AUDIO-TACTILE LOCATION MARKERS: ACCESSIBLE REAL-WORLD TAGGING FOR THE BLIND

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ABSTRACT
In this paper we present the concept of Audio-tactile Location Markers (ALMs) as a remedy to the lack of accessibility in current tag-based applications. ALMs are an auxiliary enhancement for existing real-world tags, which propagates their existence and purpose to blind and vision-impaired people in the vicinity. Users can activate an audible signal based on a pre-selection of available tags (pull) or choose to be constantly informed about nearby tags (push). We evaluated both methods with blind and vision-impaired people using an NFC-enabled smartphone. Participants experienced no problems locating the ALM based on the audible signal, but required assistance with touching the tag. Pull was favored to push in specific situations.

KEYWORDS
NFC, touch interaction, assistive technologies, accessibility

1. Introduction
Mobile devices are increasingly equipped with sensors (such as cameras or RFID readers), which enable new ways of interacting with digital information in the physical world. In the last decade a multitude of technologies for real-world tagging has been investigated, including visual codes (e.g. [1]) and Near Field Communication (NFC) (e.g. [2]).

Typical application scenarios include interactive movie posters, which allow the purchase of tickets [2] and museums equipped with tags for interactive exhibition guides [3]. Both scenarios allow users to trigger an action by touching a tag in the physical environment with their mobile device (typically a mobile phone).

Since the introduction of NFC-equipped mobile devices on the mass market, a variety of commercial applications have been deployed in the field. For example, travelers on the Vienna underground are able to buy train tickets using their mobile phone[1]. A pilot project at the island of Sylt (Germany) enabled people to access a local information portal using NFC tags attached at various locations, such as bus stops, tourist information offices, and sights[2]. These examples show that NFC applications have developed beyond custom-built solutions for a specified set of users, such as property management or manned guarding [4]. Now that these types of applications are becoming more common, it is important to consider their accessibility.

In the recent past, many efforts have been undertaken to improve the accessibility of public services, such as public transport systems. For example the city of Berlin (Germany) has pushed a policy to develop into a barrier-free city [5]. This included the installation of control-keys in elevators written in Braille throughout the underground system as well as acoustic signals that give additional information. The city of Prague (Czech Republic) uses a specific system called Tyfloset to provide vision impaired people with audio information about line number, destination, and time before approach, which is otherwise displayed on LED screens at public transport stops [5]. The audio information is triggered through a remote control, which vision impaired people carry with them. Similar attempts are necessary to ensure that real-world tagging technologies will be accessible to people with special needs. This especially includes vision-impaired people, since tags are difficult to locate due to their unobtrusive nature and because their presence is typically only indicated with visual markers and labels. Furthermore, tags are lacking affordances for user interaction [7], which means that it is often not obvious how to interact with the tag and which action it will trigger. Tags typically have a similar appearance to self-adhesive labels, making it

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[1] http://www.nfc.at/

[2] http://www.openpr.de/news/98124/

challenging for vision-impaired people to locate and identify them.

Recent studies demonstrated the potential of real-world tagging for a wide range of applications, but to our knowledge there is no prior research regarding the accessibility of this new interaction paradigm. To fill this gap we developed an audio-tactile location marker system for locating and identifying tags in a user-centered design process and evaluated the final prototype with vision impaired users in a realistic test environment.

2. Related Work

Tagging technologies, such as RFID, have been used in the past for assistive technologies and to improve the accessibility in public environments. These systems rely on tags that are specifically deployed and only accessed by blind or vision-impaired users. To our knowledge the accessibility of tag-based application for a general audience has not been investigated yet.

The Chatty Environment [6] was developed as assistive technology to help blind and vision-impaired people tracking and locating objects. Users can tag real-world objects using electronic markers and later recall information from those markers using a special mobile device. The system supports two different approaches following a push and pull model. In push mode, objects immediately present themselves to the user as soon as they are sensed by the users' device. In pull mode, users explicitly have to choose an item to receive further information. The authors further suggest two different technological approaches, which allow the detection of important objects over a large distance (up to 100m) or the identification of a high number of small items (transmission range below 5cm). However, the system does not describe approaches for guiding the user towards the objects.

Sherlock [8] and TellMate [9] are commercial tagging systems, which assist blind and vision-impaired users in identifying objects. Users attach RFID tags onto their belongings, such as credit cards, medication or CDs, and record voice messages for identification using a portable device. The recorded message is linked to the corresponding tag and replayed whenever the user touches the tag with the device.

Seeyingeyephone [10] is an NFC-based system developed by VTT Technical Research Centre of Finland. Similar to Sherlock and TellMate information is replayed when the user touches an object with the device. The system takes this approach to another level, suggesting that in the future every object (e.g. products in a supermarket) will feature RFID tags. Thus, users neither have to distribute tags nor record voice messages. Instead the system relies on a central database containing information about the product, such as list of ingredients or expiry date.

Tyfloset, which was already mentioned above, is an extension of the passenger information system of public transport in Prague (Czech Republic). Users are equipped with a radio-wave transmitter and a remote control, which allows triggering remote voice messages, such as the direction of an approaching bus at a bus stop. A smaller version of the remote control with fewer command buttons can be integrated into a cane. Use cases include announcement of line number and direction of travel in public transport, the activation of acoustic signals at crossroads, in underpasses, near hospitals and municipal authorities and voice information about passengers boarding and external transport at the Prague-Ruzyně airport. Additionally, users can issue certain commands, such as the activation of signal beacons at traffic lights or a request for assistance when boarding a bus.

A number of projects also suggest the integration of RFID tags into the floor to assist blind users following a predefined path [11], [12]. SesamoNet [13] is a prototype system, which is currently deployed in Laveno (Italy). Users receive directions via Bluetooth headsets while walking over passive RFID tags, which are encased into ceramic cells on the floor of a 2km long path. The antenna to read the tags is integrated into a modified cane, which sends the data to a smartphone.

3. Requirement Analysis

Based on literature review and initial interviews (section 4.1) we derived the following important factors for improving the accessibility of existing real-world tags: (1) providing a user awareness of tags in the vicinity, (2) locating the tag and navigating to its position, and (3) determining purpose and functionality of the tag.

3.1 User awareness and location of the tag

Real-world tags are rather unobtrusive due to their small size. Their affordance relies on visual indicators, such as markers, symbols, or labels. It can be difficult to notice tags in a cluttered environment, but this challenge is even more relevant for blind and vision-impaired users. The low-cost technologies typically used for real-world tagging make it difficult or even impossible to determine the exact location of tags. Visual codes lack remotely detectable components, NFC and passive RFID tags work only at short distances of up to 5cm. Therefore, an auxiliary technology is required to propagate the existence of a real-world tag to the environment. This technology should be (1) unobtrusive, (2) wide-spread and low-cost, and (3) easy to use. It is also important that the nature of the tag itself should not be changed in order to maintain the interaction metaphor and assure the general applicability of our approach. This means that users should not be forced to interact differently with tags because of their limited vision capabilities.

While the propagation of a real-world tag can be solved with currently available radio technologies (such as WiFi or Bluetooth), the determination of the exact location of a tag is not trivial. Common methods like triangulation or GPS require a considerable amount of effort in user interaction and may be too imprecise to be used in urban areas. It is therefore necessary to assign this task to the users themselves by employing their tactile and auditory senses.

3.2 Determining the functionality

Real-world tags can trigger a multitude of functions, such as opening a web page, making a phone-call, or displaying data retrieved from the tag. The purpose of the triggered action depends on the application, e.g. purchasing a ticket for public transportation or downloading a ring tone. Especially when using tags, which can automatically trigger actions (e.g. NFC tags) users might be reluctant to use tags they have not used before. Furthermore a recent study on user perceptions on mobile interaction with tags showed that users who are not familiar with the concept of real-world tags only develop a very vague mental model of the technology [14]. Thus they may be surprised by actions triggered through touch, such as accessing networked data resources.

It is therefore crucial to inform the user about the purpose and functionality of a tag. Arnall [14] defined a series of icons for touch-based interaction by investigating existing touch-based interactions with everyday objects. While the icons describe how to interact with the tag, they do not represent the triggered actions or the general purpose of the tag. Välkynnen et al. identified common classes of actions (CCOAs) from predesigned tag-based scenarios [16].

In our interviews we found out that blind and vision-impaired users preferred tactile pictograms to Braille letters. Therefore, we suggest using low-detail icons to allow for simple exploration through touch by blind and vision-impaired users.

4. Concept

To address the requirements described in the previous section, we introduce the concept of Audio-tactile Location Markers (ALMs). ALMs are auxiliary enhancements to existing tags. They constantly transmit a signal (e.g. using Bluetooth) to propagate their existence. The signal can also be used for a general classification of its functionality (e.g. whether it is attached to poster, a vending machine, etc.). Users can remotely activate an audio signal, which allows them to locate the tag using their auditory senses. ALMs further provide detailed information about the tag's functionality through a tactile pictogram. Thus, ALMs provide users with an awareness of tags in their vicinity (1), assist them in locating the tag and navigating to its position (2), and enable them to determine its purpose and functionality (3).

ALMs support both push and pull mode. In push mode, the ALM starts emitting an audible guidance signal whenever the presence of a blind or vision-impaired user is detected. In pull mode, ALMs are constantly propagating their existence to the environment in an unobtrusive fashion. This allows users to query for ALMs in the vicinity and receive information about their purpose before activating the audible guidance signal.

As transmission technology to detect the presence of blind or vision-impaired users and to propagate the presence of ALMs we use Bluetooth. This approach was mainly chosen for three reasons: (1) Bluetooth is a well established and low-cost technology which is supported by almost every mobile device; (2) Bluetooth has a high transmission range, allowing the detection of other Bluetooth devices up to 100 meters (class 3 Bluetooth); and (3) by broadcasting Bluetooth device names, information such as the purpose of an ALM (e.g. "Ticketing") can be propagated without the need of user interaction.

5. Design Process

To ensure the applicability and usability of our proposed solution, we followed a user-centered design process, involving formal and informal interviews with experts at various stages, a pilot study with blindfolded sighted users, and an evaluation with blind and vision-impaired people.

5.1 Expert Interviews

In the first phase of our design process we familiarized ourselves with the everyday challenges of blind and vision-impaired people. This included attending an event on assistive technologies organized by the city of Vienna, where many blind and vision-impaired people from local organizations were present. We conducted informal interviews with both blind representatives as well as companies selling assistive technologies. The results of these initial interviews mainly formed the basis for a formal interview that we conducted in a next step.

The formal interview was conducted with a blind employee at the BBI (the federal pedagogic institution for blind people in Vienna). The interview was open-structured, lasted about 60 minutes and was held at the BBI. A major issue, which became apparent in this interview, concerned the costs of assistive technologies. Although being obvious, this issue hardly ever seems to be reflected by research in this area. It is however reflected by recent developments in desktop computer usage by the blind community. While there is research on technologies that could substitute traditional input and output devices for desktop computers [17], the majority of blind users tend to stick to conventional hardware setups equipped with text-to-speech software. As we learned during the interview, the reasons for this are twofold: firstly, traditional desktop hardware is more affordable than assistive products and secondly, it allows blind users to keep pace with the fast development of computing technologies. This result motivates the investigation of the mobile device as assistive device for application scenarios beyond the desktop computer. To learn more about the navigation part of our concept, we asked questions about wayfinding in public contexts. According to our interview partner, tactile navigation assistance through leading lines physically integrated into the floor is often difficult to implement due to various constraints. He further explained that audible signals, such as found at pedestrian crossings, are preferable. According to his experience acoustic feedback is generally preferred to tactile feedback. Regarding the identification of real-world tags, the results from the interview suggest the usage of individual symbols rather than using Braille letters, since they are not multilingual. An important issue in this respect was also the suggestion to keep the information density as low as possible.

5.2 Pilot Study

Based on the results from the expert interviews we developed a functional prototype that allowed us to evaluate our approach. The prototype consisted of a speaker attached to a laptop and equipped with a passive NFC tag.

As McGookin et al. have shown [14], the approach of using blindfolded sighted users for informal studies of human computer interaction is sufficient in covering the various degrees of blindness. Therefore, we conducted the study in a lab environment with four blindfolded sighted users (between 20 and 30 years, 2 male/2 female). The task was to locate the ALM and to touch the attached NFC tag with a mobile phone. This process was repeated two times for every participant. Before starting the actual evaluation, participants received a demonstration of the ALM prototype and had to activate the NFC tag to learn how to use the technology. After this introduction, the participant had to leave the room and the ALM prototype was placed at a random location in a height between 1.20 and 1.70m. After the evaluation we conducted a short structured interview to receive qualitative feedback about the difficulty of the task, the suitability of the audio signal used for locating the ALM, and suggestions for improvement. All participants were able to locate the ALM prototype within 33 seconds or faster. No false attempts to touch the NFC tag (i.e. false positioning of the mobile phone) occurred. Overall, the feedback from the participants was very positive. They stated that they found it surprisingly easy to locate the ALM prototype by simply relying on their auditory-cognitive abilities. One participant expressed concerns about the applied sound signal because of its similarity to the ticking sound of pedestrian traffic lights, which led to a refined audio signal used in the final prototype.

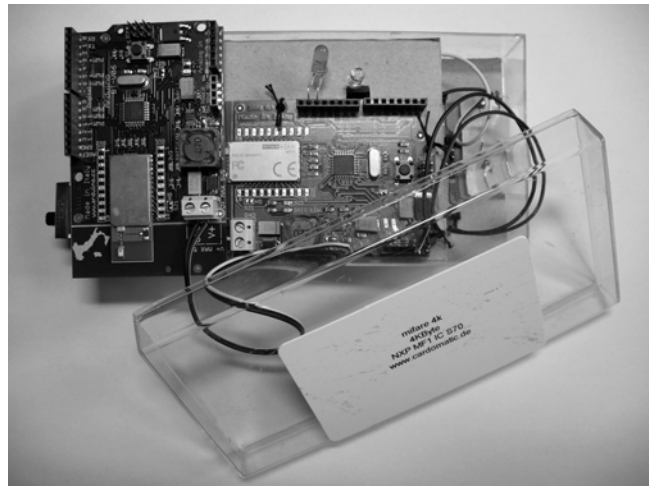

Figure 1. Prototype of an Audio-tactile Location Marker developed as auxiliary enhancement of tags.

Further details about the pilot study have been published elsewhere [19].

6. Prototype

To evaluate the concept of ALMs in terms of feasibility and user acceptance we developed a fully functional prototype. The design of the prototype was derived from the results of the interviews and the pilot study.

In our prototype system an ALM consists of two Arduino Bluetooth BT-V06 boards, one Arduino Diecimila board and a pair of battery powered Logitech Mm22 speakers (Figure 1). The first Bluetooth board acts as a *push detection device* which constantly scans the vicinity for a specific BSSID; the second Bluetooth board acts as a *pull broadcast device* which broadcasts its own BSSID (e.g. "movie poster") to inform users about the existence and the nature of a nearby real-world tag.

As real world tagging technology we used Near Field Communication (NFC). Basically, an NFC tag works like an RFID tag: a remote device builds up an electromagnetic field which powers the NFC tag and enables it to transmit its stored data over the air. NFC technology works at very close ranges of about 5 centimeters maximum distance. The currently available NFC tags can store data up to 8 kilobytes (Mifare 8k). NFC is already being used for commercial applications, including ticketing and vending machines.

As a mobile device we used a HP iPaq HW6515 smartphone running custom-built software (Figure 2). We

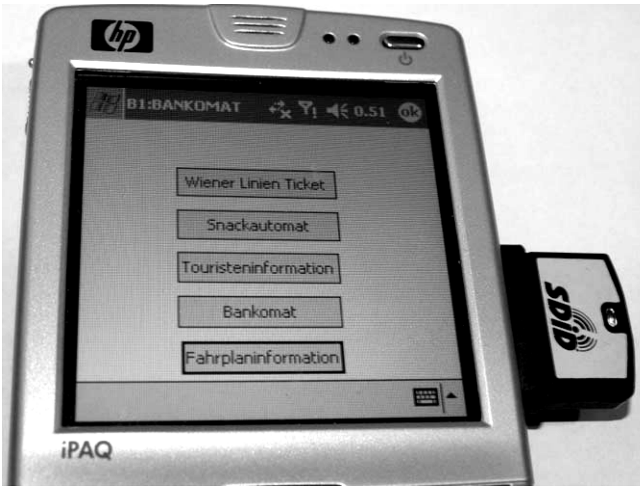

Figure 2. Smartphone running our custom-built software for activating ALMs.

chose this device primarily for two reasons: it allows us to access its Bluetooth stack directly and it features a fully-fledged built-in keyboard. The firmware installed on the device was Microsoft Windows Mobile 2003. Because the smartphone was lacking built-in NFC capabilities, we installed a SDID 1010 NFC/RFID card reader in the SD slot of the device.

The smartphone did not feature a preinstalled screen reader, therefore our software used prerecorded speech samples to provide audible feedback. The speech samples covered all available operations in our software. Thus, this approach was sufficient for the purpose of our study.

The physical dimensions of the ALM prototype used during the user evaluation were 152 x 78 x 46mm.

7. User Evaluation

The final prototype was subject to a user evaluation with blind and vision-impaired people. The goal of this study was (1) to evaluate whether users would be able to locate ALMs in a real environment, (2) to determine whether they prefer the push or pull approach, (3) to measure the user acceptance of the system, and (4) to identify user requirements for a next iteration of the prototype.

7.1 Participants

Eight study participants (4 male, 4 female, average age 28.25 years) were recruited through the BBI to voluntarily take part in the study. Five participants had no light perception at all (NLP), two had light perception (LP), one had NLP on the left and LP on the right eye. All participants used a cane for orientation; one participant had been using a guide dog for seven years until the dog passed away in January 2009. All participants owned at least one mobile phone, four participants used a screen reader for interaction, and the other four had memorized the menu structure and buttons. The participants reported using their mobile phones for making and receiving calls, writing text messages, managing their contacts and listening to music. One participant also mentioned taking photos using his mobile phone.

7.2 Method

The prototype was evaluated with 8 blind and vision impaired people using a within subject design. The ALM prototype was mounted on a tripod at a height of 130cm. A NFC tag was attached at the front, a pair of speakers which emitted the acoustic signal was mounted beneath the ALM. After a short interview to collect background information and general comments, users were given the mobile device (the HP iPaq HW6515 smartphone) and a tag to demonstrate the usage of the prototype. Once they felt comfortable touching the tag with the smartphone, we conducted a short preliminary test to demonstrate the functionality of the ALM and let the participants become accustomed to the acoustic signal. The task for the users was to navigate to the ALM and touch the attached tag with the smartphone. The ALM was activated remotely by one of the test conductors.

After the preliminary training two scenarios (which corresponded to the two experimental conditions push and pull) were presented to the participants. To avoid learning effects the sequential order of the two scenarios was counterbalanced. Additionally, we prepared each scenario for the activation methods (push and pull), which were also counterbalanced (see Table 1).

For scenario A we used a schedule, which is mounted at a bus station, based on an NFC-based public transport system in Rhein (Germany)[3]. In scenario B an ATM was simulated, which allowed for recharging the electronic wallet integrated into the users handheld, based on an NFC-based system presented in Tokyo (Japan)[4]. The scenarios were read out to the users before the test and concluded with the corresponding tasks (push or pull). To establish comparable results (time to navigate to the ALM), the ALMs were attached to a fixed spot for each scenario, which remained the same throughout the test.

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3 http://www.venyon.com/FileUpload/pics/pdf/pressrelease-rmv-eng_final_080613.pdf

4 http://www.slashphone.com/70/6644.html

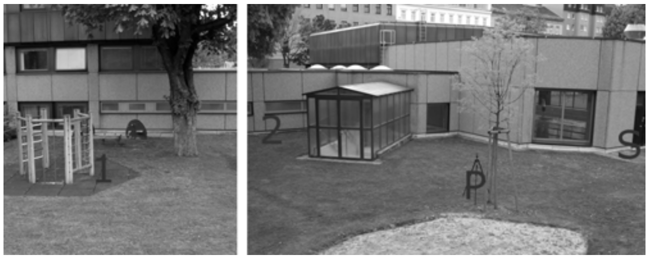

Figure 3. Environment, where the tests were conducted, indicating the positions for the ALM prototype during the initial pilot test (P), the push method (1), the pull method (2), as well as the starting position (S).

In the first condition (push) participants had to activate the smartphone to constantly signal ALMs in their vicinity that they want to navigate to them. When an ALM was within range, it started emitting an audio signal. Beforehand, participants were given the direction where the target for the pull condition was located (position 1 in Figure 3). They further received the following information: “The ATM (bus stop) is in this direction, about 20m straight forward. When you hear the audio signal, navigate to the tag attached at the ATM (bus stop), and touch it with the smartphone.” The participants were deliberately given an inexact direction, which made it necessary for them to leave the chosen path to navigate to the correct position. Once they had located the ALM they had to touch the tag to receive an acoustic confirmation signal, which finished the test. Each user was told that he or she would have to locate either a schedule attached to a bus stop (scenario A1) or an ATM (scenario B1).

In the second condition (pull) the mobile device automatically scanned the environment for ALMs in its vicinity. Because we did not have a second Arduino Bluetooth board at our disposal at the time of the evaluation, we simulated the functionality of the pull broadcast device by hard-coding the BSSID of the attached tag into our software. The scan results were displayed in a list on the mobile device, which participants could access through a simulated screen reader feature. For each scenario, the list consisted of five hard-coded items: ‘Ticketing’, ‘Vending machine’, ‘Tourist information’, ‘ATM’ and ‘Schedule’. The point of interest the participants were looking for was ‘schedule’ in scenario A2 and ‘ATM’ in scenario B2. A selection of the correct entry triggered the screen reader to output “Beacon is being activated”, other selections triggered the smartphone to play a low-frequency buzzing sound to indicate an error. Participants had to select the required point of interest (depending on the scenario) and navigate to the ALM when they heard the audio signal. Again they had to touch the tag to receive an acoustic confirmation signal once they located the ALM, which finished the test.

Table 1. Counterbalancing of test conditions. A = Schedule, B = ATM, 1 = push, 2 = pull

Participant	Scenario #1	Scenario #2
1	A1	B2
2	A1	B2
3	B1	A2
4	B1	A2
5	A2	B1
6	A2	B1
7	B2	A1
8	B2	A1

The user evaluation took place in an outdoor location on the premises of the BBI (Figure 3). There was almost no ambient noise due to the fact that the nearby roads did not carry much traffic.

Every test started at the same location to ensure comparable results. For the preliminary evaluation the ALM was positioned about 8.5 meters away from the starting point. The position of the ALM for the push tasks (A1 and B1) was about 15 meters away from the starting point. Since the ALM can detect the smartphone at larger distances, we activated the sound of the ALM when the user reached a radius of about 6 meters around the ALM. This prevented premature activation of the audio signal, which would have given away the position of the ALM at the very beginning of the test. The position of the ALM for the pull tasks (A2 and B2) was about 20.5 meters away from the starting point.

During the tests we measured the time from the activation of the ALM to successfully touching the tag. We did not consider the latency of the ALM itself (time between activation of Bluetooth on mobile device and activation of audio signal on the ALM).

After the evaluation we interviewed each participant. The interview included questions about the suitability of the current approach for real-world scenarios (e.g. audio signal for locating the tag, height of tag, push versus pull method, etc.). Additionally we presented real-world applications using tagging technologies to the participants and asked them which method they would prefer for locating them (push or pull).

7.3 Results

Before the evaluation was conducted participants were asked how they would locate an ATM in an unknown surrounding. Five participants said they would ask other pedestrians for directions to the nearest ATM, one participant said he would also ask for detailed instructions how to use the machine. One participant said that she would walk around until she found one. Only one participant told us he would never be in this situation because he would plan his route at home beforehand. One participant did not have any idea of a successful strategy to locate the nearest ATM.

Only one of the participants had heard about NFC and real-world tagging before. He stated that he was using Sherlock [8] to tag packages of his medication and the buttons on his dishwasher and washing machine. However, he had not used NFC before.

All participants were able to navigate to the ALM by following the emitted sound. The average time taken for locating the ALM during the preliminary training test was 30.0 seconds with a standard deviation of 6.1 seconds. However, all participants required assistance in touching the attached tag with the smartphone. The average time to navigate to the ALM during the push condition was 31.6 with a standard deviation of 4.9. The average time to navigate to the ALM during the pull condition was 37.9 seconds with a standard deviation of 6.4 seconds.

After the evaluation, four participants clearly favored the pull method, one participant slightly preferred the pull to the push method, two participants reported the methods to be equally useful, and one participant preferred the push method.

When asked about situations where the pull method would be useful, participants mentioned bus stations, ATMs, shops, elevators, public restrooms, staircases and vending machines.

When asked about the push method, only four participants were able to come up with a situation where the method would prove useful. The following situations were mentioned: bus stations, stations of public transportation, the entrances of 'important' buildings such as post offices or banks, audible signal beacons attached to traffic signals, ATMs, and specific places in vehicles of public transportation such as ticketing machines or unoccupied seats.

In the push condition (A1 and B1) participants were told that there was an ALM in their vicinity and given its approximate direction. One of the participants said he would also use the push method in situations where he was lacking this information. Two participants stated that they would not use the push method in that case. The remaining five participants were uncertain; two of them mentioned possible orientation problems such as loss of orientation or dangerous situations due to unintentionally crossing a road. One participant suggested a combination of push and pull method: the users should be informed when a tag is in their vicinity and query for its name and purpose in a sequential step.

During the interview we presented the different scenarios for tag-based applications to the participants and asked them about their preferred method (push or pull). The results are shown in Table 2.

Table 2. Number of participants preferring push or pull methods in given scenarios.

Scenario	Push	Pull	Both	Neither	N.A.
Vending machines	2	2	1	2	1
ATM	2	5	0	0	1
Tourist info	3	2	0	1	2
Museum guide	1	0	0	0	7

When being asked about the ATM scenario, one participant was concerned about security issues such as eavesdropping.

Six participants found that the ALM was mounted at a comfortable height; two would have preferred a lower height (about 15-20 centimeters lower). One participant mentioned that he had problems touching the ALM because it was mounted on a freestanding tripod, which caused confusions.

Six participants clearly favored the approach of using their mobile phone to locate everyday locations or things. One participant was clearly against using his mobile device, he preferred having a separate device, since he thought additional features would take up storage capacity. Two of the participants who favored the approach mentioned that specially developed systems might be more expensive.

All eight participants said that they had no problems navigating to the tag. However, three of them mentioned explicitly that they experienced problems finding the exact spot to touch the tag with the mobile device.

All participants favored the approach of providing acoustic signals for locating everyday locations or things. Additionally three participants mentioned possible problems in areas with loud ambient noise. One participant also emphasized the usage of different types of acoustic signals to avoid confusion. Another participant stated that he believed audible signals were the only reasonable way to lead blind users to specific points of interest.

8. Discussion

The prototype implemented two different approaches for raising user awareness of tags in the vicinity: With our first approach (push mode) the ALM propagated its presence using an audio signal whenever a user entered its perimeter. With the second approach (pull mode) users could query for nearby ALMs and activate the guidance signal of specific units. Push mode is a good solution for raising awareness of previously unknown tags but is only suitable for a relatively low density of ALMs. There is a risk of audio signals becoming indistinguishable, overwhelming, or confusing for large numbers of ALMs in a small area using push mode. This limitation is less critical for the pull mode, since it requires deliberate action from the user to activate the audio signal. It further allows the targeted activation of only specific ALMs of interest to the user.

Most study participants preferred pull mode to push mode. Participants said that pull mode gave them a better overview and understanding of their surroundings. Furthermore a few participants voiced their doubts whether they would investigate completely unknown tags without knowing their purpose beforehand in push mode. There were also some concerns regarding safety, e.g. when audio signals would lead the user to cross a street without their knowing or the risk of confusing the audio signals of an ALM with those emitted by pedestrian traffic lights. Furthermore, one participant was concerned with losing his orientation when an ALM would divert him from his path.

One participant suggested a combination of push and pull mode: ALMs could indicate their presence to the user's mobile device and the mobile device would inform the user of nearby tags using a subtle notification (such as a beep). The user could then query for a list of all ALMs in the vicinity, similar to the existing pull mode.

The results from the evaluation confirmed our approach of using an audible guidance signal to indicate the location of tags in the immediate vicinity. As anticipated, the navigation to the source of an acoustic signal within distances of up to 20.5 meters was easily feasible for the participants in our study. Feedback from our interviews showed that all participants consider audio signals a viable form of navigational aid, however most participants expressed their concerns regarding ambient noise. This problem was not relevant during the evaluation, since noise levels at the site were rather low.

The difference in time it took participants to locate the targets during the tasks was most likely due to the different distances to the ALM for the two conditions. Since we did not measure the time for the activation process it is difficult to track back the actual reason for the difference.

All users experienced problems touching the tag with the smartphone. We expected these issues since the ALM prototype used in the study was lacking tactile icons. This shows that the tactile highlighting of real world tags is crucial if they are to be made accessible. Part of the problem might also stem from poor ergonomics and antenna placement in the smartphone used in the study. These issues have already been addressed by recent models for NFC-enabled mobile phones.

All participants owned a mobile phone and most of them were in favor of using their mobile phone for navigational purposes. One important issue mentioned by two out of eight participants was mobile phone theft: aside from the cost of the phone itself, the necessity to repurchase software such as screen readers can dramatically increase the overall cost of replacement. Furthermore, the consolidation of additional features could lead to increased dependence on one's phone and by extension greater severity of loss.

All but one participant were not familiar with existing tagging technologies such as RFID or NFC and their current state of deployment for various end-user services. Despite their lack of familiarity with tagging technologies, most participants were able to devise potential use cases for ALMs. However, some of the proposed use cases did not rely on tagging technologies at all. This indicates that the applicability of ALMs is not necessarily limited to making tags accessible, but could prove useful in other contexts as well. The interviews showed that participants were primarily focused on possible applications concerning points of high relevancy to their everyday life; our proposal of installing ALMs in vending machines was largely dismissed as superfluous. One participant suggested that our concept could be used to augment and improve the wayfinding capabilities of existing GPS-based solutions, as these systems typically lack the necessary precision to locate smaller and very specific targets.

9. Conclusion & Future Work

Real-world tags allow for a multitude of applications and are already being applied in commercial applications, such as ticketing and payment. However, they currently lack accessibility for blind and vision-impaired users due to their small size and visually driven affordance. To propagate the existence, location, and functionality of real-world tags, we developed the concept of ALMs. Using widespread and low-cost technologies, we built a prototype to examine the applicability of using audio signals to assist blind and vision-impaired people in locating real-world tags and triggering interaction with the tag. The prototype supports two different activation modes (push and pull).

The prototype and custom-built software running on an NFC-enabled smartphone were subject to a user evaluation with eight blind participants. Participants were presented two scenarios (one for each activation mode) to evaluate user preferences for the different modes. All of the participants were able to navigate to the ALM within distances of up to 20.5m, but further assistance was required for successfully touching the tag with the smartphone. In interviews conducted after the evaluation, six out of eight participants said they preferred the pull to the push mode. Furthermore, some participants pointed out possible problems when using push mode in an unknown environment; such as loss of orientation or dangerous situations due to hazards, which are present in urban environments.

Considering the characteristics and limitations of push mode as well as the feedback from our interviews we conclude that push mode is most suitable for indicating the presence of points of great general importance such as potential obstacles or safety hazards. For points of general interest, such as public infrastructure and services (e.g. public transport ticketing, public information, or ATMs), we conclude from our interviews that pull mode is the preferred mode of exploration and discovery. Study participants considered presence indicators for points of lower general interest (such as vending machines) less important. For tags at such points of lower general interest it might be sufficient to augment them with tactile markers. This way, the accessibility of these tags at least improves for people knowing their location and deliberately seeking them.

Our results also showed the importance of tactile icons for revealing their functionality. In a next step we will therefore investigate methods for highlighting real-world tags based on a classification of existing applications. We will develop and evaluate a tactile symbology consisting of pictograms, which represent generalizations of application purposes assigned with real-world tagging. Additionally, we will refine our ALM prototype. The mounting on a tripod caused confusion during the user evaluation and therefore we will investigate alternatives to ensure a stable and flexible installation that can be used in studies. We will further redesign the casing of the ALM to enable the attachment of tactile symbols. Based on the results from our study we will also examine a combination of push and pull method: users will be informed when a tag is in their vicinity (e.g. through an acoustic signal) and can choose if they want to explore it by querying for its name and purpose in a sequential step.

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