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Exploration of verbal descriptions and dynamic indoors environments for people with sight loss

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Our study explored the navigational challenges of an unfamiliar room (with moving furniture and people) and what verbal guidance would be useful for visually impaired people(VIPs). A mainly qualitative approach of observation and interviews with ten VIPs revealed a lot about the challenges, guidance content and delivery. Further research is indicated to explore effective implementation

Additional Key Words and Phrases: Visually Impaired, Navigation, Dynamic Indoor environments

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1 INTRODUCTION

People with sight can arrive at a room new to them and quickly understand through what they can see what is in the room and how to navigate to a given location within the room. Currently people with sight loss or visually impaired people (VIPs) cannot do this. Typically they would have to ask for assistance from others and/or use a white cane or if they have a guide dog allow it to guide them - although still not able to fully appreciate what is in the room and the location of its contents. There is an intrinsic loss of independence for them. Prior studies [7, 19] mentioned that VIPs struggle in open areas and rearranged places, *e.g.*, restaurants. However, there were no studies addressed the challenges in ***unfamiliar dynamic indoor environments (UDEs)***.

1.1 Background

One of the ongoing issues is how to best present new information so that it may be mentally processed and understood, all while avoiding cognitive overload and obstructing access to surrounding sounds [12]. Introducing VIPs to unfamiliar places through direct experiences or tactile maps can be used to assist VIPs understanding urban environments [8]. Also, Lahav and Mioduser introduced unfamiliar environments to VIPs virtual environments with haptic feedback [13]. Introducing unfamiliar environments in advance to VIPs travel would help acquiring details about fixed features, but it would hlep less in acquiring details about movable features like seats and people. However, the prior studies focused on navigation and wayfinding challenges in urban or large buildings, and none addressed the challenges in UDEs.

Verbal descriptions describe how an area is laid out and/or directions on how to move about it; they may include details on landmarks, travel routes, strategies for particular circumstances [4]. The main benefits of verbal descriptions seem to be their potential for containing a wealth of information, especially when compared to tactile maps, and their accessibility without the need for specific equipment or ability, *e.g.*, reading Braille [4]. For acquiring spatial

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Table 1. Study stages and used methods for data collection

Stage	Pre-session	Walking Sessions		Reflective
		Observation	Comparative	Post-session
Method	Semi-structure interview	Think Aloud, Wizard of Oz, Observation	Time, Performance measurements, Questionnaire, Observation	Semi-structure interview
No. of tasks	-	One	Four	-
Variable	-	-	Brief and detailed descriptions	-

knowledge through verbal descriptions, Giudice *et al.* suggested that VIPs can learn spatial knowledge for exploration and wayfinding through only verbal descriptions [10]. In addition, Connors *et al.* found that VIPs can acquire spatial knowledge through audio description of virtual environments [5].

Thus, part of this study aimed to identify the challenges in UDEs and exploring verbal descriptions to acquire spatial knowledge about fixed and dynamic features in UDEs. The study research questions are:

(1) What are the challenges and strategies in navigation and wayfinding for VIPs in UDEs?
(2) What kind of information are VIPs looking for when they visit UDEs?

2 STUDY DESIGN

Before conducting the user study, we conducted a participatory consultation to reduce flawed assumptions and improve the user acceptability of the study. Based on the consultation, simple setups and utilizing the Wizard of Oz method [6] delivered by a following person in walking sessions. The study received University ethical approval.

2.1 Participants

Ten participants with sight loss were recruited from the local community, five males (P1-P5) and five females (P6-P10) who were cane and smartphone users. Based on the UK NHS classification of sight impairment[1], P1 was classified as sight impaired, and all the rest as severely sight impaired. Some participants had residual sight either central (P1, P2, P5, P7, P8, P10) or peripheral (P3), while others had light perception (P6, P9) and one was congenitally blind (P4). Participants, except P9, reported that they travel independently to familiar places and occasionally UDEs.

2.2 Procedure and Data analysis

The study was composed of a pre-session interview, walking sessions and reflective interview, shown in Table 1. The participants were interviewed to gain their perspective about independent navigation and visiting UDEs. Then participants performed the ***observation and comparative*** sessions. Lastly, a reflective semi-structured interview was conducted to explore their concerns and suggestions about the verbal description.

In the observation session, the objective for participants was finding a chair and sitting down without prior description. During the journey, the participants were encouraged to speak their thoughts as in the Think Aloud method [9]. The Wizard of Oz method [6] was used in which the following person walked behind the participant and answered their questions about their surroundings and for extra participant safety.

The second part of the walking session was the comparative session in which the participants performed four journeys to find the chair and sit. Each journey was conducted with different layouts to reduce learning effects, two base

[1]https://www.nhs.uk/conditions/vision-loss/

layouts and two mirrored. Prior to each journey, the participants received verbal descriptions of constructed layouts. The verbal description is an experimental variable, of which two versions were examined (brief and detailed). The brief and detailed descriptions described the object name, distance from starting point and direction in degrees. The brief description only described the chair, whereas the detailed description described the chair and tables. After finding and sitting in the chair, the participant verbally answered situation awareness (SA) questions [1] and 5-level Likert scale user satisfaction questions. The SA questions ask about the number of surrounding tables, their distance and direction from the chair when the participant sits down. The completion time and the walked distance from the starting point to the chair were recorded. Note that, each participant conducted two journeys for each verbal description version and, the order of the layouts and experimental conditions were assigned randomly.

Six phase thematic analysis [17] was applied to the data from the semi-structured interviews. Qualitative observation was used to analyse the data from the walking sessions (observation and comparative). Descriptive statistics report the user performance, situation awareness and feedback in the comparative sessions.

3 FINDINGS

All participants completed the tasks. The following list summarized the participants' behavior and comments during the walking sessions.

(1) Participants who have residual sight took a brief moment to explore the space using their sight. Because of The good lighting conditions, some of them recognized objects with high contrast to the surroundings.
(2) Participants mostly asked confirming questions, *i.e. "Is this a table?"*. A couple of them asked about the number of chairs in the room as well as the direction to the chair. P9 started the observation session by asking whether the room was big and whether the chair was far away. Then she went forward and asked directional questions whether the chair was on the right or left.
(3) Participants made assumptions about the space based on their experience. All participants, except P10, did not identify the targeted chair from the start point. All participants assumed that the chair would be next to a table, so when they located a table, they searched for the chair around it. P10 explained she could identify the chair from a light reflection on the chair.
(4) Participants queried object identity from different distances. P1, P3, P7 and P8 asked about the object from a distance, roughly 1-2 metres away. Whereas others asked about the object when the cane touched the object.
(5) Most participants used their free hand to touch and identify objects. P6 used their free hand to identify the height of the object. P7 kept their free hand touching the tabletop while walking next to the table.
(6) Participants asked for descriptions to be repeated. The detailed descriptions were asked to be repeated more often than brief descriptions. P6 and P7 were converting the directional information from degrees to clock while listening to the description and asked to confirm if the conversion was right. Also, P2 and P5 asked once about the direction (whether the chair is right or left) in the middle of the journey.

Table 2 summarizes the comparative session participation. The performance measurement is based on completion times and traveled distances. The result of P10 was excluded from these result as she identify the chair's location from the starting point. During this, P3 and P7 independently reported that they felt listening to detailed descriptions is slightly stressful compared to brief descriptions since they may miss part of the description. P1 added *"the problem is that you don't think in distances [...] it's just in front of me and getting closer or getting further away."*.

Table 2. The average (and standard deviation) results from the comparative sessions

	Performance		Situation Awareness			User Satisfaction		
Description	Time	Distance	Objects	Direction	Distance	Stress	Confidence	Satisfaction Level
Brief	30.9 (14)	7.6 (1.5)	1.8 (0.4)	1.6 (0.5)	1.3 (0.8)	2.9 (1)	3.5 (1)	2.8 (1.4)
Detailed	29 (13.3)	7.7 (1.7)	2 (0)	1.8 (0.4)	1.7 (0.6)	2.3 (1)	4.3 (0.5)	4 (0.5)

From the interview data, challenges in UDEs, sighted assistant roles, used tools, assumptions and the function of descriptions as well as verbal descriptions were main themes. For reasons of space only a summary of the most interesting findings are reported below.

THEME 1: Challenges in UDEs, The participants reported the difficulties of finding their way and acquiring information about what is inside. *P3: "I'm okay, walking around. But finding somewhere, if I don't know where it is, is different, that then becomes work."*. Defining a Point of interest (PoI) may vary from one place to another. *P1: "if you're going into business premises, there are certain things you need to know. Where's the counter? Where's the toilets? Where are the exits?"*. When entering an unfamiliar place, VIPs often don't know where the first PoI to which they need to go. *P4: "Well, to be honest, I was dependent on staff assistance [...] However, in other places, they will not provide assistance unless you ask for it."*.

In addition, all participants agreed that looking for a seat is not an easy task when there are people around. *P7: "probably, if it's [...] busy, it is difficult to spot a table that's not got anybody sat at it,"*. Some participants mentioned embarrassing or awkward situations. *P6: "you just hitting your cane, finds all the obstacles eventually. It's just quite embarrassing. If you were trying to find an empty seat and you know, nearly sit you down on someone."*. P3 gave a detailed description of the process of finding a seat that most participants use.

"Because then you're looking for a white surface table with basically a lot of space around it, which means there's no one sat at it. So that's what I'm looking for. I'm not necessarily looking at the seats, I'm just looking for big open white space. Chances are, there's no one sat there. And then you go there, you got to look-see is there something been put down [...] (a) jacket or (a) bag down to reserve it. Okay, there's something there, move on. See, that's not easy.". - **P3**

Finding a PoI or seat is not the only goal of the visit. *P2: "I'm not coming just to sit on the chair. I want to like, enjoy being in the place, feeling confident and independent."*. Most participants commented on having multiple journeys from and to seats. *P2: "I'm moving my chair around, going and coming back to the same place,"*. They need navigational support when they return from toilets, for example.

Some internal features could cause VIPs to be stressed and not enjoy the visit. Having steps or different floor levels make VIPs uncomfortable and fearing falling down. Also, reflective surfaces such as mirrors and COVID-19 cashier protection screens could confuse VIPs. *P8: "when you go to a till you can't always see the person if there's lots of reflection [...] in some of the shops, it's hard to find where the person is."*. In addition, lighting conditions have a significant effect on the usefulness of their residual sight, *e.g.*, when facing a light source or there low light levels.

In term of other people present, participants reported that their canes informed others of their sight loss, so some participants expected the sighted people would make the effort to avoid collisions. *P6: "just walk straight and expect the people to move"*. However, the challenge still remains when people are facing away or when people wait in a queue and can not move to free the path. *P1: "If someone's in front of me, it's impossible. Because you don't know whether they've seen you, or whether they're not even facing you"*.

THEME 2: Sighted assistant roles, Participants reported that they often received descriptions about the surroundings and nearby objects from a sighted assistant. Asking about the place when they have seated also is common among participants. P3 added that the spouse would go first inside the place, and then back to describe the place giving P3 a better understanding of it. Regarding used tools, participants reported that the cane was used to avoid obstacles and make other people aware of their sight loss. *P6: "just walk straight and expect the people to move".*

THEME 3: assumptions and the function of descriptions, Most participants make assumptions about places they visit. *P8:"you've not got anybody with you kind of have to guess or even if you've got a cane. Sometimes it's guesswork".* P1 reported that a direction to a counter could be determined based on hearing the barista making coffee. P3 and P4 mentioned that they searched for a table when they were looking for a seat. They assumed that a seat would be next to a table. P3 mentioned that he makes assumptions based on what he can recognize. *P3: "I can make lots of assumptions based on what's in that limited distance. This replicates out so many times [...] you can sort of figure that out. And it's going to repeat because they want to get people in.".* When VIPs have a description about the space, the description would help in saving time and effort in wayfinding and correct false assumptions. *P7: "the more information that you could have When you enter a building, the better".* Some participants reported that knowing the location of things inside the space could be enough to guide them.

THEME 4: Verbal description of indoors, All participants valued having descriptions of visited places. *P8: "So for something to describe what (is) in that room for me, the more the better."* They discussed the description's content and how it should be formatted and delivered. Participants acknowledged the variability of personal experience and remaining functional sight, so developing one size fits all solutions will not be helpful. *P1: "if it's a one size fits all then I think you may have a problem.".* The differences between VIPs are not limited to their eyesight, *e.g.*, *P8: "because my short term memory can be a bit sketchy sometimes. So if you give a lot all in one go, I'll probably forget what you've just said".* They pointed out that their ability to understand surroundings could be affected by unstable eyesight, *e.g.*, due to light changes, or their understanding of distances. *P1: " I can visualise one metre ten metres I have problems, because I've never seen 10 metres away".* P3 defined the term ***'working distance'*** as a way of describing the range he is able to understand and work with. He added that the working distance is reduced in crowded room.

The content of descriptions could contain details about PoIs, internal room features, people occupancy, seats availability and room layout, *e.g.*, size and shape. *P7: "this is a square room or this is a long thin room".* Also, describing the current layout of the room and how objects are arranged was desirable, from the first person perspective and based on landmarks. For describing people, an approximate number of people in the place and describing crowdedness level, slight or very crowded, were suggested. Some participants wanted to be informed about people in their route, especially if people are facing away and still. It is also important to know if there is a queue and how to join it.

Most participants wanted first to know about available tables. *P8: "If it could tell you that there's a table for four, and nobody sat at this table".* They wanted to share a table with others if there was no empty table. P7 mentioned that it is good to know the easiest way to an available table. *P7: "if it was to say, there are three empty tables, the easiest one to get to (and) tell you [...] the easiest route".* Some added that knowing tables' shape and colour would be useful especially when the person is able to recognize them. Most participants agreed on the importance of distinguishing between coffee and dining tables since they have different heights. *P8: "it's useful to know if it's, like, below knee [...] the difference between coffee table and dining tables probably significant".* Participants also wanted details that can help them find the available seat. *P6: "there is a vacancy at 10 o'clock on your left or something more specific".* Just knowing there is availability may not be useful. *P6: "10 Random seats in a building that really doesn't help".* P10 added that knowing chairs' type, *e.g.*, armchair, would be useful in some cases.

When describing the distance and direction of objects, some participants suggested describing the close objects first and then describing the further objects and how far they are from each other. *P3: "the first table is six metres away. And then there are 3 more tables each 2 metres apart. I can work that out. If you go 6, 8, 10, 12. I'm having to remember (more) numbers."*. Most participants valued direction details more than distance when they entered the environment. Tables in their way could be considered as landmarks instead of treating them as obstacles. Participants also emphasised on having options to choose from and decide where to go in the place. Choosing a destination (seat or PoI) should not be always determined by ease of access or convenience. Some participants suggested providing first options which are easy to access followed by the remaining options.

Participants reported that descriptions were needed at entrance, during movement within the place and after sitting. They were looking for different details when they were entering or being inside a place. The level of provided details may have an inverse relationship with their remaining functional sight. *P7: "assuming I couldn't see anything at all, you would need more detail"*. The participants suggested that there are limits on how many details should be given in descriptions at the entrance and during navigation. When they have a seat, they don't mind listening to more detailed descriptions. However, providing descriptions without any filtration or structuring might not be desirable. *P7: "I don't think you can have too much information really, unless it's just bombarding you"*.

For entrance descriptions, participants wanted enough detail that could help them know what is inside and where they can go. They could not stay at an entrance for a long time exploring the available options because someone else will come and enter the place. This suggests that providing descriptions at entrance is constrained by available time to decide where to go. Some participants suggested that they requested details by keywords like "layout" or "people"; while others suggested that the given descriptions at the entrance contain some details about the nearest available seat. Further details could be requested by keywords or by pushing a button. P6 suggested having an option for replaying the description.

For navigational guidance, most participants agreed on limiting the description to their immediate surroundings. However, the range of the immediate surroundings is subjective and might vary based on the internal structure, surrounding people and remaining functional sight. *P1: "just a rough estimate [...] (it's) a subjective idea"*. They expected the description would be provided as they approaching or passing something. *P7: "when you've passed it, you know"*. When they were sitting down, many participants suggested that they want to know more about the place and their surroundings, including surrounding people. When a person with sight loss has a seat, P3 suggested that the description could be organised based on direction or based on head orientation. *P2: "whenever I want to move the chair [...] to any other direction. So I know the distance [...] between me and the other person"*.

4 DISCUSSION

The finding from participants' behavior and comments showed challenges regarding wayfinding, orientation and identifying objects. Some of these are inline with findings from prior studies [14, 19]. However, UDEs have unique challenges not previously explored relating to movable objects and surrounding people. The challenges include:

- **Acquiring details about current setup and state of the place and people.** Participants expressed their needs for understanding surrounding rearrangeable objects and people which may affect their choice of where to go or block their way to a specific PoI, *e.g.*, finding and joining a queue. Existing approaches in advance familiarisation, like tactile maps, are not very useful in dynamic environments due to not able to acquire details about entities that move, *e.g.*, people or objects. Acquiring details about current lighting conditions is important

for people with residual sight. Determining the connection between their sight ability and the current lighting condition is important in designing the user interface and its content - as inline with Ability-Based Design [20].

- **Multi journey challenge.** VIPs may travel multiple times inside a building from a room to another. In this case, the points and paths between the points are stable and less likely to be frequently changed. However, in UDEs, VIPs may carry out multiple travels, as reported, which can be between two fixed points, *e.g.*, from the entrance to a counter, or includes movable point, *e.g.*, from or to a seat. Although a generic framework for mapping spatial data for indoor navigation has been proposed [18], defining temporary points for each user was not considered.
- **Finding seats.** Locating a place to sit is a challenge that has been acknowledged in indoor scenarios [14] and in public transportation accessibility [15], but they are missing insights about the locating process and factors that affect the search process. In UDEs, the process of seat finding and selection is affected by personal preference (*e.g.*, closest or lighting level), surrounding people and furniture, and, other internal features. This includes the need to determine that a particular chair is associated with a particular table.

Participants showed and expressed their usage of other senses and experience to guess what is inside, inline with findings in [12]. Based on interview and walking session data, the alignment between the guesses and current layout could determine difficulty of the visit. Knowing more about the visited site prior or during the visit would improve the alignment between the guesses and current layout should lead to increased independence and confidence. Receiving verbal descriptions from sighted guide is quite common among VIPs during walking and sitting. Developing a mental map or spatial knowledge about unfamiliar environments by acquiring the detail from narrative maps or tactile maps is evidenced [11, 16]. The current study explored the verbal descriptions of rearrangeable objects which has not been discussed in previous studies.

Participants showed and expressed their interest in requesting descriptions and being notified about their surroundings, which is partially inline with the defined pull and push interactions [3] which considered only user's input and location to determine the content of the description. The data from current study suggests the importance of considering user's goal besides user's input and location in the space. Based on the findings here one approach for UDEs could be to offer three forms of verbal guidance, namely ***Fast, Navigation and Rich***. The *fast interaction* would usually occur at the entrance and aims to present what is in the room and where to go. Furthermore, the interaction should provide sufficient details to make a decision whether to go inside and what action they need to take, *e.g.*, having a seat or reaching a front desk. The interaction would involve promoting a structured description followed by pull requests for further details. Findings from the comparative walks showed increases in VIPs understanding of the place and in their confidence and comfort. At the end of this first interaction, VIPs may prefer asking for a route overview to the determined destination.

The next interaction, *navigation*, is suggested by participants next objectives of path-following and collision avoidance. The navigation interaction would be mostly push notification about the path and passing/approaching objects/people. The focus would be more about their immediate surroundings which would be range from one to five metres depending on sight ability and the crowdedness. During navigation, users should be able to request further details, *e.g.*, changing destination, replays of the destination. The *rich interaction* starts when users reach a destination and settled. The users' objective change back to familiarization and wayfinding where would be used to increase their awareness of their surroundings and plan for the next journey. There is less limit on what can be offered at this interaction compared to two prior interactions.

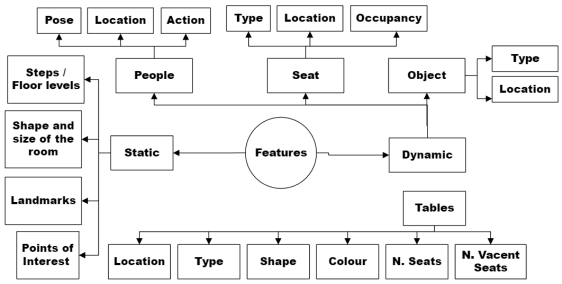

Fig. 1. Content of verbal descriptions

Descriptions could describe internal features, layouts, PoIs and details about people and seats. Based on the user preferences and ability, the content of the description would be adjusted. The participants mentioned the importance of connecting navigation instructions and description, so some movable objects, *e.g.*, tables, in the path would be considered as landmarks that can help in following a selected path. During their stay inside, they may want to plan next travel which may contain temporal PoI, *e.g.*, current seat. This would require the ability to define personal PoI in the space, so the user can go back to the seat, *e.g.*, after going to a toilet.

Based on the participants feedback, the preferred length of the descriptions varied based on their current attempt action, exploring, wayfinding or navigation. Aziz *et al.* [2] also found fixed-length descriptions are not always desirable. In the fast interaction, the length of the description should be sufficient enough to make a decision, so the description would be longer than the descriptions during navigation. For the rich interaction, VIPs may not mind listening to lengthy descriptions. Recognizing the different between the three interactions are important to decide how much information should be delivered. Based on that, its clear that VIPs seem to want something that is contradictory, brief guidance but with lots of information. This highlights a possible approach to guidance for VIPs within UDEs that needs further research and evaluation to determine the right content, access and operation.

5 CONCLUSION

Although the study was conducted with a limited sample which may not reflect the needs of the whole VIPs population it did successfully generate a lot of useful data to address the research questions. The study revealed that VIPs face wayfinding and navigational challenges in visiting UDEs. For developing an assistive tool (AT), it is important to consider users' abilities and preferences as well as capturing the required details. Thus, the sensing capability of AT should gather required details about dynamic objects. Fig. 1 shows the required data to support VIPs at UDEs. The static features or details could be provided manually since they are stable for a long time, whereas the dynamic features required constant updating. Thus, there is a need for installed sensors to capture and monitor dynamic aspect of UDEs.

Future research avenues have been highlighted by this study, including to observe more VIPs in navigating in simple UDEs, and also in more complex and light varying UDEs, the need to test delivery of verbal guidance information in a variety of UDEs, explore further the breadth of variations needed in building the user interface and the guidance itself, particularly with regard to the difference between those with useful residual sight and those with none.

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