TIMING, FREQUENCY AND QUALITY OF INSTRUCTIONS FOR AUDIO-BASED NETWORK NAVIGATION SYSTEMS FOR PERSONS WITH VISION IMPAIRMENT

Analysis and Recommendations from Wayfindr's Barcelona Trial

JANUARY 2018

Abstract

In November 2017, an audio navigation trial was carried out at the Las Arenas Shopping Centre in Barcelona. The purpose of the trial was to provide supporting evidence for updates to International Telecommunications Union Recommendation F.921 (ITU-T F.921). Wayfindr in collaboration with Ilunion and the Oslo and Akershus University College of Applied Sciences carried out the trial, which lasted two weeks.

The study collected data from four pedestrian routes designed to test the outstanding items in the form of surveys and measurement of fails and hesitations of the registered blind participants when walking independently following only audio instructions from a supplied smart phone and navigation application. Two Research Assistants introduced participants to the study and collected the data without intervention, with the exception of reorienting and placing participants onto the intended track according to the protocol instructions.

Following the data analysis, there are two recommendations that emerge to support the recommendations for the outstanding items of ITU-T F.921.

The first recommendation is that a 6 metre notification distance for actions is more usable and results in fewer fails that the current recommendation.

The second recommendation is that reassurance notifications should be given every 10 metres when walking in long straight distances. Participants that were aware of the required action at the end of such a route (e.g. exiting through a door) also found it usable.

Both recommendations are supported by usability surveys and fail counts.

The trial also collected survey data to provide better quality messages on nine scenarios and provided information on issues around obstacle avoidance when a series of manoeuvres are required in quick succession.

Introduction

Blind and partially sighted (BPS) persons face significant obstacles to mobility and navigation. There exists a body of research examining the use of audio navigation devices and systems for BPS persons, both in outdoor environments using Global Positioning System (GPS) signals, and increasingly in indoor environments. (Giannoumis et al., 2018)

https://link.springer.com/article/10.1007/s00779-005-0350-y

https://link.springer.com/chapter/10.1007/978-3-642-02710-9_44

http://ieeexplore.ieee.org/abstract/document/4373786/

https://dl.acm.org/citation.cfm?id=591430

In March 2017, ITU-T Recommendation F.921: Audio-based network navigation system for persons with vision impairment was approved by the International Telecommunications Union (ITU). It is the first Open Standard for accessible indoor audio navigation in the world. The Recommendation reflects best practices in the design of interoperable, inclusive audio navigation systems for persons with vision impairment or living with other forms of disabilities, which ultimately, can also benefit anyone among the public seeking help for orientation or information on their immediate environment.

The International Telecommunications Union (ITU) is the specialised United Nations Agency for information and communications technologies (ICTs). Formed in 1865, the ITU is the pre-eminent global body for ICT standardisation. Notable ITU standards include the international telephone numbering system and standards for video compression and playback. The ITU encourages the development of standards that take account of the widest range of characteristics and abilities of persons, including in particular those of older persons, children and persons with disabilities.

The international indoor navigation market is set to grow exponentially in the next few years, to the benefit of millions of people. The widespread adoption of audio indoor navigation as part of this trend has great potential to improve the accessibility of the built environment for people who are blind or vision impaired. The use of a recognised, high-quality Open Standard providing a consistent user experience is the key to realising this potential. Indoor navigation systems can use a variety of different technologies to provide positioning and navigation services, including Bluetooth Low Energy (BLE), Wi-Fi, Radio Frequency Identification, and magnetic field sensors. GPS signals are normally not sufficiently strong to use for indoor navigation and positioning.

Following the adoption of ITU-T F.921, there remain outstanding items requiring further investigation, including the quality of audio messaging and refining the timing and frequency of the audio messages. Additionally, as more and more audio navigation systems are deployed across the world, it is desirable to investigate a mechanism that allows for audio instructions to be communicated to users in their choice of language while complying with the ITU Standard.

In November 2017, Wayfindr, along with Ilunion, Fundacion ONCE, and the Oslo and Akershus University College of Applied Sciences carried out an audio navigation trial at the Las Arenas Shopping Centre in Barcelona, Spain. The trial was made possible with the support of D-Lab, a programme of Mobile World Capital. Wayfindr was one of the first winners of D-Lab's societal challenges competition, under the theme of empowering people with disabilities through mobile technology. The trial investigated the areas outlined above with a view to updating the ITU Recommendation based on the results.

Protocol

Definitions

Hesitation: A person stopping or slowing down for 2 seconds or more. Exclude obstacle avoidance. Each Hesitation is recorded.

Fail: A change in the expected direction/path as marked on the route charts. E.g. wrong turn. Research Assistants (RAs) will assist the Participant to return to the correct route, query and record the reasons at the end of the route.

Translations in other languages: In case of dispute or misunderstanding arising in a translated document, the English version holds.

Confounding Variables

This paragraph discusses the confounding variables that apply to all tests in this trial and comments on the mitigation strategy, where possible.

People walk at different speeds. We assume that subjectively the distance between the delivery of an instruction and the execution of a request is significant. If this is true, the optimum distance of announcing the instructions will vary according to a person's walking speed.

Other confounding variables that are applicable in this trial are listed below along with comments, where available:

Beacon Location: This trial does not depend on beacon locations. The fingerprinting algorithm creates virtual waypoints that are placed en-route.

Location of Phone: The protocol will require the users to hold the phone as steady as possible in the same location. The app collects data regarding the accuracy level and the video recording will show the actual location of the messages being delivered.

Mobility Impairment.

Noise Levels: The Research Assistants will record hesitations or instruction repeats and enquire about the nature of these whether they were attributed to the clarity of the spoken message, noise or other reasons.

Self-Confidence

Method

Participants

Thirty-eight participants volunteered to participate in this study. The group consisted of a relatively equal number of men (20) and women (18) with ages distributed as in Figure 1. There were 8 Guide dog users and 30 long cane users. There was a relatively equal number of Blind (18) and Low Vision participants (20). All participants are registered as blind in Spain.

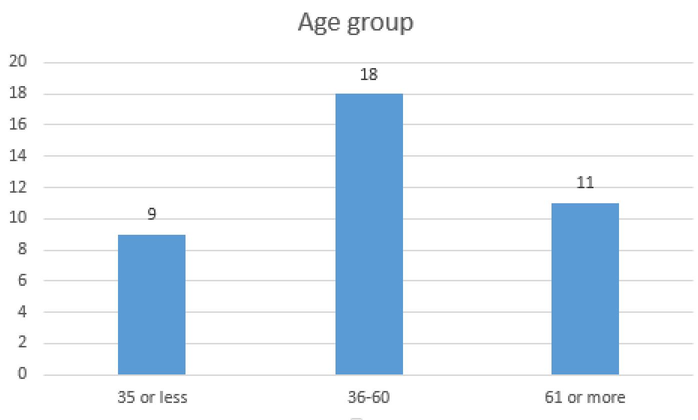


Figure 1

Procedure

The Research Assistants were trained before the arrival of the participants to detect and record hesitations and errors/failures, record and return the participants onto the intended path. This involved a pre-trial training session of the Research Assistants where a demonstrator performed predefined intentional errors and hesitations. The training was conducted by the Oslo and Akershus University College of Applied Sciences on site.

Each route section is marked with the number of fails and hesitations on the Research Assistant's form.

The participants were greeted by the two Research Assistants, of which the Lead Research Assistant had Sighted Guide training. Participants completed the first survey, the General Self Efficacy Scale (GSES) before they were introduced to the details of the trial, thus providing a score that is not affected from views or experience of the particulars of the trial. Following the GSES survey, they were asked to agree and sign the consent form, a process and form designed to comply with the relevant Spanish legislation. They received the compensation (in cash) and they received the details of the trial and the app. Part of the text read to the participants included the key message that this is a research that will collect data from failures and as such, these are expected as part of the evaluation mechanism. It was explained that the Research Assistants will only intervene to correct the participants that diverted from the intended route by means as specified in the protocol definition of a Fail. Each participant has been randomised to use the timing and frequency of the notification parameters. These parameters were configured in the App before the Research Assistants handed the phone to the participants. At the end of each of the four routes, the participants complete the SUS survey and reported on the reasons of each recorded hesitation or failure.

Participants were asked to confirm and adjust where necessary, that the audio volume level and speed of the speech was appropriate for their level of hearing.

At the end of the four routes, the participants completed the Quality of Message survey. Due to timing constraints and participant availability, 7 participants did not complete the last survey.

Technology

The trial used the open source Wayfindr demo app and adapted the location algorithm and sensor engine to use the Ilunion beacon constellation. The Ilunion beacons are interactive and capable of transmitting audio signal (beeps) when remotely triggered by an application. For the purposes of this trial, this functionality was not used. The App algorithm was adapted to use the Ilunion proprietary Fingerprint Algorithm thus allowing the route planning to define virtual waypoints that are independent of the beacon location. This allows the route planning to define waypoints and prescribe the announcements on the desired distance from the waypoint. Ilunion supplied the smart phones with the application and the fingerprint beacon data pre-installed.

Problems

Problem 1 - Timing Notification

Questions

The current version of the Open Standard recommends an 8 metre instruction notification distance. This test provides and measures fails for notifications at 6, 8 and 10 metre distances from the action waypoint.

Hypotheses

The following four hypotheses are the base of the Timing Notification trial:

> **H0 :** Providing notifications at 8 meters correlates to lower number of fails or higher system usability scores reported by persons with visual impairments of network navigation systems.
>
> **H1 :** Providing notifications at <>8 meters correlates to lower number of fails or to higher system usability scores reported by guide dog users of network navigation systems.

H2 : Providing notifications at <>8 meters correlates to lower number of fails or higher system usability scores reported by white cane users of network navigation systems.

H3 : Providing notifications at <>8 meters correlates to lower number of fails or higher system usability scores and higher perceptions of self-efficacy reported by persons with visual impairments of network navigation systems.

Measurement

Standard System Usability Scale survey at the end of each route plus deviation observations from expected route, use the Research Assistant's notes to record fails and hesitations and where required, and use the video/photo recording to locate the actual distances of the message being delivered, accounting for the tolerance in detecting the exact point of the announcement.

Analysis

Compare SUS scores and errors recorded between RAs and verified, where necessary, by video evidence.

Problem 2 - Frequency of announcements

Question

What is the optimal frequency for reassurance notifications? For example, on a 30m straight path, should there be none, 1, 2 or more notifications?

On a straight line, insufficient notifications are likely to result in slowing or stopping.

Hypotheses

H0 : Providing reminder notifications is independent of perceived usability.

H1 : Perceived usability is dependent on providing reminder notifications.

H2 : Providing reminder notifications is independent of perceived self-efficacy.

H3 : Perceived self-efficacy is dependent on providing reminder notifications.

Methods

Each participant will be randomized to receive 0, 1 or 2 reminder notifications along the long path of 30m after a turn.

After making the turn, the participant will receive an instruction to proceed, and then the participant will receive no, one or two notifications until they reach the destination.

At the completion of the route, participants will be requested to fill out the System Usability Scale (SUS).

Frequency measures, descriptive statistics and chi square test will be used in the analysis. These methods were used in earlier trials and recommend by the Oslo and Akershus University College of Applied Sciences.

The three frequencies will be tested on totally blind persons in equal distribution.

Measurement

Standard System Usability Scale survey at the end of each route plus measurement of Stops (2 seconds or more), Repetition of last instruction and Subjective feedback on specific issues.

Problem 3 - Quality of Message

Question

Formal specification of speech parameters that constitute 'ease of comprehension' represents a formidable challenge. The Quality of the Message depends partially on some user defined parameters such as the 'verbosity' (speed of speech) and the loudness. As these parameters are user controlled on by the mobile device, each participant will need to adjust these parameters to their own preference at the start of their tour.

Hypotheses

H0 : Notification message type is not dependent on user preference

H1 : User preference is dependent on notification message

Methods

At the end of the trial, each participant will be given an A/B test for notification messaging. The A/B test will relate to the environmental features outlined in the Wayfindr standard sections 4.1.1 to 4.1.8.

Each participant will be asked eight sets of questions with three questions in each set. Each set of questions will provide the standard notification message for the environmental feature indicated in the Wayfindr standard and one of three alternative phrasings of the same message. Participants will be asked to select the message that they prefer.

Frequency measures, descriptive statistics and correlation measures will be used to analyse the data.

Data from the trials will be used to inform the Wayfindr standard and provide a basis for contributions to the ITU.

Two messages will be available at two routes in identical paths. Participants will be asked, in addition to the survey, to express their preference. Recorded evidence of their performance, hesitations, repeat instructions and video will support the findings.

Results

Barcelona data analysis

SUS based analysis

Overall the data from the Barcelona trial supports prior data collected in laboratory experiments in London that indoor network navigation systems are considered usable by persons with visual impairments - for comparison, median values are used in this analysis. Specifically, persons with visual impairments consider the system usable for all routes (median 87.5) and for individual routes (median value range from 86.25 to 90). The range of the scores was greater for Routes 1, 3 and 4 (min 20, 30 and 32.5 respectively and max 100) than for Route 2 (min of 55 and max of 100).

In terms of timing of the notifications, persons with visual impairments considered 6 meter timing (median 90) more usable overall than 8 or 10 meters.

In terms of gender, age and disability type, male participants considered the indoor network navigation system as more usable (median 92.5, min 32.5, max 100) than female participants (median 85, min 20, max 97.5). Participants under 35 and 61 and older considered the indoor network navigation system as more usable (median 90, min 55 and 30 respectively, max 100) than participants 36 to 60 (median 87.5, min 20, max 100). Participants that identify as blind and partially sighted considered the indoor navigation system as equally usable (median 87.5). With the exception of the female participants, the variation in scores between demographic variables is negligible.

In terms of frequency of notifications, participants considered two notifications as more usable (median 90) than zero or one notifications (median 87.5). While the range of scores for one notification was high (min 32.5, max 100), the differences in scores are negligible.

In terms of general self-efficacy (scored from 10 to 40), participants overall had high levels of self-efficacy (median 34, min 25, max 40), which may reflect selection bias as persons who volunteer for an experimental trial may feel more confident of their abilities than those who do not. Regarding the relationship between self-efficacy and usability, while the relationship is statistically significant ($p<.001$), which means that there is a low likelihood that the relationship is due to chance, the correlation was low ($r=.08$), which means that the results show a weak relationship between self-efficacy and perceived usability.

SUS Sores

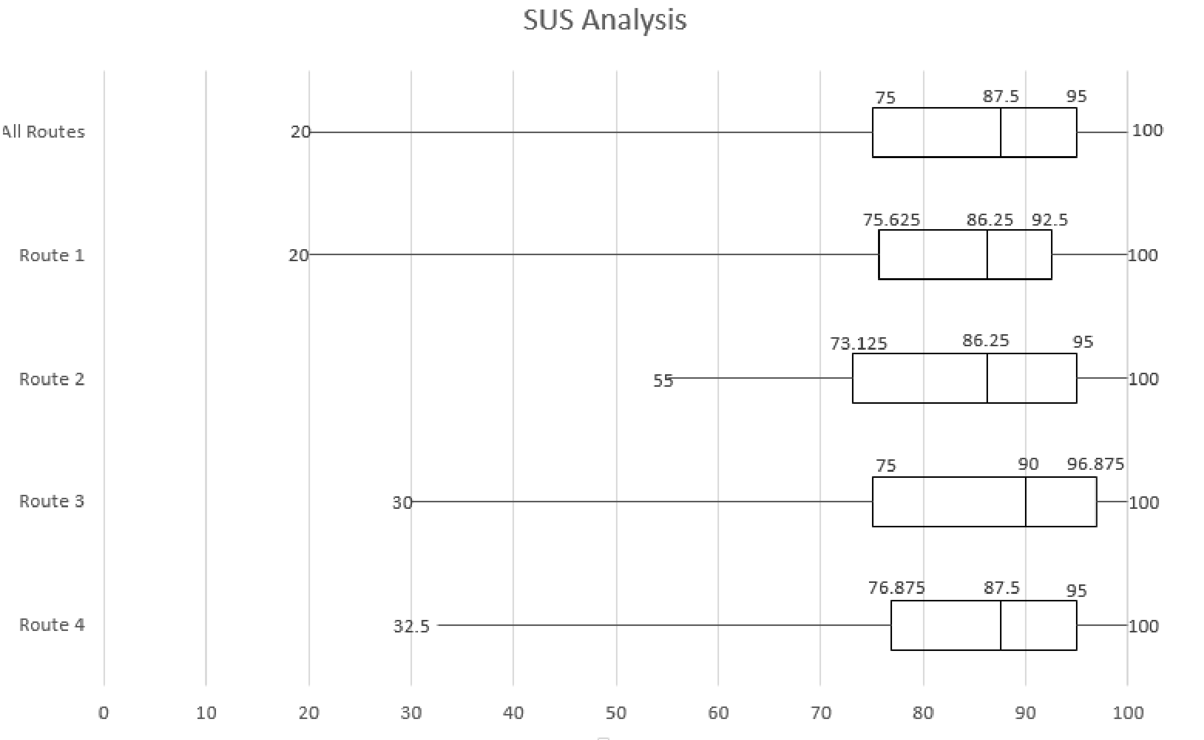


Figure 2

Failure based

The Research assistants recorded 347 incidents amongst the 38 participants and the 152 routes. There were 148 hesitations where the participants stopped for 2 or more seconds and continued the route as intended. There were 199 failures where the research assistants had to correct the direction and return the participants to the intended track.

The table below shows the analysis of the failure and hesitation count per assistance type (long cane and dog users)

	Failures		Hesitation	
	Cane	**Dog**	**Cane**	**Dog**
Min	1	4	1	2
Q1	4	5.75	3	2
Median	5	6	3	3.5
Q3	6	7.25	4.75	4.25
Max	9	10	15	5

Table 1

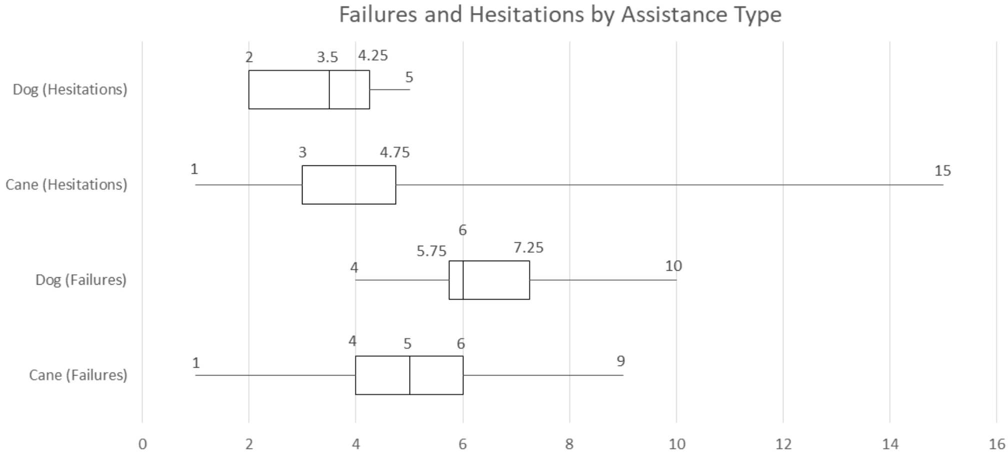


Figure 3

Table 2 lists the average of failures and hesitations per participant across all routes next to the average self-efficacy of each age group.

The correlation between average failures and the self efficacy is low (r=0.36) while we observe a stronger reverse correlation between the hesitations and self-efficacy (r=-0.65).

Age Group	Failures Avg	Hesitations Avg	Self-Efficacy
35 or less	4.89	4.33	3.28
36-60	5.11	3.89	3.48
61 or more	5.73	3.55	3.40

Table 2

	Correlation (r)
Failures vs Self Efficacy	0.36
Hesitations vs Self Efficacy	-0.65

Table 3

Timing of Notification

The SUS Analysis on the three timings show participants found the 6 metre notification distance more usable (median 90) compared to the 8 (median 87.5) and the 10 metre (median 85) notifications.

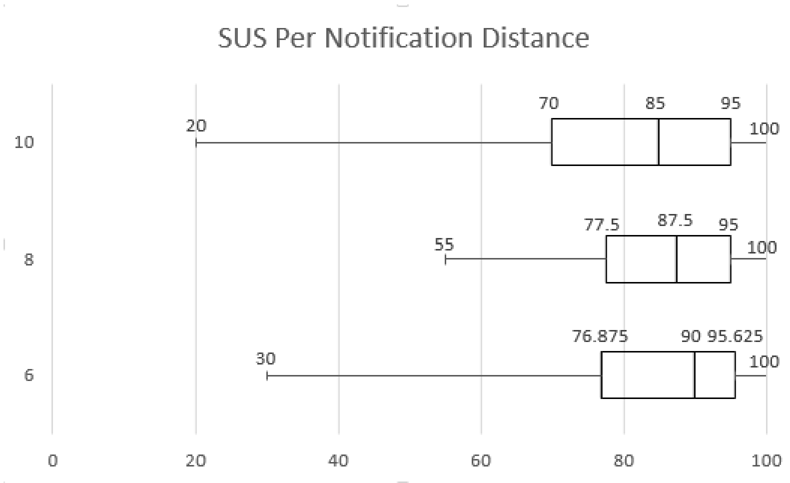
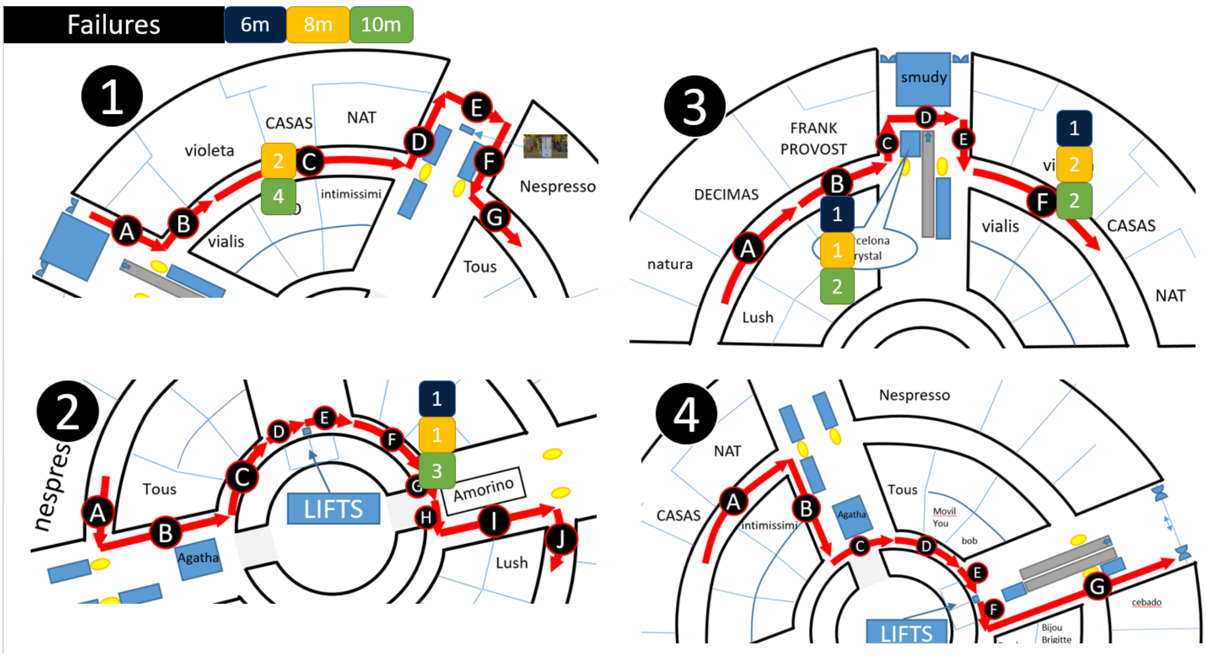


Figure 4

Distance	MIN	Q1	Median	Q3	Max
6	30	76.875	90	95.625	100
8	55	77.5	87.5	95	100
10	20	70	85	95	100

Table 4

The number of failures that were recorded in the specific legs also support that the 6 metre notification resulted in the fewest failures (3). The 8 metre notifications recorded 6 failures and the 10 metre notification recorded 11 failures. The fourth route was not monitored for the notification.



Frequency of Notification

In a 30m straight path, we gave the participants the instruction to proceed to the exit at three different frequencies. Figure 5 below, shows the last leg G. The test gave a particular focus to distribute the different frequency levels amongst the Blind group.

	Frequency		
	0	**1**	**2**
Blind	5	7	6
Partial VI	8	6	6

Table 5

Group 1 (Zero notifications) received the information about the exit location at the start of the leg, near the end of the short leg F.

Group 2 (1 notification) received a reassurance instruction (Straight on) half way through the leg F and the exit information upon approach.

Group 3 (2 notifications) received 2 reassurance notifications at one third and two thirds distance and the exit information upon approach.

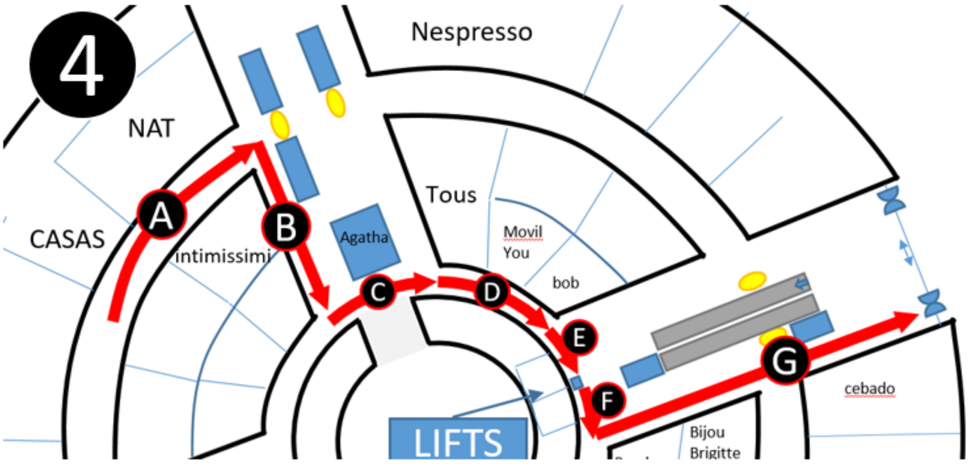


Figure 5 – Route 4

We asked the participants to rate the exit information message on their understanding of the instruction, the clarity of the distance to the exit, the confidence of understanding how to find the exit and whether the messages were too few, just right or too many.

	Frequency	Failures	Hesitations	Failures	Hesitations
Blind	*0*	**2**	**1**	11%	6%
Low vision	*0*	**1**	**4**	5%	20%
Blind	*1*	**4**	**3**	22%	17%
Low vision	*1*	**0**	**5**	0%	25%
Blind	*2*	**2**	**1**	11%	6%
Low vision	*2*	**1**	**4**	5%	20%
Blind	*Total*	***8***	***5***	44%	28%
Low vision	*Total*	***2***	***13***	10%	65%

Frequency of Notification by Impairment - Table 6

Dog User	Frequency	Failures	Hesitations	Failures	Hesitations
No	*0*	**1**	**3**	3%	10%
Yes	*0*	**2**	**2**	25%	25%
No	*1*	**2**	**7**	7%	23%
Yes	*1*	**2**	**1**	25%	13%
No	*2*	**3**	**5**	10%	17%
Yes	*2*	**0**	**0**	0%	0%
No	*Total*	***6***	***15***	20%	50%
Yes	*Total*	***4***	***3***	50%	38%

Frequency of Notification by Assistance - Table 7

There were no dog users who made any mistake or hesitated when instructed with 2 notifications which indicates that a 10 metre notification is better for dog users.

Low vision participants made 2 failures compared to 8 blind participants of which, 4 participants failed on the single notification (the 15m distance) while the 10m notification and the zero notifications had only 2 failures out of the 18 blind participants.

In percentage terms per population, Low Vision participants made fewer errors (5% of Low Vision participants) when instructed at 10 metres or had no notifications but none made any error on the 15 metre notification.

Blind users were more susceptible to errors (44% of Blind participants) than Low Vision (10% of Low Vision participants). 22% of Blind users made errors with the 15m compared to the 11% with the 10 metre notifications. This means that Blind people make fewer errors with the 10m notification or no notifications on long distances. In Figure 6 we observed the perception of confidence level of the Blind participants (max 5), where we see mid-level confidence for the 15m notification, the distance at which they made most errors.

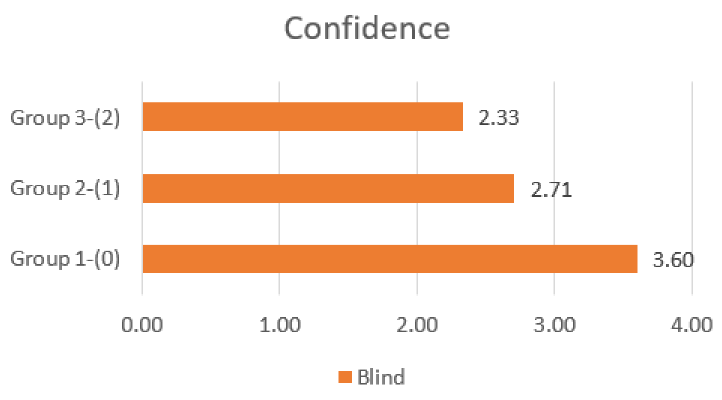


Figure 6

Quality of Message

Comments

The users returned their answers at the end of their trial. There were 31 complete answers and one partially filled. Due to the timing and necessary changes in the timing of the trials, some participants did not have sufficient time to complete the questionnaire. The selected answers are listed in the Appendix, Table 10.

The second part of the Quality of Message test relates to the instruction given in an obstacle avoidance set of instructions. The Instruction was given in multiple messages on the first route and in one single message on the third route. Both obstacle avoidance tracks have an identical layout due to the circular layout of the venue. Participants were not aware of the test. Each participant experienced both.

	Failures		**Hesitations**	
	Route 1	**Route 3**	**Route 1**	**Route 3**
First Leg	1	11	4	14
Second Leg	14	1	7	10
Third Leg	16	8	6	8
Total	*31*	*20*	*17*	*32*

By Failures/Hesitations, Table 8

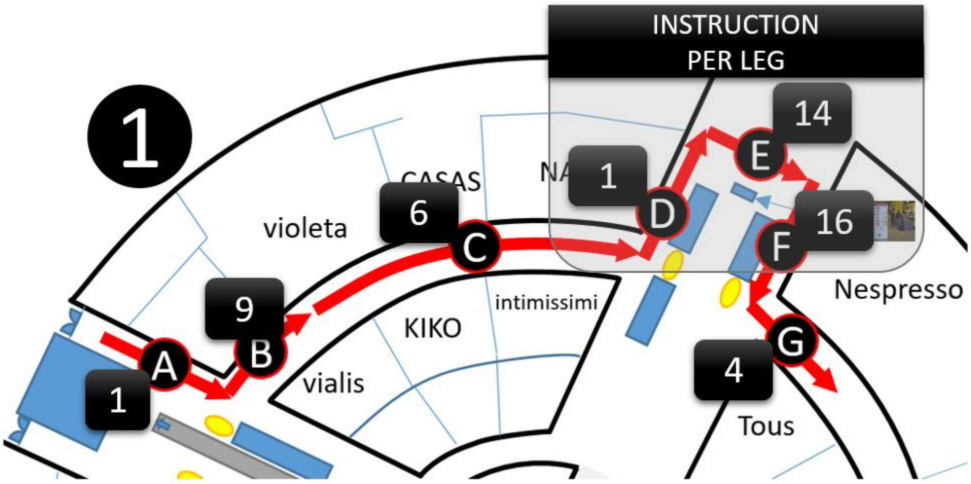
	Route 1 (Multiple Instructions)		**Route 3 (Single Instruction)**	
	Failures	**Hesitations**	**Failures**	**Hesitations**
First Leg	1	4	11	14
Second Leg	14	7	1	10
Third Leg	16	6	8	8
Total	*31*	*17*	*20*	*32*

By Routes, Table 9

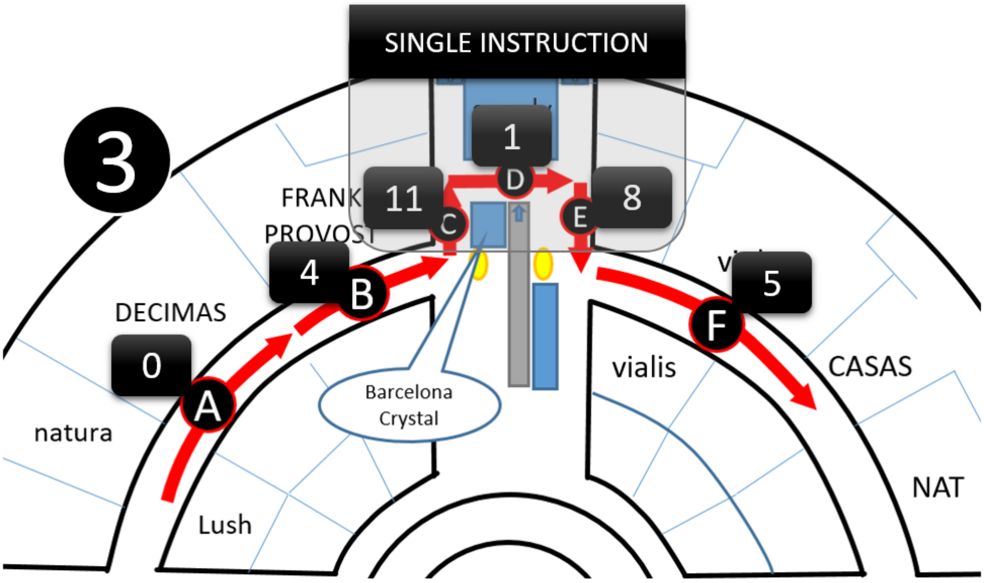
Discussion

The data demonstrate that the participants made fewer errors when given one instruction at the beginning of an obstacle avoidance route. The participants were more hesitant (32 hesitations) when listening to one long instruction covering the three legs compared to listening to multiple instructions (17 hesitations). The participants made fewer errors when following a single instruction (20 failures) compared to the multiple instructions (31 failures). The SUS analysis on the two routes finds the Single Instruction Route 3 to be more usable (Median 90) versus the Multiple Instructions Route 1 (Median 86.25).

On the Multiple Instructions Route 1, the participant comments show that 10 of the 31 failures were due to the Timing of instruction given. As the distances were in the region of 3 to 6 metres for each of the legs, it seems that the technology may have delivered the individual instructions at the wrong position.



Route 1, Failures on Single Instruction per Leg - Figure 7



Route 3, one instruction for legs C-D-E, Figure 8

Conclusions

Distance and Notifications

SUS reports and the measurements demonstrated that a shorter distance of 6 metres for announcing changes in direction, result in fewer failures and participants felt it was more useful.

Consecutive notifications in shorter distances of around 3-4 metres, as observed in routes 1 and 3, resulted in multiple errors. Indicative analysis of the comments suggests that the accuracy and message timing from the app failed to keep at pace with the person for short distance notifications.

The Recommendation is to announce the intended action at 6 metres before the action point.

Reassurance notifications on long legs were found to be useful at a 10 metre distance on a 30 metre long leg. An equal number of people also found it useful and with the same number of errors, to have no reassurance notifications. On the same leg, people with 15m reassurance notification made more errors and found it less usable than the other two groups.

The group that received no notifications were told that they were heading for the exit in advance and they were presumably aware of the surrounding cues and were confident in arriving at the door. On the videos, participants were observed turning towards the middle exit door on their left side, presumably following the cues from the outdoor noise or the hot air curtain machine above the exit door that was operating at the time.

The Recommendation for Notification Frequency, is to give option to users when walking on long straight line legs, for either zero notifications with an advance description of the expectation at the end of the leg, or a reassurance notification every 10 metres.

Obstacle Avoidance

The test on the quality of the message resulted in a high number of errors (max 16 of 38 participants) when they were directed to go around a large obstruction. The instructions to avoid the obstructions when given all in advance, resulted in a lower number of errors with 11 people making errors at the start of the obstruction avoidance routes.

The Obstacle Avoidance will require further analysis as the data and participant comments suggest that an initial full description of the sequential steps provides a cognitive challenge to recall a sequence of 3-4 instructions thus resulting in early errors. Comments from the participants that listened to step-by-step instructions, suggest that messages were coming too fast, too late, or not being delivered at all at critical points of the route, pointing to a technology issue on the accuracy and location on short distances.

The recommendation is to design and test a set of Standard Messages to facilitate safe and confident obstacle avoidance at a future trial.

Appendix

Quality of Message Questionnaire and Responses

	Theme (T) Selected Answer (A)
1	**T: Turning into a two-way corridor.** A: Turn left and move forward and keep left.
2	**T: Announcing the pathway type** A: I prefer to know the exact type of the pathway such as corridor, paved path, tunnel, bridge.
3	**T: Advising which side of stairs to use: Move forward and take the stairs up to the ticket hall.** A: The stairs bend to the right after 20 steps.
4	**T: Announcing open riser stairs: Move forward and take the stairs up to the ticket hall.** A: The open riser stairs bend to the right after 20 steps.
5	**T: Determining position in relation to the platform length: You are arriving at the platform to take a train.** A: You are standing in front of carriage 3 position.
6	**T: Determining orientation in relation to the direction of travel** A: The train will arrive from your left as you face the platform edge.
7	**T: Announcing close proximity of two platforms** A: Your trains leaves from the platform on the left.
8	**T: Warning if platform is part of pedestrian route** A: Be aware, this platform is part of a pedestrian route.
9	**T: Announcing nearest way out before leaving the train** A: After stepping off from the train, proceed left.

Table 10