

User experience of assistive apps among people with visual impairment

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Received 18 February 2022

Accepted 27 April 2022

Abstract.

BACKGROUND: Today, various emerging assistive applications (apps) running on smartphones have been introduced such as Seeing AI, TapTapSee, and BeMyEyes apps. The assistive apps are designed to assist people with visual impairment in navigating unfamiliar environments, reading text, identifying objects and persons. Yet, little is known about how those with visual impairment perceive the assistive apps.

OBJECTIVE: This study aims to advance knowledge of user experience with those assistive apps.

METHODS: To address the knowledge gap, this study conducted phone interviews with a convenience sample of 30 individuals with visual impairment.

RESULTS: The results indicated that those with visual impairment showed a range of preferences, needs, and concerns about user interfaces and interactions with the assistive apps.

DISCUSSIONS: Given their needs and concerns, this study offered a set of facilitators to promote user adoption of the assistive apps, which should be valuable guidance to user interface/interaction designers in the field.

Keywords: Disability, smartphone, accessibility, usability, usefulness

1. Introduction

1.1. Mainstream and assistive technologies for people with visual impairment

People with visual impairment use a wide range of technologies for communication, entertainment, socialization, office work, and so on with supports of assistive technologies [1]. Abraham et al. [2] administered a survey with people with visual impairment ($n = 166$) living in Ghana and found that the survey respondents used smartphones for social media, web browsing, voice chatting, news, emails, online banking, music, movies, and games. The most frequently used assistive features included voice assistants (VoiceOver and Talk-Back) and voice recognition, while they did not much use the following assistive features: color inversion,

color contrast, magnification, and backlight illumination. Griffin-Shirley et al. [3] also conducted a survey to explore how smartphones have been used by people with visual impairment. The majority (86.1%) of the survey respondents ($n = 259$) lived in the United States and used mobile devices (smartphones and tablets) for emails, social media, entertainment, and leisure reading. They used various assistive apps for visual identification, screen reading, and navigation. Over 95% of the survey respondents use smartphones, followed by tablets (40.5%), both (37.1%), and other (19.7%). Almost 80% of the respondents used iOS followed by Android (7%).

1.2. Individual differences in user experience

Individual differences were found in user experience with smartphones among people with visual impair-

ment. Buzzi et al. [4] observed that a group of users with visual impairment preferred rounded gestures while another group of those with visual impairment preferred steep-angle shapes and right-angled gestures. Individual differences were also found with regard to the number of strokes per gesture, i.e., a single stroke versus two strokes. In a study by Arditi et al. [5], a group of users with visual impairment preferred a touch-based communication channel to obtain information while others preferred a speech/sound-based communication channel. Kim et al. [6] also found that 75% of participants with visual impairment assigned higher ratings on the combination of inbound and outbound call systems to verbally interact with voice technology but also more appreciated structured navigation menus systems over unstructured ones. In previous studies, they all share the same disability category, i.e., visual impairment; however, it does not necessarily mean that they share identical needs for user interface and interaction designs.

1.3. Lack of understanding of user experience with camera-based assistive apps

The frequently used camera-based assistive apps include Seeing AI, TapTapSee, and BeMyEyes [7,8]. The BeMyEyes app is a video call connecting users with visual impairment to sighted volunteers online. Once connected with sighted volunteers, users with visual impairment share their view via a built-in video camera and then the volunteers inform users of what users are trying to read, recognize, and see in real time. The Seeing AI and TapTapSee apps rely on computational algorithms that help to identify texts, objects, and people in real time. When a user scans or takes a picture of, for example a can of food, the app reads out loud the label printed on the can [9]. The TapTapSee app uses a matching system in which a picture/video is sent to the image database (CloudSight API) and the picture/video is then matched to another in the database to identify what the user is trying to read. Assistive apps such as the TapTapSee app are, however, unable to identify one that does not exist in its database [10]. Dockery et al. [7] conducted a small-sized phone survey with 11 users with visual disabilities to explore how users perceived of using mobile apps specially designed for people with visual disabilities. The survey respondents appreciated such app features as navigation, person-to-person interaction, reading texts, portability, and affordable price. Granquist et al. [11] conducted a small study with 7 individuals with visual impairment to compare the performance between the Seeing AI app and

the Orcam MyEye (a device converting texts to speech via a small camera attached to eyeglasses). Both assistive technologies provided approximately 95% accuracy for text recognition; users could successfully complete 71% and 55% of tasks using the Orcam MyEye and the Seeing AI respectively; and there was no significant difference in time needed to complete tasks between the two systems' users. Yet, there are still a handful of studies on the camera-based assistive apps for people with visual impairment and furthermore little is known about indepth understanding of user experiences (needs and concerns) through a combination of qualitative and quantitative user data [9,12,13].

To address the knowledge gap, this study employed a user experience interview and a quantitative user experience questionnaire. This study focused on exploring the degree to which users have positive attitudes toward the assistive apps; are willing to try and experiment; perceive the apps as useful resources and easy to use; and intend to adopt the apps. In addition, this study assessed the effects of various sociodemographic backgrounds on user experience and perception toward the assistive apps. Based on the research findings, this study was to introduce facilitators to the assistive app adoption.

2. Methods

2.1. Participants

As shown in Table 1, this study was accomplished with a convenience sample of 30 individuals with visual impairment. The inclusion criteria include English speaking, 18 years old or older, visual impairment (i.e., visual acuity equal to or lower than 20/70 [14]), and user experience with at least one of the following assistive apps – Seeing AI, BeMyEyes, and TapTapSee apps, but also people without experience are included to gain insight into user expectations. Thus, this study can comprehensively explore both *user expectations* and *real experiences*. All participants were already aware of the three apps and had used them all once but used a particular app among the three apps on a daily basis. Table 1 shows how many participants use a particular app when it comes to daily usage.

2.2. Materials

A set of inquiries to assess user experience with the apps were adopted from the work by Gao et al. [15]. The

Table 1
Characteristics of the participants

Participants	Experienced-users (n = 24)	Prospective-users (n = 6)
Visual acuity		
Between 20/200 and 20/400	2	1
Between 20/400 and 20/1200	5	2
Less than 20/1200, but has light perception	14	3
No light perception at all	3	0
Duration of visual impairment (years)	29.17 ± 21.46	35.17 ± 22.75
Onset of visual impairment (years)	21.42 ± 23.53	31.33 ± 33.36
Age (years)	57.63 ± 18.43	66.50 ± 15.08
Gender		
Male	9	4
Female	15	2
Race/ethnicity		
African American	9	4
European American	14	1
Others	1	1
Education		
High school or equivalent	10	2
Associate	4	3
Bachelors (BA or BS)	4	1
Masters	6	0
Seeing AI users	7	0
BeMyEyes users	11	0
TapTapSee users	6	0

Table 2
Mean differences in intention to adopt the assistive apps

Constructs	User Group	M ± SD	Mann-Whitney U Tes		
			U	z	p
Perceived Usefulness (PU)	Experienced-Users	5.67 ± 1.01	62.00	-0.52	0.60
	Prospective-Users	5.40 ± 2.32			
Perceived Ease of Use (EOU)	Experienced-Users	5.48 ± 1.66	66.50	-0.29	0.77
	Prospective-Users	5.57 ± 1.02			
Personal Initiatives and Characteristics (PIC)	Experienced-Users	6.15 ± 0.71	54.50	-0.92	0.36
	Prospective-Users	5.83 ± 0.86			
Context (CT)	Experienced-Users	6.19 ± 0.77	57.00	-0.92	0.36
	Prospective-Users	5.75 ± 1.26			

inquiries were related to five themes: Perceived Usefulness (PU), Perceived Ease of Use (EOU), Personal Initiatives and Characteristics (PIC), Context (CT), and Intention to Use (IU). The inquiries include, for example, “Using the system would increase the efficiency of my daily work”, “I would find the user interface of the system clear and intuitive”, “I have fun using the system”, “I could use the system if I am being out of home or the office”, and “I intend to use it.”

2.3. Procedures

Participants were invited to the interviews by phone. An interviewer did read out loud each inquiry to participants. Participants should respond to each inquiry on a seven-point Likert type scale from *strongly disagree* (1) to *strongly agree* (7), which was followed by open-ended questions to learn more about their responses and

personal experiences with the apps. It lasted no longer than 60 minutes for each participant. This study was approved by the Institutional Review Board. This study was conducted amid the COVID-19 pandemic such that the IRB recommended meeting with participants over the phone.

3. Results

3.1. Questionnaire

3.1.1. Positive attitudes toward the assistive apps

The two groups of participants (experiencedusers and prospectiveusers) completed the technology adoption questionnaire. Cronbach’s alpha was found to be 0.84 for the experiencedusers’ responses while 0.89 for the prospectiveusers’ responses. As shown in Table 2,

Mann-Whitney tests compared the mean scores of responses for each construct of the questionnaire, i.e., PU, EOU, PIC, and CT between the experienced users and the prospective users. No significance was detected. Their scores on average were close to the maximum score on a scale from 1 to 7. The results suggest that prospective users with visual impairment have a high level of expectation for the assistive apps, and experienced users with visual impairment also have a high level of satisfaction based on their actual experience. Regardless of experience with the assistive apps, people with visual impairment had positive attitudes toward the assistive apps and were willing to adopt them.

3.1.2. Relationship between intention to use and other constructs

This study used Spearman's correlation coefficients to evaluate the relationship between the construct of "intention to use IU" and each construct of "PU, EOU, PIC, and CT." Among the prospective users, there was no significant relationship of adoption intention with the other constructs. Among the experienced users, there was a significant relationship of adoption intention with the construct PIC, $r = 0.54$, $p < 0.01$. Further analyses with Spearman's correlation were, then, conducted to examine which items of PIC was specifically related with adoption intention among the experienced users. Positive relationships were found for PIC item #1 ($r = 0.43$, $p = 0.04$), PIC item #3 ($r = 0.44$, $p = 0.03$), PIC item #6 ($r = 0.62$, $p = 0.001$), and PIC item #7 ($r = 0.59$, $p = 0.03$). The results indicated that those with visual impairment were likely to adopt the assistive apps when they were equipped with high technology literacy (item #1); when they were an early adopter (item #3); when they were able to observe significant benefits of using the apps; and when they maintained a good favor of using assistive technologies (item #7).

3.1.3. Effects of sociodemographic backgrounds

This study also conducted Mann-Whitney U tests to investigate individual differences in mean scores of participants' responses by referring to the participants' sociodemographic backgrounds. Younger experienced users responded with higher scores (6.07 ± 0.93) to the construct PU as compared to older peers (4.91 ± 1.19), $U = 29.50$, $z = -2.28$, $p = 0.02$. Experienced users without higher education degrees responded with higher scores (6.23 ± 0.93) to the construct PU as compared to peers with higher education degrees (4.80 ± 0.92), $U = 20.00$, $z = -2.95$, $p = 0.03$. European-American experienced users (6.45 ± 0.52) responded with higher

scores to the construct PIC as compared to African-American peers (5.80 ± 0.73), $U = 29.50$, $z = -2.15$, $p = 0.03$. The results confirmed that perceived usefulness was the critical determinant for both "younger" experienced users and experienced users "without" higher education degrees in assessing the assistive apps and deciding to adopt the apps, as compared to their counterparts. In addition, European-American experienced users tended to be influenced by their personal initiatives and characteristics to make a decision on adopting the apps, as compared to their counterparts. A Mann-Whitney U test found no significant difference in the "overall" intention to adopt the apps between the experienced users (6.67 ± 0.99) and the prospective users (6.57 ± 1.14), $U = 71.00$, $z = -0.08$, $p = 0.98$. The result indicates that people with visual impairment tend to adopt the apps as long as they are designed to serve as assistive technologies promoting independent living for people with visual impairment.

3.2. Content analysis

Participants shared their preferences, experiences, and recommendations for the assistive apps via qualitative interviews. The content analysis of their comments resulted in five themes with several subthemes. The content analysis results are fully described in Table 3. Another coder helped to assess the interrater reliability using Cohen's kappa statistic, which resulted in substantial agreement among the coders as the interrater reliability was found to be $k = 0.70$ (95% CI: 0.26 to 1.04), $p < 0.05$.

3.2.1. Advance

Participants appraised the assistive apps in terms of how much the quality of the apps was better than that of existing technologies (Theme 1. *Advance*). All features provided by the assistive apps must be accessible (Theme 1.1) and user-friendly (Theme 1.2) to users. Yet, some participants living in rural area suffered from limited access to the Internet; therefore, even though all features of the apps maintain good accessibility, they would end up with no access to the services from the apps. The apps may, alternatively, be designed to be still operable without the Internet (e.g., option for an offline mode).

3.2.2. Compatibility

They would like to be ensured that the assistive apps were compatible (Theme 2. *Compatibility*) with their attitude toward technologies (Theme 2.1); with their be-

Table 3
Content analysis results leading to a set of facilitators to technology adoption among assistive app users with visual impairment

Themes			Samples of participants' comments	Facilitators to adoption
1. Advantage	1.1 Accessibility	1.1.1 Essential for adoption	<i>"If the apps have good accessibility features, we will use the apps to our advantage (P20)."</i>	User interfaces accessible to users with visual impairment
		1.1.2 No Internet service in rural area	<i>"Although the accessibility of these apps is really good, the Internet goes 'Not Accessible' sometimes as I am currently living in the rural area (P10)."</i>	Apps equipped with an option for working without Internet connection
	1.2 Usability	1.2.1 Effectiveness	<i>"The app relies on volunteers online and how effectively they are communicating with me. Previously I used the app to get some help, but the volunteer did not speak English very clearly, so I could not understand her [explanations] (P22)."</i>	Matching system connecting users with volunteers who speak the same language
		– Unable to understand volunteers' English	<i>"My overall feeling is mixed because the idea is great, but the application is not consistent. If a restaurant menu is laminated, the app fails to read texts (P14)."</i>	Sophisticatedly designed system for accurately identifying, reading, and navigating environments
		– Less accurate at identifying, reading, navigating	<i>"It helps when I am at home alone as well as when I am looking for something in the pantry like a can or to set my oven correctly (P26)."</i>	Sophisticatedly designed system for accurately identifying, reading, and navigating environments
		– Accurate at identifying, reading, and navigating	<i>"It all depends on how I use the app. I have never thought of using the app in my house but use it in other places (unfamiliar places) (P2)."</i>	Navigation features suitable and customizable for inside and outside
		– Not use it to navigate in my house but other places	<i>"You don't need to go through a lot of different steps to be able to use the apps. They are easy to remember and intuitive. So, even if you do not use them for a while, you can use them right away (P26)."</i>	Simple user interfaces
		1.2.2 Efficiency	<i>"I cannot correctly focus on the target object. I do not know whether I am correctly aiming at the target (P11)."</i>	Easy to handle the camera to focus on a target object
		– Simple UI	<i>"I rated this way (highly rated) because one of the apps I have used makes sense to me and was really useful (P4)."</i>	Usefulness
		– Having difficulty focusing the camera	<i>"The usability of these apps definitely plays a key role in allowing people with visual impairment to navigate through their day (P9)."</i>	User-friendly interfaces
		1.2.3 Satisfaction	<i>"If I am at home by myself or walking by myself, I find the apps helpful to be able to get information that I want. For example, reading street signs, looking up colors, having somebody tell me what's around me when I go for a walk. So, what it does really makes me more independent and keeps in touch with my environments (P26)."</i>	App features designed to facilitate a range of activities of daily living in people with visual impairment
		– Usefulness	<i>"It is fun to use as I talk with my grandchildren (P6)."</i>	Fun to use
		– User-friendly	<i>"My brother (one with blindness) hates getting others' help but uses the apps (P25)."</i>	Human-centered designs for users who feel uncomfortable with technology assistance
		2.1.2 Fun to use	<i>"If I needed to see something and if there was no one around me, I would then use the apps. I would relay rely on 'person' over computer/machine (P2)."</i>	Safety measures to protect personal information
		2.1.3 Individual differences in preferences for technology vs. human assistance	<i>"If it is something personal, I will try not to use the app; but, if I have to, I will then use it as my last option (P3)."</i>	App features designed to facilitate a range of activities of daily living in people with visual impairment
2. Compatibility	2.1 Attitude	2.1.1 Appreciation of any assistive technology promoting independent living	<i>"As I am currently with my family, I would not like to use the apps. However, if I am living alone, I would surely use the apps (P10)."</i>	
		2.1.2 Fun to use		
		2.1.3 Individual differences in preferences for technology vs. human assistance		
		2.1.4 Safety measures to protect personal information		
		2.1.5 Conditional adoption		

Table 3, continued

Themes			Samples of participants' comments	Facilitators to adoption
3. Complexity	2.2 Behavior	2.2.1	<i>"I spend time working in my office, so I would use the app for professional work at workplace (P12)."</i>	App features suitable for professional work
		2.2.2	<i>"I have a fantastic memory; I know how I plan each day so I will not be using the app to schedule my tasks (P8)."</i>	App equipped with reminder features
		2.2.3	<i>"I am a retired person; I do not have to be that much organized in every life. I would depend on the app a bit more if I was still working (P13)."</i>	App features customizable to accommodate a range of users who have different needs
	2.3 Technology	2.3.1	<i>"I might want to look into the other apps that have features that my BeMyEyes app does not have (P22)."</i>	Digital compatibility with other assistive apps for users with visual impairment
		2.3.2	<i>"Apple's VoiceOver cannot do everything, but BeMyEyes can do alternatively. I use both (P2)."</i>	Digital compatibility with a built-in voice-controlled personal assistant
		2.3.3	<i>"I use my Android phone more often than my desktop computer because it is more convenient to use, and I can carry it anywhere I go (P5)."</i>	Good mobility over stationary PC at home
		2.3.4	<i>"You can use the app, but it depends on what level you are capable of using computers, smartphones, and so on. If you are familiar with them, it would be easy to use the app anyway. It's computer literacy! (P12)."</i>	Enhancement of computer literacy
		2.3.5	<i>"Because I have other devices that help me as much or more, so I have not used the app much (P24)."</i>	Uniqueness as a competitive advantage
	3.1 Not easy to learn	3.1.1	<i>"It is always hard to learn the app at the beginning. Once you start using the app, you will then repeat using it and then it gets easier and easier (P5)."</i>	Training programs, suitable and accessible to people with visual impairment
		3.1.2	<i>"Even if someone explains how to use the app, a steep learning curve will still be expected (P1)."</i>	App designs for easy-to-use but also easy-to-learn in order to avoid a steep learning curve
	3.2 Preferred learning style	3.2.1	<i>"I really need a "one-to-one" teaching format, instead of focus group styles to help me understand these apps. For example, someone would show me where I place my fingers. I prefer such hands-on training in person with only me and a teacher, not a group session (P2)."</i>	One-to-one teaching
		3.2.2	<i>"Well, at first, learning how to use the app took a while! (P30)."</i>	Supervised learning (over self-education)
		3.2.3	<i>"Well, when I first downloaded the app and when I was trying to learn it by myself, it was not easy! The user manual was not clear to understand, and not particularly helpful to learn the app (P14)."</i>	User-friendly user guidebook, facilitating self-education
		3.2.4	<i>"I know if I am able to use the app correctly, then it will be a benefit to me. The only problem I have is not knowing the full information and using it correctly (P18)."</i>	Supervised learning
		3.2.5	<i>"I usually ask my son-in-law to help me with a new application (P8)."</i>	Supervised learning

Table 3, continued

Themes		Samples of participants' comments	Facilitators to adoption
	3.2.6 Learning with an instructor	<i>"Once I know how to do it, then it will not be a problem. Initially, it may be a problem, but if someone shows me how it is done, it will be easy. Training is needed (P15)."</i>	Supervised learning (over self-education)
4. Observability	4.1 Adopt dependently	<i>"I was introduced to these apps through an organization (social worker) that works with people with visual impairment. They put it on our iPad and we all just started using it (P13)."</i>	Professional training of social workers
	4.2 Adopt independently	<i>"I do not keep following organizations' recommendations, so it doesn't matter (P3)."</i>	Provision of education and training for users
	4.3 Encourage others to adopt	<i>"It would be advantageous for me to use the app as much as I can, and I would recommend it to people with visual impairment (P17)."</i>	Accelerating technology adoption via technology champions with visual impairment and blindness
	4.4 Late adopter	<i>"I would not like to become a 'beta tester' for the app company. I would not like to be the first one using the system, so I would wait and see (P10)."</i>	Sharing of user experience (e.g., testimonial)
5. Trialability	5.1 Free of charge	<i>"Most of the time we (people with visual disabilities) are all on a fixed income, so that anything that is free is helpful (P15)."</i>	Free trial prior to being charged
	5.2 Ease of installing	<i>"I would definitely say that the easier it for blind people to install it, the more they are going to use it (P9)."</i>	Easy-to-install

havior of interacting with technologies (Theme 2.2); and with other technologies that they had been using (Theme 2.3). For instance, some participants felt more comfortable with obtaining help from humans over the apps, such that human-centered designs could be employed to make users feel comfortable while interacting with the apps. Some participants tended to avoid relying on the apps to identify objects or navigate the environment as their life is simple and they would rather rely on their memory. Thus, the apps could be designed to handle a variety of daily living activities (ranging from simple to complicated and complex daily tasks) to accommodate different needs of everyone. Participants also mentioned that computer literacy was one of critical factors leading to successful user adoption. User training programs would, then, be helpful to enhance the computer literacy of users with visual impairment

3.2.3. Complexity

Participants did not appreciate any technologies equipped with complex user interfaces (Theme 3 *Complexity*). They tried to teach themselves using a user manual, but they could not fully understand the instructions or often ended up with understanding and using only a few features. They empathized the need of a training program, suitable and accessible to people with visual impairment (Theme 3.1). Yet, there were groups of participants expressing different learn-

ing styles (Theme 3.2). They would like to learn the assistive apps in a preferred way, i.e., learning "individually" versus "in a group."

3.2.4. Observability

Participants tended to be influenced by themselves or other people when it comes to technology adoption (Theme 4 *Observability*). Part of participants appreciated it that organizations who provide services to people with disabilities often introduced and encouraged them to use new assistive technologies (Theme 4.1). Several other participants would like to independently decide to adopt (or decline) a new technology, solely based on their appraisal (Theme 4.2). When they found the assistive apps useful and beneficial to people with visual impairment, they also recommended the apps to their peers with visual impairment (Theme 4.3). Some participants intended to start using the assistive apps after many others had already started using them (i.e., late adopters) (Theme 4.4). Technology champions are considered as members of a community or an organization who are well informed of a new technology (i.e., early adopters). Such technology champions among people with visual impairment may be able to contribute to introducing the apps but also teaching their peers as to how to use the apps, i.e., promotion of user adoption.

3.2.5. Trialability

Participants also emphasized trialability in which

they could have an opportunity to try a new technology before making a decision to permanently adopt it (Theme 5 *Trialability*) For example, they would like to obtain technologies free of charge (Theme 5.1) and easily install them onto their existing devices (e.g., smart phones and smart tablets) (Theme 5.2). They have informed that many of people with visual impairment are on a fixed income, such that *easy access to technology* means “affordable” technology in addition to accessible user interfaces of technology. Free or trial versions would contribute to promoting user adoption. Participants also mentioned that they have been using other smart technologies, and they wanted to be ensured that any new technologies should be compatible with their existing technologies.

4. Discussion

This study found no significantly different level of overall intention to adopt the apps between experienced-users and prospective-users. They all had a good favor toward assistive apps that are designed to help people with visual impairment. Such good perception was also observed in the literature. Asghar et al. [16] administered a survey with a total of 991 adults from the United Kingdom and Pakistan, including both “experienced” users of assistive technology and “non-experienced” users to examine their perception on assistive technology. They found no significant difference in perceived usability between the two groups. Expected-values and experienced-values were both highly rated toward assistive technologies that are aimed to help people with visual impairment.

Participants also shared insights into better assistive technology designs for people with visual impairment. Based on the content analysis, this study delivered a set of facilitators to user adoption of the assistive apps (see Table 3). Some of facilitators were also reported by previous studies. For example, Deibel [17] suggested a heuristic model for assistive technology adoption. The model includes a set of facilitators leading users to a greater intention to adopt assistive technology. For example, “*motivation*” and “*necessity of device*” serve as facilitators, while “*physical and cognitive efforts*” prohibit users from adopting assistive technology. Deibel’s model is consistent with what participants in this study mentioned. For instance, participants had to make a considerable amount of effort to aim the smartphone camera onto a target object, which was not easy for them to do so due to their vision loss, leading to poor

performance of the assistive apps and likely resulting in technology abandonment. User-centered designs should be considered to promote user adoption, and detailed guidance is available in Table 3.

The correlation analyses have suggested that the apps are more likely to be adopted by those with visual impairment who are equipped with higher technology literacy. However, there have been multiple studies observing a low level of technology literacy among people with visual impairment [1,18–20]. Yet, Arslantas et al. [21] found that college students with visual impairment who had higher computer literacy spent more time using the Internet. In fact, those students with higher computer literacy were found to be participants who had already received training for basic computer skills, office software, and assistive technology applications before participating in the study [21]. It infers that technology literacy is a critical determinant leading to technology adoption among people with visual impairment and can be enhanced via training. Thus, there is an immediate need to provide an adequate training to people with visual impairment.

This study also found that various sociodemographic backgrounds (e.g., younger age, no higher education degrees, and European Americans) contributed to intention to adopt the assistive apps. For example, perceived usefulness was highly rated among younger participants, leading to greater intention to adopt the assistive apps. This result is consistent with research findings of Czaja et al. [22] in which younger adults tended to show greater intention to adopt technology (e.g., computers and Internet). In addition, they found that people who were younger, better educated and European Americans used more various types of technology. Their study results also support the need of training because the relationship between age (younger/older) and technology adoption was successfully mediated by one’s computer self-efficacy, which could be enhanced via training [22]. Participants in this study also emphasized the need of training programs in which they could learn how to operate the assistive apps. A research team by Goodman et al. [23] provided evidence that a training program helped college students with disabilities to gain technology literacy, leading to user adoption of assistive technologies. Jimenez-Arberas et al. [24] argued that a lack of meaningful training was associated with assistive technology abandonment. Further, participants in this study elaborated in detail as to how to effectively learn, e.g., some participants wanted to learn via a group session while others wanted to learn individually with an instructor. Such individual differences

in learning style were well documented in the education literature. Majid et al. [25] conducted an empirical study with 100 high school students with visual impairment to examine which learning styles were most preferred among the learning styles of *Visual*, *Auditory*, *Reading/Writing*, and *Kinesthetic* (also known as VARK learning styles [26]). They found that those students generally preferred the read/write learning style, while male students particularly preferred the kinesthetic learning style more than other styles. Oakland et al. [27] compared the preferred learning styles between students with visual impairment and their sighted peers (aged 10 to 17). Those with visual impairment more preferred practical, thinking, or organized learning styles as compared to their sighted peers. Learning environments should be customizable to meet the needs of people with visual impairment who have a range of learning styles [28]. Fuglerud et al. [29] empirically confirmed that a well-structured training program was effective for people with visual impairment to learn how to use a smartphone.

This study has a limitation. Participants experienced all three apps once and used a particular app on a daily basis. This study was not designed to ask participants to differ their experience with a particular app from that with other less-used apps. All three apps run based on simple user interfaces, i.e., users aim a smartphone camera onto a target and are informed via a smartphone speaker about what they try to see. As the three apps share such simple user interfaces, it might also be difficult for them to differ their experience if they were instructed to do so. This study could be considered as a natural, quasi-experimental research as the group of participants were not intentionally assigned to a particular app only. Further research may be needed to recruit user groups who have exclusive experience with a particular app only and assess their experience.

5. Conclusion

Today, a variety of assistive technologies have been introduced to promote independent living and facilitate professional works. For example, people with visual impairment take advantage of emerging technologies e.g., camera-based assistive mobile apps (Seeing AI, TapTapSee, and BeMyEyes). Those camera-based assistive apps share a common feature – i.e., scanning objects, people, and the surroundings through the camera and verbally describing them to users. Yet, there has been a lack of knowledge about user experience of those

apps among people with visual impairment. This study uncovered a range of user requirements, i.e., user needs concerns and a set of app adoption facilitators associated with *advance*, *compatibility*, *complexity*, *observability*, and *trialability*. Such user requirements will, in turn serve as valuable guidance to user interface/interaction designers in designing, developing, evaluating, refining, and disseminating the apps. For example, designers could refer to the user requirements associated with *advance*, *compatibility*, and *complexity* when taking care of user interface designs. They could also refer to the user requirements associated with *observability* and *trialability* when taking care of implementing the apps in the user domain and obtaining user feedback for iterative evaluations and redesigns. Thus, a deep understanding of the user requirements is anticipated to contribute to the success of user-centered designs [31], which would ultimately bring many benefits, including increased productivity, enhanced quality of work, reductions in support and training costs, and improved user satisfaction [30].

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. 1831969.

Ethical considerations

Ethical approval for this study was obtained from the Institutional Review Board. Informed consent was obtained for all study participants.

Conflict of interest

The author has no conflicts of interest to report.

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