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“Another Eye For the Visually Impaired”: A Study Exploring the Experience of Using Camera-based Mobile Assistive Applications

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"Another eye for the visually impaired": A study exploring the experience of using camera-based mobile assistive applications

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Abstract: More and more visually impaired people rely on assistive technology to live independently, and camera-based applications are a typical technology used to capture and recognize objects. While the researchers have provided ample information on this technology, more studies are needed on user experience. To explore how visually impaired people perceive and resolve the issues in daily use and what factors may affect their usage intention, we conducted semi-structured interviews with 14 visually impaired participants based in London, and all the data was transcribed through thematic analysis. We identified three main themes in the study: i) recognition, ii) encouragement, and iii) adjustment and change. These interviewees expect to improve their social attributes (identity, interpersonal communication, learning ability) through specific mobile applications. We suggest that the user acceptance of the camera-based app is determined by intrinsic factors (self-ability, emotional needs) and external factors (learning behavior, attitude).

Keywords: visually impaired people; technology acceptance; user experience; mobile assistive technology

1. Introduction

Visual impairment is a global public health problem. According to the WHO, at least 2.5 billion people worldwide are damaged by myopia or remote vision, of which at least 1 billion (accounting for almost half) vision damage can be prevented or can be prevented waiting for the solution (WHO & UNICEF, 2022). Visual impairment affects the quality of life and social participation and causes the stigma or the lack of independence in people's lives. In order to help visually impaired people improve their quality of life and social participation, assistive technology came into play. "Assistive technology" refers to any device or system that helps

people with disabilities perform tasks that might otherwise be difficult or impossible. For visually impaired individuals, it can be the devices that provide audio or tactile feedback to convey visual information (Phillips & Proulx, 2019). In terms of the mobile assistive technology, they use a smartphone camera to provide real-time image recognition for visually impaired people through artificial intelligence, computer vision, and communication with volunteers: scene description, text reading and other functions (Bigham et al., 2010). There are already a variety of camera-based auxiliary apps in the market. The two common used apps are Be My Eyes (Lakhani et al., 2022) and Seeing AI (Granquist et al., 2021a), due to their portability, ubiquity and diversity, these applications bring more possibilities to the lives of the visually impaired. It is worth noting that people with visual impairments who use camera-based assistive applications may face issues related to disability identity, which also requires attention and discussion among researchers. The study shows that disabled people experience negative attitudes, prejudices and stereotypes, leading to discrimination and labelling (Buljevac et al., 2012), the stigma associated with disability prevents users from living independently. Existing studies need to be more detailed for people who use camera-based assistive apps, especially from the user behavior perspective. We cannot ignore the perception, attitude and the emotion experienced when they use assistive apps. Therefore, the study aims to explore the views and expectations of the people who use camera-based assistive apps to provide new insights and suggestions for the design and improvement of assistive apps.

1.1 Camera-based mobile apps

Camera-based mobile apps are the type of assistive technologies that use cameras to provide image recognition to visually impaired users. The workflow of the camera-based system is shown below (Figure 1). Unlike other traditional physical assistive devices, camera-based technology uses smart devices to solve the challenges caused by the lack of visual information and improve user autonomy and participation to a certain extent (Martiniello et al., 2022). There are two widely used applications in the field of recognition, "Be My Eyes" is an application that uses video calls to connect visually impaired users and sighted volunteers, allowing volunteers to see them through the visually impaired user's mobile phone camera surrounding environment and provide voice assistance (Avila et al., 2016). It builds a direct communication platform between sighted people and visually impaired users, using human resources to help users complete daily tasks such as reading product labels, identifying object colors, and navigating routes. “Seeing AI” is an artificial intelligence visual aid that uses the iOS device's camera and can be operated through Voiceover (a standard component of the iOS operating system) screen reading. It typically uses optical character recognition (OCR) technology to recognize and read text to the user and computer vision technology to identify objects and scenes(Granquist et al., 2021b). Seeing AI can help visually impaired users complete a variety of tasks in daily life, such as scanning barcodes, identifying currency, and reading handwriting.

The camera-based technology is more than a single visual assistance developed in recent years; it is still regarded as an innovative technology that provides image/scene recognition for visually impaired users. Patterns identified from questions from visually impaired users will enable designers to improve the design of similar applications and provide meaningful input for future camera-based visual question-answering systems (Brady, 2011). The designers use the system to observe some common usage patterns among users as they started using the recognition technology and became more familiar with it. Therefore, applications equipped with visual question-answering systems are expected to become alternatives to vision assistants for visually impaired users.

Figure 1 Workflow of the proposed camera-based system

1.2 Technology acceptance and theorical model

Acceptance of technology is a concept that indicates the willingness within a group of users to various of tools to support the tasks that it is designed to support (Clark et al., 1985). The intention is affected by many factors, such as the user's cognition, emotion, motivation, society and culture (Taylor et al., 2014). Acceptance of assistive technology is an important research topic as it relates to the quality of life and social participation of visually impaired people. Different technologies have various functions, advantages and limitations, and the acceptance by users will also be affected by various factors (Mariano et al., 2022).

Technology Acceptance Model (TAM) is widely used in research studies when exploring user attitudes towards different types of technology. The original TAM model is shown in Figure 2, it believes that users' acceptance of technology depends on perceived usefulness and ease of use (Marangunić & Granić, 2015). Perceived usefulness refers to the user's belief

that using a specific technology can improve the efficiency and effectiveness of work or life; perceived ease of use refers to the user's belief that using a specific technology does not require too much effort or cost. A study on software usage used the typical TAM model, which is shown in 3 (below), and added four dimensions to it to better explain the influencing factors of information technology (Wallace & Sheetz, 2014). There is no doubt that TAM is a useful theory framework to reveal a relationship between users and technology and applies to different technologies. Moreover, the TAM2 (Venkatesh & Davis, 2000) and TAM3 (Venkatesh & Bala, 2008) added external factors to the original basis, such as social influence, cognitive beliefs, and personal characteristics, to explain more users' acceptance of technology.

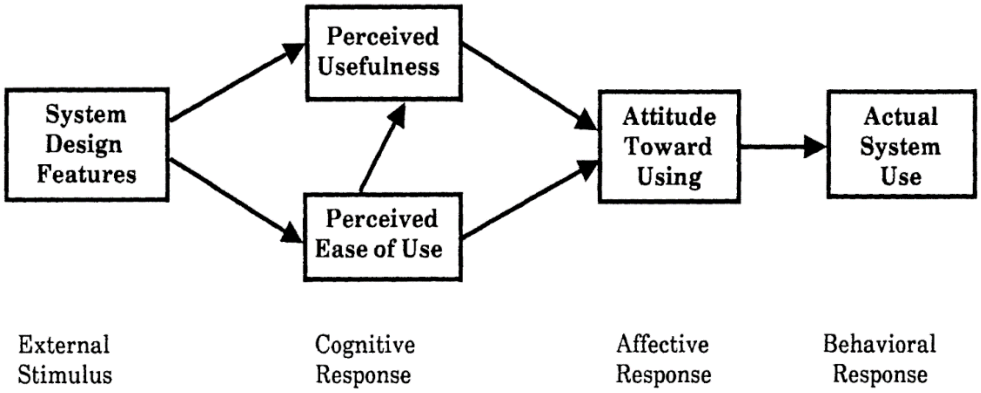

Figure 2 The proposed technology acceptance model (Magsamen-Conrad et al., 2022)

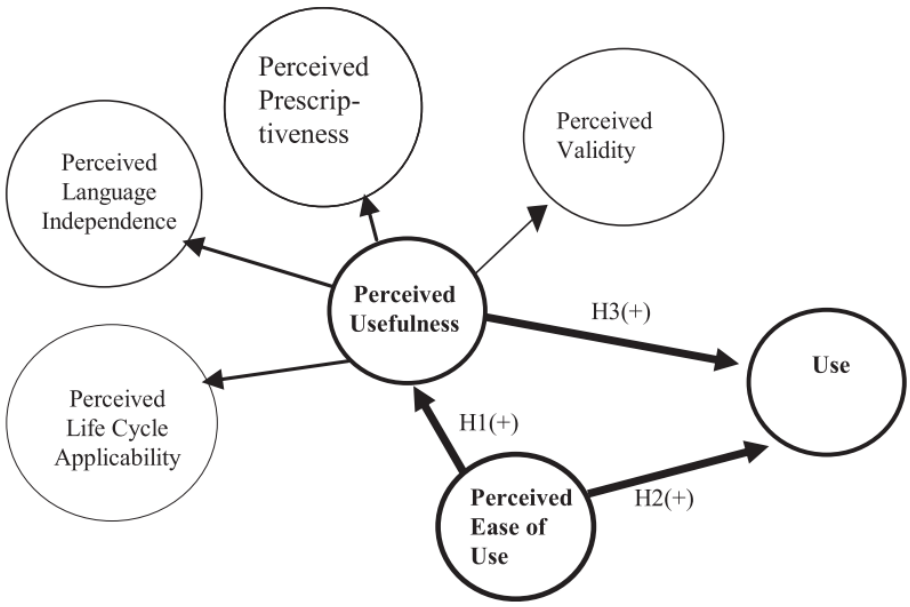

Figure 3 A TAM-based model of software measure use (Wallace & Sheetz, 2014).

A particular need appears to be encouraging the adoption of assistive tools by elderly visually impaired people, which could be done for example either by designing new tools or improving the current tools (Paajala & Keränen, 2015). On the one hand, the trend of aging has promoted the application and development of assistive technologies. On the other hand, it also shows that the elderly may face problems adapting to new technologies, even if they are not so willing. Older adults' perceptions and use of technology are rooted in their personal, social, and physical environments (Peek et al., 2016).

Generally, TAM can be relevant to research on visual impairment in disability. The focus on user perceptions can help understand the factors that influence the adoption of assistive technologies by visually impaired users and provide insights into how to design technologies to increase their acceptance (Djamasbi et al., 2006). In the context of inclusion, researchers ensure that technology is not only easy to use, but also welcoming and efficient for users with visual impairments. Although the existed theories provide references for users' intention, there still needs sufficient evidence to support whether it is suitable for visually impaired people. To seek how visually impaired people response to the assistive mobile apps we organized the following research questions to advance the investigation of technology use experiences of visually impaired users:

1. How do visually impaired people view the impact of assistive technology on their lives?
2. What expectations do visually impaired people have for the design of camera-based mobile apps?

2. Methods

The study followed a co-design process. As part of the work with visually impaired users, the paper primarily reports on the interview findings and how these contributions will support the following research phase. The purpose of the user interview is to understand the views and expectations of visually impaired people on camera-based applications, and to further refine the design strategy for assistive applications through the pilot study and design workshop. The Figure 4 represents the research framework of the different stages of the entire collaborative design.

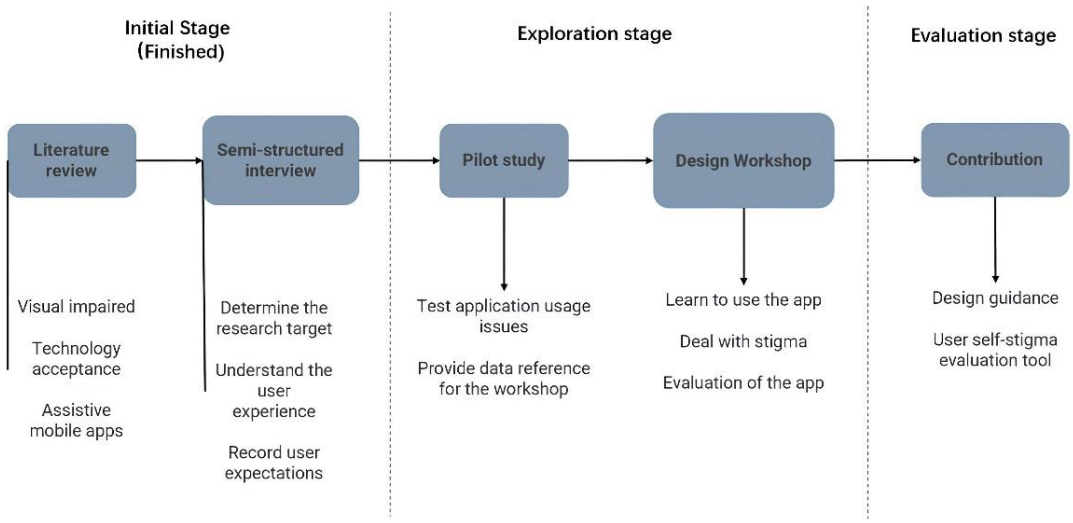

Figure 4 Research method flow chart

The methodology's rationale was based on the principle that visually impaired people have unique perceptions of and usage requirements for different situations (Zhang et al., 2022). The study divided interview questions into three parts, based on the perceived usefulness and ease of use in the TAM model. The aim was to assess how respondents view their disability and how it affects their attitudes towards technology. The questionnaire is divided into three parts. The first part asks about the interviewee's experiences and connections, which will lead them to discuss their struggles and sources of support. In the second part, interviewees will share their experiences with assistive technologies, including how they evaluate these products. The third part will guide users in conceiving their desired design functions and future product appearance. Furthermore, these questions are linked with external factors of the TAM, specifically whether respondents take into account the accessibility and affordability of technology.

2.1 Participants

The selection of participants for the study is that they are adults aged 18-60, who are willing to communicate, have some experience in using mobile phone assistive apps, and there are no restrictions on the level of visual impairment. Therefore, a total of 14 partially sighted participants accepted the interview. All the interviewees are based in UK with the experiences of using at least one assistive device/mobile app. This study employed a convenient sampling method, that is, to find qualified volunteers through personal contact with individuals and social platforms of local agencies (Table 1). The research was supported by “DASH” and the “RNIB”, which are public welfare organizations in London that specialize in helping a various of the disability. The third-party agencies helped recruit volunteers and provided experience working with visually impaired people before interviews. The complete interview lasts 45 minutes and are held online/in-person. Interviews in person are carried out in a quiet and non-disturbed place, and online interviews are conducted by phone or video calls.

Table 1 Participant recruitment details

Number (n=14)	Gender	Age	Resources	Technology usage experience
User 1	Male	68	Members from RNIB	Crutch and wheelchair
User 2	Female	41	Members from DASH	Mobile apps and crutch
User 3	Male	29	Social platform recruitment	Text Magnifier and crutch
User 4	Female	30	Social platform recruitment	Mobile app only
User 5	Female	29	Recommended by friends	Laptop only
User 6	Female	33	Members from DASH	Mobile app and braille display
User 7	Female	32	Members from RNIB	Mobile app only
User 8	Female	33	Members from RNIB	Mobile apps, laptop and screen reader
User 9	Female	28	Members from RNIB	Mobile app only
User 10	Female	25	Members from DASH	Smart phone and laptop
User 11	Female	39	Members from DASH	Mobile phone and crutch
User 12	Female	36	Members from DASH	Mobile app only
User 13	Female	32	Recommended by peers	Mobile apps, computer and screen reader
User 14	Female	36	Recommended by peers	Mobile apps and laptop

2.2 Ethical review

This interview has passed the approval of the school's moral committee. Before the start of the interview, we introduced the research goals and content to the participants and obtained their contents of recording and citing agreement. After that, each interview participant filled in the Consent Form to obtain the right to know the content of the interview.

2.3 Procedure

At the beginning of the interview, we asked interviewees about their personal lives. The main questions are "How do you think visual impairment affects your quality of life?" and "What aspects of support do you need most? These questions relate to their experiences of growing up and different living environments. Respondents were then asked about their views on the role of assistive technology, with the key question "Which assistive products or services do you think have the greatest impact on your life? We recorded life cases mentioned by users, including some positive feedback and some unpleasant experiences. We then asked respondents about their knowledge of camera-based mobile apps. Our questions were: "How do you see the role of this kind of assistive technology?" and "In what situations do you think you will use them? In the last part of the interview, we asked participants about their expectations for product features: "What features do you think a good mobile app should have?". The entire list of questions is adjusted according to the participants' answers to ensure that the interview is in line with the direction of the research. Most interview

questions are open-ended, starting with "how" or "what" to lead users to share personal experiences. Within the limited time, all interviewees talked about the use of technology from their personal experiences to their expectations for design.

2.4 Data analysis

The text obtained by the interview has been transcribed in verbatim, and the researcher used the thematic analysis method to analyses the interview data (Clarke & Braun, 2006), through the steps shown below (Figure 5), the core themes and concepts in the interview materials are refined. This article uses NVIVO 12 software to assist the theme analysis process, which improves the efficiency and accuracy of analysis (Dhakal, 2022). In the first stage, words or phrases were extracted and tagged with codes, and codes related to the same phenomenon were grouped to form initial concepts and themes. Eight themes were screened through interviews, representing different user experiences and issues. During the second and third stages of coding, themes were searched for by grouping related codes. Finally, the researcher reviewed and refined the themes by checking whether they made sense and were supported by the data and identified three themes.

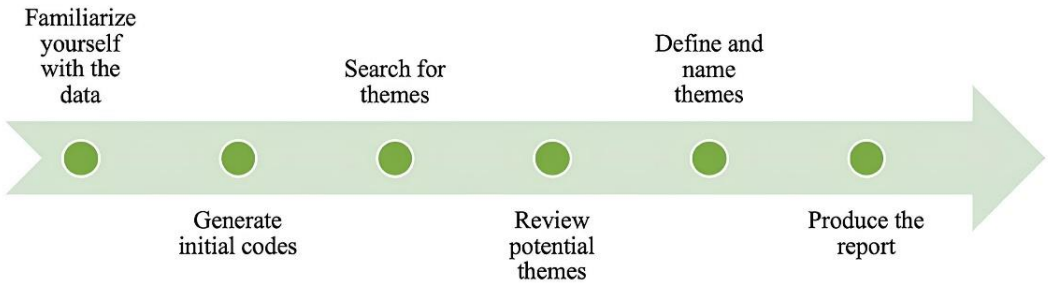

Figure 5 Six-step thematic analysis

Themes	Issues Identified
Personal experiences of visually impaired users	Visual impairment affects reliance on and frequency of assistive apps. Independent living styles can affect functionality and performance requirements for assistive apps. Visually impaired users overcome difficulties through independent learning and seeking help from others. Support from family and society is essential for psychological development. Visual impairment can affect a user's sensitivity to disability identities. Visually impaired users fear being alone and neglected.
User experience and preference for mobile apps	Users can objectively evaluate the benefits and problems that assistive apps bring to them. Satisfaction with applications is related to user learning ability. Mobile applications have become essential for users, and navigation and identification functions have well-supported independent living. The third-party agency helps users familiarise themselves with and use typical mobile apps with navigating and recognising. Assistive apps should be more intelligent, more stable, and more affordable. The application needs to increase the function of identifying people to make up for social needs. The results of navigation and recognition should be more accurate. Users need to demonstrate their learning ability and self-confidence in technology.
Potential Threats of Camera-Based Apps	Software compatibility issues may lead to program crashes and data loss. Stigma is felt when using assistive apps. Stigma of varying degrees can damage users' self-identity. Threats to identity may reduce some users' trust in assistive technology. Users resist or adapt to stigma in different types and ways, and sometimes seek external resources such as counselling or support. Stigma concerns may influence future learning behaviours.

Figure 6 Organized issues and themes

3. Results

The results of this study come from data collected from user interviews. The researcher coded and categorized the data (Figure 6), and discovered three main themes namely recognition, encouragement, adjustment and change.

3.1 Recognition

We asked the interviewees how they felt about using mobile apps in a day-to-day basis. We found that visually impaired people used camera-based assistive apps to meet their visual needs and show their social identity and personal characteristics. Some participants expressed their desire to use these apps to improved their “sense of presence” in society and to enhance their self-confidence and self-esteem. Two participants said they cared about whether the technology could demonstrate their abilities, value and dignity and improve their quality of life and social participation. Moreover, two participants commented on Be My Eyes. They hoped that the recognition function could preserve the features of people because they valued human interaction and wanted to keep this memory through digital technology, which is consistent with some literature and reflects the needs and expectations of visually impaired people for social recognition (Cachón & Igartua, 2016).

> "Sometimes I try to use apps that can recognize people's faces and expressions, especially at some parties, so I can know who I'm talking to and whether they're happy or angry. I feel like being able to recognize 'people' is important to me Connecting with others is helpful and makes me feel like I’m not an outsider. " (27, female)

> "Honestly, I don't want others to think that I am just a visually impaired person. I am also a person with thoughts and emotions. I hope there can be some apps designed for us to increase communication, so that I can participate in some gatherings or activities. I want to express myself and let others think that I am also a talented person." (25, female)

Some participants mentioned *"attention"* and *"memory"* several times, expressing their expectation of receiving attention. They hoped that the camera on their phone could attract others' attention and interest in them and increase interaction and communication with more sighted people. User 13 praised Be My Eyes and said communicating with volunteers could make sighted people more memorable. She suggested that in future updates, volunteers should be better remembered through Be My Eyes so that the users could have a more profound and lasting impression on them. However, most participants said they would use these apps to identify things around them only when they were in unfamiliar scenes, two of whom said they did not use Be My Eyes and Seeing AI daily because they were already familiar with their surroundings.

3.2 Encouragement

We interviewed visually impaired users of learning software based on social cognitive and technology acceptance theories. We found that their learning ambition was influenced by others' opinions and performances, which affected their emotions and actions. For example, one user said he cared about how others perceived his use of mobile apps. Two users from DASH mentioned *"imitation"* and *"comparison"*, saying that they observed other users to judge their suitability for learning. Two other users were intensely interested in new technologies before losing their vision. They compared their learning abilities with others to assess their motivations and beliefs about using assistive apps. This result agrees with some literature and reflects the needs and expectations of most visually impaired users for learning support and encouragement.

> "I feel that if I use a mobile phone, I would be happy to make others more curious and interested in me. Like if I use it to identify objects or colors, other visually impaired people may ask me how to use this app and whether it can What to do. I will introduce it to them, and then they will remember me and say hello to me next time we meet. I think this is a great friendship." (32, female)

We also asked them what other factors might motivate them to use these apps. Three users said that observing others' successful use of technology and gaining benefits and satisfaction from it would enhance their beliefs in technology's utility and capabilities, thus increasing their motivation and confidence in using assistive technology. On the contrary, if they saw others' failures or heard negative comments, they might reduce their beliefs in technology and themselves, thus decreasing their usage frequency. For instance, most users who tried Be My Eyes said they were influenced by seeing similar people using it and finding it convenient. Three users who registered in rehabilitation institutions said they became interested in Be My Eyes' recognition function under the guidance and cooperation of the staff, which was driven by the volunteers' help. Although some users did not think others could easily

change their beliefs and wishes, most agreed that sighted volunteers and positive feedback would boost their enthusiasm. This phenomenon shows that external encouragement can encourage individuals to accept or adapt to specific technologies.

3.3 Adjustment and change

We investigated how visually impaired users adapted their social roles and felt about using mobile phone assistive apps. Most users agreed that "technology changes life" and were positive about learning. One user said he became more independent and productive with technology. User 5 and 13 said they were amazed by the new features of the apps. They said they wanted to avoid being seen as "low-ability" by sighted people, so they tried to improve their technology skills. And also, they faced some challenges, such as finding options or adjusting fonts and colors. When we asked them about functionality and usability, most users showed curiosity and exploration. User 4 said they wanted to learn more skills and tricks beyond the basic functions. Two users from RNIB said technology needed to change with the users' learning abilities. Some users tried to rely on themselves to get new user experiences from the "changes" in the apps.

> "You know, I can't see some things clearly, so, for example, if I want to know what's on the table, I point my phone at the table, and then it will tell me that there are books, cups, or other things. The app works great, but sometimes, I'm not sure if I'm aiming at something or if the light is bright enough...so, I figured out some ways to adapt. For example, I put the things I use frequently in fixed places at home so that I don't have to rely on them to find them every time. I would chat with other people like me and share experiences and tips on using the app. Gradually I got used to this application." (32, female)

We also asked them about the dependence and autonomy when using the app. Most users said they needed both human help and technology to live. However, four users said they switched between dependence and autonomy when using apps and other devices. They regarded them as necessities and avoided them because they felt they could do some tasks independently. The behavior change might be related to the different roles of the people around them, such as professionals or family and friends. The feedback shows the dilemmas and choices visually impaired users face when using assistive apps. Two users mentioned that they had similar feelings when using crutches, and they thought the dependence on technology was reasonable and necessary because it came from awareness, acceptance, trust, and satisfaction with their vision condition and the app.

4. Discussion

4.1 Camera-based technology and independence

First of all, we have an essential finding that when visually impaired users talk about mobile phone assistive technologies, they have a lot of thoughts and experiences to share because mobile phones are one of the most commonly used products in their daily lives. We observed that most interviewees will undergo a process of adjustment and change. They will

switch their thoughts and mentality between relying on tools and completing independently, thus forming different levels of behavioral intentions. Different interpretations of "independence" emerged in user feedback. Some respondents described it as being able to complete daily activities and work autonomously. In contrast, some respondents may believe that independence refers to working independently without relying on others or technical help. We see differences in behavioral motivations for technology use among visually impaired users, which may result from various factors.

We also observed a dynamic and interactive relationship between mobile assistive apps and user independence. In using the apps, users will constantly adjust their perceptions and evaluations of assistive technology and independence, thereby affecting their needs and satisfaction with assistive technology and independence. These users also said that with the technological advancement and popularization of camera-based assistive apps in the future, people's expectations and experiences for independent and dependent behaviors will also change, and they believed that they will have more unified opinions on the experience of using the assistive technology.

4.2 Assessment of individual abilities

Another finding is that visually impaired users said that they would be affected by the behavior of others before using several camera-based auxiliary apps. This behavior mainly includes learning, evaluation and sharing experiences. More than half of the respondents with technology experience said they sometimes evaluate whether their abilities match the technology by imitating and referring to others. The positive learning behavior of other users will stimulate their desire to learn, enhancing their self-confidence and recognizing their own learning ability. If they witness negative learning behaviors or evaluation, the interviewees will also question the product and their learning ability, even if it does not affect the final decision. Disabled people especially need encouragement and support from others to enhance their enthusiasm for accepting new things, which was confirmed in the interviews. Some interviewees said that comparing their abilities with others can generate a clearer understanding of themselves. In other words, the attitudes and beliefs of visually impaired individuals towards mobile phone assistance apps are potentially related to the experience of the visually impaired group.

Some participants have high confidence in their abilities due to unique experiences. In contrast, some users may need a more precise judgment of their abilities and, therefore, need to compare with the behaviors of others. User feedback attempts to prove that there is no direct relationship between an individual's learning ability and disability but rather a combination of personal experience and social evaluation. In addition to experiencing the app's essential functions, participants want to master more operating skills through their trials and practices. They said they would share their experience with other visually impaired friends, regardless of whether the experience was good or bad, and the private sharing promotes the development of similar friendships and helps more users improve their understanding of assistive technology.

4.3 Improvement

Overall, most respondents are satisfied with the experience of using recognition applications such as Be My Eyes and Seeing AI and are willing to try more assistive applications. The camera-based apps are considered to be able to solve some challenges in life and also show that visually impaired people have a certain degree of trust and dependence on assistive technologies. We regard this as a positive aspect of assistive technologies improving their lives. Regarding ability differences, the interviewees unanimously believe that technology acceptance will be affected by changes in the behaviors and ideas of others, which is related to previous research on TAM. In addition, the expectations of the visually impaired for assistive technology are also reflected in the hope that it can meet the user's needs for personalized and intelligent feedback. We consider this a customized need for assistive technology to improve users' lives.

When asked about optimizing the recognition function, participants would hope that the camera's recognition function can recognize more targets to remember others or leave a good impression on others, which shows that visually impaired people have specific challenges and confusion about assistive technology. They are worried that assistive technology cannot meet their adaptability and safety in different scenes and environments. It may be necessary to provide more guidance to help users better aim the camera, sacrificing speed to improve recognition accuracy. Also, visually impaired people are concerned about their image and social status, as they discussed the considerations of dependence and independence. Users always seek for a balance between confidence and self-efficacy in technology(Shinohara & Wobbrock, 2016). Therefore, the conflict related to disability identity reveals that users hope to gain freedom of choice through assistive technology while also avoiding losing themselves due to over-reliance.

5. Limitation and future work

The study has several limitations that should be improved and expanded upon in future work. First, the sample size covered by this study is limited, with most of our respondents coming from visually impaired rehabilitation institutions in London. Moreover, there were only two male participants in this study, and the male-to-female ratio may affect the accuracy of the result. Future work could consider expanding the area, increasing the sample size, or using some quantitative methods to verify the interview results. Secondly, interviews will be affected by some subjective factors. Although some interviewees have experience with assistive technologies, they may need help fully expressing and elaborating on user experiences due to memory and interview length constraints. In the future, questionnaires can be used to understand each interviewee's situation better before the interview begins. In addition, further questions covering self-determination or social cognitive theories can be added in follow-up work to explain the understanding of further use behavior and optimize interventions.

6. Conclusion

Results so far have been encouraging in the sense that they showed that most visually impaired people are willing to accept mobile apps and their trust, satisfaction, fun and novelty in technology also have varying degrees of impact. Technology acceptance theory helps researchers explain users' attitudes and influencing factors towards information technology, while visually impaired people have different social identities, unique experiences and learning abilities. Visually impaired people's concern for identity is a social psychological need, and when this need is reflected in some technology use scenarios, it may even transcend the functionality of the product. Therefore, the psychological condition is regarded as a design factor and will affect the acceptance of assistive technology (Al Shehri et al., 2022).

In this work, the feedback from interviews reflects the perceptions and interests of the visually impaired towards camera-based technology. The study's interview results highlight the importance of users' social needs in technology, with the desire for social interaction and recognition of identity. Through the responses of these interviewees, the study determined that some visually impaired people have more sensitive psychological response than those with normal vision, which is reflected in online communication with volunteers and paying attention to the evaluation of people around them. We therefore suggest that the design of mobile apps for the visually impaired should enhance their personal abilities and social recognition. Additionally, we hope that future designers can incorporate considerations of psychological needs into the design strategies of more assistive mobile apps to improve society's tolerance for the visually impaired and their willingness to use technology.

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