A Scoping Literature Review and Content Analysis of Navigation Apps for Blind and Visually Impaired Users

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Wayfinding can be challenging for blind and visually impaired people. While some applications exist in helping individuals with low vision to reach their desired destination, no study has examined currently available commercial navigation applications. The aim of this study was to understand what features are useful and should be considered when designing assistive applications for individuals with visual impairment. We conducted a scoping literature review of navigation applications on iOS designed for blind or visually impaired users. Fourteen unique applications were identified to be relevant based on our inclusion criteria. Twenty-eight features that have been included in these apps were summarized and discussed in this study. Finally, we elaborated a set of design recommendations based on these features for future assistive navigation application development.

INTRODUCTION

Vision is the most important information source for people to recognize surrounding environments and navigate around barriers (Patla, Tomescu, & Ishac, 2004; Kandalan & Namuduri, 2020). Thus, navigating around unfamiliar places and performing daily activities have become the most challenging tasks for blind or visually impaired individuals (Brady et al., 2013). About 11 million adults in the U.S. are blind or have serious difficulty in seeing, about 4.6% of the U.S. population (National Center on Birth Defects and Developmental Disabilities, 2020). On a worldwide scale, about 2.2 billion people have vision impairment (World Health Organization, 2019). In addition, the number of people with visual impairment is dramatically increasing due to age-related macular degeneration and increase in chronic health conditions such as diabetic retinopathy, among other causes (World Health Organization, 2019). Therefore, there is a growing attention on the development of technologies and tools designed for individuals with low-vision (Joseph, & Namboodiri, 2019; Namboodiri, 2019). In recent years, an increasing number of assistive technologies and systems have been developed to promote their health, wellbeing, and independence (Cheraghi, Namboodiri & Walker, 2017; Prémont, Vincent, Mostafavi, & Routhier, 2019; Kandalan & Namuduri, 2020). Specifically, there has been many mobile navigation applications (apps) developed in helping these individuals to locate and navigate both indoor and outdoor environments (Woodill, 2016; Zanetti, 2018; Cheraghi, Almadan, & Namboodiri, 2019; Corrigan, 2020). However, there has been no study that evaluated these apps to assess whether their designs satisfy the needs and requirements of users with visual impairment.

Although some studies systematically described how they developed their navigation apps for blind or visually impaired people (Blum, Bouchard, & Cooperstock, 2011; El-Shimy, Grond, Olmos, & Cooperstock, 2012; Blum, Greencorn, & Cooperstock, 2012; Panëels, Olmos, Blum, & Cooperstock, 2013; Panëels, Varenne, Blum, & Cooperstock, 2013; Blum, Bouchard, & Cooperstock, 2013), there is a lack of guidance on how a commercial app should be developed to ensure its effectiveness. Moreover, some of those studies or apps have not been updated for years. Thus, rapid and effective research is needed to bridge this gap.

Content analysis involves the studying and interpreting of documents of various formats, such as texts, pictures, or videos (Duriau, Reger, & Pfarrer, 2007). The method has been identified as an effective approach to gain a deeper understanding of commercial apps (Jake-Schoffman et al., 2017). Several studies have successfully applied content analysis to qualitatively interpret the content, features, and user reviews of mobile apps (Widnall et al.; West et al., 2012; Salehinejad et al., 2021).

The objective of this study was to summarize all of the features that have been included in current assistive navigation apps and to come up with a set of design recommendations based on user interface design principles. The findings of this work can provide a roadmap to guide the future development of these software applications. To accomplish this objective, we applied a scoping literature review approach to select relevant apps from the app store. Then, we conducted a content analysis by directly downloading those apps and exploring their features and by qualitatively interpreting the information provided in the app store.

In the following, we included our search strategy to find the relevant applications, and the detailed steps on how we conducted the content analysis for those apps. We then illustrated our results and findings from the content analysis. Finally, we discussed our results and explored how our work can be further improved in the future.

METHOD

Scoping literature review of navigation applications

Search strategy. A scoping literature review was conducted to search for navigation apps that can assist people with visual impairment. The search terminologies included “navigation”, “guide”, and “wayfinding” in combination with “blind” and “visually impaired”. The search was completed in February 2021. Initial search results using each category of keywords are shown in Table 1.

Table 1. Search results based on each terminology.

Terminology	Number of Apps
navigation + visually impaired	41
guide + visually impaired	2
wayfinding + visually impaired	1
navigation + blind	87
guide + blind	4
wayfinding + blind	4

Inclusion and exclusion criteria. In total, 139 apps were identified in the initial search (Figure 1). Before directly downloading all potential apps, the titles and descriptions of those apps were checked carefully to determine the relevance. After excluding the irrelevant apps (N=45), duplicated apps (N=43), and outdated apps that have not been updated for more than four years (N=2), we downloaded all selected apps that had a free basic version to interact with for further assessments. Then we removed the apps that were not either in English (N=20) or we did not have access unless with a license (N=15). Therefore, 14 unique apps were used to conduct a content analysis.

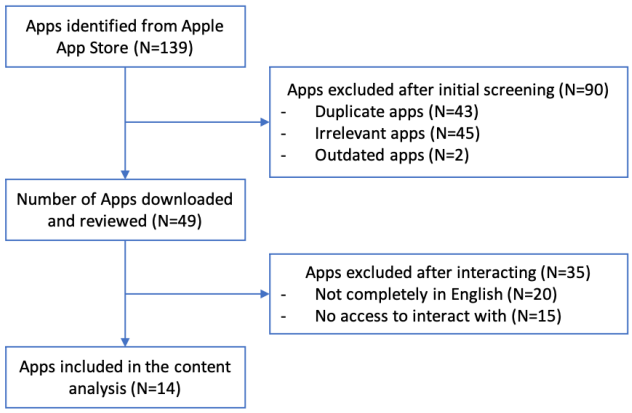

Figure 1. The process of reviewing navigation applications

Qualitative content analysis

To understand the features and content of the selected assistive navigation apps, a qualitative content analysis was conducted including the following five phases:

1) Coding the basic descriptive information for each app, such as the app name and developer;
2) Interpreting the written descriptions of apps and the version updating reports provided by the app developers;
3) Developing a preliminary framework to organize a list of features;
4) Describing and evaluating the content included in those apps by interacting with them based on the Mobile App Evaluation Checklist listed in Table 2;
5) Revising and reordering the identified features during the interpretation of results in phase 4.

Table 2. Checklist adapted from Ultimate IT Guys (2021).

Checklist
1. Is the app user-friendly to people with vision impairment?
1A. If not, what is missing?
2. Does the app currently have all of the key features that are important to fulfill the navigation tasks?
2A. If not, what is missing?
3. What is the feature that I like most about this App?
4. What is the thing that I dislike most about this App?
5.How good is the support?

RESULTS

Description of the apps

The characteristics of the 14 relevant apps are summarized in Table 3. All apps have been updated within one year. While 5 apps were rated 4.5 stars or above, the average rating across the 13 apps (with valid ratings) was 4.3. In total, the 14 apps had 168 reviews in the Apple App Store. Due to the limited access to view full reviews and ratings, we were not able to retrieve information by performing a content analysis with user reviews in this study. However, we do believe this can be a future direction if we can gain more access to those reviews. Among the 14 apps, there were 10 apps supported multi-language interfaces with 4 supporting more than 9 languages. While one of the apps was designed specifically for indoor navigation, nine were designed specifically for outdoor navigation, and four were developed to support both indoor and outdoor navigations (Table 3).

Table 3. A summary of selected apps' characteristics

Name	Developer	Version	Last update	App rating	Number of reviews	Number of supported languages	Application
RightHear - Blind Assistant	ZIKITAPP LTD	3.7.1	Feb, 2021	4.3	4	3	Indoor & outdoor
WeWALK	WeWALK Teknoloji A.S.	2.5.6	Feb, 2021	4.5	12	10	Outdoor
Lazarillo - Accessible GPS	LAZARILLO TEC SPA	3.4.20	Oct, 2020	3.9	19	34	Outdoor
Nav by ViaOpta	Novartis Pharmaceutical	2.1.0	Dec, 2020	4.3	4	19	Outdoor
Aware Audible Wayfinding	2020 Sensible Innovations	1.1.32	Oct, 2020	4.2	5	1	Indoor
Seesing Assistant Move	Transition Technologies S.A.	2.4.9	Oct, 2020	3.8	5	13	Outdoor
Autour	The Royal Insititution	1.8.0	Feb, 2020	5	2	2	Outdoor
Auggie Personal Safety	Vincent Spagnolo	2.0.16	Feb, 2021	5	3	1	Outdoor
Microsoft Soundscape	Microsoft Corporation	3.2.0	Dec, 2020	4.3	81	5	Outdoor
Seeing Eye GPS	Aira Tech Corp	3.7.4	Feb, 2020	3.6	17	6	Indoor & outdoor
GoodMaps Explore	GoodMaps Inc	1.3.0	Nov, 2020	4.8	12	1	Indoor & outdoor
NavCog	Kris Kitani	1.33.19	Feb, 2020	3	3	4	Outdoor
FAR Vision Pro	Foresight Augmented Reality	5.32.0	Oct, 2020	5	1	1	Indoor & outdoor
Waymap	WAYMAP LIMITED	1.19.0	Jan, 2021	NA	0	5	Outdoor

** Note that the NA represents not applicable. It indicates that the app has not yet received enough ratings or reviews to display a Ratings & Reviews summary.*

Content analysis of apps

Twenty-eight (28) features were found from the assessed navigation apps, which are summarized in Table 4. These features were categorized into five groups. The frequency (n) and percentage presence (%) of each feature across the 14 apps were also included in this table.

Table 4. Features included in navigation apps

Features	Prevalence of features in apps n (%)
I. Wayfinding and Directions	
(a) Built-in map with Zoom feature	9 (64)
(b) Convey user's current location & orientation	13 (93)
(c) Allow for specific searches of any places using inputs	11 (79)
(d) Allow for category searches such as food, shopping, etc.	9 (64)
(e) Allow for nearby searches	12 (86)
(f) Provide detailed information for each place such as address, phone, and hours of operation.	11 (79)
(g) Support reverse route search feature	3 (21)
(h) Provide live turn-by-turn navigation instruction	11 (79)
(i) Provide estimated arrival time and distance of travel	7 (50)
II. Visually-impaired-friendly features	
(a) Offer auditory directions, alerts, and notifications	13 (93)
(b) Use of tactile/haptic/vibration feedback to guide user	8 (57)
(c) Support voice command	7 (50)
(d) Use of large icons/buttons/font	8 (57)
(e) Use of high color contrast	10 (71)
III. Customization and preference setting	
(a) Include customizable favorites list	9 (64)
(b) Include language preferences	10 (71)
(c) Include distant unit preferences	10 (71)
(d) Provide routing preferences such as avoiding stairs	1 (7)
(e) Provide direction preference such as clockface, cardinal	1 (7)
(f) Provide customizable color theme interface	5 (36)
(g) Provide adjustable text size	2 (14)
(h) Provide adjustable speaking rate, pitch, voice, and volume	8 (57)
IV. Help and support	
(a) Provide instant live help and remote assistance	2 (14)
(b) Include "Contact us" option	10 (71)
(c) Include tutorials	8 (57)
V. Other useful features	
(a) Can share user's current location/destination	6 (43)
(b) Give continuous instructions when the app is in background	8 (57)
(c) Provide emergency/hazard alerts	1 (7)

I. Wayfinding and directions. In the first category, we identified the features that can assist in navigation, to find where the users are, what is around them, and how to follow the instructions to reach their destination. Items classified into this category demonstrate the essential features to perform the navigation task. These features can also be useful for users without any vision impairment.

A majority of the evaluated apps have the ability to interface with a third-party map (e.g., Google map, Apple map, transit map) or have their own designed built-in maps that allow the users to preview the route configurations. Among the five apps without built-in maps, four can direct the users to open Google or Apple map apps to receive step-by-step wayfinding instructions. Only one app (Autour) is designed to provide auditory only guidance, so no user interface or map is provided within this app. One app (NavCog) cannot convey information to users about where they are located now and what direction they are facing towards. Three methods for searching places were observed among these apps: (1) specific places could be searched by manually typing in the name or address with the keyboard or voice command; (2) places in some apps were organized in categories and could be quickly searched by types; and (3) a list of nearby places was provided to support a quick search. In most apps, the retrieved results of searched places allow the user to preview relevant information regarding the places, such as the address, phone number, and hours of operation. Only three apps offer the reverse route search feature that allows the user to quickly switch between the starting point and destination. While most of the apps provide live turn-by-turn instructions, only seven provide a concise estimation of arrival time and distance to the destination for review.

II. Visually-impaired-friendly feature. Features included in this category are especially helpful for individuals with visual impairment. It was found that auditory and vibration cues have been widely used to provide instructions and notify the users during the navigation process. Half of the apps have built-in speech user interfaces that allow blind or low-vision users to interact with the system through voice commands. Large-scale displayed items and high color contrast principles have also been applied to improve the readability and accessibility of these apps.

III. Customization and preference setting. In this category, we summarized some customization options offered by the apps. In most apps, the users are allowed to create and organize their own list of favorite places, which makes it easier to search for a direct route to their favorite restaurants, museums, etc. The other preference settings observed from those apps include: language settings, distance unit settings, preferred route options and direction settings, color scheme settings, text size settings, and audio parameter settings.

IV. Help and support. Features under this category can provide some insights on how these apps are designed to support the users in using the product and get help when needed. Based on our review, eight apps provide well-developed tutorials within their apps to teach users how to use their products step by step. Ten of them provide their contact information by email or social media to allow the user to contact them with feedback or questions. While live but remote assistance can be helpful, only two apps (RightHear - Blind Assistant; Auggie Personal Safety) offer this service to their users.

V. Other useful features. Three additional features were identified that can be potentially valuable for navigation app development. While only one app has emergency alerts built-in their product, six of the apps offer the ability to share the user's location, which may be helpful if the user is lost and needs to contact someone. Around half of these apps provide continuous navigation instructions during background operations or when another app is running.

DISCUSSION AND FUTRURE WORK

The aim of this study was to conduct a scoping literature review and qualitative content analysis of all available navigation apps for individuals with visual impairment. We evaluated 14 wayfinding apps on iOS. The apps' description and the version updating reports provided by the app developers were qualitatively assessed. In addition, a set of

design recommendations for the apps were generated in terms of these identified features and user interface design principles developed by Blair-Early and Zender (2008), which is discussed in the following sections.

Features to keep in mind

We identified two major features that assistive navigation apps should include in their design. First, it was found that most apps utilized auditory interface to provide step-by-step instructions and alerts to the users to interact with the system and navigate. The system could read the information such as the current location, direction, and nearby places to the users. Users can also listen to the audio instructions to find which direction to go or when it is time to turn. Audible tutorials in some cases are provided to teach the users how to use the apps. In several apps, not only do they provide audio cues to the users, but they also have added vibration alerts into their designs; thus, large amount of information can be conveyed rapidly and in parallel. Providing information in multiple sensory modalities can provide timely notifications to the users with low vision even though they might not see the information displayed on the screen clearly. However, only half the available apps are able to support voice commands that allow people to interact with the system via voice inputs. Lack of this feature can make an app useless for people that are blind or have extremely low vision. Therefore, a speech-based interface is a valuable feature to include in increasing the accessibility of these apps for individuals with visual impairment.

Lack of effective assistance and support was another noticeable problem. Wayfinding can be a challenging task for users with visual impairment. For example, in an emergency situation, these individuals are more vulnerable and may require more help to evacuate from a building. However, after the full review of these assistive apps, it was surprising that only two apps provided instant help to their users. One app included shortcut keys with numbers that allowed their users to call for medical and emergency help or call their family for instant help. Another app provided the option to get local representative assistance by phone. A well-designed approach to offer instant help through the app is an urgent need. Adding this feature can help the users feel safer and less stressed in emergencies, since they will know that someone can provide them with an immediate help. Thus, including features like a chatbot, live chat with a human representative via a dialog box, voice chat, or even video chat can be beneficial to make instant help more accessible to the users.

We also found two additional features that are worthy to be considered in the future development of navigation apps. One is to allow the users to share their live location and destination with their family and friends. This will be helpful if the user is lost and needs help from their family and friends. Another beneficial feature is to develop an effective way of notifying people with visual impairment when an emergency or hazardous situation occurs. For example, using a special sound or vibration in specific patterns to provide real-time alerts.

Design recommendations

Using the 10 user interface design principles proposed by Blair-Early and Zender (2008), we came up with a set of design recommendations that should be considered in the process of developing navigation apps for blind or visually impaired people. The design principles (in *italics*) and the corresponding recommendations are listed in the following with a cross-reference of design features (using letters (a)-(i)) from Table 4:

1. Obvious Start (Design an Obvious Starting Point): (A) "Obvious" items should be visually presented and grab the attention of users with visual impairment, which means the color contrast needs to be high, and buttons, text, and icons need to be designed in large sizes to stand out. Thus, the users can clearly see the content and be able to interact with the system (II. (d), (e)). (B) For blind users, a voice-user interface is required to support the speech-based interaction such that they can input voice commands (e.g., start to navigate) into the system and receive voice prompts based on the commands (II. (a)(c)). (C) A tutorial that explains how to interact with the system should be included in the app so that the user knows where to start and how to use the application (IV. (c)). Specifically, an audio tutorial should be provided to users with low vision.

2. Clear Reverse (Design an Obvious Exit or Stop): (A) Intuitive reverse options (e.g., return key, exit command) should always be provided to the users. (B) Instructions on how to reverse some actions should also be included in the tutorial (IV. (c)).

3. Consistent Logic (Design an Internally Consistent Logic for Content, Actions, and Effects): (A) Use specific type of vibration for a particular situation (e.g., an emergency alert, or event alert) (II. (b)). (B) Otherwise, the use of different vibration modes (with distinct frequency and duration) under different circumstances should be well-defined (II. (b)).

4. Observe Conventions (Identify and Consider the Impact of Familiar Interface Conventions): (A) Allow the users to customize the appearance and behavior of the app based on their familiar interface conventions, which may include the settings of language, distant unit, route type, color theme, text sizes, and speaking rate or pitch (III. (b)-(h)).

5. Feedback (Design Tangible Responses to Apt User Actions): (A) Observable feedback should always be provided to the users; thus, they can be aware of their interaction with the system (I. (h), II. (a)-(b), V. (b)). For example, a map should show up (visually changes in the interface) after they click the "start to navigate" button; or for blind users, when the navigation starts, add an auditory or tactile feedback.

6. Landmarks (Design Landmarks as a Reference for Context): (A) Always let the users know where they are, what direction they are facing, and what places are close by, which can assist them to make judgments on where they can go based on the landmark information (I. (a), (b), (f)).

7. Proximity (Design Interface Elements in Consistent Proximity to Their Content Objects and to Each Other): (A) Provide updates on time and distance estimations to the users while they are traveling (I. (i)). (B) A real-time location of the users should be provided in the built-in map (I. (a)-(b)).

8. Adaptation (Design an Interface That Adapts): A) Allow users to customize the favorite list, which can provide easy access to the frequently traveled places (e.g., home, work place) (III. (a)).

*9. Help (As Necessary, Provide a Readily Accessible Overall Mechanism for Assistance): (*A) Offer live help and support either via a chatbot or via a human representative whenever the users need assistance (IV. (a)). (B) Include a "contact us" page to allow them to provide feedback in using the app and request further instructions (IV. (b)). (C) Allow the users to share their location and destination with families or care providers for help when they get lost (V. (a)). (D) Find effective solutions to timely notify and alert visually impaired people with emergency or hazardous situations. For example, use distinct audible tones or vibration patterns to differentiate specific situations (V. (c)).

10. Interface Is Content (Design Interface Elements That Minimize Interface and Maximize Content): (A) Use metaphor icons to help users identify the functionality behind the button quickly. For example, use a compass icon to lead the user to find the orientation information, use a knife and fork icon to guide the user to search for food and drinks.

Besides these recommendations, we found one additional design recommendation that may benefit blind individuals, which is to use spatialized audio messages to deliver supplement navigation instructions to help the user differentiate between situations. For example, tell the user to "stop when you feel the carpet underfoot (Giudice et al, 2019)."

Limitations and future work

Given the exploratory nature of this study, we have found some valuable features and provided a roadmap for the future design of navigation apps for individuals with visual impairment. However, this study has several limitations that need to be addressed and improved. The search was conducted only on iOS platform since the researchers were all iPhone users. We plan to expand our search in the future to include apps from Google Play Store. In addition, since we did not have the full access to view all the ratings and reviews by the users in Apple App Store, we were not able to qualitatively interpret the information in those reviews at this time. We do believe more insights from a consumer perspective can be obtained if we can have a full assessment on those reviews.

In our future work, we plan to expand our search and review other applications (not related to navigation) that are designed for blind or visually impaired individuals to get more insight on the design features that can improve the accessibility of these apps. We also plan to design prototypes based on our findings and conduct case studies with visually impaired users to validate the functionality and accessibility of such apps.

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