Multi-Dimensional Context-Aware Adaptation of Service Front-Ends

Project no. FP7 – ICT – 258030

Deliverable D.5.3.2 Second Evaluation (users, development tools)

Due date of deliverable: 30/09/2013

Actual submission to EC date: 30/09/2013

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination level		
PU	**Public**	**Yes**

Document Information	
Lead Contractor	Telefónica I+D
Editor	ISTI-CNR
Revision	24.09.2013
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Changes			
Version	**Date**	**Author**	**Comments**
1	17/9/2013	ISTI, SAP, TID, W4	Partners contributions
2	20/9/2013	ISTI	First Integrated Version
3	23/9/2013	ISTI	Version for Review
4	24/09/2013	UCL	Review
5	26/09/2013	ISTI	Review Integration
6	30/09/2013	ISTI	Final Version

Executive Summary

This report describes the results of a second round of evaluations that have been conducted within the SERENOA Project in order to assess the adaptation platform and four applications.

In particular, it reports the evaluation carried out at SAP on the adaptive HMD-based prototype, the test conducted by CNR to assess the multimodal augmentation of Web applications obtained through adaptation, the work done at W4 on evaluation of a prototype in a business scenario, and the evaluation carried out by TID on an e-health application.

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1 Introduction

1.1 Objectives

The objective of this document is to report on a second round of evaluations carried out in SERENOA. The purpose is to collect some empirical data that can provide useful suggestions to understand the effectiveness of the current solutions and identify areas that require further work.

1.2 Audience

Being a public deliverable, this document will be available outside the confines of the project's consortium and is intended to be of interest to the following parties:

a) Members of the consortium, who will find here a detailed description of the evaluation results.
b) Researchers in the relevant fields: adaptation of SFEs, UI evaluators, designers and developers.
c) EC officials that will use the information in this document as an account of the activities taken in the project tasks that report this work.

1.3 Related documents

- **D2.4.1 Criteria for the Evaluation of CAA of SFEs (R1)** indicated a first set of criteria that can be relevant for the project. This deliverable aims to provide a self-contained update of such set of criteria.
- **D2.4.2 Criteria for the Evaluation of CAA of SFEs (R2)** aims to provide a self-contained update of D2.4.1 (R1), by indicating a revised set of criteria that can be relevant for the project. This document D2.4.2 provided a set of relevant criteria that have been used to evaluate the SERENOA prototypes.
- **D5.2.3 Application Prototypes (R2)** includes the second release of the scenarios design and implementation
- **D5.3.1 First Evaluation**, reported the results of the first round of evaluations

1.4 Organization of this document

Section 1 describes the scope and the organization of this document. Section 2 describes the HMD evaluation conducted at SAP. Section 3 reports on a user test concerning the platform for multimodal augmentation of Web applications conducted by CNR. Section 4 presents W4's work on evaluation in a business domain. Section 5 presents the results of TID evaluation on an e-health adaptive application. Section 6 presents the conclusions of this document and the planned future work.

2 Smart Glass Evaluation at SAP

This section continues the evaluation of the prototype for an adaptive warehouse order picking system already introduced in the previous version of this deliverable. The details of the prototype architecture can be found in the Serenoa deliverable D5.2.3 Application prototypes (Rev. 2). Based on the first two user studies results we have extended the complexity of the scenario and added a new modality to be evaluated, i.e. vibro-tactile feedback.

2.1 The Smart Glass Evaluation Intelligent-Picking Prototype

The objective of the Intelligent-Picking prototype (IPP) is to demonstrate the possibilities offered by adaptive user interfaces. So, instead of focusing on system business logics, we have addressed the implementation of adaptive rules for this application. Comparing to traditional user interfaces, in this prototype the UI is audio-based since the users are hand free when they interact with the system. However, the associated issue is the imperfect speech recognition and the burden of memorizing audio commands, which make audio interface not always able to suit for interaction. Therefore, adding the adaptability to UI may make up for the deficiency of audio interface. By decreasing the number of input actions, the adaptive features enable users to finish the picking task more efficiently and effectively.

In the previous release of this deliverable the architecture was described as a UI component based on web-technologies that communicates with the Application servers containing the Adaptation Business Logic, Adaptation Rule Engine, and the Context Manager. It was described that the multimodal interaction happens visually through the UI screen on the HMD and vocally through the mobile device (wearable computer). The adaptation was described as being requested by the Adaptation Engine (server) after being triggered by the Context Manager (i.e. a change in the context). It was foreseen that some changes might be triggered by tracking the picker's position.

It can be verified by looking at Figure 1 that these main concepts have remained though they are depicted now in more detail and with some extension.

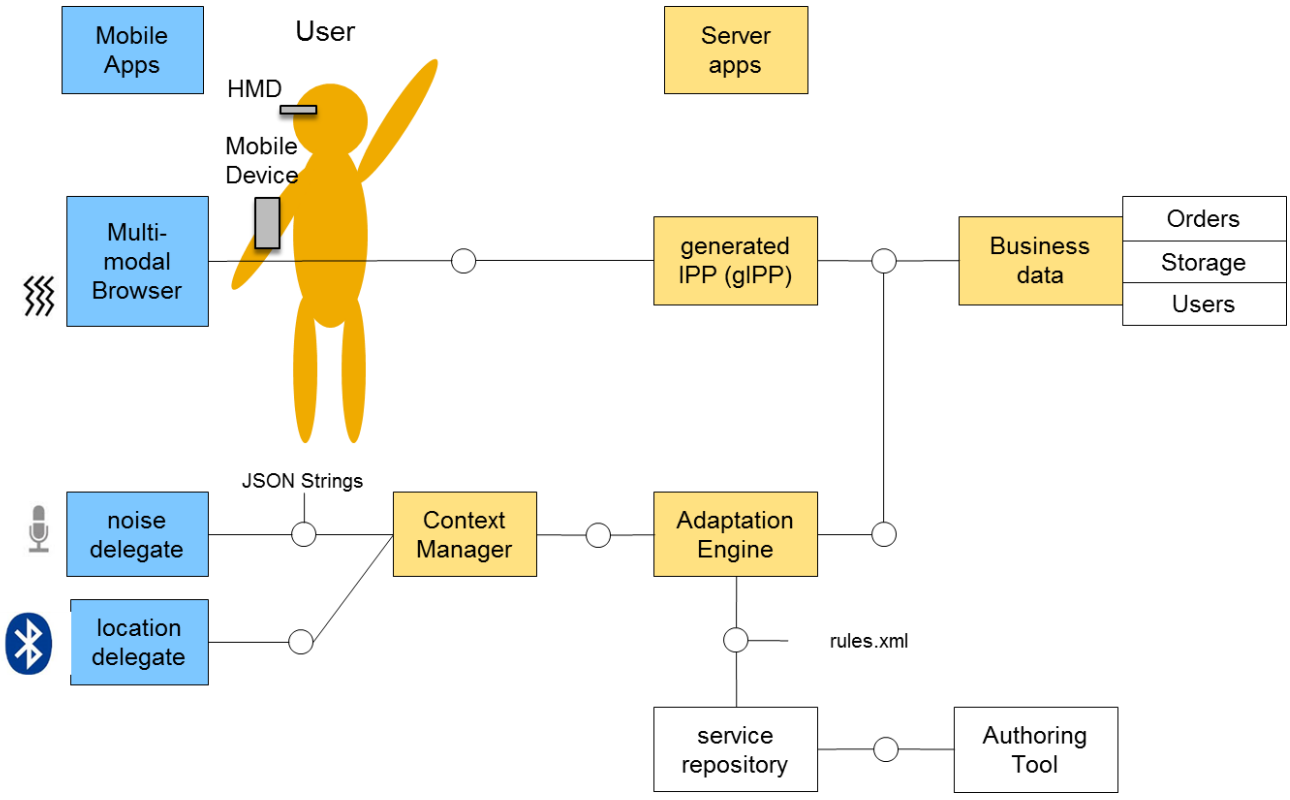


Figure 1: Adaptive prototype architecture

The IPP has now been generated using the Maria RUIGE (described in D4.1.2). The Business data is provided by REST services containing the data of the actual orders, the storage infrastructure (i.e. a map of the shelves) and the users. The Adaption Engine holds the rules specified according to the AAL-DL and that can be created by the Authoring Tool (described in D4.5.3). The Context server connects to two context delegates running on the mobile device able to sense noise and location. The multimodal application, which is also running on the mobile device allows voice out- and input and a vibro-tactile feedback.

Figure 2 shows the adaptation to minimize distraction when picking a fragile item as a sequence of screens and the respective vocal interaction. After reaching the destination shelf 2.02 (a) a multimodal (vocal and visual) notification will be triggered (screen b-d). After that the visual modality will be switched off. The confirmation will use only the vocal modality (e). The following task will switch back to multimodality (f).

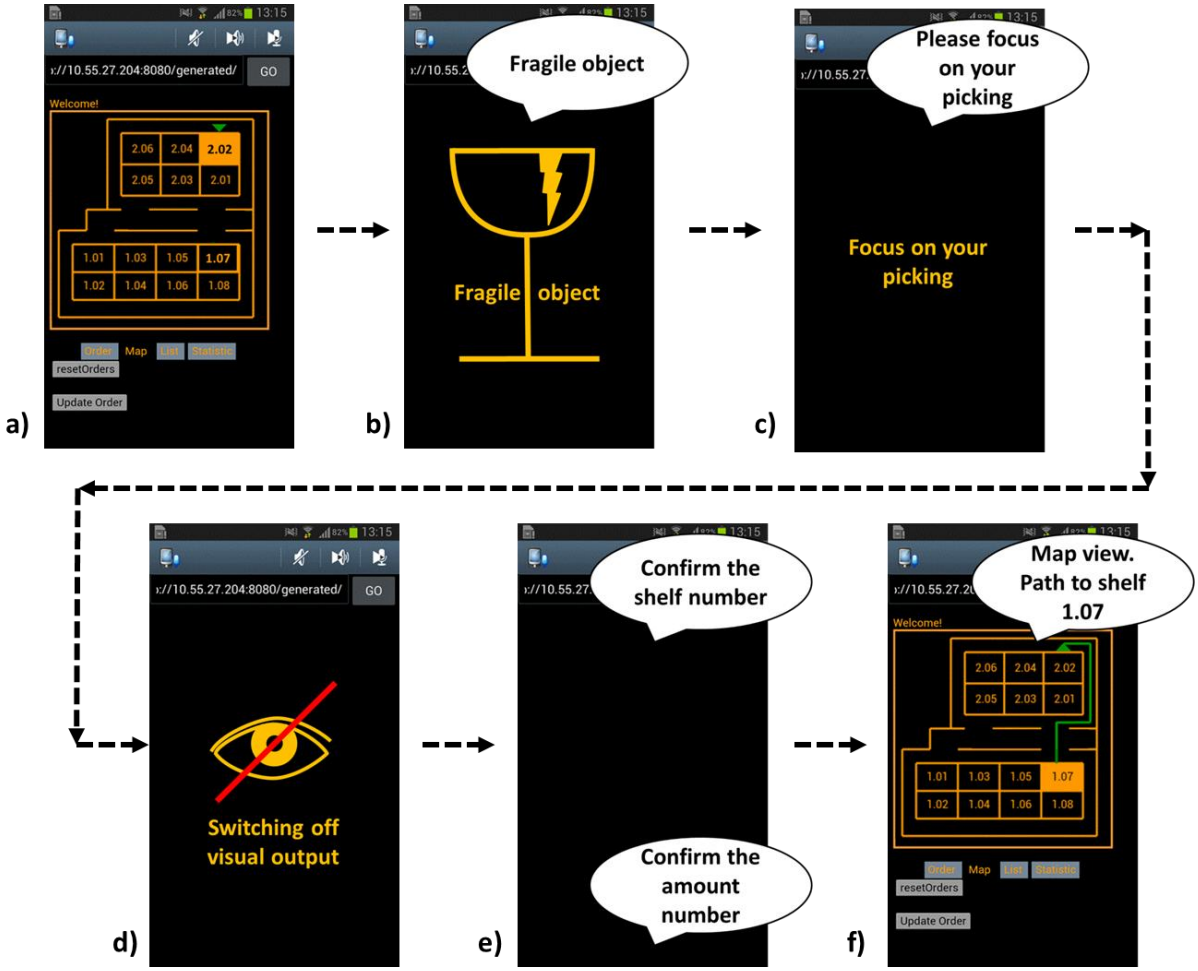


Figure 2: Adaptation to minimize distraction when picking a fragile item. After reaching the destination shelf (a) the notification will appear and the visual modality is switched off (b-d). The confirmation will use only the vocal modality (e). The following task will switch back to multimodality (f).

2.2 Previous studies

Following the principles of User Centred Design (Rubin, J. 1994) in the design process of our IPP, we conducted three evaluations. After addressing the usability problems found in the first study, the second study was planned and conducted, aiming at evaluating the effect of subsequent improvements on the prototype, while the third study extended the IPP with an additional modality.

We conducted a first user study in order to evaluate the five adaptation rules from the end-users point-of view (see (Bongartz et al., 2012)). Those three rules that are also used in the last study are shown in Table 1. In order make the first and the second study statistically and conceptually comparable, we used similar questionnaires and study design in all studies.

Context variation	Interaction consequence
The items to be picked are fragile	After vocally confirming the arrival at the destination by the picker, the visual output will be switched off, only vocal remains.
The route is blocked by other pickers	The Map view marks the blocked path and suggests an alternative route.
The environment is noisy	The vocal input and output is switched off, only visual output remains.

Table 1. Variations of the context and its consequences for the interaction modalities

The study aimed at evaluating the applicability and usefulness of the adaptation rules by assessing their quality based on the subjective perception of the participants. The general concept "quality" was operationalized by several more specific constructs, e.g. usefulness, comprehensibility or simplicity, which were assessed by a questionnaire. The abrupt darkness in the HMD was perceived as a break-down of the system and therefore caused confusion. Rather, subjects had wished to receive a short warning message before turning off the display.

We found similarities between those rules that were ranked well and those that were ranked poor. The group of poorly ranked rules was omitting information like the visual output and the Map view with regard to the Basic Interaction Flow. This also explains why the fragile item rule was ranked worst as it triggers to shut off the visual output which is the basic modality of the system. Those rules that were ranked well, however, delivered additional information like the blocked path or the image of the item.

Therefore, in the second study, we investigated the role of adding vs. removing information in the course of interface adaptation. The second study tested the hypothesis that the poorly ranked adaptation rules will be higher ranked when information is not only removed but the removal of information is actually explained beforehand by adding information. There were three main interesting observations:

- The user rating (on a scale from 0-7) of the Fragile rule improved significantly compared to the first study (see table).
- The Experienced Worker rule performs consistently worse (see table) than the other rules (although pairwise comparison did not reach significance).
- The four other rules Experienced Worker, Traffic Jam, Pick Timeout and Noisy did not change in the course of the second experiment (see table).

	Study 1	Study 2
Fragile	3,9	6,6
Experience	5,0	5,2
Traffic	6,6	6,6
Pick Timeout	6,4	6,5
Noisy	5,8	5,8

Table 2. Comparison of the user rating on a scale form 0-7 for study one and two

2.3 Methodology

We have conducted a third user study in order to investigate usability for adaptive UIs in a warehouse scenario. The specific research questions were the investigation of the usefulness of multimodal interaction focusing on vibro-tactile system output.

In the general research question the goal was to investigate the user satisfaction for the adaptive UIs used in the usage scenario. Hypothesis was that:

Interaction solutions including adaptive UIs are well understood and accepted by the users.

In the evaluation, the methods of Thinking aloud, interview, and quantitative questionnaire were used. The participants were members of a homogeneous group of researchers at SAP Darmstadt. The warehouse was simulated in the lab, a smart phone with arm band, a Head-Mounted Display (Smart Glass) and location sensors were used.

In the specific research question on multimodality the vibro-tactile feedback was used as an adaptation alert. The goal was to investigate the usefulness of vibro-tactile output as notification before an adaptation takes place. The hypothesis was that

Vibro-tactile notifications improve acceptance of adaptive UI.

As independent variables vibro-tactile signals (in addition to visual / aural information) were introduced before an adaptation took place (experimental condition) or no signal (control group), respectively.

The dependent variable was user satisfaction, which was gathered through Thinking aloud, post-test interview and post-test questionnaire.

The procedure was that participants accomplish given tasks in a warehouse-related use scenario similar to the first and second user study. However, in user study 1, we used a paper-based map to simulate the warehouse layout, in user study 2 we simulated the warehouse environment on the ground of a meeting room and in user study 3 we simulated the warehouse environment on the tables of two separate meeting rooms, having boxes as shelves and real items in the shelves representing the items to be picked (see Figure 3).

Figure 3: Evaluation Environment of User Study 3

Consequently, users needed to move and navigate between two separate rooms, which made the setting more realistic. The conditions for the adaptation rules were also implemented in a more realistic way, e.g. by shutting doors in the path for the Blocked Route rule.

2.4 Results

Participants again were company staff or students of the local university (who did not participate in the first study). A total of 10 participants took part, 7 were male and 3 were female. The average age of participants was 33 years (SD = 9.0) with few experiences with voice interfaces and no experience with HMDs.

The following aspects were rated with a value on a 1-7 Likert Scale, with 7 as the strongest or most positive score:

- Difficulty of navigating to the shelf;
- System support for navigating to the shelf;
- Difficulty of picking from the shelf;
- System support for navigating to the shelf;

For the following aspects the three adaptations with and without vibro-tactile were ranked where 1 was the best and 6 was the worst position:

- How much did you like the adaptation?
- How useful was the adaptation?
- How pleasant was the adaptation?

In general the participants preferred the adaptations with vibro-tactile over those without (see Figure 4). This can be explained by the assumption that the vibro-tactile strengthens the user awareness of the adaptation. Still some users remarked in the free-form answers of the questionnaire that the intensity of the vibration was too low.

When we compare blocked route with the fragile items adaptation the former was ranked more useful but the users liked it less. This is most likely because it was not possible to trigger the blocked route adaptation well in advance before the block.

In the free-form answers of the questionnaire many participants remarked problems due to the fact that the map view does not align with the direction of the gaze.

In the case of noisy environment the adaptations were ranked quite badly in terms of usefulness. An explanation for this is that, as the vocal input is switched off, the participants need to push some buttons on the smart phone. This action is, compared to the vocal input quite tedious. Also due to the fact that the smart phone is used directly the usefulness of the HMD allowing hands-free interaction gets lost.

Among the positive informal considerations, participants highlighted that the map view, the automatic switching between screens and the vocal output were very helpful. The system was perceived as very supportive in the tasks of navigation and picking.

On the negative side most of the participants criticized the design of the HMD, which requires a very long adjustment phase at start-up. The adjustment might even get lost during the run and some participants remarked that they were not able to reach a comfortable adjustment at all. The voice interaction was mainly criticized for its timing. While some outputs take too long, some inputs are triggered too early.

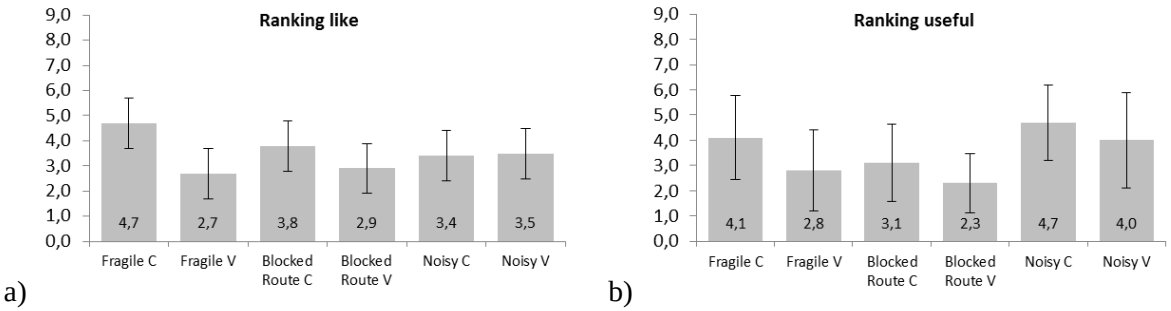


Figure 4: Study 3: a) Ranking upon a) how much the participants liked the adaptation and b) how useful the adaptation was for the participants.

2.5 Discussion and Conclusions

Participants recommended improving the map view and the speed of the system. The map view was not able to rotate with the user's gaze which appeared to be a problem for those shelves in row 1 and 3 (see Figure 2 screen 1). As the Serenoa framework is highly modular a message coming from e.g. the location sensor needs to pass through the context manager, the adaptation engine, the generated UI and finally back to the smart phone's browser. If the network is overloaded this can lead in the worst case to a number of seconds until the change is perceived. Still the participants acknowledged the benefit of map-based navigation and the reception of information based on the context.

The final prototype represents the Serenoa framework encompassing the description language for adaptation, the context manger, an adaptation engine and a generated UI. Thus, it is not surprising that the improvement

of speed was mentioned quite often by the participants. Indeed this will be one of the priorities for the further development of the prototypes. Still, the feasibility of the Serenoa framework to produce context-aware adaptive UIs was proven by the study. What remains are design aspect (e.g. map-view) which is a challenge not specific to the Serenoa framework.

3 Evaluation of Web MultiModal Augmentation

3.1 Introduction

CNR has carried out a user test to analyse how users perceive the solution for multimodal augmentation of existing mobile Web applications. With this study we aimed to evaluate some aspects characterizing context-based multimodal augmentation of existing graphical Web applications, and to what extent they are considered useful and usable. Reactivity to context changes, adaptation process performance, intuitiveness of adaptation notification, appropriateness of multimodal adaptation and usability of adapted page are examples of aspects considered.

3.2 Experimental Settings

Ten users were involved in the test, 6 males, 4 females. Their age ranged between 21 and 45 y.o. (mean 30.4). Only four users had previous experience in the use of UIs combining graphical and vocal modalities.

Participants were requested to interact with the English mobile Wikipedia home page (http://en.m.wikipedia.org) in order to find information about cities and countries. Interaction occurred through an Android smartphone, which was equipped with support for multimodal Web user interface execution obtained through an instance of a WebView components and libraries accessing the Google Text-To-Speech and Augmented Speech Recognition. The calls to the functionalities of such libraries are created by the generator from the MARIA multimodal concrete description.

In the test, the users first had to search for a city, and find out its population, and then to search for a country and find its surface area. The city and country names were the same for all users, in order to have homogeneity in the task complexity.

Users had to complete the same tasks through two versions of the application: the original one (only graphical) and the one with multimodal augmentation based on the context of use obtained through our adaptation environment (see Figure 5). In order to balance the learning effect half of the users started with the original version and afterwards continued with the context-based multimodal augmentation one, while for the others the order was inverted.

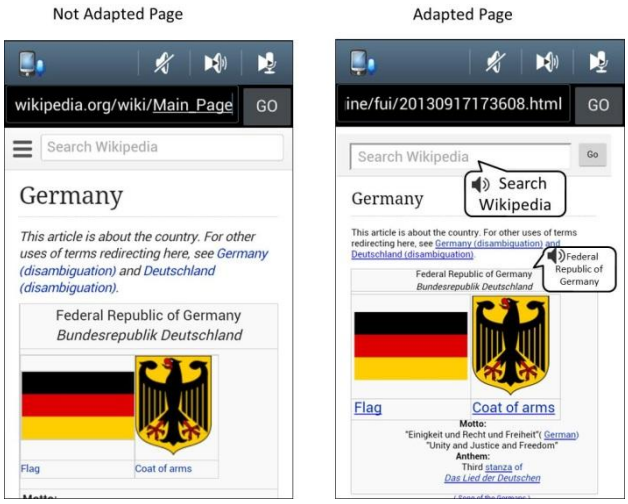


Figure 5: The two application versions considered in the test.

Users had to stand and walk while performing their tasks. In the case with multimodal augmentation, at the beginning some loud music was played in the environment and the original graphical version was activated. Then, the augmented multimodal version was triggered by dynamically reducing the environment noise. The adaptation platform provided a multimodal version (graphical and vocal) of the currently viewed page as soon as the music was switched off. This was enabled by the context delegate running on the smartphone, able to detect the environment noise reduction.

The user received notification of the activation of the multimodal interface through vibrotactile feedback immediately before the multimodal page was uploaded in the smartphone.

3.3 Test Results and Discussion

The following aspects were rated with a value on a 1-5 Likert Scale, with 5 as most positive score (min and max value are expressed into square brackets, mean scores graph is also shown in Figure 6):

A) Awareness of context-dependent interface adaptation [3,5]; mean: 4.1; std.: 0.88;

B) Adaptation appropriateness [1,4]; mean: 3.4; std.: 0.97;

C) Adaptation continuity [1,5]; mean: 3.2; std.: 1.03;

D) Rendering of adaptation transition [1,5]; mean: 2.4; std.: 1.35;

E) Impact of adaptation in improving user experience [1,5]; mean: 3.2; std.: 1.03;

F) Utility of multimodal augmentation for improving Web applications usability [2,5]; mean: 3.7; std.: 0.82.

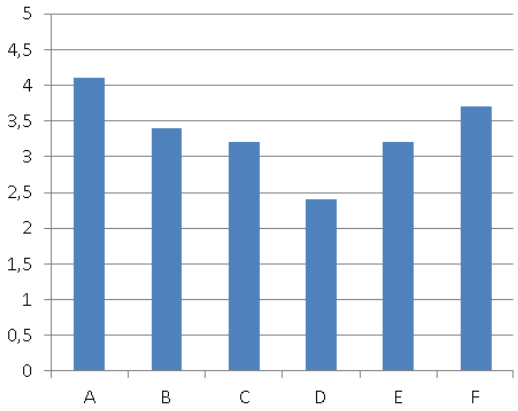


Figure 6: Mean scores for usability aspects of multimodal augmentation.

Overall, we can argue that users were quite aware of the context-dependent interface adaptation being performed. This is because, as soon as the environment noise dropped, the adaptation was triggered and the user received a vibrotactile notification. Some users declared to have been aware of the adaptation due to the vocal prompt given by the browser.

Utility of multimodal augmentation has also been considered: in the free-form answers of the questionnaire, a couple of users highlighted the flexibility of being able to perform the same task in different modalities.

Adaptation appropriateness got instead lower ratings, which may be due to minor inconsistencies that the users found in the adapted page (e.g. some link not very visible because of the slightly altered layout).

Adaptation continuity (i.e. easiness of continuing interaction after adaptation) and impact of adaptation in improving user experience received a borderline mean rating. We motivate this because some users, due to their English pronunciation, had issues in providing the vocal input properly. Also, some users raised some issues about the prompt strategy, i.e. the “beep” that tells the user to start talking. In detail, the “beep” is considered to be unintuitive and to be provided “too late” (i.e. sometimes the participants started speaking to the system before the “beep”).

The way adaptation transition was rendered received the lowest mean score. We can argue that, even if the device vibrated before launching the multimodal page, the loading process took longer than a typical page. In addition, before being able to vocally interact with the page, users had to wait for its complete loading. The indication of the loading percentage given by the progress bar started only when the adapted page was being uploaded in the device, but no explicit feedback was given about the performance state of the previous

processes (Reverser, etc.).

Among the positive informal considerations, participants highlighted the benefits that the multimodality can provide in various situations, such as when hands free interaction is needed, and/or when it is not possible/safe to look at the screen. One participant also mentioned possible benefits in the social aspects of interaction that can arise from such multimodal adaptations (e.g., accessibility for the visually impaired). We also got some positive observation on the multimodal adaptation potential, for which our platform was considered to be a good starting point.

In general, the main technical issue of the multimodal augmented version seemed to be the latency of the adaptation process.

4 Evaluation E-Commerce Adaptive Application

The W4 prototype aims at using Serenoa's adaptation rules on traditional business applications. It includes one Business to Consumer (B2C) prototype (wide public, customers, without prior knowledge about the application), one Business to Business (B2B) prototype (typically, employees with good knowledge and frequent usage of the application).

The E-commerce scenario is based on the idea of a bicycle online shop selling bikes and bike related equipment or parts.

The default application (prior to adaptation) presents:

- A web application accessible on the Internet, for the consumers (who can see items with their description, price, add product to a basket and confirm the order). Additionally, a page shows the order status but this status is updated by the other modules.

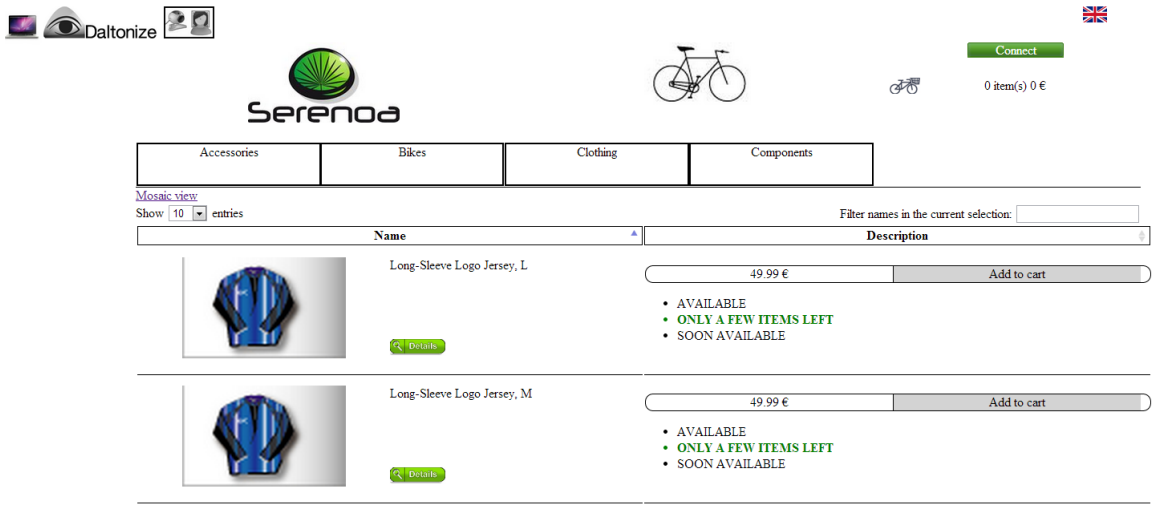


Figure 7: The application considered in the e-commerce scenario

- A web application accessible from the intranet of our bicycle shop, sharing the same database and content, in order to validate the customer order, checks product availability and request for shipping.

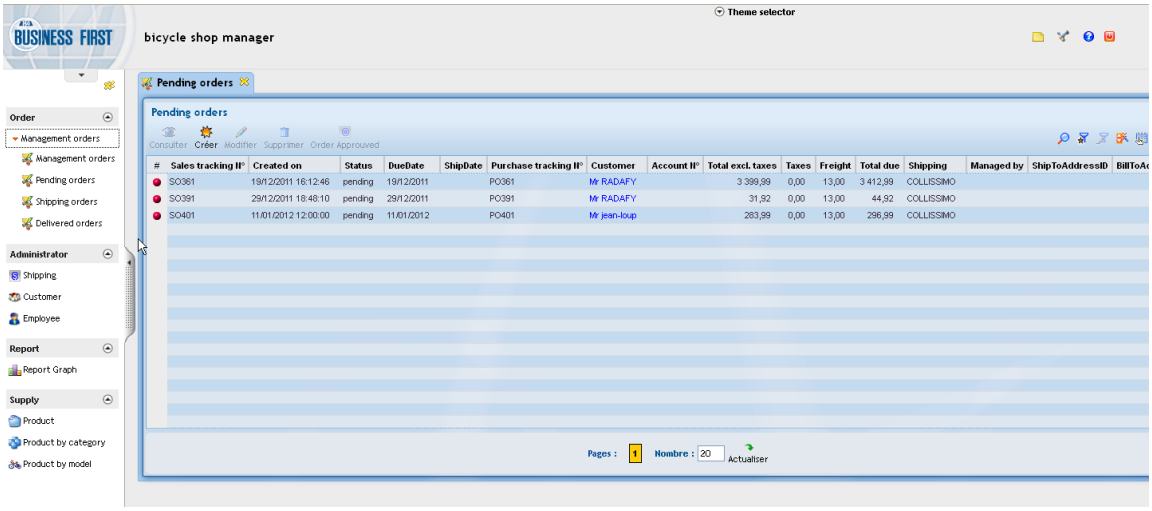


Figure 8: UI for checking product availability

- A dedicated screen allows simulating the shipping process and changing the status of the order

(prepared, shipped, received ...)

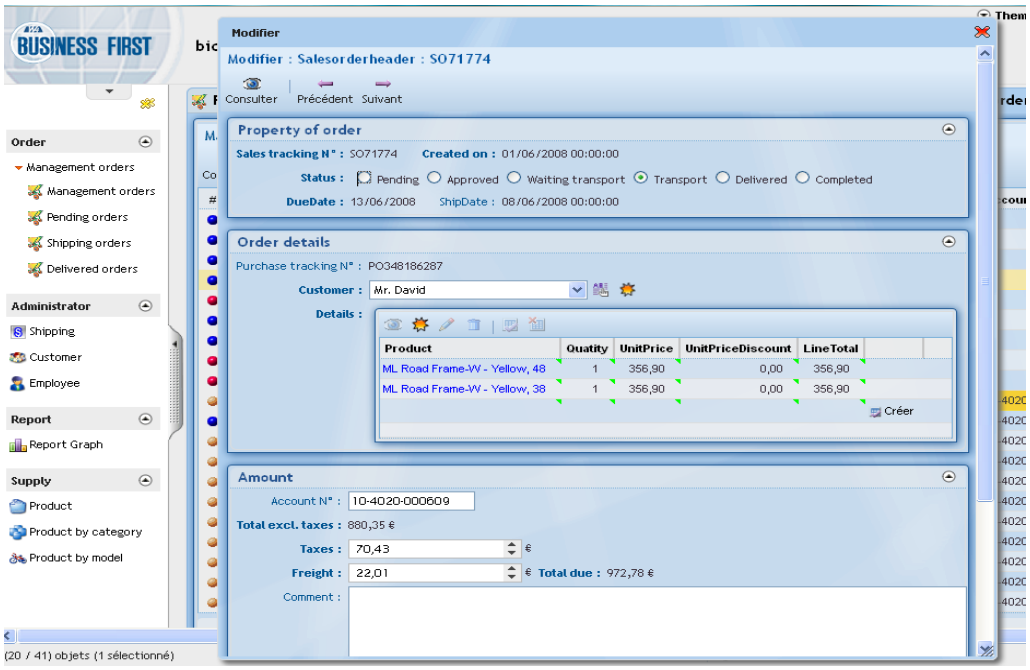


Figure 9: The UI for checking the status of the order

We have evaluated the suitability of several adaptation rules for these prototypes.

4.1 Methodology

4.1.1 Participants

Two evaluations were carried out for the E-commerce scenario. One in March 2013, with the first version of the prototype (which gathered 4 participants) and one in September 2013 (with 4 participants as well) was using the second (and improved) version. The first evaluation was performed by participants who were people working at ISTI/CNR and students having an internship at W4, These users have rather good knowledge of IT as users and even application developers. The second evaluation was performed by both W4 employees (for half) and external users who can be considered as representative of web consumers.

4.1.2 Evaluation criteria

The evaluation criteria are the same as for TID's prototype, as described in section 5.1.2 (Evaluation criteria).

The evaluation form was also shared among the different partners in order to have more comparable results. So the same form, as described in Annex A.1 Questionnaire, was used.

4.1.3 Procedure

The e-Commerce prototype was installed on an external website (accessible to participants from any location). The website intended for the bicycle shop consumers was made accessible without any prior login. Authentication was only requested when the participants purchased a product. At that point, the user was able to create an account online or to use given account credentials.

The web application intended for the corporate (B2C: Bicycle shop manager application) was also accessible from the internet (though, unreal, this should be limited to an intranet access) in order to make the evaluation easier for participants. However, an authentication (login / password) for the roles described within the evaluation process below was provided when starting the evaluation.

The web server needed for connexion through mobile devices (such as Android tablet/phone or iPhone/iPad) were made accessible from any compatible device providing the right URLs and authentication procedure to participants (Using Wi-Fi or, possibly, a 3G connexion).

The evaluation process was divided into 5 steps. After each step, a common questionnaire (described below) was proposed to the evaluator about this adaptation and his/her overall impressions and usage experience. Each step was evaluated individually. When the evaluation form was complete, the evaluator proceeded to the next evaluation step.

Thus, the procedure occurred as follows:

- The facilitator introduced the main goal of the study.
- He explained the role of the participant and provided the needed information to start the test (URL, authentication, installation procedure).
- After each step, the facilitator stopped for a moment and presented to the user a form to collect his opinion about the evaluation criteria, as listed in Section 5.1.2. Once the user had filled out this questionnaire, the facilitator went on with the story until the next adaption rule, where the process was repeated.

4.1.4 Questionnaire

For each evaluation scenario, the questionnaire included 10 questions consistent with the evaluation methodology as described in document *"D2.4.2-Criteria for evaluation of CAA of SFEs (R2)"*. Figure 10 depicts the questionnaire proposed to the users who have evaluated the e-Commerce prototype and Figure 11 shows the different possible grades that are proposed for rating.

D2.4.2 Criteria Category	Question	Rating				
		Front-end			Back-end	
		Mobile Adaptation (evaluation A)	Daltonize Adaptation (evaluation B)	Head tracking Adaptation (evaluation E)	Language Adaptation (evaluation C)	Mobile adaptation (evaluation D)
Appropriateness	The adaptation of the application is appropriate…					
Timeliness of the adaptation	The application is changed to user's/context's characteristics at the right moment…					
Continuity	After the adaptation happened I went on normally with the task I was carrying out…					
End-user disruption caused by adaptation	The adaptation doesn't cause disruption					
Impact of adaptation on user experience	The adaptation makes the interactive experience more appealing…					
Impact of adaptation on user performance	The adaptation doesn't decrease the performance of the application					
Impact of adaptation on error-prevention	The adaptation decreases the risks of errors					
User's perceived confidence and trust in the adaptation	I trust the system to find out about my needs and to apply the most suitable adaptation…					
Consistency of the across-device adaptation	The user experience is maintained on the different devices.					
General likeability	I would recommend the use of the application to other users					

Figure 10: Questionnaire

Status	Rate
Strongly disagree	1
Disagree	2
Undecided	3
Agree	4
Strongly Agree	5

Figure 11: Rating

4.2 Adaptation rules

4.2.1 Bicycle shop public web site

Erik is from The Netherlands, living in an Amsterdam neighbourhood. Like most of his fellow countrymen, Erik is quite fond of bicycle. His mother language is Dutch but Erik is rather fluent using English and usually browses on-line shops to find good (and cheap) products for his weekend leisure activity: cycling.

He has just discovered the bicycle shop website and browses the on-line product catalogue at home (using a web-browser on a laptop).

Unsure whether to buy the product or not, Erik has to leave home and must to go to work, without ordering the product. In the bus, Erik thinks about a product he has seen on the website. Erik connects to the bicycle shop website with his mobile phone (a quite recent smartphone with a web browser and 3G data access). He navigates to find the product description and additional details. He wants to find the exact colour of the product from the textual description (Erik is colour-blind: the image is not completely sufficient). While navigating, Erik sees a link to a colour-blind adaptation of the website, and of course, interested by this option, tries to activate it.

At the end of the day, he decides to purchase the product from home: Erik selects the product, activates the colour-blind mode, adds the item to the basket, fills in the purchase order form, edits his own credit card information and finally validates his purchase order. Table 3 describes the adaptation rules considered.

	Event	Condition	Action
Mobile web adaptation	Public website is accessed from a mobile device.	Web browser is recognized as a mobile application	Runtime adaptation of the page content to improve usability and user experience.
Colour-blind adaptation	Website 'colour blind' option is toggled on by user choice or profile	The user is colour blinded and activates this mode.	Images and text and page colours are adapted in order to improve user experience

Table 3: Specifying the ECA rules (Mobile web adaptation and Colour-blind adaptation)

4.2.2 Bicycle shop manager: order validation

Juliette is working for the bicycle shop company. She is French but works in Luxembourg. She is in charge of the validation process of customer orders. She has just received the purchase order from Erik. She opens the order form and check if everything is fine before sending the order form to the shipping team. She connects to the corporate website, selects French (her mother language) displays the order list and validates the order. Erik receives a validation email to confirm that his order has been approved.

	Event	Condition	Action
Language adaptation	a multilingual UI has been accessed.	User's preferred language is French	The system displays the information in French

Table 4: Specifying the ECA rules (Language adaptation)

4.2.3 Bicycle shop manager: customer representative

Peter is the customer representative; he is German but currently travelling to the company's headquarters in Luxembourg. He would like to see the latest orders and sales figures. He connects to the corporate application with his Android tablet, using the mobile android adaptation. After authentication, Peter is enabled to visualize daily orders and details, and some graphical charts about monthly sales.

	Event	Condition	Action
Mobile tablet adaptation (Android)	The corporate application is accessed through an android tablet	the Android application is used	The system uses native Android screens to display information

Table 5: Specifying the ECA rules (Mobile tablet adaptation - Android)

A second optional test (if available or depending on 'tablet' availability may be performed using an iPhone or iPAD): same results but using iOS instead of Android.

	Event	Condition	Action
Mobile tablet adaptation (IOS)	The corporate application is accessed through an apple mobile device	the iOS application is used	The system uses native iOS screens to display information

Table 6: Specifying the ECA rules (Mobile tablet adaptation - iOS)

4.2.3 Bicycle Shop public web site – second evaluation

The Bicycle Shop opened a physical shop in Luxemburg and wants to challenge the curiosity of the pedestrians walking by its shop front. It installs a computer screen connected to the website in the shop front and activates the head-tracking adaptation.

John, who passes near this place sees the installation and takes a look at the screen. After noticing that his head position and movements are recognized by the displayed application, John moves right and the item page is automatically updated as a response to his movement. He moves left and the previous page is restored. John notices an interesting item in the online catalogue, so he moves his head towards the screen and the detailed information about this article is shown. He finally goes backward and the previous item page is restored.

	Event	Condition	Action
Head tracking adaptation	The user moves his head	the head tracking adaptation is activated	The system updates the displayed page based on head gesture

Table 7: Specifying the ECA rules (Head traking adaptation)

4.3 Results

The results and consequent analysis take into account the two evaluations as a whole, although users testing the second version of the prototype evaluated an improved version of the software, with additional adaptation rules related to the new head-tracking feature.

The evaluation was performed by 8 persons including 5 males and 3 females, of different age and IT skills. Among them, 4 have a high technical knowledge, 2 a medium one and 2 a low one.

When analysing results, values are interpreted in two different ways. The first analysis takes into

account the whole set of results while the second one ignores the responses that provide a "Not Applicable" value. This second point of view is relevant because it is not easy to know if the user considered that the criteria was impossible to evaluate or if the result means that evaluation reflects an average grade.

The prototype has evolved during its evaluation to take into account the different comments of the previous users. In Figure 12, one can see the chronological evolution of the global score of the evaluation. After the 4th user, some instability was corrected and the score has improved afterward.

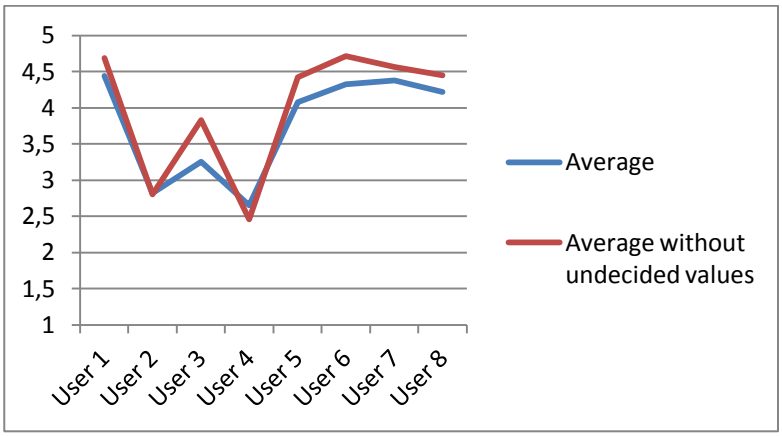


Figure 12: The chronological evaluation score by user

The complete data of our evaluation is available in annex C. The goal of this section is to analyse the results and draw conclusions.

4.3.1 Analysis

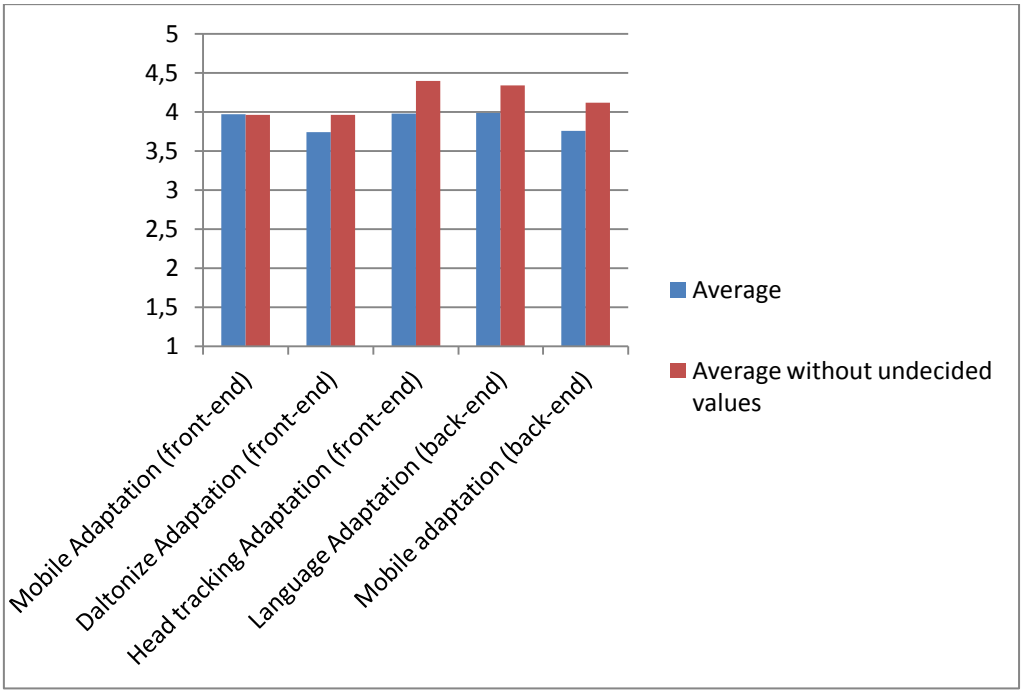


Figure 13: Evaluation results

Mobile adaptation (front-office):

On the one hand, adaptation for mobiles allows selection of categories of items in an easier way thanks to the menu adaptation for mobility. On the other hand, buttons providing access to the main features are easier to activate because their size is relatively greater. Besides, the mobile mode is automatically detected, which

makes things easier for the end-user. However, the fact that all controls are not adapted and the fact that not all features are available in the mobile version bothers some of the users.

Daltonize adaptation:

Opinions regarding the « daltonize » mode and its adaptation rules are more divided. Some of the users have judged the adaptation as "interesting" and "uncommon", even though one may think that providing a relevant point of view would require to really be a color-blind person, which was actually only the case for one user. The fact that adaptation is performed by the client terminal has introduced some performance problems that bothered some of the users, especially when evaluation took place on mobile terminals (where processing time was longer). In its concept, this is probably an interesting use case for adaptation of the Front-office to the user's context, but implementation, as well as the color adaptation algorithm would require to be improved for really providing added value to color-blind users.

Head-tracking adaptation:

This is the most successful adaptation, based on the gathered evaluations. It was actually introduced later in the evaluation and only evaluated by four users. Being able to control screen navigation based on head gesture, without using any connected physical device for input is seen as innovative as having a good "technical potential". The webRTC technology on which this adaptation was based is quite new and not standardized yet. This explains why a beta version of the browsers is needed and why its usage is therefore limited on mobile terminals based on which device is used.

Language adaptation:

This adaptation has not been really noticed as innovative during our evaluation. This is probably due to the fact that users are already used to see systems performing multi-language adaptation. That being said, this adaptation seems natural (even "obvious") to users and is therefore a relevant use case for the SERENOA framework

Mobile adaptation for the back-office system:

Contrary to the mobile adaptation for the front-office that makes use of a web browser, adaptation for mobiles on the back-office system relies on the usage of native Android and iOS applications. This is why the user experience is significantly different from the one when using a desktop. Besides, it takes longer for users to get familiar with the way of interacting with mobile terminals (at least with the ones who are not already used to the iOS or Android native controls). Apart from this particular reason and from the small functional bugs that still exist in these native apps, users where globally satisfied about this adaptation use case.

5 TID Evaluation

Also Telefónica I+D has deployed a prototype which takes advantage of the automatic adaptation offered by the Serenoa framework. This prototype is aligned with two projects developed by Telefónica I+D in the eHealth area as well, namely *HealthDrive project*, intended to anyone interested in managing their medical information and *SARA project*, focused on chronic patients. This alignment will make it easier the exploitation of the prototype.

In the second year of the project, one of the main focus of TID has been the creation of a version of our prototype running in Android, given the growing importance of Android nowadays and also the much bigger exploitation opportunities having a prototype running in Android, and also as a mean of showing the adaptation to the device, then numerous devices like state-of-the-art smartphones and tablets are nowadays powered by Android.

In this second and final report, we evaluate different adaptation strategies in our prototype, showing the different adaptation capabilities provided by Serenoa framework and their integration in state-of-the-art prototypes.

5.1 Methodology

5.1.1 Participants

For the final evaluation, a gender-balanced group of users have been selected. The group is composed of 5 men and 5 women and the age range is between 30-55 years. The degree of closeness to new technologies of the participants is heterogeneous, then while some of them use daily state-of-the-art technologies like smartphones and tables, another are not so familiar with new technologies and devices and only own a conventional mobile phone that only use to make calls and not for internet connection.

In the evaluation, users will test different adaptation situations implemented using Serenoa framework and they will have the opportunity of giving feedback through filling out a questionnaire, mainly focused in assessing the adaptation.

5.1.2 Evaluation Criteria

In this evaluation, the criteria specified in the document *"D2.4.2-Criteria for evaluation of CAA of SFEs (R2)"* will be taken into consideration. In that document, a comprehensive list of evaluation factors relevant to evaluate the quality of context-aware adaptation of SFEs is presented. In the current evaluation, we deal with those user-oriented aspects closely related with the adaptation strategies followed in TID case study.

In detail, the following criteria from those specified in the mentioned document have been taken into account, and therefore, they are also reflected in the questionnaire to be filled out by the users:

- *Appropriateness:* the aim of this criterion is to understand whether the system selected a good/appropriate adaptation strategy. Briefly, it measures how the adaptation matches the mental model of the user. For example, if users considered that the quality of the interaction had improved when the avatar were showed with a sequence of images if the device were changed to another one unable to support the avatar engine.
- *Timeliness of the adaptation:* it refers to the application of the adaptation at the right moment (i.e. neither too late nor too early) when there is a need of changing some aspects of the user interface to better support the user needs.
- *Continuity:* it assesses the capability to easily continue the interaction after an adaptation. At this stage, we are interested on the users' perception of continuity when interacting with the system. For example, how the adaptation of the avatar engine is perceived when the user change of device and whether they consider that the session had not been lost.
- *End-user disruption caused by adaptation:* This criterion evaluates if the user experiments some disruption or frustration by the adaptive behaviour. We want to know whether the system pro-activity to switch the modality from voice to only text is perceived as annoying.

- *Impact of the adaptation on user experience:* intended to understand to what extent adaptive behaviour (in terms of e.g. adaptation rules) can be effective with regard to user experience. For example, whether the activation of avatar's voice in a silent environment improves the user experience.
- *Impact of adaptation on user performance:* to evaluate until what extent the adaptation is able to decrease the interaction complexity and then having some positive effects on the user's performance. For example, whether the avatar is considered useful for guiding the interaction and does not represent a higher complexity.
- *User's perceived confidence and trust in the adaptation:* this factor is about the user confidence in the ability of the adaptive system to predict future needs. It is related with the user's concerns regarding privacy, user control, consistency, and system competence. For instance, users could be worried about that some sporadic environmental noises could trigger the change of modality when they really do not want it.
- *Consistency of the across-device adaptation:* this criterion refers to the level of consistency between the UI design before an adaptation and after an adaptation to a different device. Avatar adaptation from desktop to mobile device is an example of an across-device adaptation where UI harmony needs to be preserved.
- *General likeability:* it assesses the intention of a person to use a particular system in the future. This criterion seems to have relationship with the perceived usefulness of the system, the easiness in using the system itself and also the likeability of the system (to what extent the user likes the system and whether he is satisfied by using it) that the user might have perceived the first time s/he interacted with the system.

5.1.3 Procedure

The goal of the evaluation is to assess the quality of the adaptation rules and how they are perceived by the participants.

The evaluation procedure is as follows: firstly the facilitator introduces the main goal of the study to the participant and then, two different devices are presented to him: a tablet PC powered by Microsoft Windows and an Android-based state-of-the-art mobile device.

Before starting, the facilitator describes the main aims of the application and then the evaluation starts, giving the users the capability of autonomously interacting with the application. The different adaptation situations are assessed and the opinion of users is collected through a questionnaire that has been created taking into account the evaluation criteria described in the previous section.

5.2 User Evaluation

The prototype provides a user interface for the self-monitoring of user's health. In the first evaluation, the only device used was a Windows-based tablet PC, but now, a multi-device framework is being provided and besides the mentioned tablet PC, now an Android-based mobile device will be used as well, testing in this way the change of device adaptation capability.

All the functionalities tested now are working functionalities, then in the first version some of them were simulated because of the primary state of development at that moment. Some of them are simple functionalities, but we want to stress that Serenoa framework is always being used to perform the adaptation and the primary goal of this prototype is probing that Serenoa is able to perform different adaptation tasks and in the future, as exploitation beyond the end of the project, much more complicated applications could be developed based on Serenoa framework and its adaptation principles.

Given the strong alignment between Serenoa and the internal *HealthDrive and SARA projects* from eHealth area at TID, the future potential is large and we can benefit from the existing collaboration between Telefonica and the Andalusian Health Authorities, that is the official public health system for the Andalusian region in Spain, providing universal health care to its nearly 8.5 million inhabitants. Telefonica cooperation focuses on helping them thanks to our expertise to have all its centres and processes completely digitalised, providing in this way a faster and more efficient service to its beneficiaries.

In the following Table, an ECA (Event-Condition-Action) format is followed to specify the context and subsequent actions associated to each adaptation strategy.

Adaptation Strategy	Event	Condition	Action
Language adaptation	Users with different native languages (English / Spanish)	UI language preferred by the user	Language is automatically selected depending on the user
Avatar adaptation	The user has changed to an Android mobile device	The avatar engine cannot run on the Android mobile device	The avatar is displayed using a sequence of representative images
User interaction preferences adaptation	The user switches off the avatar	An avatar is used to help the interaction	The avatar is not displayed in future user sessions
Noisy environment adaptation	The environment gets noisy	The noise level gets higher than a certain threshold	The application turns off the voice modality

Table 8 Adaptation strategies

5.3 Results

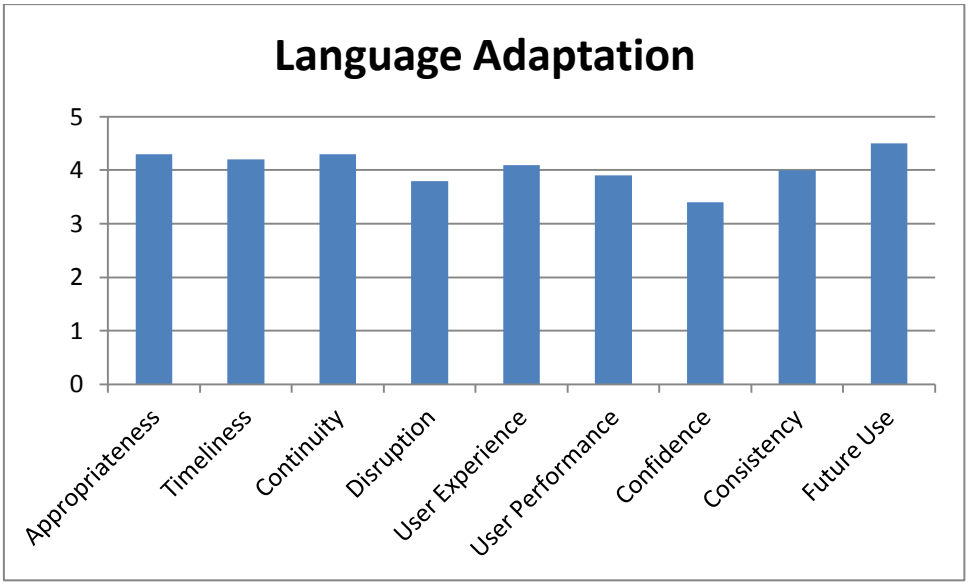
In this section, the evaluation results are presented according to the different metrics defined in 5.1.2 section, i.e. appropriateness, timeliness, continuity, disruption, user experience, user performance, confidence, consistency and future use.

The targets for the evaluation are the four different adaptation strategies, i.e. language adaptation, avatar adaptation, user interaction preferences adaptation and noisy environment adaptation.

5.3.1 Evaluation of the Language Adaptation

The Language Adaptation feature to be evaluated assesses the capability of the system to select the UI language according to the native language of the user and the capability also to remember the selection in future interactions. Currently, the UI is available in Spanish and English.

In the following graph, the evaluation of the language adaptation capability is shown:

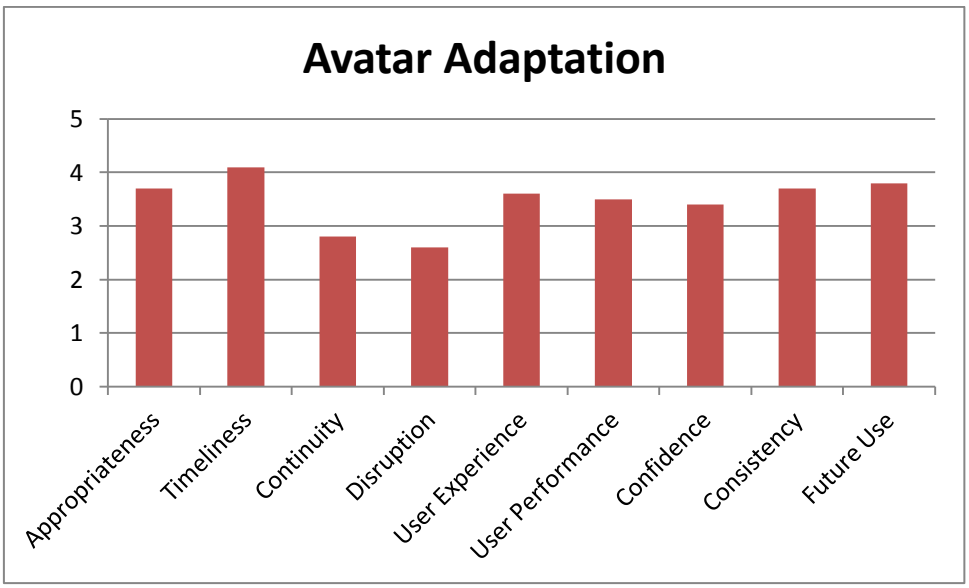


We can see that most of the different metrics obtain a good rating, highlighting the continuity of the interaction and the great interest of the users in continue using a system like this in the future. This ability of the system is perceived as something common to many systems, so it would be a mandatory capability to take into account for the future implementation of commercial products.

5.3.2 Evaluation of the Avatar Adaptation

The Avatar Adaptation feature assesses the capability of the system to continue using the avatar when a device change is done by the user. The limitation is that in Android-based mobile devices, the avatar engine cannot run, so a simulation using pre-recorded videos is done to show continuity.

In the following graph, the evaluation of the avatar adaptation capability is shown:

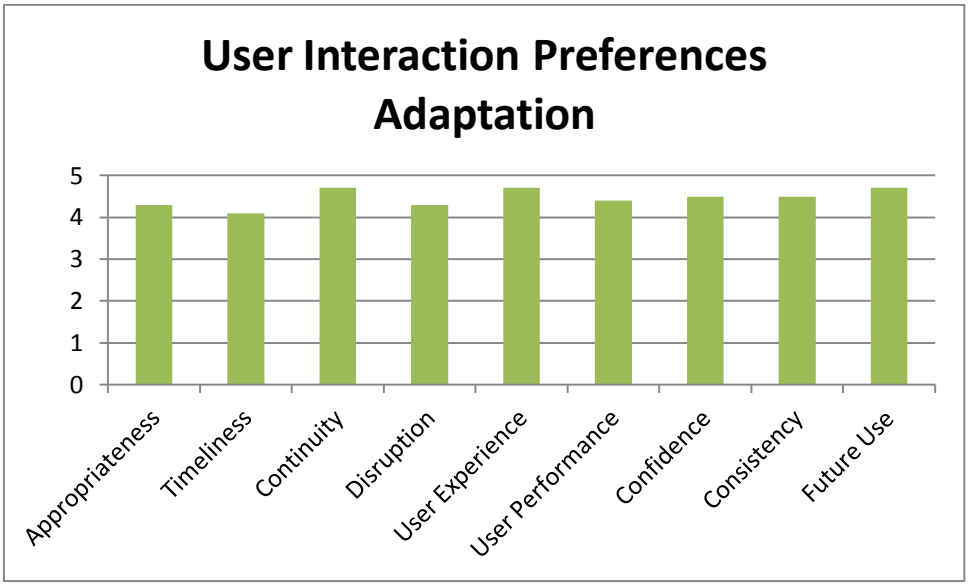


This adaptation is perceived in a different way by the different users and although for most of them it is appreciated, the ratings are lower than for other adaptations. Here, the users more familiarized with the new technology of devices, appreciate more this feature, and those not so familiarized do not really understand a change of capabilities of the avatar between the Windows-based version and the mobile device version.

5.3.3 Evaluation of the User Interaction Preferences Adaptation

The User Interaction Preferences Adaptation feature assesses the capability of the system to take into account the preferences of the user. At this moment, this adaptation consists of the ability of the system to remind the preferences of the user according to the presence of the avatar, being able to keep the avatar disconnected if the user decided to switch it off and keep it on otherwise. In the future, more user preferences could be taken into account in this adaptation feature.

In the following graph, the evaluation of the user interaction preferences adaptation is shown:

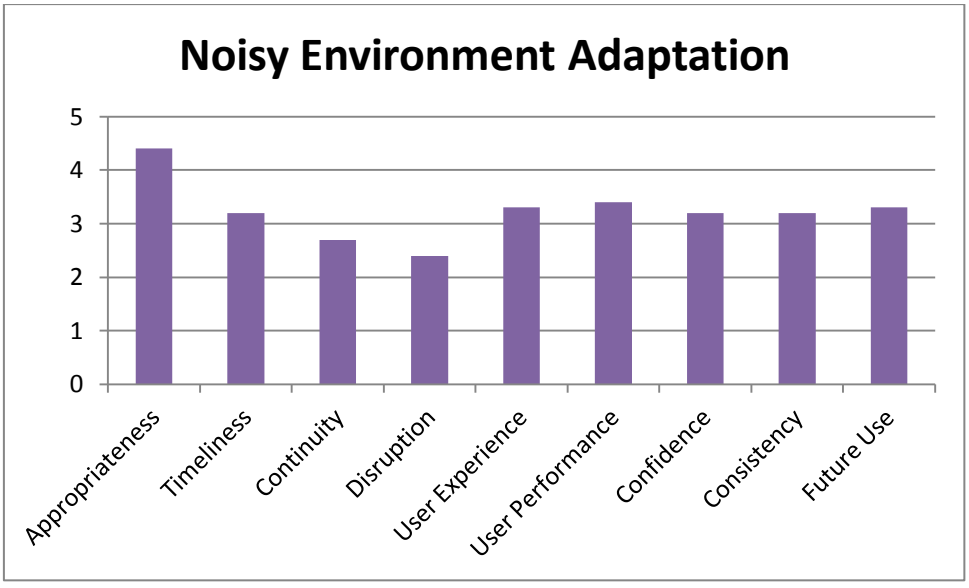


The perception of this adaptation is very high, highlighting the continuity, user experience and future use. In real products, the scope of this adaptation can be much bigger and the system should be capable of taking into account numerous preferences from the user.

5.3.4 Evaluation of the Noisy Environment Adaptation

The Noisy Environment Adaptation feature consists of the capability of the system to be aware of an environmental factor to modify the interaction. In this case, when using the application on a mobile device and moving it to a noisy environment, the avatar voice is muted, keeping only the gestures and subtitles. A threshold is set to decide when an excessive noise level is reached.

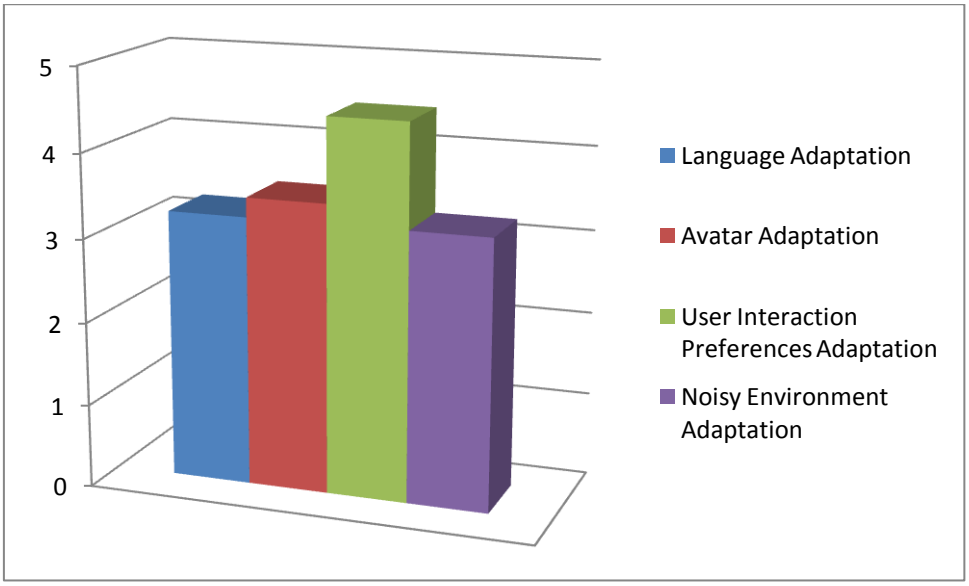
The evaluation results are shown below:



This adaptation is also well perceived by the users in general, however, it can be confusing for some users the muting of the avatar. Maybe the threshold should be user-dependent instead of global, then the perception of the noise different is not homogeneous for all users.

5.3.5 Overall Evaluation of the Adaptation

To sum up, an overall evaluation of the different adaptation strategies is shown in the following graphic, where the overall values has been obtained doing an arithmetic mean of the 9 individual metrics for each of the cases.



5.4 Conclusions and Future Work

As final conclusion, the acceptance and suitability of the adaptation rules designed for TID eHealth scenario is well perceived by the users, although for future products based on Serenoa framework, it would be necessary to broaden the adaptation capabilities of the prototype, being very careful with sensitive parameters such as the noise threshold that could be user-dependent and that also for some users minor changes in the lookout of the application in the mobile domain can be impacting.

Some of the adaptation features like the language adaptation is perceived as something basic for any system, so any future product should implement it.

In general, Serenoa provides an excellent framework to develop adaptable applications and the evolution of the current prototype into a commercial product can be an excellent opportunity for Serenoa, given also the links existing between this development and *SARA* and *HealthDrive* products from Telefónica.

6 Conclusions

This deliverable reports on a number of user tests that have been conducted by various partners with applications in various domains, still exploiting SERENOA concepts and components of the SRENOA framework to achieve context-dependent adaptation.

Even if the working prototypes are not yet completely engineered the test scenarios were more realistic than those considered in the first round of evaluation, and we have considered a variety of interaction modalities (augmented reality, avatars, various combinations of graphics and voice, …) and different sets of adaptation rules. This shows that the SERENOA approach has a potential impact on a wide set of applications and technologies.

We plan to continue the empirical validation of our prototypes in order to identify the most effective solutions in the various phases of the service front-ends adaptation in broader contexts of use.

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Acknowledgements

- TELEFÓNICA INVESTIGACIÓN Y DESARROLLO, http://www.tid.es
- UNIVERSITE CATHOLIQUE DE LOUVAIN, http://www.uclouvain.be
- ISTI, http://giove.isti.cnr.it
- SAP AG, http://www.sap.com
- GEIE ERCIM, http://www.ercim.eu
- W4, http://w4global.com
- FUNDACION CTIC http://www.fundacionctic.org

Glossary

- http://www.serenoa-fp7.eu/glossary-of-terms

Annex A. TID's prototype evaluation support material

Annex A.1 Questionnaire

1. The adaptation of the application has been appropriate...

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
❑	❑	❑	❑	❑

2. The application has changed to user's/context's characteristics at the right moment...

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
❑	❑	❑	❑	❑

3. After the adaptation happened I went on normally with the task I was carrying out...

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
❑	❑	❑	❑	❑

4. The adaptation has made the interactive experience more appealing...

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
❑	❑	❑	❑	❑

5. Thanks to this change I would use the application better...

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
❑	❑	❑	❑	❑

6. I think this adaptation would help me to use the system without errors...

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
❑	❑	❑	❑	❑

7. I trust on the system to find out my needs and then, to apply the most suitable adaptation...

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
❑	❑	❑	❑	❑

8. It was easy to use the mobile version of the service...

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
❑	❑	❑	❑	❑

9. I would be likely to use this tool in the future (if needed)...

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
❑	❑	❑	❑	❑

10. Does the adaptation annoy you?

11. Do you have any additional comments?

Annex A.2 Supporting material

Figure A.1: Motivation slide to avatar adaptation (HealthDrive)

Figure A.2: Motivation slide to noisy environment adaptation (HealthDrive)

Annex B. TID User testing results

Annex B.1 HealthDrive

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
User1	4	3	4	4	5	5	3	-	4
User2	4	4	4	5	4	4	4	-	4
User3	4	5	5	4	4	4	5	-	5
User4	5	5	4	5	4	4	4	-	5
User5	4	4	3	4	4	4	3	-	4

Table B.1: Language adaptation scores

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
User1	3	3	2	3	4	2	3	4	4
User2	3	3	3	4	4	4	3	4	5
User3	4	4	3	4	4	5	4	4	5
User4	4	3	3	4	5	4	3	3	5
User5	4	4	2	3	4	2	3	3	4

Table B.2: Avatar adaptation

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
User1	4	2	4	3	2	3	3	-	3
User2	5	3	4	3	3	4	3	-	4
User3	4	2	4	4	3	3	3	-	3
User4	4	4	4	4	3	3	3	-	4
User5	4	3	4	4	3	3	3	-	4

Table B.3: Noisy environment adaptation

Annex B.2 SARA (Chronic patients)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
User1	4	3	4	4	4	4	4	-	4
User2	4	4	4	4	5	4	5	-	4
User3	4	4	4	3	4	3	4	-	4
User4	5	5	4	4	4	4	4	-	5
User5	4	5	4	3	4	4	5	-	4

Table B.4: Patient's adaptation scores

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
User1	4	4	4	4	4	4	4	-	4
User2	5	4	4	5	5	4	4	-	5
User3	5	4	5	4	5	4	5	-	4
User4	4	4	5	4	5	4	5	-	5
User5	5	4	5	4	5	4	5	-	5

Table B.5: Visual impairment adaptation scores

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
User1	5	4	4	4	5	5	4	-	5
User2	4	4	4	4	5	5	3	-	4
User3	2	3	4	4	4	4	4	-	4
User4	4	3	4	4	5	5	5	-	5
User5	4	4	4	4	4	4	4	-	4

Table B.6: Error management adaptation scores

Annex C. E-Commerce Evaluation Results

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
User 1	4	5	5	5	3	5	2	5	4	5
User 2	4	4	4			1				
User 3	3	2	3	3	3	4	3	3	3	3
User 4	2	3	2	3	2	4	2	3	2	2
User 5	5	5	4	5	5	5	4	5	3	4
User 6	4	5	5	5	5	4	3	3		5
User 7	5	5	4	5	5	5	5	4	3	5
User 8	5	5	3	5	5	5	4	5	3	4

Table C.1: Mobile adaptation (front-office)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
User 1		5	5		3	5				
User 2	1	1								
User 3	4	4	4	3	4	3	3	3	4	3
User 4	4	3	2	2	4	1	3	3	1	2
User 5	4	4	4	2	5	2	3	3	4	4
User 6	3	4	5	5	5	5	3	3	5	5
User 7	4	3	4	5	4	5	4	4	5	5
User 8	5	4	5	5	5	4	4	4	5	5

Table C.2: Daltonize adaptation (front-office)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
User 1										
User 2										
User 3										
User 4										
User 5	5	5	5	3	5	4	3	3	3	5
User 6	5	5	5	5	5	5	3	3	5	5
User 7	4	3	4	4	3	4	3	3	4	4
User 8	3	5	5	2	5	2	3	5	1	5

Table C.3: Head traking adaptation (front-office)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
User 1	5	5	5	5	3	5	5	5	5	5
User 2	3	1	4	4	3	4				
User 3	4	4	3	3	4	3	3	3	4	3
User 4	3	2	4	4	3	4	3	2	4	3
User 5	4	4	3	5	3	5	5	3	4	4
User 6	4	5	2	5	2	5	3	3	5	5
User 7	5	5	5	5	5	5	5	5	5	5
User 8	5	3	2	4	5	5	5	5	3	4

Table C.4: Language adaptation (back-office)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
User 1	5	5	5	5	3	5	2	5	3	4
User 2	4	4		2	2	2				
User 3	3	3	3	3	3	4	3	3	3	3
User 4	3	3	2	2	2	2	3	3	2	2
User 5	5	3	4	5	5	5	4	3	4	5
User 6	5	5	5	5	5	4	3	3	5	5
User 7	5	4	5	5	4	5	4	4	4	4
User 8	4	5	3	4	5	5	3	5	3	5

Table C.5: Mobile adaptation (back-office)