digital ticketing has made public transport accessible more directly than before. But also the availability of realtime information and the introduction of public digital information systems have changed the usage of public transport. As a next step, the application of Internet of Things (IoT) technologies for public transport is discussed, which could, among other things, leverage context-aware applications based on rich sensor data [9].

In addition to sensor data, digitization also generates real-time information on vehicles, schedules and on traffic situations that affect public transport. Considering this large amount of available data and increasingly intelligent ways to handle this information, smart public transport systems are within our reach [8,15]. The adaptation of passenger information systems to current situations plays a critical role in making public transport systems smart, more efficient and more attractive for their passengers. Passenger information systems turn

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into personal mobility assistants, that not only know the overall public transport situation and take delays, detours or even the amount of passengers in single vehicles into account, but on the other hand, they react according to the situation of the user, their current position, their goals and preferences, enabling a personalized mobility experience [22].

Additionally, interactive devices permeate our surroundings and, increasingly, public space and public transport [12]. Not only are most passengers carrying their own smartphone or other mobile computing devices, but public displays and public information systems are also familiar in cities and in public transport by now [3,8,19]. Intelligent or advanced traveller information systems leveraging these technologies are becoming an important component of the services for public transport agencies [4]. Besides improving core factors of public transport, such as punctuality or efficiency, Camacho et al. also argue for the development of more passenger-centric services that additionally enhance the passenger's experience [5]. From our perspective, an adaptive and smart passenger information system tackles both - the core factor of high-quality passenger information as well as enhancing the passenger's experience by adapting to their situation and actively supporting passengers according to their needs.

However, adaptive systems are not usable just because they are adaptive [21]. The acceptance of adaptivity depends on many factors and may vary between users. The design and development of an adaptive passenger information system should be approached carefully, in order to maintain usability and usefulness.

In our research project, we explore the application of adaptivity in passenger information systems of public transport. Our goal is to improve passenger information on every step of their trip and in any situation. As a part of this project, we investigate the integration of semi-transparent, multi-touch enabled displays in passenger information systems. These displays can be installed in public transport vehicles instead of windows or at stops and stations and serve as an interactive point of information. We also consider mobile applications and the possibility of multi-device interaction. In this setting, we explore suitable modeling of adaptation and the realisation of an adaptive and interactive passenger information system using said devices. In order to keep this adaptive system usable and useful, we also developed options to increase the intelligibility of adaptive features. In a first evaluation phase, we designed an online questionnaire to study how people would rate different adaptation options in an passenger information system.

The rest of this paper is structured as follows: in Sect. 2, we summarize our research of similar systems in related work. We then describe our development of adaptive features as well as intelligibility features for an adaptive passsenger information system in Sect. 3. We present our take on prospective users, multi-device interaction as well as different categories of adaptation we considered. In the following Sect. 4, we describe the design of our study, bringing the dimensions of device combinations, adaptivity categories and the variation of public transport situations, persona and multiple features together. In Sect. 5, we describe the results of our study, followed by a discussion and outlook on future analyses in Sect. 6.

2 Related Work

We conducted our investigation of related work focusing on adaptive, context-aware and interactive passenger information systems for public transport that involve public displays, smartphones or other media in public transport vehicles. The usability and usefulness of adaptive systems is also of particular interest to us, specifically in the public transport domain or in similar settings.

A very early context-aware system, which was actually deployed, is the GUIDE system by Cheverst et al. [6,7]. It did not utilize public transport but as a context-aware tourist guide, it provided information customized to the user's context. Being developed in the pre-smartphone era, it was implemented on a pen-based tablet PC and the communications network was specifically engineered for this system. Information and functionality were tailored based on the context categories of personal context, related to the user, and environmental context. The GUIDE system adapted the presentation of information by sorting the displayed lists of locations and points of interest. Cheverst et al. also implemented indications on adaptivity. When the user was presented a list of interesting locations, a note was displayed on the sorting rules, that were based on context. In their evaluation, the authors report a high acceptance rate for the overall system. The context-aware recommendations were found useful by the participants of the study. The authors also describe that the restriction of information by context was considered frustrating, a finding that emphasizes the careful design of adaptive systems. The work of Cheverst et al. is interesting, since it not only considers location as a context factor to adapt to, but considers the situation of the user in more detail, similar to our approach.

Tumas and Ricci describe a personalized and mobile city transport advisory system with the rise of smartphones in 2009 [22]. They focus on the implementation of a routing algorithm that computes personalized alternatives for a travel request. The personalization of their approach is based on travel preferences the users enter while entering the travel request in their mobile client and the adapted presentation of the responses is a ranking based on the user's preferences. While they describe that in a usability testing with students no usability issues were found, they do not report on the acceptance of the personalized ranking of results or other details.

Handte et al. present an application called Urban Bus navigator (UBN) [13]. This novel service provides micro-navigation and crowd-aware route recommendation for bus riders. The UBN system is built upon a distributed IoT infrastructure which enables the passenger's smartphone to interact with buses in real-time and allows buses to register the presence of on board passengers. The micro-navigation service provides a context-aware guidance of passengers along a bus journey by recognizing boarded bus vehicles and tracking the passenger's journey process. The crowd-aware route recommendation collects and predicts crowd levels on bus journeys to suggest better and less crowded routes to bus riders. The UBN system was tested collecting qualitative feedback from real-world bus users. The results indicate reduced cognitive effort for managing bus journeys, increasing motivation of using bus transport and better accessibility of travel information.

Chow et al. developed an adaptive mobile application for planning trips in Hong Kong public transport [8]. The system considers the location of the user via their mobile phone's GPS sensor as well as their walking speed, measured by a wearable device. The application supports planning as well as re-planning of trips due to real-time information, for example in case of missed buses, which is one of our use cases, too. The authors implemented are commendation algorithm that computes trips considering the walking speed of the user, as well as the real-time transport situation. However, walking speed and location are the only context factors taken into account, whereas we considered some more factors. Also, the authors did not yet publish an evaluation on the acceptance or usability of their system and its adaptation.

Abu-Issa et al. describe the development and test of a recommendation system in an Android app [1]. This system considers several context factors and then proactively suggests matching points of interest to the user. The user can then navigate to these points of interest. The authors report a high acceptance rate in their survey of test users. Their approach of using a proactive recommender system that suggests items to the user without specific user request is comparable to the approach of active adaptation that we chose to evaluate in our survey. However, the authors do not report specifically on the acceptance of this feature and they did not compare this feature to any passive alternative.

In a recent study, Oliveira et al. investigated the experiences and requirements of passengers in rail travel [17]. Their findings resulted in a experience visualisation as a customer journey experience map, the identification of critical points in rail travel, such as ticket collection or the finding of a seat, and some indications where technological innovations might mitigate negative experiences of passengers. Their findings, among other things, point towards the passenger's need for guidance in unknown settings - stations or coaches alike. Subsequently, the authors developed four personas for rail transport in the UK and investigated the user's openness towards technological advances in electronic ticketing and seat reservations [18]. Their paper proposes a system that, for example, directs passengers towards free seats and informs about occupancy levels of trains. They found that passengers highly value supplementary information and they emphasize the importance of correct information. Supplementary information and guidance on trips are goals of our system as well, especially considering the question if adaptation can enhance the aspect of guidance for public transport passengers.

An analysis of context-aware systems in general shows that successful adaptive user interfaces are still hard to find in practice [11,21]. However, incomprehensible adaptions can have an adverse effect on the usability of a system. To reduce this negative effect of adaptive behaviour, Paymans et al. have attempted to help users to build adequate mental models of such systems [11]. They developed a user support concept and applied it to the adaptive user interface of a context-aware mobile device. The authors evaluated their approach with users and reported that the user support improved the ease of use, but unexpectedly it reduced learnability. In addition, the support concept only provided real-time information about active modality and contextual factors, but not for system adaptations. Following the example of Paymans et al., we also developed features that are designed to help users understand the adaptive user interface of our system.

Lim et al. [16] present another approach that provides explanations to increase the intelligibility of an adaptive system. They examined the effectiveness of different types of textual explanations (why, why not, how to, and what if) in a controlled study with over 200 participants. The authors developed a web-based infrastructure that provides a functional input-output interface of an intelligent system prototype that provides different types of explanations. They found that providing reasoning trace explanations for context-aware applications to novice users can improve user's understanding and trust in the system, but their findings were not further tested in real-world-settings.

3 Adaptation for Smart Public Transport

Our goal is to better understand how adaptive mobility systems can support passengers in public transport and to design an adaptive passenger information system based on that understanding. We want to know how passengers accept different kinds of adaptations. In one step further, we take a look at intelligibility features for adaptations and assess their effectiveness. As a basis for further research and the development of several prototypes of an adaptive passenger information system, we analyzed and identified contexts and types of adaptation that are relevant in public transport scenarios. We then developed adaptation scenarios for different public transport situations and adaptation categories. We designed mockups for those scenarios and developed an online questionnaire to evaluate responses towards these adaptations in a first evaluation phase.

3.1 Personas for Adaptation

In order to design adaptive passenger information systems for public transport, we used the persona method to analyze and illustrate the prospective users of such a system. This method has been applied to the public transport domain before, for example by Hoerold et al., and only recently by Oliveira et al. [14,18]. We built on results by Hoerold et al. as they describe personas for passengers in german public transport specifically. During the analysis phase of our project, we refinded and extended those personas. We classified passenger types according to their type and frequency of public transport usage, their knowledge of the region and of the public transport system and their smartphone usage.

For our first evaluation phase of adaptation scenarios, we focused on four personas. We chose them based on different requirements the personas would have towards an adaptive passenger information system. We selected the commuter persona, the pupil or student, the casual user and the power user. Commuter and pupil/student have in common that they have distinct regular trips and times. They have good knowledge about the trips they are taking regularly. The power user and casual user both have no regular work or school trips but use public transport for alls kinds of other reasons. They are distinguished by the frequency they use public transport and by their familiarity with the public transport system. While a power user is using public transport very often and is very comfortable in doing so, a casual user is using it only once in a while and may need more assistance, because they are not as familiar with it. In our study, we investigated if the assessment of adaptations would be different between people that match different personas.

3.2 Devices and Interactions for Adaptation

Our adaptive passenger information system is designed with different interactive devices in mind. We are considering apps for smartphones, but also public digital information systems on platforms and in vehicles. In our research project, we are studying the application of semi-transparent, multi-touch enabled displays in passenger information systems. When placed at stops and platforms, we call them public displays, while it is also possible to use such a display in a public transport vehicle as a window, which we call a smart window.

In addition to designing adaptations for smartphones and for public displays or smart windows, we are also considering possible interactions between public information systems and personal devices, in order to achieve an understanding of smart public transport systems as a whole. We designed adaptation scenarios for each of the devices independently but also developed some scenarios that consider the interaction between a smartphone and a public display or a smart window.

3.3 Public Transport Situations for Adaptation

As a basis for the development of our adaptation scenarios, we identified situations in which passengers might need information about their journey or about journey-related topics. A public transport journey can roughly be divided in three parts: pre-trip, on board and post-trip, following, for example, Oliveira et al. [18]. We would rename the "on board" part to "on trip", since we are considering trips with multiple legs, where a passenger can be at an interchange during their trip and is not on board a vehicle. Depending on the situation in public transport, the information need of passengers changes. We therefore identified several information needs for passengers in public transport, beginning with the information on a journey and reminders, for example for planning or starting a trip. On trip, passengers need information on interchanges, delays or disruptions. We developed adaptation scenarios for each of those situations.

3.4 Adaptation Categories

In our first evaluation phase we explored, if different kinds of adaptations were rated differently. For the development of our adaptation categories, we took six categories of adaptation into consideration. These categories are based on the categories of context-awareness described by Alegre et al., who proposed an extension to the categorization of Dey and Abowd [2,10]. The categories describe the subject of the adaptation in a context-aware system, which can be:

– the *presentation of information*, including the modification of the presentation of information
– the *active execution of a service*, where the system autonomously executes a service
– the *passive execution of a service*, where the system proposes the execution of a service to the user
– the *active configuration of a service*, where the system autonomously configures a service
– the *passive configuration of a service*, where the system proposes the configuration to the user
– tagging context to information for a better understanding of this information

We excluded the last category, because it does not directly result in adaptations that the users become aware of. In our study, we specifically investigated the difference between active and passive adaptations, in both categories, the *execution of a service* and the *configuration of a service*. A pair of scenarios with active and passive adaptations is described in Subsect. 3.6.

3.5 IFeatures - Understanding Adaptation

Incomprehensible adjustments can negatively impact the usability of a system. Therefore, we examined, if additional explanations make the system adjustments more intelligible. We also analyzed, which kind of explanations are more understandable to the users and which they would prefer. We developed three versions of intelligibility features (which we call IFeatures) based on the Why and Why Not Explanations of Lim et al. [16] and the support concept of Paymans et al. [11]. The intelligibility features provide explanations about a system's adaptation decision. We distinguished the following three versions of IFeatures and applied them to every adaptation scenario (Table 1):

Table 1. Versions of intelligibility features

Version	Description
Version 1	Display icons
Version 2	Display of icons and textual explanations
Version 3	Textual explanations

3.6 An Adaptive Passenger Information System

Our basic design of the adaptive passenger information system uses three different types of context for adaptations. We consider personal context, spatial context, interaction context and socio-technical context, following a categorization of Schlegel and Keller [20]. We assign users to personas that match their personal context. Personas are a first step to filter scenarios and adaptations for a user. Based on a user's history of trips, regular trips and times can be identified. They serve as a context factor for system adaptation. In the personal context of a passenger, their calendar and appointments are also considered.

The interaction context is determined by the available interactive devices that can be part of the adaptation. Adaptation based on interaction context fundamentally depends on availability of the devices. However, in further phases of our project we plan to broaden our scope and additionally consider usability factors in adaptation decisions based on interaction context.

As spatial context we consider the location of a user. There are different forms of location that are considered here. The absolute location of a user in terms of GPS positions is a basic context factor and on top of that, the location of a passenger in relation to public transport facilities are relevant to the system. The location at a certain stop point as well as in a certain public transport vehicle is used in some adaptations. Furthermore, the direct position of a user in front of a public display or a smart window is also relevant for some of the adaptations.

The socio-technical context considered in our scenarios, comprises of different public transport situations, as described in Subsect. 3.3. Based on these situations, the system can identify the passsenger's information need.

We developed 21 adaptation scenarios in total. We tried to comprise them covering different aspects of devices, situations and adaptation categories each, as shown in Fig. 1. Ten of these scenarios are part of a pair of active and passive adaptations. We will introduce three exemplary adaptation scenarios in the following.

Scenario	Situation	Device	Adaptation Category
1	Reminder	Smartphone	Active execution of a service
2	Change	Smartphone	Active execution of a service
3	Information on a Journey	Smartphone, Public Display	Presentation of information
4	Delay	Smartphone, SmartWindow	Active execution of a service
5	Delay	Smartphone, SmartWindow	Passive execution of a service
6	Disruption	Smartphone	Active execution of a service
7	Disruption	Smartphone	Passive execution of a service
8	Information on a Journey	Public Display	Active configuration of a service
9	Delay	SmartWindow	Active execution of a service
10	Disruption	Public Display	Passive execution of a service
11	Information on a Journey	Smartphone	Active configuration of a service
12	Information on a Journey	Smartphone	Passive configuration of a service
13	Change	Smartphone	Active execution of a service
14	Change	Smartphone, SmartWindow	Active execution of a service
15	Delay	Smartphone	Active execution of a service
16	Delay	Smartphone, SmartWindow	Active execution of a service
17	Delay	Smartphone, SmartWindow	Passive execution of a service
18	Disruption	Smartphone, SmartWindow	Active execution of a service
19	Disruption	Smartphone, SmartWindow	Passive execution of a service
20	Disruption	SmartWindow	Passive execution of a service
21	Disruption	Public Display	Passive execution of a service

Fig. 1. The adaptation scenarios for our first evaluation phase.

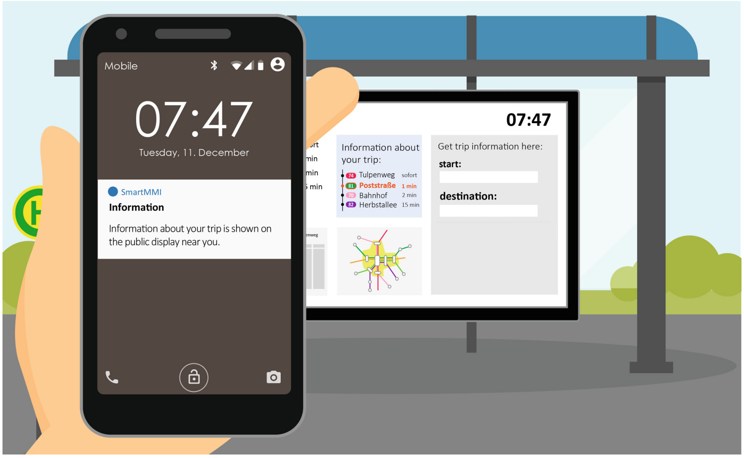

Fig. 2. Mockup of scenario 3: information on a journey

Scenario 3 - Information on a Journey: This scenario is based on the combination of a smartphone app that serves as a travel companion and a public display at a stop point. The intended user group is the group of commuters and pupils or students that are traveling on a recurring trip. The scenario is taking place in the morning, when the passenger is leaving their home and is on their way to school or to work. As a prerequisite, the app has been started and a trip was chosen or set. As the passenger approaches the stop and the public display, they can see that the information on the vehicle they will be taking is highlighted, as is shown in Fig. 2. In the textual description of the scenario, we describe that additional information is then displayed. This is information on the occupancy of the coaches of this train as well as the information on how many coaches there are. The detailed information on this vehicle is presented and highlighted based on the trip of the user, known by their smartphone app.

Scenario 16 and 17 - a Delay: The scenarios 16 and 17 address all personas and include a smartphone and a smart window. They are a pair with active and passive adaptation of the category *execution of a service* and are therefore based on the same basic situation. In this situation, the participant wants to visit someone using public transport. In their travel companion app they started the trip they want to take and have already boarded their tram where they are seated next to a smart window. The tram is experiencing a delay and from this point onward, the scenario description differs.

In scenario 16, displayed in Fig. 3, a notification opens on the smart window that informs the user of the delay. Since the intended next connection might be missed, three alternatives are presented to the user. They can choose one and transfer the trip to their smartphone. In this scenario, a service is actively executed by the system. The passenger's destination and other information on their trip is used for automatic planning of alternative routes.

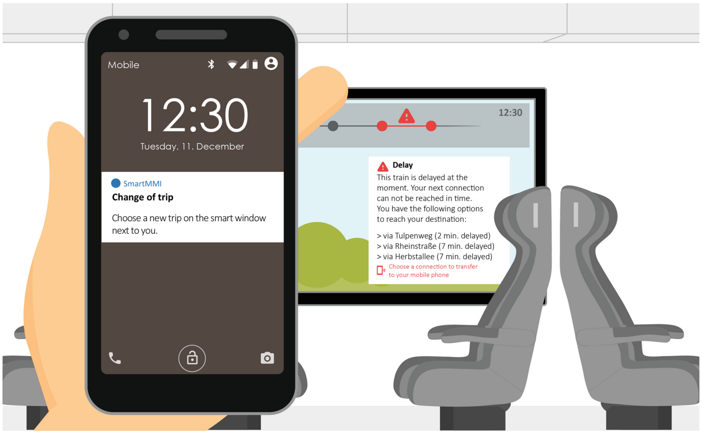

Fig. 3. Mockup of scenario 16: a delay with smartphone and smart window

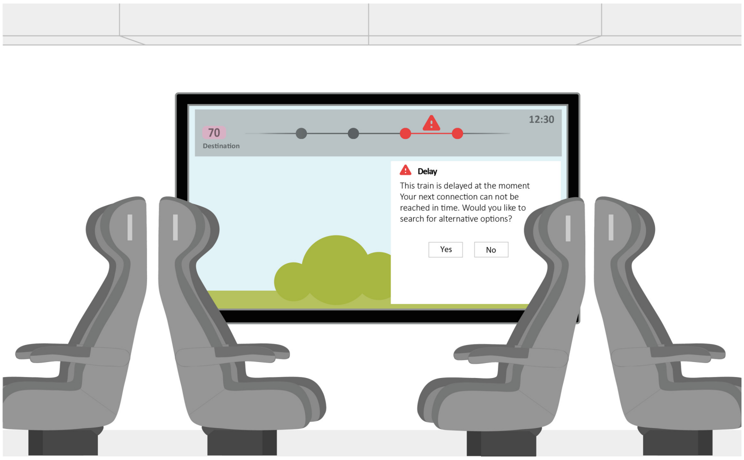

Fig. 4. Mockup of scenario 17: a delay with smartphone and smart window

Scenario 17 on the other hand, is passively executing a service, which is shown in Fig. 4. The user is presented with the information on the delay and can then choose to get alternative routes. They can transfer their destination from their smartphone to the smart window and a list of alternatives is displayed. A chosen alternative trip can also be transferred to their smartphone for further use in their travel app. Instead of a system that proactively uses the passengers data to plan ahead and directly present results, the passenger in scenario 17 is asked and then can take action to re-plan their trip. Consequently, scenario 17 requires more user interaction than scenario 16.

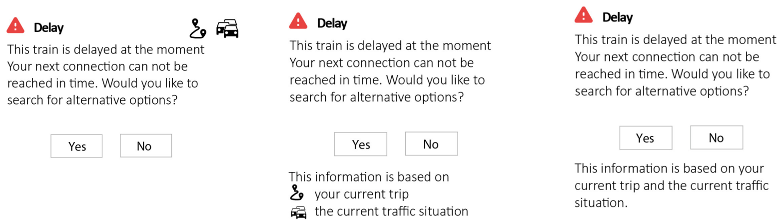

Fig. 5. Mockups for scenario 17 using IFeatures 1, 2 and 3

We developed IFeatures for each scenario and included them in the mockups for comparison. Figure 5 shows the three different IFeatures for Scenario 17. In order to compare the IFeatures, only the relevant part of the original image is shown.

4 Questionnaire Design

For our study we designed an online questionnaire with adaptive and randomized questions. The first questions for all participants are about age, occupation and about public transport and smartphone usage. We ask about the confidence of the participants regarding public transport, but also regarding their smartphone usage. Based on the given answers, we are able to present the participants public transport situations relevant to their public transport experiences. Participants that use public transport regularly to get to work, school or university are categorized as commuters and pupils/students, where other participants are grouped in the generic group of users. If participants did indicate that they do not possess or use a smartphone, they are only presented with scenarios where no smartphone is involved.

For each scenario that is presented to a participant, the textual description and the visual mockup is displayed. We ask a question on the usefulness and comprehensibility of this adaptation and then present versions of the mockup using the IFeatures, each alongside the base version without IFeature. Each IFeature is presented with questions on their intelligibility and usefulness. The order in which the IFeatures were shown is chosen at random. After all three IFeature versions, the participant is shown an overview over the base version and each IFeature version and asked to rate them in comparison.

Normally, all participants are presented three different scenarios which are chosen at random. When one of the randomly selected scenarios is one half of an active/passive pair, we overwrite one of the other random scenarios and present both parts of such a pair of scenarios. After two scenarios of an active/passive pair are presented, we ask a question comparing these two adaptations. The textual description and mockup of both adaptation scenarios is then shown for comparison.

Participants in the pupil/student or commuter group are first presented with two scenarios for pupils/students and commuters. Afterwards, one scenario of the general user category is shown. If this scenario is part of an active/passive pair, the participant will be shown the second part of this pair as a fourth scenario.

5 Results

We distributed the link to the online questionnaire to different users and mobility groups. We used different media and channels to reach out to a highly diverse audience. The only feature the study participants have in common is the potential usage of public transport in their local region.

After three weeks, 133 questionnaires were completed and 213 questionnaires were not completed, meaning participants aborted at different stages of progress. The age of participants was widely distributed, starting at 15 to 19 years of age and going up to 65 and older. The majority of participants, 66% are between 20 and 39 years old.

In order to assess the familiarity with the local present public transport system, we asked about frequency as well as purposes of public transport usage. The frequency of public transport usage was quite evenly distributed. Leisure and daily routes to work or school/university were most frequently reported as purposes of public transport usage. Asked about their familiarity with public transport, over 90% reported at least moderate familiarity with their local public transport system.

Regarding media and smartphone usage, also over 90% of the respondents stated that they possess and use a smartphone. Asked about their confidence in smartphone usage, only about 5% were not very confident or not confident. We also asked how confident they feel about buying tickets for public transport using an app, where 12% indicated they feel unconfident or very unconfident and 32% feel very confident. Overall, we can safely say that the participants of the study were rather familiar with smartphones and apps.

Since the adaptation scenarios shown to the participants depended on some of the answers they provided before, the scenarios were shown at different rates. In total, 504 adaptation scenarios were shown to participants. One scenario that was only shown to students and pupils was only rated five times, while 8 scenarios were shown between 30 and 40 times. On average, each scenario was shown 24 times. 41% of our respondents were commuters and 18% were students or pupils, which leaves 41% in the user category.

5.1 Adaptive Smart Public Transport

We asked participants to rate usefulness and comprehensibility of adaptation scenarios. Overall, the ratings of the adaptation scenarios were better than we expected. Figure 6 gives an overview over all ratings of our scenarios. Usefulness and comprehensibility werde both rated on a scala from 1 as *very useful* or *very comprehensible* to 5 as *not useful at all* or *not comprehensible at all*.

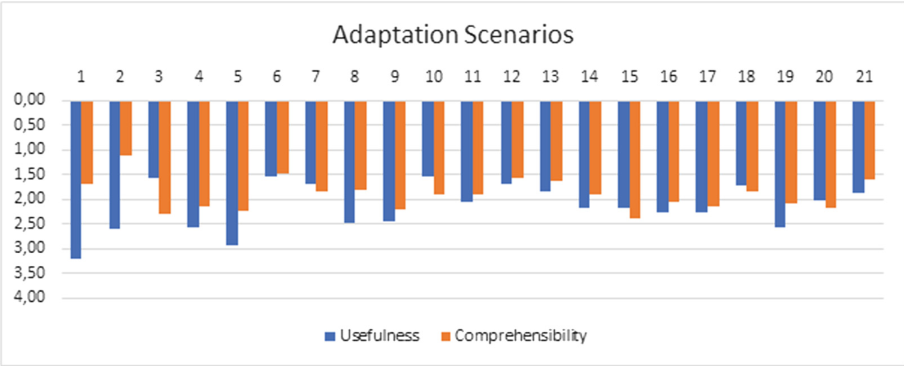

Fig. 6. Overview over ratings of usefulness and comprehensibility of all scenarios

Usefulness of Adaptation. On average, usefulness was rated as 2.16. Scenario 6 was considered the most useful with a score of 1.53. Scenario 6 only considers a smartphone app and the situation is a disruption of a service. It is a scenario for commuters, pupils or students. The user is notified that their usual tram is out of service. The smartphone application chooses an alternative and gives directions on which tram to use and when.

Scenario 1 was rated the least useful with a score of 3.20. Scenario 1 is a scenario based on regular trips of commuters, students or pupils. In this scenario, the user is reminded via their smartphone that they have to leave home in five minutes if they want to use their usual trip.

Comprehensibility of Adaptation. Comprehensibility was rated 1.91 on average. Scenario 2 was rated as the most comprehensible scenario, scoring 1.13. This scenario is a reminder via smartphone to get off the train at the next stop. Scenario 15 was rated as the least comprehensible scenario with a rating of 2.39. In this scenario, a notification on their smartphone alerts the user to alight the vehicle at the next stop instead of the one after that and to take a certain tram at the next station. We assume that this is rated as not very much comprehensible because the notification does not indicate why the system suggests this change of plans. Overall, comprehensibility tends to be rated better by persons with better knowledge of public transport, a result that is not surprising to us. However, it leaves the question how to better reach and support people with less familiarity to public transport.

We also looked at averages of ratings by devices and situations, as shown in Fig. 7. The group of scenarios with smart window or public display both contained those scenarios that used smartphones together with a smart window or a public display as well as the scenarios that featured only the displays. Overall, the usefulness of scenarios with public displays was rated best and scenarios with smartphone only were rated second. However, in terms of comprehensibility, the smartphone only scenarios scored best, which can probably explained by higher familiarity of most people with smartphones on contrast to public displays and smart windows, which are more unfamiliar to passengers in public transport.

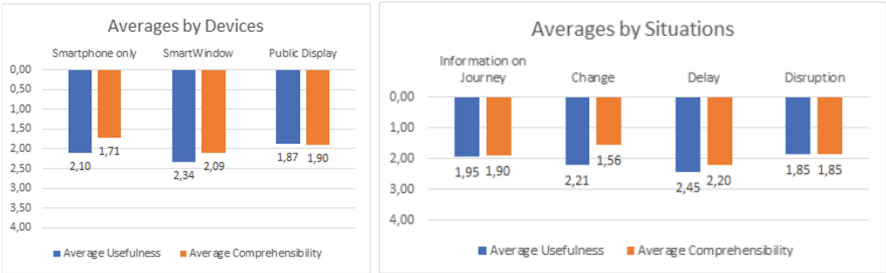

Fig. 7. Average ratings by devices and situations used in scenarios.

With regard to the situations, scenarios that take place during interchanges were rated most comprehensible, while scenarios of situations with disruptions were rated best regarding usefulness. Disruptions are situations when passengers need much information, because their trip is not only late, but they possibly can not carry on as planned. We think that adaptive systems can support passengers best when they need dynamic and up-to-date information the most and this result supports our theory.

In both categories, usefulness and comprehensibility, ratings of participants with moderate to low confidence in smartphone usage are worse than ratings of participants with more confidence. Since the numbers of respondents in the first category is quite low, we have to look into this connection more deeply, gathering more data.

5.2 Active vs. Passive Adaptivity

We had five pairs of scenarios based on the same situation and using the same devices that differed in the realization of the adaptation. One part of a pair implemented an active execution or configuration of a service, whereas the second part implemented the same adaptation in a passive way. An example of such a pair is explained in Subsect. 3.6. After seeing and rating both scenarios independently, participants additionally were asked to compare those scenarios directly.

Figure 8 shows the average rating of all scenarios using active adaptation and all scenarios using passive adaptation when rated independently. These groups do include the paired scenarios but also all scenarios using active or passive adaptation that were not part of a pair. Active adaptation scenarios were rated slightly better regarding comprehensibility than passive adaptation scenarios, which came as a surprise for us. We plan to look into this in more detail in future work. Passive adpatation scenarios were rated as more useful on average, however.

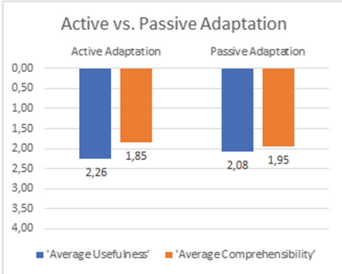

Fig. 8. Average usefulness and average comprehensibility of scenarios using active or passive adaptation.

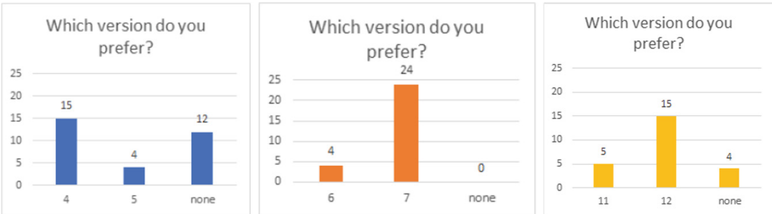

Fig. 9. Numbers for preference of scenarios when comparing pairs of active and passive adaptation, pair 4, 5, pair 6,7 and pair 11, 12.

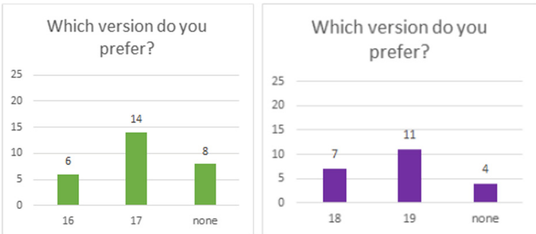

Fig. 10. Numbers for preference of scenarios when comparing pairs of active and passive adaptation, pair 16, 17 and 18, 19.

Regarding the comparison of pairs, shown in Figs. 9 and 10, the pair of scenarios 4 and 5, which are in a situation of delay considering smartphone and smart window, is the only pair where the active adaptation is mostly chosen over the version with passive adaptation. For all other pairs, participants mostly chose the passive version over the active version. We are planning to look into these results in more detail in the future, with more detailed evaluations of active and passive adaptations in passenger information systems.

5.3 IFeatures for Adaptivity in Smart Public Transport

Comprehensibility of IFeatures. We examined wether additional explanations make the system adjustments more intelligible. For this reason, we evaluated the comprehensibility of the different versions of the intelligibility features (IFeature). We assumed that users would prefer the reduced representation of version 1. In contrast to our assumption, version 2 was rated best for comprehensibility among all participants. Figure 11 illustrates the results for the scenarios 7, 11, 16 and 17. These scenarios have received the most replies in the dynamic compilation of the questionnaire.

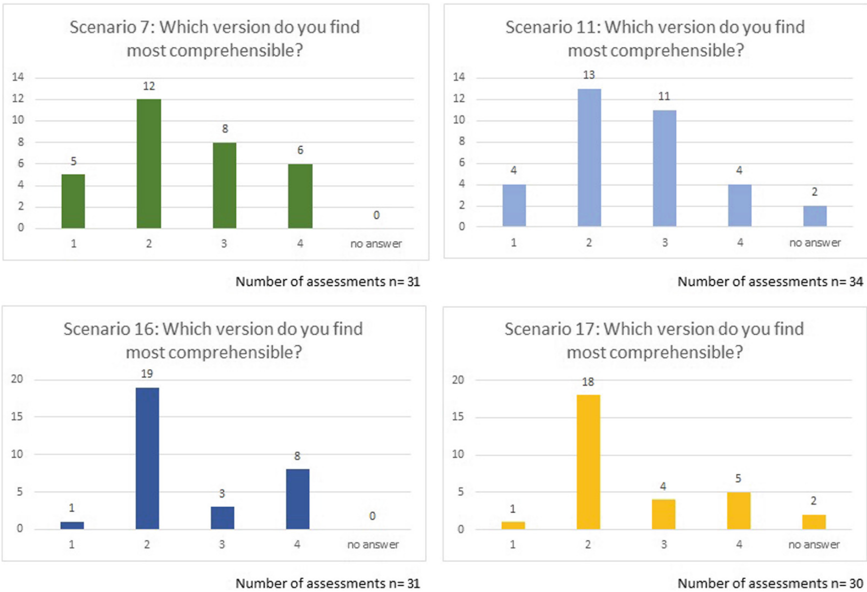

Fig. 11. Results for the scenarios 7, 11, 16 and 17 in terms of comprehensibility

We compared the three IFeature versions and an additional version 4 without IFeature. In Scenario 17, we had 30 participants who answered the question of comprehensibility. For the question which version is most comprehensible, version 2 received the highest approval with 60%. Version 4, the presentation without IFeature was rated with only 16.67% followed by version 3 with 13.33%. Version 1 received the lowest approval with 3.3% while 6.67% did not answer the question. A similar tendency could be found in all 21 scenarios. The combination of icons and text (version 2) were preferred by most participants.

Comprehensibility of IFeatures Related to Devices. We also differentiated the scenarios according to the three interactive devices: public display, smart window and smartphone. We summarized the results to compare wether there are any differences between the devices in terms of comprehensibility. Figure 12 illustrates the results.

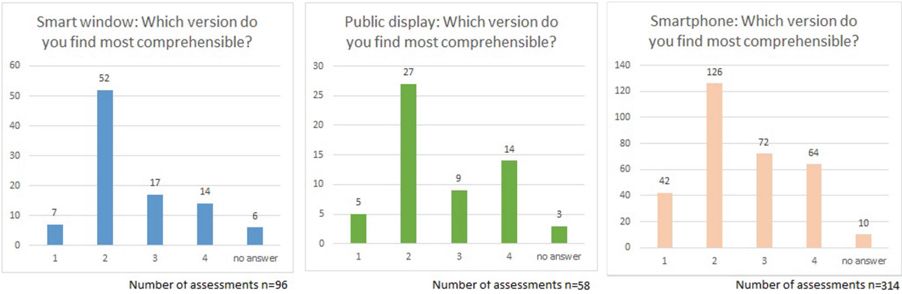

Fig. 12. Summarized results for the three devices: public display, smart window and smartphone in terms of comprehensibility

The summary of scenarios with smart windows resulted in 96 replies. For the question which version is most comprehensible, version 2 received the highest approval with 54.17%. Version 3 was rated with only 17.71% followed by version 4 with 14.58%. Version 1 received the lowest approval with 7.29% while 6.25% did not answer the question. This comparison also shows that version 2 was the most comprehensible for the participants. We conclude that the preference of a type of intelligibility feature does not depend on any device and will try to reproduce and support this conclusion in our future work.

6 Discussion and Outlook

In this paper, we presented a first analysis of the results of our study and have already drawn some conclusions on future work. Due to time and space constraints, we were not able to report fully on all results we were able to get from our data and hope to discuss those results in some future publications in greater detail. However, we could examine the usefulness and comprehensibility of our scenarios and found indications that adaptive information in situations with disruptions might be most interesting to investigate in the future. We also will look into the preference of passive adaptations over active adaptations when we perform studies with our prototypes.

The comparison of the different versions of the intelligibility features for comprehensibility showed that the combination of icons and text (version 2) received the most approval from the participants. In the next steps, we have to examine these results in real-world applications as well.

Unfortunately, some of our research questions could not yet be answered based on the results of our questionnaire, due to a lack of data. We therefore plan to conduct this study in a longer time period and with intensified efforts on the acquisition of test persons. We are planning in particular to reach more persons that are unconfident using their smartphones and apps and to examine their understanding and assessment of adaptation scenarios. On top of that, we plan to conduct separate studies with a greater focus on the comparison of active and passive adaptations and on the intelligibility features.

However, we have seen that the usefulness of adapatation in passenger information systems is rated positively by the participants and also comprehensibility is assessed better than we expected. This is a very good basis for future developments. We now strive to implement some of the adaptations we designed for this study as prototypes and to evaluate those in our laboratory. This evaluation of our adaptation scenarios is the first basis for our selection of scenarios for implementation.

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