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User Requirements Analysis for the Development of Assistive Navigation Mobile Apps for Blind and Visually Impaired People

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***Abstract*—**In the context of the development process of two assistive navigation mobile apps for blind and visually impaired people (BVI) an extensive qualitative analysis of the requirements of potential users has been conducted. The analysis was based on interviews with BVIs and aimed to elicit not only their needs with respect to autonomous navigation but also their preferences on specific features of the apps under development. The elicited requirements were structured into four main categories, namely, requirements concerning the capabilities, functionality and usability of the apps, as well as compatibility requirements with respect to other apps and services. The main categories were then further divided into nine sub-categories. This classification, along with its content, aims to become a useful tool for the researcher or the developer who is involved in the development of digital services for BVI.

***Keywords*—**Accessibility, assistive mobile apps, blind and visually impaired people, user requirements analysis.

I. Introduction

THE introduction of the iPhone in 2007 determined the direction that the design and the capabilities of "smart" mobile devices would follow in the subsequent years. Since then, the mobile phone market has been flooded by an increasing number of slim and light devices, the "smartphones", equipped with touchscreens that almost cover their larger surface, and at least two cameras. Apart from their external features, these devices are nowadays equipped with strong micro-processors, able to run operating systems which allow access to the web and other devices, including satellites. Most importantly, however, these operating systems allow access to a continuously expanding universe of mobile applications ('apps').

The ability of mobile apps to operate as a medium of socialization, to offer entertainment or access to education, and to assist people to carry out a wide variety of tasks, has placed the smartphone as one of the most useful and often used device. The design of most of these apps, however, does not consider the case where the user is a BVI. Specifically, the majority of the mobile apps require from the user to visually observe how the app responds to her gestures and how the app interacts with the environment (when interaction features exist, such as the use of a camera, or other sensors of the smartphone, etc.), while their output includes visual content. It is, therefore, implied that in most cases, the benefits which stem from the use of mobile apps are not directly accessible to a BVI. In order to reduce this accessibility gap, the BVI use especially designed apps that act as interfaces, as, for example, screen readers, speech to text and text to speech apps, as well as virtual agents that can listen to natural language and enable human-computer or human-smartphone interaction, such as Apple's Siri or Microsoft's Cortana.

Quite recently, it is observed an increasing interest for the development of mobile apps that aim to assist BVIs in everyday activities which include interaction with the environment. Navigation in interior or exterior spaces is a good example where a BVI encounters significant difficulties because of her inability to visually perceive the environment. This has a strong negative impact on the ability of the BVI to use public spaces, including urban areas, transport systems, and public buildings [1]. To design policies that reduce this type of accessibility gaps, one must consider that the number of BVIs at the global level is approximately 285 million [2]. Therefore, any attempt to address the accessibility gaps caused by severe vision loss should consider methods that can be massively adopted. The design, implementation and distribution of mobile assistive apps might be one of these methods. Our research team at the University of Piraeus, Greece, is implementing two mobile apps that aim to assist the BVIs in autonomous navigation. Specifically, the first app is being designed to facilitate the pedestrian navigation of blind people outdoors, while the second app aims to facilitate the navigation of a BVI in interior spaces of interest, as, for example, in tactile museums, stations of the underground railway, hospitals, shopping malls, etc.

The design of assistive navigation apps must consider the particular needs and requirements of the BVI user. The identification of these particularities relies on the efficient implementation of the threefold 'user needs analysis', 'requirements elicitation' and 'engagement maximization'. It is also important that the apps ensure the safety and well-being of the users [3].

Needs analysis aims to reveal the goals, aspirations or needs of the users. On the other hand, user requirements elicitation concerns the identification of the requirements of a system from potential users (see [4] as an example of user requirements analysis in mobile services). On the other hand, because assistive navigation apps for BVI are voluntary use

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systems, the degree of user's engagement with them directly depends on the perceived quality of experience and benefit of usage [5], and the existence of competitive alternatives [6]. User engagement can be also considered as an assessment of the response of the BVI to the assistive app. Specifically, it should combine user's interest, focus and enjoyment that "encompasses self-direction, interaction, emotion, and choice naturally motivated by stimulating activities/actions" (see [7] and [8], among others).

During the first steps of development of our mobile apps, interviews were conducted with BVIs, aiming to identify in detail needs and requirements of the potential users with respect to autonomous navigation. The elicited information from the responses of the interviewees has been structured into four main categories, namely, requirements concerning the capabilities, functionality and ease of use of the apps, as well as compatibility requirements with respect to other apps and services. The main categories were then further divided into nine sub-categories. In this paper we present this classification along the results of the analysis of the responses of the BVI. The classification along with these results aims to become a useful tool for the researcher or the developer who is involved in the development of digital services for BVI.

The following section (Section II) presents the setup of the interviews and the categories into which the responses of the BVI were classified. The results of the analysis of the responses are presented in Section III. Section IV concludes the paper.

II. Interviews with BVIs

In this section we present the setup of the interviews with the BVIs, which were conducted to determine the user-side needs and requirements for indoor and outdoor navigation assistive mobile apps. The interviews were conducted as part of the requirements analysis for the assistive apps which are being developed in the framework of the research project "MANTO Blind Escort Apps", undertaken by our research team at the University of Piraeus.

The overall discussion during the interviews was aiming to elicit user characteristics and needs, as well as recommendations concerning specific functions (and the corresponding modules) of the apps under development. A proper consideration of these characteristics and recommendations during the design of the apps is expected to enhance both interest and engagement of the future users.

A. Characteristics of the Participants in the Interviews

The interviews were held at the premises of the Lighthouse for the Blind of Greece, the main non-profit organization for education and assistance of BVIs in Athens, Greece. Eleven male and female BVIs, with vision problems ranging from complete blindness to severely impaired vision participated in interviews with Ms. Theodorou. The duration of each interview was at least 45 minutes.

B. Classification of the Subjects Discussed during the Interviews

Next, we present the subjects which were discussed during the interviews with the BVIs. The discussion of each subject was separated into two sections. The first concerned the presentation of possible related to the subject features that were initially considered during the conceptualization of the apps. The second section concerned the discussion on the subject and the recording of the answers of the interviewee. Specifically, the interviewee was asked about how he perceived the efficiency of the initial app design. Then he was urged to propose features for the app, which he believes that are either necessary or that would significantly enhance the functionality of the app with respect to the specific subject. The discussion of each subject included references to general characteristics of the BVIs, as for example, those concerning psychological factors, or particular needs in their everyday activities.

The initial design of the interviews, along with the feedback from the answers and suggestions of the interviewees, led us to a specific classification of the subjects of interest with respect to the design and development of assistive mobile apps for the BVI. This classification is summarized in Table I.

TABLE I
Requirements' Classification for the Development of Assistive Mobile Apps for BVI

1) Requirements concerning usefulness and capabilities	a) Obstacle detection
	b) Navigation
	c) Additional characteristics
2) Functionality requirements	a) External stimuli
	b) Sound (or voice) BVI-smartphone (or app) interaction
	c) Tracking accuracy and the devices that aim to improve it.
3) Usability Requirements	a) Characteristics/features of apps and devices.
	b) Device handling
4) Compatibility and parallel operation with other apps	a) Compatibility and parallel operation with other apps

The first category includes the requirements concerning the usefulness and capabilities of an assistive navigation mobile app from the BVI perspective. The structure of the interviews allowed the interviewees to focus on the issues that they find more important. Specifically, we observed that the main subjects of interest of the BVIs can be classified in three sub-categories: a) Obstacle detection, b) navigation, and c) additional characteristics (including general but significant requirements).

The second category includes the functionality requirements, as the BVI perceive them. Again, we identified three sub-categories: a) requirements concerning the treatment of external stimuli, b) requirements about the way sound (or voice) could be used to facilitate the interaction between the BVI and the smartphone (or the app), and c) requirements about the accuracy of tracking and the devices that could be used to improve it.

The third category concerns the usability requirements of the apps and the interconnected devices. Apart from the first

sub-category which concerns the characteristics or features that a BVI requires from the assistive navigation apps and devices, it is of special interest to identify the optimal way of handling the smartphone (the apps) and the interconnected devices.

Finally, the BVIs showed particular interest in the way the assistive apps will seamlessly collaborate with the usual apps a BVI uses, as for example, screen readers and web mapping services. Next section will present the findings of the interviews with respect to this classification.

III. BVI Requirements for Assistive Navigation Mobile Apps

The previous section presented a structure for the classification of user needs and requirements, as it was derived by an examination of recorded interviews of the BVIs. In this section we present the findings of the interviews, properly classified in this framework.

A. Requirements Concerning Usefulness and Capabilities

When we were initially introducing to the BVIs the purpose and aims of the apps it was important for us to understand their perspective with respect to what they would require from an assistive navigation app to offer them for it would be most useful to them. We identified the following needs and requirements:

1. Object Detection

(i) The app should be capable to simultaneously detect multiple obstacles and report them appropriately (for example, guiding the BVI to maneuvers with good precision.
(ii) Any sonar device should be able to detect obstacles that are relatively high, such as low balconies, awnings, signs, etc., and not only ground-based in front of the BVI.

2. Navigation

(i) The app should be capable to assist the BVI throughout routes that combine both pedestrian and navigation and navigation by any other means of transport.
(iii) The app should be capable to detect a wrong route and to correct or adjust it accordingly.
(iv) It is desirable that the app could manage multiple destinations or stops along a route.
(v) The app should provide real-time information on public transport (e.g., connection to bus telematics services).

3. Additional Characteristics or Features of the Apps

(i) It is important to be able to notify a trusted person or the police about the BVI's position.
(ii) When visiting interior spaces, such as museums, it is important that the BVI is able to request assistance by from the staff through the app.

B. Functionality Requirements

Going through the details of the possible implementation of the apps, the BVIs had the opportunity to express their point of view with respect to apps' features related with their functionality.

1. External Stimuli

(i) It is very important that sounds from the environment are not covered by the sounds of the apps. All the BVIs believe that such a case would put the BVI user in great danger. This remark excludes the use of headsets that cover both ears. One ear should be able to hear the sounds of the surrounding environment
(ii) Only important cellphone information should be reported phonetically in order not to cover or suppress the ambient sounds.

2. Sound (or Voice) BVI-Smartphone (or App) Interaction

(i) The app should offer voice menus of the key destination options. These options must be able to include combined pedestrian navigation and use of other means of transport.
(iii) The app must provide audio signal for the traffic lights.

3. Tracking Accuracy and the Devices that Aim to Improve It

(i) GPS and sonar amplifiers should be discreet and not too obvious.
(ii) Positioning accuracy must be high (at least at the centimetre level).
(iv) Any sonar or GPS device must refresh the information it provides at high frequency because some BVIs can move at a fast pace.

C. Usability Requirements

Apart from the capabilities and functionalities of the apps and the interconnected devices, the BVIs showed particular interest on specific features and modules of the assistive navigation system with respect to the ease of use of the apps.

1. Device and Application Features

(i) The BVIs would prefer that the smartphones would be equipped with simple, easy-to-learn keyboards or pads. The apps should respond to clear and simple gestures on the touchscreen.
(ii) They prefer to use Bluetooth headphones because cables are often entangled.
(iii) They require smart and fast access to the service of assistance call (possibly through a specific gesture on the touchscreen, or a devoted key combination on a keyboard).

2. Device Handling

(i) The BVIs should be able to set the destination on their own (the autonomy and independence of the BVIs is very important).
(ii) As far as outdoor navigation is concerned, it would be desirable that the app provides a list of "favorite" destinations that the BVI can edit.
(iii) The BVI should have the ability to dictate the destination address on the device.

D. Compatibility and Parallel Operation with Other Apps

(i) The apps should be accessible to screen readers.

(ii) In case that the navigation app requires de-activation of the screen reader, the screen reader should be automatically re-activated when the app goes into the background.
(iii) In general, however, other applications (including the screen reader) should be able to run in parallel with the navigation apps.
(iv) It would be useful that the apps could interconnect/ collaborate with an application that describes images.

IV. Conclusion

In this paper we highlighted the fact that the design of assistive navigation apps for BVI people is a very important step in the process of offering functional and easy to use solutions for the problem of location accessibility of the BVIs. To optimize the benefits of these apps we proceeded in interviews with BVIs, aiming to elicit not only their needs and requirements with respect to blind navigation, but also their preferences with respect to special features of the corresponding apps.

The analysis of the responses of the BVIs, who participated in the interviews, yielded a classification of their requirements and needs into four categories that include nine subcategories. This classification may be used as a guide for the development of assistive apps for BVIs.

As far as the assistive navigation mobile apps, the analysis of the interviews helped us identify specific needs and preferences of the BVIs. For example, that the apps should be capable to simultaneously detect multiple obstacles, to manage multiple destinations and stops, to notify persons of trust or an ambulance in case of need. Moreover, we learned how important is for the BVIs that the apps do not cover sounds of the environment, as well as the capability to produce an audio signal for the state and proximity of traffic lights. Another example of interesting elicited preference of the BVIs concerns the amplifiers of the GPS signal, which should be discrete, and if possible, not visible, while a practical issue concerned the preference of the BVIs to Bluetooth headphones because it is difficult to them to untangle cables. These interesting and significant observations, along with the rest described in Section III, will be central to the design of our two assistive navigation mobile apps. They may also be useful to any researcher or developer who aims to offer effective digital accessibility solutions to BVI.

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