THE JOURNAL ON TECHNOLOGY AND PERSONS WITH DISABILITIES

Innovative Affordances for Blind Smartphone Users: A Qualitative Study

Shrirang Sahasrabudhe, Rahul Singh PhD, Don Heath PhD
University of North Carolina Greensboro, University of North Carolina Greensboro, University of Wisconsin Oshkosh
S_sahasr@uncg.edu, Rahul@uncg.edu, Heathd@uwosh.edu

Abstract

Blindness imposes various functional limitations on the blind and visually impaired (BVI) individuals. Anecdotal evidence suggests that BVI use their smartphones in various innovative ways to overcome those limitations. We conduct a qualitative field study with three BVI participants to understand how they use their smartphones to overcome their functional limitations in the personal and professional contexts. We use the lens of theory of affordances to analysis the BVI participants' use of smartphones. Affordances emerge from the contextually situated interaction between users and technologies to achieve specific objectives. Our analysis reveals many meaningful affordances which can be systematically incorporated in the smartphone design to enable BVI to overcome some of their functional limitations.

Keywords

Affordances, smartphone, assistive technology, blindness.

Introduction

Many visual impairments have specific effects on the blind and visually impaired (BVI) individuals and impose various functional limitations on them (Machell). Functional limitations are defined as significant limitations in accomplishing one or more everyday tasks in both personal and professional contexts. such limitations range from difficulties in completing personal tasks such as exchanging cash on a shop counter (Bikson and Bikson) to difficulties in completing professional tasks such as filling up online forms (Theofanos and Redish). Assistive technologies (AT) are the technologies which assist BVI to overcome those functional limitations. Advancements in smartphones have profoundly impacted the quality and kind of the AT available to BVI (AFB) offering considerable potential to promote independence and participation of BVI. Extant research focuses on improving the smartphone accessibility and usability through designing newer AT or through studying BVI smartphone users' accessibility and usability challenges such as difficulty in acquiring touchscreen targets (Oliveira et al.), lower accuracy of gesture recognition (Kane et al.), difficulty in use of gestures (McGookin et al.), and the accessibility and usability challenges in interacting with iPhone using VoiceOver screen reader (Leporini et al.) etc. Research has designed various smartphone-based AT to help BVI complete a few specific personal and professional tasks such as navigating in-door/out-door (Makino et al.; Gallagher et al.; Murali and Coughlan), identifying and matching clothes (Burton et al.; Paisios, Rubinsteyn, and Subramanian), shopping independently (Kulyukin and Kutiyanawala), recognizing currency bills (Paisios, Rubinsteyn, Vyas, et al.), and safely exchanging cash (Paisios, Rubinsteyn, and Subramanian) etc. Such solutions utilize one or more affordances which emerge through BVI users' smartphone interactions. Affordances result from the contextually situated interaction between users and technologies to achieve specific objectives. Anecdotal evidence suggests that BVI take an advantage of such affordances in various innovative ways to overcome numerous functional limitations. However, as per our knowledge, no research till date, has attempted to identify the innovative affordances produced through BVI users' smartphone interactions. Consequently, we do not yet know the potential affordances produced through BVI users' smartphone interactions. Without that knowledge, our endeavors remain confined to designing smartphone-based solutions to enable BVI to successfully complete a few specific tasks instead of improving the overall smartphone design to facilitate the creation of various meaningful affordances to enable BVI to overcome functional

limitations they face. As a first step, we ask, "what are the various affordances which are produced through BVI users' smartphone interactions?" in this paper, we present the results of a qualitative field study eliciting various innovative affordances which were produced through BVI participants' iPhone interactions in the personal and professional contexts.

Methodology

We conducted a qualitative field study with three BVI participants (P1, P2, and P3). All three participants were adult, English-speaking, expert iPhone users working at the Industries of the Blind- Greensboro North Carolina. P1 and P2 were completely blind and worked in manufacturing function. P3 was partly sighted and worked in human resources function. We requested the participants to describe the personal and professional situations where they use an iPhone to overcome various functional limitations. We engaged in a free-flowing conversation with the participants individually. Each interview was thirty to forty minutes long. We audio-recorded the interviews and subsequently transcribed the recordings for interpretive analysis. The interviews are described below.

Participant P1:

P1 narrated a situation when she wanted to find out what were her options for cooking. She was required to read the labels printed on multiple boxes in her refrigerator. She used the TapTapSee app. The app allows its user to take a picture, and then it transmits the picture to a remote human assistant. Within a minute, the assistant relays back the text describing the picture. Earlier, when she did not know about TapTapSee, she relied on various cues such as size of the box, weight of the box, and her memory to draw a probabilistic inference which often resulted into "refrigerator surprises." Now, the app enables her to avoid refrigerator surprises. P1 used that app also as a mirror to check her appearance before going to work. P1 used the WalkingGPS, a GPS navigation app, to navigate in outdoor spaces. The app could inform her about the obstacles on her way and her distance from those obstacles. Which enabled her to navigate safely and effectively in outdoor spaces. However, she did not find the app useful for indoor navigation. P1 used the KNFB reader, an optical character recognition app, to read the machine operation instructions painted on the machine. P1 used the Digit-Eyes, a QR code and barcode reader app, to label and identify her clothes at home. P1 used the ColorIdentifier, a color

recognition app, to match the colors of the clothes before wearing them. P1 narrated a situation when she was left alone in a large hall and was trying to find the way out. She used the LightDetector, an app which can sense the ambient light, to figure out the direction of the doorway.

Participant P2:

P2 told us that she had used the TapTapSee app to read the numbers on her credit card. P2 used that app to see if the room floor was clear so that she could safely roll the vacuum cleaner. She also used that app to read the labels on the raw material boxes at work. At work, P2 used ColorIdentifier app to identify the colors of fabric and threads so that she could ensure that the thread color matches the fabric color while stitching the garments. P2 used the LightDetector app to determine if any lights in her home were left on by chance. She could thus avoid the wastage of energy.

Participant P3:

P3 told us that she had used the CamFind app, an app similar to the TapTapSee app, to monitor the visual appearance of a food item to ensure that the item was sufficiently baked. She mentioned that she took pictures of the food item at regular intervals to monitor the visual appearance of the item. P3 used the Digit-Eyes app to label and identify documents at home as well as at work. P3 used that app also to identify various products while shopping at a store. P3 used the KNFB reader app to read printed documents and notice boards at work. P3 worked into the HR function. Which required her to read many printed documents to successfully perform her job. She relishes the sense of independence the app gives her while performing her job.

Analysis and Findings

Using the theory of affordances as a theoretical lens, we conducted an interpretive analysis of the BVI users' smartphone interactions to complete various task. In an effort to explain how animals perceive their environments, James Gibson (Gibson) a perceptual psychologist, suggested that surfaces and objects offered certain affordances for action. For example, if a terrestrial surface is nearly horizontal, nearly flat, sufficiently extended, and if its substance is rigid then the surface affords support. It is stand-able, permitting an upright posture

for quadrupeds and bipeds. It is important to note that the four properties (horizontal, flat, extended, and rigid) would be physical properties of a surface if they were measured with scales and standard units used in physics. As an affordance of support for a species of animal, however, they need to be measured relative to the animal. Essentially, they are unique for that animal owing to the unique capabilities of that animal which allow the animal to take the advantage of the object properties to stand or walk on the support. Thus the affordance is realized only through the interactions between relevant capabilities of an animal and the capabilities/properties of its environment. Therefore, the concept of affordance is useful in explaining why human and material agencies become imbricated: Technologies have material properties, but those material properties afford different possibilities for action based on the contexts in which they are used.

We identified BVI user capabilities, technology properties/capabilities, the context in which the interaction took place, and the action potential/affordance that was produced through each interaction. The following table shows the results of our analysis.

Table 1. Affordances Indentified.

Relevant iPhone App	Technology capabilities/Properties	Users' Action Capability	Context	Affordance produced
TapTapSee/ CamFind	To capture a picture, to transmit the picture to a remote human assistant, and to announce the text description relayed by the human assistant.	To click a picture of the desired object	Work	Read the printed labels on packs of raw material.
TapTapSee/ CamFind	To capture a picture, to transmit the picture to a remote human assistant, and to announce the text description relayed by the human assistant.	To click a picture of the desired object	Home	Avoid refrigerator surprises, check the appearance of food item during cooking, read the numbers on credit cards, check the status of the room floor, see oneself.
Walking GPS	To capture the user's location by utilizing the global positioning system.	To orient oneself in a desired direction, to walk.	Work	To commute safely to/from workplace.
Walking GPS	To capture the user's location by utilizing the global positioning system.	To orient oneself in a desired direction, to walk.	Home	Not applicable
Light Detector	To sense the variation in the surrounding light intensity, to play sounds of varied intensity	To perceive variations in sound intensity that indicate light intensity	Work	Find a doorway.
Light Detector	To sense the variation in the surrounding light intensity, to play sounds of varied intensity	To perceive variations in sound intensity that indicate light intensity	Home	Avoid wastage of energy.
Color Identifier	To determine the color of an object facing the camera	To focus the camera on the desired part of an object, to stitch.	Work	Stich the garments with the right color thread.

Relevant iPhone App	Technology capabilities/Properties	Users' Action Capability	Context	Affordance produced
Color Identifier	To determine the color of an object facing the camera	To focus the camera on the desired part of an object.	Home	Match the pair of clothes
Digit-Eyes	To scan a barcode/qr code, to store and retrieve the text description associated with that particular code from its repositary, and to announce the description.	To focus the camera on the bar code/QR code on an object	Work	Label and identify documents.
Digit-Eyes	To scan a barcode/qr code, to store and retrieve the text description associated with that particular code from its repositary, and to announce the description.	To focus the camera on the bar code/QR code on an object	Home	Label and identify documents, label and identify clothes, identify desired products while shopping.
KNFB Reader	To capture a picture, to detect iPhone's alignment with the text to be read, to extract the text from an image using Optical character recognition, and to convert digital text to digital speech.	To click a picture of the desired text	Work	Read printed documents, read notice boards, read machine operation instructions.
KNFB Reader	To capture a picture, to detect iPhone's alignment with the text to be read, to extract the text from an image using Optical character recognition, and to convert digital text to digital speech.	To click a picture of the desired text	Home	Read printed documents.

Discussion

Our findings show that all three participants took an advantage of various apps on their iPhones to overcome their functional limitations. In the case of TapTapSee/CamFind, an iPhone is capable of capturing a picture, of transmitting a picture to a remote human assistant, and of announcing the text description relayed by that human assistant. The user, on the other hand, is capable of pointing the camera in a desired direction and of clicking a picture. At work, the interaction affords the user to read printed labels on the raw material boxes. At home, the interaction affords the user to avoid refrigerator surprises, to check the appearance of food item during cooking, to read the numbers on credit cards, to visually inspect the room floor, and to see oneself. In the case of WalkingGPS, an iPhone is capable of capturing the user's location by utilizing the global positioning system. The user, on the other hand, is capable of orienting herself in the desired direction and of walking according to the walking guidance provided by the app. At work, the interaction affords the user to commute to her workplace. At home, however, the interaction affords nothing. In the case of LightDetector, an iPhone is capable of sensing the variation in the surrounding light intensity and of informing its user of that variation by playing peculiar sounds of varied intensity. The user, on the other hand, is capable of perceiving the variations in the sound intensity, and of judging the direction of the light source and her distance from that light source. At work, the interaction affords the user to find a doorway. At home, the interaction affords the user to understand if the lights in her home are switched on or off to avoid the wastage of energy. In the case of ColorIdentifier, an iPhone is capable of determining the color of an object held in front of its camera. The user, on the other hand, is capable of pointing the camera in a desired direction. At work, the interaction affords the user to stich the garments with the right color thread. At home, the interaction affords the user to match the pair of clothes. In the case of Digit-Eyes, an iPhone is capable of scanning the barcode/QR code on an object, of storing and retrieving the text description associated with that particular barcode/QR code from its repository, and of announcing the retrieved description. The user, on the other hand, is capable of focusing the camera on the bar code/QR code on an object and of clicking a picture. At work, the interaction affords the user to label and identify documents. At home the interaction affords the user to label and identify documents, label and identify clothes, and to identify desired products while shopping. In the case of KNFBReader, an iPhone is capable of capturing a picture, of detecting its alignment with the text to be read, of extracting the text from an image

using Optical character recognition, and of converting the digital text to the digital speech. The user, on the other hand, is capable of pointing the camera in a desired direction and of clicking a picture. At work, the interaction affords the user to read printed documents, to read notice boards, and to read machine operation instructions. At home the interaction affords the user to read printed documents.

Conclusion

We conducted a qualitative field study with three BVI expert iPhone users to understand the innovative ways in which they used their iPhones to overcome various functional limitations they face due to their visual impairment. Using the theoretical lens of theory of affordances our analysis of the participants' iPhone interactions revealed various innovative affordances which can be produced through BVI users' interactions with their iPhones in various personal and professional contexts. Future research needs to identify ways to inform the smartphone design to systematically facilitate the creation of meaningful affordances for the BVI population in diverse personal and professional contexts.

Works Cited

AFB. "Impact of the American Foundation for the Blind." *American Foundation of the Blind*, 2014, http://www.afb.org/info/about-us/our-impact/12.

Bikson, Thomas, and Tora Bikson. *Functional Problems of the Visually Impaired: A Research Approach*. 1981.

Burton, Michele, et al. *Making Fashion Accessible for People with Visual Impairments*. 2012, http://web.ist.utl.pt/tiago.guerreiro/pervasive-accessibility/docs/1.pdf.

Gallagher, T., et al. "Indoor Positioning System based on Sensor Fusion for the Blind and Visually Impaired." *Indoor Positioning and Indoor Navigation (IPIN), 2012 International Conference on IEEE,* IEEE Xplore.

Gibson, J. J. *The Theory of Affordances*. Lawrence Erlbaum Associates, 1977.

Kane, S. K., et al. "Slide Rule: Making Mobile Touch Screens Accessible to Blind People using Multi-Touch Interaction Techniques." *Proceedings of the 10th International ACM SIGACCESS conference on Computers and Accessibility*, 2008.

Kulyukin, Vladimir, and Aliasgar Kutiyanawala. "From ShopTalk to ShopMobile: Vision-based Barcode Scanning with Mobile Phones for Independent Blind Grocery Shopping." *RESNA Annual Conference*, 2010, pp. 1–5.

Leporini, Barbara, et al. "Interacting with Mobile Device via VoiceOver: Usability and Accessibility Issues." *Proceedings of the 24th Australian Computer-Human Interaction Conference*, 2012, pp. 339–348.

Machell, J. *Library and Information Services for Visually impaired People: National guidelines*. Library Association Publishing, 1996.

Makino, Hideo, et al. "Development of Navigation System for the Blind using GPS and Mobile Phone Combination." *Engineering in Medicine and Biology Society, 1996, Bridging Disciplines for Biomedicine. Proceedings of the 18th Annual Conference of the IEEE*, IEEE Xplore, 1996, p. Vol. 2, pp. 506–507.

McGookin, D., et al. "Investigating Touchscreen Accessibility for People with Visual Impairments." *Proceedings of the 5th Nordic conference on Human-computer interaction: building bridges*, 2008, pp. 298–307.

Murali, Vidya N., and James M. Coughlan. "Smartphone-based Crosswalk Detection and Localization for Visually Impaired Pedestrians." *2013 IEEE International Conference on Multimedia and Expo Workshops (ICMEW)*, IEEE Xplore, 2013.

Oliveira, J., et al. "Blind People and Mobile Touch-based Text-entry: Acknowledging the need for Different Flavors." *The proceedings of the 13th International ACM SIGACCESS conference on Computers and accessibility*, 2011, pp. 179–186.

Paisios, Nektarios, A. Rubinsteyn, and L. Subramanian. "Exchanging Cash with No Fear: A Fast Mobile Money Reader for the Blind." *ACM Workshop on Frontiers in Accessibility for Pervasive Computing*, 2012.

Paisios, Nektarios, A. Rubinsteyn, V. Vyas, et al. "Recognizing Currency Bills using a Mobile Phone: An Assistive Aid for the Visually Impaired." *Proceedings of the 24th annual ACM symposium adjunct on User interface software technology*, 2011, pp. 19–20.

Theofanos, Mary Frances, and Janice Redish. "Guidelines for Accessible and Usable Web Sites: Observing Users who Work with Screen Readers." *Interactions*, vol. 10, no. 6, 2003, pp. 38–51.

Journal on Technology and Persons with Disabilities

ISSN 2330-4216

LIBRARY OF CONGRESS * U.S. ISSN CENTER
ISSN Publisher Liaison Section
Library of Congress
101 Independence Avenue SE
Washington, DC 20540-4284
(202) 707-6452 (voice); (202) 707-6333 (fax)
issn@loc.gov (email); www.loc.gov/issn (web page)