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Towards a Training Framework for Improved Assistive Mobile App Acceptance and Use Rates by Blind and Visually Impaired People

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Abstract: The development of mobile apps, which are either suitably adapted or especially designed for use by sensory-deprived people, have contributed significantly to the continuously increasing adoption of digital assistive technologies by people with disabilities. Throughout the design of two assistive navigation mobile apps for blind and visually impaired people (BVI), a set of everyday practices and psychological features of the BVIs with respect to the use of mobile technology was identified. Specifically, interviews with BVIs were held at the first stage of the design process. The analysis of the responses revealed that appropriate training of a BVI on how to use these apps plays significant role on the anticipated app adoption and use rate. This study presents the everyday practices and psychological features of the BVIs, as they were inferred from the analysis of the interviews. It is argued that these psychological features and practices must be considered in the development of training practices concerning the use of the proposed technology. Towards this direction, a framework for the adequate training of BVIs on the use of assistive mobile apps is presented. Consideration of this framework during the development of assistive mobile apps for BVIs could contribute towards higher adoption rates.

Keywords: assistive mobile apps; blind and visually impaired people; qualitative analysis; training framework

1. Introduction

"Smart" devices, and particularly smartphones, have characterized the massive adoption of digital technologies during the last two decades. Along these devices, an extensive universe of smart digital applications (apps) have emerged. Surprisingly, however, little or no research appears to have been focusing on the particular characteristics and circumstances that drive the take-up of technology by people with disabilities, which stem from the differing needs of these groups, as well as from significant usability problems. These problems mainly arise from the fact that both devices and apps may not be designed or adapted for use by people with disabilities. On the other hand, even in the case that an app (or a version of the app) is equipped with accessibility features, these mainly concern basic functions, while the design of these features usually takes for granted the ability or the will of the disabled person to use them properly.

According to international statistics, the number of blind people and people with severe vision problems is approximately 36 million [1] and 285 million [2] worldwide, respectively. Their majority lives in poor and developing countries, while most of them are young and in productive age. Their demand for improved accessibility, self-service, and autonomous living has been identified by digital app developers and researchers who are providing an increasing number of solutions that contribute catalytically to social inclusion, promote the educational and cultural level, independence in social and professional life, and consequently upgrade the quality of life of blind and visually impaired people (BVI).

Assistive mobile apps aim to play a significant role in the autonomous navigation of BVIs. Apps such as Loadstone GPS [3], Mobile Geo [4], and Seeing Eye GPS [5] use GPS positioning to assist the BVI during pedestrian navigation. Other apps, such as BlindSquare [6], provide information concerning points of interest during outdoor navigation. Academic research has been focusing on the requirements and the development of systems that assist outdoor navigation [7–10], indoor navigation systems ([11–16] among others), or both [17] for the BVI. In this context, there is significant and increasing demand for autonomous navigation systems especially designed for BVIs.

Our research team at the University of Piraeus, Greece, is developing two assistive systems for the autonomous navigation of blind and visually impaired people. These systems are mainly based on two corresponding mobile apps. The first app is being designed to facilitate the pedestrian navigation of blind people outdoors. The second app aims to facilitate navigation of a BVI in interior spaces of interest, as, for example, in tactile museums, stations of the underground railway, hospitals, etc.

At the first steps of development of the two assistive apps, interviews were conducted with BVIs aiming to identify in detail needs and requirements of the potential users with respect to autonomous navigation. During the interviews, the main goals and features of the apps were described. The responses of the participants to a wide set of questions revealed that appropriate training of a BVI on how to use these apps plays a significant role on the anticipated app adoption and use rate.

On the other hand, user engagement is also related to multiple psychological constructs, as, for example, interest, focus, and enjoyment [18,19]. It also depends on the perceived quality of experience and benefit of usage [20]. Interestingly, during the interviews a set of particular practices (including stated preferences, habits, etc.) and psychological features of the BVIs with respect to the use of mobile technology were also identified. We argue that these psychological features and practices must be considered in the development of optimal training practices concerning the use of the proposed technology. Based on this argument, we introduce a framework for the adequate training of BVIs on the use of assistive mobile apps.

The next section presents the materials used and the methods followed in our research. Specifically, it provides a brief introduction of the two assistive navigation mobile apps for BVIs, which are developed by our research team, followed by a description of how and with whom the interviews were conducted. In Section 3, the results of the interviews are presented, followed by an analysis of their implications on the training methods that aim to maximize the adoption of mobile apps by BVIs. Section 4 concludes the paper.

2. Materials and Methods

At the University of Piraeus, two assistive navigation apps for BVIs are being developed. The first app aims to help the BVI to travel safely, while the second will guide the BVI in interior spaces of interest (accessible or tactile museums, hospitals, shopping malls, etc.).

Specifically, *Blind RouteVision* is being designed to facilitate the pedestrian navigation of BVIs outdoors. It has an enhanced GPS functionality and connects with the Google Maps service for navigating, enriched with additional voice prompts. Its design accommodates an ultrasound sensor for real-time recognition and avoidance of obstacles along the BVI's path. Additional features of *Blind RouteVision* include:

(a) A simple keyboard for the interaction of blind people to enable them to select routes and other available functions,

(b) application synchronization with traffic lights and weather information, and

(c) the utilization of information telematics of the Athens Organization of Civil Transport (OASA) for routes and urban transport stops.

The initial version of the *Blind RouteVision* system is presented in the third section of [15].

Blind IndoorGuide is an application for the autonomous blind navigation in indoor spaces available in both Android and iOS. It is supported by a highly accurate indoor location determination subsystem, including accessibility mapping of indoor spaces with overlays of the positions of points of interest (POIs), Bluetooth beacons as proximity sensors and location indicators, as well as unobtrusive assistive tactile indications on the floor according to international standards for BVIs. It will inform the BVI about POIs and will allow selection of POIs and the dynamic issuing of voice navigation instructions towards POIs considering the current position of the BVI. *Blind IndoorGuide* inherits the features of the *Blind MuseumTourer* system, as they are presented in [15]. It aims to extend the functionality of the *Blind MuseumTourer* beyond the case of museums. The conceptualization of the *Blind IndoorGuide* is discussed in [15].

In the context of the development process of the two assistive navigation mobile apps, 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 their needs with respect to autonomous navigation but also psychological characteristics and practices that are related to their impaired vision.

Interviews with BVIs

The interviews were conducted 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. Each interview lasted at least 45 min. Table 1 presents descriptive characteristics of the interviewees.

Table 1. Characteristics of the participants in the interviews.

	Gender	Age	Degree of Vision Loss	Cause of Vision Loss	Digital Sophistication
P1	Male	55	Complete	By birth	High
P2	Female	35	Severe	By birth	Average
P3	Male	36	Complete	Diabetes	High
P4	Male	40	Almost complete (95%)	By birth	Low
P5	Male	40	Almost complete (95%)	By birth	Low
P6	Female	55	Complete	Retinopathy (23 years old)	Low
P7	Male	40	Almost complete (90-95%)	By birth	Low
P8	Male	40	Complete	Cancer (7 years old)	Low
P9	Male	35	Almost complete (>95%)	Benign tumor (15 years old)	Low
P10	Male	60	Complete	By birth	High
P11	Male	30	Complete	By birth	High

The interviews started with an introduction of the participant, where the BVI was asked about characteristics such as age, degree of vision loss, cause of vision loss and the age at which this occurred, job description and status, familiarity with digital apps, etc. Then, the features and capabilities that were initially considered during the conceptualization of the apps were presented to the BVI. After the description of the characteristics of the apps, a discussion followed concerning the BVI's travelling habits. Along with characteristics which were directly relevant to blind navigation, the BVI was encouraged to state preferences, doubts, and general needs and habits. In other words, the discussion included references to general characteristics of the BVIs. For example, those concerning psychological factors or particular needs in their everyday activities.

The answers, suggestions and comments of the interviewees were recorded and classified into categories that affect the design and development of assistive mobile apps for the BVIs.

Interestingly, it was identified that psychological factors and everyday practices, particular to the BVIs, underlie their preferences and perceived needs significantly. The results of the analysis of the interviews are presented in the next section.

3. Results and Discussion

Two important aims of the assistive navigation mobile apps are to enhance the sense and the degree of autonomy and independence of the BVIs. This enhancement will be achieved not only in practice (i.e., when the apps will be used in real world conditions), but even before the first use of the apps, during their introduction to the BVI community and during the learning procedure of the apps.

The first step in the derivation of appropriate approaches concerning the design and implementation of the apps, as well as the way they will be introduced to the BVI community, involves the identification and understanding of particular characteristics of the potential users. These characteristics can be classified as everyday practices and psychological features of the BVIs. In contrast to previous studies which focus on the user interface design and specific features of mobile assistive apps [10], the present study focuses on the set of psychological features and everyday practices of the BVIs as they were elicited from the interviews. These features and practices of the BVI are presented in this section. Moreover, when the primary interview data allow it, we present possible links between evidence and theoretical (or qualitative) characteristics by relating these features to corresponding practices of the BVIs. We note that these connections are not derived from an extensive quantitative analysis (which would usually incorporate proxies of the psychological properties), but rather depicts possible relationships for which further study may be required. On the other hand, the focus of our investigation is not to conduct such a quantitative study, but to use the elicited psychological features and practices of the BVIs within a specific educational framework for the adoption of assistive mobile apps.

3.1. Particular Characteristics of the BVI

The characteristics of the BVI were elicited from an analysis of the recordings of the interviews. First, we present psychological features of the BVIs, with links (when possible) to everyday practices.

(A) *Psychological Features*

(1) BVIs need to be organized in order to feel secure. They are afraid of being lost and not being able to find the items they need.
Possible Related Evidence or Common Practices of the BVI:
  a. They map in their mind any space or object they perceive.
  b. This mapping also includes dimensions that correspond to other senses. For example, they memorize and relate sounds and smells to specific points or places of their route.

(2) The fear of being lost intensifies for the BVI when they visit an unfamiliar place.
Possible Related Evidence or Common Practices of the BVI:
  a. To avoid getting panicked, the BVIs are often advised to only visit alone places they are familiar with.
  b. Otherwise, they prefer using a taxi the first time they go to a destination.

(3) BVIs are reluctant (or they feel insecure) to use or trust someone offering a service which is not supported by a well specified and understood system.
Possible Related Evidence or Common Practices of the BVI:
  a. They do not trust taxis which are not connected to central reservation/call systems. In other words, they don't pick a taxi randomly from the road. They always call a taxi by phone or the internet because this assures them that it will be a real one.

(4) Social inclusion is a very important need of the BVI. They often feel different, even ashamed, when they have to use the white cane (e.g., right after getting off the bus).
Possible Related Evidence or Common Practices of the BVI:

a. They feel that they are not as capable as other people.
b. The idea of getting noticed by others is unpleasant to them.

(5) The BVIs learn not to be spontaneous when the move. They have learned to be systematic and not to leave emotions or sudden thoughts interrupt their concentration to their travel. They rarely are relaxed when they travel.
  a. The BVI do not answer phone calls or, generally, use a smartphone while walking. In order to use their smartphones they first have to stop walking.

(6) In fact, often BVIs (especially those who were born blind) are afraid of the idea of having (or gaining) their vision. This would dramatically change their way of living, while they would have to confront with the true shapes and colors of objects, animals, and persons (as most importantly with their appearance).

(7) The image that a BVI creates for something or someone is usually better than the real one.

(8) BVIs that have some minimal vision often place their smartphones near their faces as if they can see, despite the voice functionalities of the apps they intend to use. This possibly implies that they do not easily surrender to the idea that their vision is obsolete.

(9) The mentality of a BVI that once had functional vision is often much worst that this of a BVI by birth (or one that does not remember how it was to be able to see) ceteris paribus.

(10) BVIs are conservative and fear to change their way of living. As this could be a consequence of adopting a new technology, they usually are not eager do so.

(11) Another reason which makes them reluctant to use new technologies is the lack of confidence in their abilities. In other words, they fear that they will not be able to properly use new technologies, or even that they will cause problems in their attempts to use them (for example, blocking a cell phone).

Next, the everyday or usual practices of the BVI are presented. It must be noted that the interview data mainly referred to navigation practices, because the main subject of the interviews concerned the assistive navigation mobile apps which are being developed at the University of Piraeus.

(B) BVI Practices (Preferences, Habits, Facts, etc.)

(1) In general, taxis are the most preferable means of transport for a BVI.
(2) The younger BVI use the internet for choosing a means of transport while the older ones prefer to be accompanied.
(3) Most of the BVIs choose (and prefer) to have someone to escort them.
(4) They use 'smart stops' when they take a route they already know.
(5) They ask the bus driver where to get off the bus.
(6) They use hearing to perceive when cars are moving or if a car is coming toward their direction.
(7) If they are confused by the narrow streets, they recall odors they have retained from previous times.
(8) They recall particular details along the track to their destination.
(9) When they follow a track for the first time, they memorize characteristics of their route (step counting, direction, sounds, and odors).
(10) They also often ask people that they meet on their way.
(11) When they get off the bus, they rely on hearing, smell, and touch, and count steps in order to move on the sidewalk.
(12) They always follow the special tactile paving on the sidewalk to avoid permanent obstacles.
(13) If they make a mistake (step counting, loss of direction, etc.) and feel lost, they try to return back to the sidewalk and start again from the beginning.
(14) BVIs are often employed in professions that require particular ability to identify by touch (for example as physiotherapists).
(15) They learn mostly by word of mouth that an application is good and useful (e.g., e-radio, google translate, and OASA telematics).

(16) They lose their smartphones more often than a sighted person does.
(17) Blind people are also familiar with having a wearable device. They believe it is a good solution to attach such device on the cane or to develop a cane with such additional functionality.

Both everyday practices and psychological features of BVI can be used to set directions for the specification of a training framework for improved assistive mobile app acceptance and use rates by the BVI. This framework will be adapted suitably in order to reduce the effects of BVI specific inhibitors or to enhance the effects of BVI specific enablers or facilitators, respectively, which concern the adoption of assistive mobile apps. These directions are presented in the following subsection.

3.2. Discussion—Towards a Training Framework for the BVI

The term "training of BVI" most often corresponds to the method followed within an educational framework and goal with aim to overcome the consequences of visual impairment. As early as the 1960s [21] and 1970s ([22–29], among many others), information and communications technology has proven to be capable of providing very useful tools that significantly have been facilitating the educational process of the BVI.

Another trend concerning the training of people with visual impairment has been focusing on enhancing their ability to use signals from their other senses, as well as their spatial perception through them. The latter is very significant not only concerning the autonomous navigation of a BVI, but also with respect to the accuracy of motion, for example, as it is required for handwriting [30]. Another approach that consists a good example of such a training for BVI is that through audio-based computer games [31–33], the games provide virtual environments in which the BVI exercise their ability to process audio signals in order to perceive the (virtual) surrounding space.

The introduction, however, of mobile devices and the development of pattern recognition apps, screen readers and artificial intelligence-based virtual assistants or other assistive apps specially designed for the BVI, outline a trend towards the substitution of the need for enhancement of the functional senses of the BVI by the requirement that a BVI can easily adopt and use assistive apps.

Apart from other factors such as perceived usability and usefulness of these apps, their adoption and use rate is directly related to the perceived by the BVI degree of difficulty to learn how to use them. However, as new apps aim to carry out more complex tasks, their complexity increases. The results presented in the previous subsection imply that this complexity may create a barrier concerning the adoption of the complex assistive apps by a BVI. Specifically, the analysis of the interviews reveals that the mentality, fears, and concerns of an average BVI do not coincide with those of an average sighted person. Because vision is the most important of the senses concerning the observation of the environment, the BVIs are afraid that they would be easily lost or that they would easily lose their portable property (such as mobile phones). However, these are not the only fears that a BVI must encounter. For example, because they use their imagination in order to produce images of objects and people they cannot see, they are afraid of what they would see if somehow their vision was recovered.

The analysis also revealed that the attachment of a BVI to specific practices offers the feeling of security. The need for this feeling seems to be greater for a BVI than for an average person, and this seems to be reasonable when one considers that the consequences of a negative non-anticipated event would be probably significantly enhanced by the inability of visual perception.

The answers of the BVI to questions about autonomous navigation and the use of new technological solutions implied that although they seem to be willing to hear or learn about new assistive technologies, they are reluctant to adopt solutions or services of a certain degree of complexity. The BVI seem to be more conservative and in fact, do not have the confidence in their abilities to meet the requirements that more complex applications impose. They have adapted to a way of life that requires form them not to be spontaneous but rather more self-controlled than the average person. In order to overcome difficulties caused by their inexistent or reduced sense of vision, the BVI learn to be systematic and methodic. However, these characteristics do not suppress the expressions of their need for social inclusion and autonomy.

A training framework for the use of mobile assistive apps by the BVI aims to optimize the adoption and use rates of the apps considering the findings of this analysis. Such a BVI oriented framework seems to be a significant factor for the adoption of complex assistive apps. It is important to note that by the term "framework", the preparation of the training is also considered. In other words, it also involves actions that aim to convince the BVI to participate in the training. Given the findings mentioned in the previous paragraphs, the following procedure is proposed (accompanied, of course, by standard non-BVI specific approaches for technology adoption):

First, any contributions of the assistive mobile apps with respect to social inclusion and autonomy of the BVI should be highlighted since the initial communication of the apps' aims.

Secondly, the aims of the apps and the initial description of their main features should be followed by an analytic description of the "safeguards" that will reassure the BVI about the controllability of the consequences of any unanticipated event that will be related to the use of the app. These "safeguards" would correspond to specific features and modules of the app, the design, and functionality of which should be implemented after a thorough identification of the BVI's fears and needs concerning the app related activities. The purpose of these features or modules would maintain and ensure the sense of safety for the BVI user during the use of the app's services.

A third issue, which is related to the conservatism of the BVI, concerns the necessity that the BVI becomes familiar with the idea of using the app autonomously. The BVI would have to change everyday practices which possibly work at a satisfactory degree. The effort of the people who will introduce the apps to the BVI should concentrate on making this transition a pleasant experience.

It must be noted that a pleasant experience is not synonymous with an effortless experience. In fact, learning how to use mobile apps (such as navigation apps) which involves interaction with the environment or other appliances usually requires effort from the BVI user. In such a case, as mentioned above, the existence of an option that the BVI could be trained on how to use the app may play a significant role in whether the app will be adopted or not. Based on the previous analysis, a training framework for the BVI would optimally be adapted to the particularities of people with visual impairment. Specifically, it is proposed that the following directions are followed:

(a) Training in familiar environments: the BVI employ their functional senses to perceive the environment. In case that the training takes place in an unfamiliar environment, mental resources of the BVI will be assigned to this function.
(b) Tasks to be learned must be easily feasible and understandable: in case that the BVI must be trained to perform more complex tasks, these tasks will be divided into a series of smaller tasks, each of them not requiring much effort from the BVI. The aim of this process is to prevent the BVI from questioning their abilities to successfully complete the tasks.
(c) Adaptation of the tasks to the systematic way that a BVI acts: the BVI have adopted a very methodological way of doing things in order to compensate (or be protected) from the implications of their visual impairment. The learning and exercise of these systematic practices by a BVI can be clearly considered as training and applications of algorithmic thinking, respectively. This observation provides a clear perspective concerning the approach that must be optimally followed when the apps are introduced to people of this group. Specifically, this observation leads to the following suggestions:
    a. The tasks on which the BVI will be trained must require sequential smaller actions. These actions should be analytically presented to the BVI.
    b. Before teaching the BVI about each task, exactly one goal must be described. This suggestion stems from the fact that the BVI find perplexed any multidimensional grid of actions. In other words, the description of multiple options within a task should be avoided when this is possible. This is in line also with the first suggestion about the sequential structure of the tasks to be taught.

The three above suggestions along with a proposed pre-training approach described at the beginning of this subsection outline the direction that would be followed in order to derive a training framework that would aim to maximize the adoption and use rates of assistive mobile apps by the BVI.

4. Conclusions

Along with the ambition of digital technologies to assist blind and visually impaired people overcome the barriers caused by their vision impairment, the complexity of the tasks that assistive mobile apps aim to perform has been continuously increasing. In this study, the need for training of the BVI on how to use mobile assistive apps was first highlighted. Specifically, an analysis of BVI interview responses revealed that they have particular characteristics (practices and psychological features) which are related to their inability to visually perceive people, objects, images, as well as their position in the surrounding environment.

Second, the particular everyday practices and psychological features of the BVI, as elicited by the interviews, were presented. In some cases, possible links between psychological features and specific practices were suggested.

Third, based on these characteristics, a framework was proposed for the training of BVI on how to use assistive mobile apps. This framework is naturally divided into two sections. The first concerns the way the apps (goals, benefits, and features) are presented to the BVI in order to enhance motivation and decrease the causes of negative attitudes towards the adoption and use of these apps. The second section corresponds to simple suggestions concerning the training method that the BVI should follow.

It must be noted that the proposed framework is far from complete, as the continuous tendency for the development of assistive apps that correspond to more complex tasks will naturally reveal additional requirements or needs of the BVI. This implies that this framework must be continuously enriched and adapted towards the main ideal goal of optimal adoption and use rates of assistive mobile apps.

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