This is the Author-created version of the article

Smart Tourism in Cities: Exploring Urban Destinations with Audio Augmented Reality

Costas Boletsis and Dimitra Chasanidou

Citation:
Costas Boletsis and Dimitra Chasanidou (2018) Smart Tourism in Cities: Exploring Urban Destinations with Audio Augmented Reality. In: PETRA '18 Proceedings of the 11th PErvasive Technologies Related to Assistive Environments Conference ACM. DOI: 10.1145/3197768.3201549

This is accepted manuscript version.
It may contain differences from the journal's pdf version.

This file was downloaded from SINTEFs Open Archive, the institutional repository at SINTEF
http://brage.bibsys.no/sintef

Smart Tourism in Cities: Exploring Urban Destinations with Audio Augmented Reality

Costas Boletsis
SINTEF Digital
Forskningsveien 1, Oslo, Norway
konstantinos.boletsis@sintef.no

Dimitra Chasanidou
SINTEF Digital
Forskningsveien 1, Oslo, Norway
dimitra.chasanidou@sintef.no

ABSTRACT

Audio augmented reality (AR) allows for the simultaneous perception of the real environment and a virtual audio overlay. This is especially important in a mobile use context, where users should be continuously aware of their surroundings, such as in the case of urban tourism, when tourists explore foreign cities and their tourist sights. In this work, we investigate the design and implementation of audio AR systems in urban tourism. Our prototype, called AudioNear, is designed to support tourists' exploration of open, urban environments while providing speech-based information about surrounding tourist sights, based on the users' location. At this stage, we present the design concept of AudioNear, its hardware implementation and the first usability feedback. Overall, the study indicated the promising potential of audio AR for providing informative tourist services and engaging experiences.

CCS CONCEPTS

• Information systems → Location based services; **• Human-centered computing → Ubiquitous and mobile computing systems and tools**;

KEYWORDS

Audio augmented reality, exploration, eyes-free interaction, tour guide, urban tourism

ACM Reference Format:

Costas Boletsis and Dimitra Chasanidou. 2018. Smart Tourism in Cities: Exploring Urban Destinations with Audio Augmented Reality. In *PETRA '18: The 11th PErvasive Technologies Related to Assistive Environments Conference, June 26–29, 2018, Corfu, Greece.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3197768.3201549

1 INTRODUCTION

In the context of tourism, smart applications of technologies (e.g. cloud computing, location-based services, virtual reality, augmented reality) enhance the tourism experiences and services and generate creative tourism business models [13]. Among these applications, mobile augmented reality (AR) tour guides have found their place in the tourism industry, assisting tourists in accessing valuable information and improving their knowledge regarding touristic attractions while enhancing the tourist experience and offering increased levels of entertainment throughout the process [20, 34]. In a typical mobile AR tour guide application, users navigate an area and receive location-based, audiovisual information about their surroundings by interacting with their mobile devices [21, 22, 34]. These applications rely heavily on visual augmentation of reality and interaction with graphical interfaces, thus forcing users to divide their attention between observing the environment and interacting with the mobile device [12, 15, 21]. This type of interaction can limit the users' field of view and add extra cognitive load [12, 15].

Audio forms an interesting alternative to vision as a display modality in mobility settings, avoiding the physically and cognitively challenging interaction with graphical user interfaces while on-the-go [12, 15, 27]. Audio AR systems operate in mobile use contexts, overlaying the physical space with a virtual audio layer that is perceived through headphones [12, 15]. Audio AR stays close to the interaction goal of AR, that is, to enhance reality, by supporting the simultaneous perception of the real environment and the virtual overlay [12]. Channelling information to the ears reduces the visual and cognitive load and frees the user's eyes to observe this new environment [12]. This is especially important in a mobile use context, where users should be continuously aware of their surroundings, such as in the case of urban tourism, when tourists explore foreign cities and their tourist sights.

Urban tourism places cities in the centre of tourism activity, utilising city areas as social, cultural, physical and aesthetic stages upon which tourist activity can be played out [1, 14]. In the context of urban visitation, the spatiotemporal behaviour of tourists can be much more complex compared to their behaviour in indoor settings (e.g. museums) or outdoor confined spaces (e.g. zoos), where the exploration options and tourism activities are limited and/or predefined [6, 34]. In these open environments, one can come across all different types of tourists (e.g. drifters, explorers, mass tourists, et al. [7, 8]) exploring unfamiliar areas individually or along with other tourists in a variety of ways, from playful, unstructured, spontaneous and unorganised explorations to completely structured and fixed navigations [7, 8]. As a result, unlike systems for other indoor or outdoor application contexts, audio AR tour guide systems for outdoor, urban environments must satisfy different and potentially more complex user needs, such as freedom of choice, exploration of open spaces and social interaction [17]. This differentiation creates the motivation for further empirical research in the field, on the integration of these user needs and, more specifically, on the design

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.
PETRA '18, June 26–29, 2018, Corfu, Greece
© 2018 Copyright held by the owner/author(s). Publication rights licensed to the Association for Computing Machinery.
ACM ISBN 978-1-4503-6390-7/18/06…$15.00
https://doi.org/10.1145/3197768.3201549

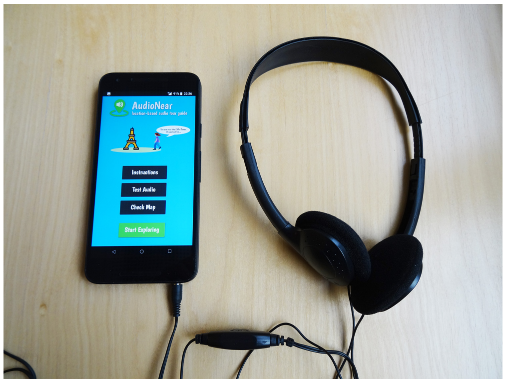

Figure 1: The AudioNear tour guide system setup (main menu screen).

and development of audio AR tour guide systems for urban tourist sites.

In this work, we present the design, development and evaluation of a prototype audio AR tour guide, namely AudioNear (Fig. 1), with which we investigate the design of audio AR systems for urban tourism. The main objective is to develop an audio AR tour guide that provides useful information about sights, offers unobtrusive interaction in urban settings, addresses various types of tourists and enables groups of tourists to have shared experiences and social interaction. At this early stage, we have designed the infrastructure and main functionality of the audio AR tour guide, we have developed a prototype, and conducted an empirical feasibility study examining its usability while we elicited user feedback on the design and technical features that the next version of the tour guide should integrate. The overall, long-term vision of the project is to acquire a better understanding of the design and use of audio AR systems for urban tourist sites, so that, ultimately, we can provide a robust design framework for developing efficient, user-friendly and informative urban tourism services for all users, regardless of their technical and technological expertise.

2 BACKGROUND

Audio AR is a mature subfield of mobile AR and its application in the tourism industry has a long research tradition. The literature analysis of visual, audio and haptic AR research and applications in tourism by Kečkeš and Tomičić [18] supports the potential of audio AR and the need for further research in the field. Their analysis concludes that non-visual interfaces, like audio and haptic, have 'considerably less distracting elements in comparison with the visual overlays'; however, 'such technologies are currently in need of further development and research in order to reach the availability and utilisation level of visual-based applications and devices' [18].

Over the years, audio AR tour guides have found applications in indoor settings, such as in museums, where mobile devices can be used to provide location-based auditory information about objects in the vicinity of the user. Bederson [2], in his work, describes an *audio AR prototype tour guide*, using infrared transmitters for the exhibits and receivers for the users, in order to track users' position inside the museum and activate informative audio tracks accordingly. Zimmermann and Lorenz [35], in the *LISTEN* project, highlight the potential of tailored audio augmented environments designed for museum guides. From a technical standpoint, Heller and Borchers [15], in the *AudioScope* system, utilise the built-in sensors of smartphones for orientation measurement and for spatial audio rendering in indoor environments, so that audio guides for museums do not require special hardware but can run on the visitors' smartphones with standard headphones.

For outdoor use, audio AR tour guides make use of the users' position (usually tracked by GPS technology) to provide location-based auditory information about the surroundings. Stahl [30], in the *Roaring Navigator* tour guide, utilises a minimal-attention user interface to guide groups of zoo visitors and provide auditory information about zoo exhibits. The tour guide utilises radius-based activation zones around the exhibits so that users moving together can have the same shared-audio experience, with the audio tracks playing automatically at the same time. A very similar track-activation technique is described and used by Vazquez-Alvarez et al. [33] in their work, where they evaluate four different auditory displays for navigating a sound garden. Dow et al. [10], in *The Voices of Oakland* guide, provide visitors to the Oakland cemetery with auditory narratives, that is linear stories about the deceased inhabitants, utilising a Wizard of Oz technique for triggering the audio tracks and targeting a strictly linear tour experience. The *Lund Time Machine* by Szymczak et al. [31] adds tactile interaction to the audio AR experience by utilising the vibrations of the mobile device to guide tourists along a specific trail and automatically provide relevant auditory information when the user is close to places of interest (POIs). As a hardware solution, D'Auria et al. [9], describe a 3D audio AR system, consisting of custom-made smart headphones that interact with the *Caruso* personal guide application to offer cultural information about places near the user in 3D audio.

The works of Holland et al. [16] on the *audio GPS interface*, Pascoe et al. [27] on the *MAUI interface*, and Kristoffersen and Ljungberg [23] on the *MOTILE interaction style* examine the design of minimal-attention user interfaces and techniques in mobile use contexts, using audio feedback, thus potentially addressing the development of audio AR tour guides from an interaction design perspective.

The related work in the field and its gaps allow for more investigation of the design process of audio AR tour guides for urban environments. Supporting free user exploration, enabling eyes-free interaction and creating shared user experiences within the application context of unfamiliar urban environments are topics that can be further addressed and empirically researched. It is certain, based on the works mentioned above, that most if not all of the technical components exist; however, more user-centred work is necessary on which components should be utilised and how they should be combined to form a practical audio AR tour guide for urban tourist sites.

3 AUDIONEAR: AN AUDIO AR TOUR GUIDE

The AudioNear tour guide utilises audio AR to enable tourists to navigate on foot and explore outdoor tourist sites by providing 'on-the-go', speech-based, auditory information about various sights

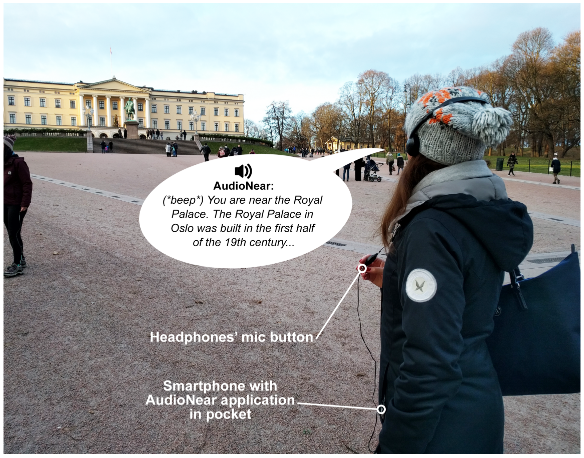

Figure 2: Exploration functionality: the user utilises AudioNear to explore Oslo. When the user approaches a landmark (Royal Palace), an audio track with cultural information begins to play.

(buildings, landmarks, monuments, etc.) that are located in the vicinity.

AudioNear supports two functionalities: *exploration*, utilising the audio AR interface (Fig. 2), and *route planning/navigation*, offering assistive visual functionality (Fig. 3). When exploring, users put on their headphones and then launch the audio tour guide application from their personal mobile devices (smartphones or PC tablets). Based on their location (GPS-based), when they walk within a specific, pre-defined radius of a sight, an audio track with various information about that place commences playing. Users can control the audio track playback with the headphones' mic button, so that interacting with the guide's graphical interface is not necessary in mobility settings. AudioNear also provides users with an interactive map of all the tourist sights for route planning and navigation purposes. At any time, users are able to check a map to locate the nearest sights, choose the ones they want to visit based on the provided information and navigate towards them through the 'Take me there' option powered by Google Maps (Fig. 3).

3.1 Design Rationale

An audio AR system has specific features that set it apart from regular human-computer interfaces [12]:

- an audio playback system that allows the simultaneous perception of real and virtual sounds
- motion tracking that enables interactivity and location-awareness
- auditory displays that deliver auditory content
- spatial rendering that displays spatialised auditory content

The design approach for AudioNear integrates these features while drawing inspiration from previous cases of mobile AR and audio AR tour guides, as well as from established tourism theories and human-computer interaction (HCI) principles, in order to address the application domain of urban tourism. To reach this work's main objective, we formed four design suggestions (DS) around interaction, interface and content delivery issues, based on existing literature. We consider these issues to be important when designing for urban environments; thus, we also present the way these suggestions were tackled when designing AudioNear (Table 1 provides a summary).

DS1: *The tour guide service should minimise the distraction coming from the interaction with mobile devices.*

When exploring unfamiliar urban environments, tourist information should be accessed and delivered in an unobtrusive and undisruptive way so tourists can focus on their surroundings; therefore, minimising the distraction coming from the interaction with their mobile devices is important [18, 24, 30]. Auditory information and minimal-attention interfaces can offer a promising alternative to graphical user interfaces, accomplishing eyes-free interaction and minimal distraction [12, 15, 16, 27]. AudioNear utilises audio AR to deliver auditory content, and a series of important design decisions were made to develop a minimal-attention interface and further limit distraction. More specifically, AudioNear was designed to work right out of the box upon launch, through a simple and informative menu page (Fig. 1), without requiring extra user information or further adjustments. Interaction with the audio tracks was designed to take place through the headphones' mic button, so the user does not need to interact with the mobile device. The audio tracks were designed to be short and concise, and no sound is produced when the user is not inside the radius of a sight. That way, the user can still pay attention to the external, environmental sounds while exploring.

DS2: *The interaction with the tour guide should minimise the cognitive load coming from extensive use instructions.*

Even if distraction is minimised, auditory content can still cause cognitive load if it depends on instructions for interpretation [24]. To minimise the user's cognitive effort, AudioNear utilises intuitive interaction metaphors for conveying navigation and sight-related

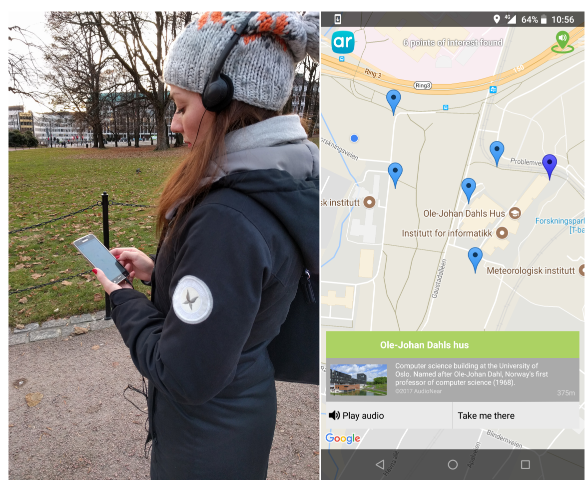

Figure 3: Route planning/navigation functionality: the user utilises the AudioNear map to navigate around Oslo and its tourist sights *(left)*. A screenshot of the AudioNear map *(right)*.

Table 1: A summary of the formed design suggestions and how they were appplied in AudioNear.

Design suggestions ⟹	Applied in AudioNear	Related work
Minimise the distraction coming from interaction with mobile devices	Implementation of a minimal-attention user interface	[12, 15, 16, 27, 30]
Minimise cognitive load coming from extensive use instructions	Utilisation of intuitive interaction metaphors	[16, 24, 27]
Utilise a robust spatial audio activation method that supports shared, multi-user tour experiences	Implementation of radius-based audio activation zones	[2, 30, 33]
Satisfy various tourist types	Implementation of two different touring functionalities	[7, 8, 30]

information. A simple earcon ('beep' sound) notifies users that they have entered a sight's radius before the speech-based auditory information about the sight is provided (Fig. 2), while a map-based approach is implemented for navigation purposes (Fig. 3). Even though sonification and the use of non-speech audio are discussed for the above-mentioned purposes, they were not utilised, since that would require further instructions and cognitive effort for users to learn how to interpret these non-speech sounds.

DS3: *The tour guide should utilise a robust spatial audio-activation method that supports social interaction and shared multi-user tour experiences.*

The tour guide should activate the audio tracks in a technically reliable way while creating a shared auditory experience and operating uniformly for users that are moving in groups (e.g. families) [2, 30]. To fulfil this suggestion and avoid extra interaction with the mobile device or restrictions due to specific hardware (e.g. headphones for directional audio), we utilised a radius-based approach to define activation zones in close proximity to the tourist sights (Fig. 4) [30, 33]. This implementation allows for automatic triggering of the audio track when a user is inside the radius of a tourist sight, so a group of users moving together will receive the same auditory information at the exact same time when within the radius, thus creating a shared auditory experience [30, 33]. In AudioNear, the radius around the sights was strategically and manually placed for each sight, so that it only contained areas where the sight was clearly visible. If two sights were very close, they would share a common radius area and a common audio track. Moreover, to facilitate social interaction and not isolate the user from other users and the environment, no sound was produced when the user was not inside the radius of a sight.

DS4: *The tour guide service should satisfy various tourist types.*

AudioNear, being a tour guide, should satisfy tourists' complex spatiotemporal behaviour, thus addressing the possible combinations of familiarity and novelty sought by different tourists [28, 34]. Cohen's tourist typology in the space of familiarity and novelty in travel is considered a fundamental work in tourist-host social contact studies [11, 28]. Based on Cohen's tourist typology [7], there can be institutionalised tourists (individual and organised mass tourists) and non-institutionalised ones (drifters and explorers). Non-institutionalised tourists have closer contact with the local environment and people, and they try to immerse themselves more in the local culture, experiencing new places with a sense of freedom and spontaneity. On the other hand, institutionalised tourists seek more familiarity; they are not very adventurous and normally purchase ready-made packages, which include few or no personal choices [7, 8]. In order to address the different styles of experiencing a new environment as a tourist, tour guides can provide content in different modes [30]. AudioNear supports two modes/functionalities: *exploration* and *route planning/navigation*, as described in Section 3. These functionalities are designed for serving both users who prefer unstructured touring experiences, that is users who prefer to explore a tourist site based entirely on what they see and like (i.e. non-institutionalised tourists), and users who need structure and planning for their tours (i.e. institutionalised tourists).

3.2 System Implementation

The AudioNear prototype was written in PHP and MySQL, using the AR Layar API.[1] The Layar platform enabled the development of the designed location-based, radius-activated audio AR experience (Fig. 4) and the map-based navigation (Fig. 3). The prototype was developed as a web-based application, utilising a 4G broadband connection, though in the future AudioNear will operate offline.

On the back-end, AudioNear operates as follows (Fig. 4). Utilising the device's GPS coordinates, the client sends a *getPOIs* request to the AudioNear service provider and database (forwarded via proxy) to get the basic AR content about the AudioNear POIs (*getPOIs* response), as well as sends direct requests for external links to accompanying content (e.g. audio tracks, images/icons). On the front-end, when the user launches the AudioNear app, the main menu appears (Fig. 1). There, the user can read the basic use instructions, listen to a test audio track, open the AudioNear map or start using the main exploration functionality.

Sixteen sights in the Oslo city area were included as places of interest in the prototype version of AudioNear. Their radius values ranged between 25 and 65 metres. The audio tracks for these 16 sights contained information about their history, architecture, visiting hours, etc., narrated by a native English speaker. Each track started with an earcon ('beep' sound) to notify users that they had entered a sight's radius and that speech-based auditory information was coming, followed by a 3-second pause before the speech-based

[1] https://www.layar.com

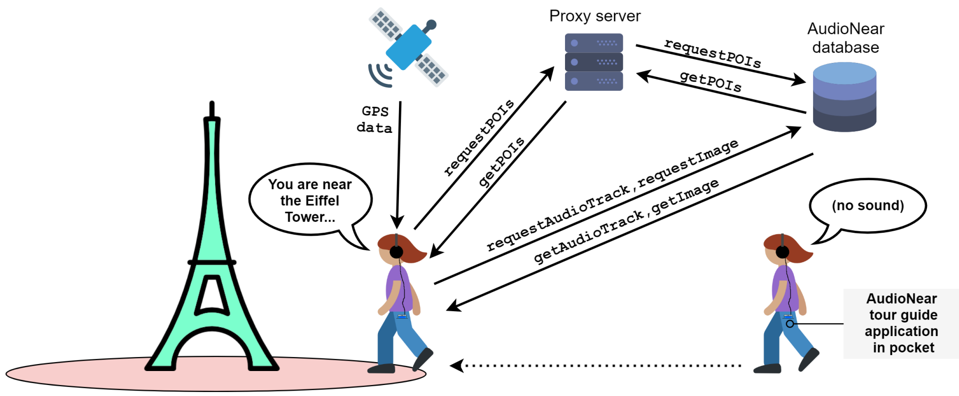

Figure 4: The architecture of the AudioNear prototype, describing its location-based, radius-activated functionality for a user entering a tourist sight's radius.

track started with the words 'You are near <name of tourist sight>'. The duration of the tracks was between 65 and 90 seconds, in order to present distinct values and allow us to investigate user preferences for track duration. The tracks were encoded and compressed in MP3 format to reduce their file size. The playback of the audio tracks was controlled by the headphones' mic button (Fig. 2), that is, tap button once to pause/stop playing track, tap button twice to replay track.

4 EVALUATION STUDY

To evaluate the feasibility of the AudioNear prototype, a user study was conducted to collect feedback on usability and technical issues and suggestions for further development.

First, a session with AudioNear took place. Participants explored six sights in the area surrounding the research institute where the study was conducted (the sights can be seen in the screenshot of Fig. 3). At the beginning of the session, participants were given a basic description of the tour guide's functionality, and an Android smartphone and headphones were provided for running the application. Then, they launched the AudioNear app and examined the map of the sights. Participants were entirely in charge of route planning and navigation, aiming to visit most or all of the nearest sights.

Next, the tour commenced and a usability walkthrough [3] took place with one of the authors, who was also the AudioNear designer/developer, accompanying each participant while they explored the area. During the walkthrough, the researcher assumed the role of a typical user, testing AudioNear within the context of that two-person user group while observing the participant's interactions with the tour guide and discussing its usability.

After the session, participants were asked to fill in the 10-item System Usability Scale (SUS) questionnaire [4]. The System Usability Scale is an instrument that allows usability practitioners and researchers to measure the subjective usability of products and services, and it has the distinct advantage of being robust with a small number of participants and technology agnostic [4, 5, 19, 32]. Then, a semi-structured interview took place, asking the participants about the positive and negatives points of their interaction with AudioNear and discussing what they would improve or add to its current version. Open questions, based on the researcher's observations from the AudioNear session, were formulated and addressed at this point.

4.1 Results

Twelve users (mean age: 30.25, SD: 5.77, male/female: 7/5) participated in the usability study. All participants had used personal tour guides, such as travel books or mobile applications, at least once before in their travels. All six sights in the area were visited by the participants, with a tour duration of between 26 and 34 minutes (mean duration: 29.42, SD: 2.50). The prototype received an SUS score of 82.92 (SD: 4.63, range: 72.5-87.5), indicating that AudioNear is at the high end of the SUS scale, achieving a 'good' to 'excellent' ranking [4].

The usability walkthrough managed to foster a shared auditory and social experience, with the users discussing the sights and the performance of AudioNear with the researcher. The usability topics observed or discussed during the walkthrough were further analysed during the interview. During the walkthrough, AudioNear did not present any technical issues.

At the interview, participants commented positively on the audio tour guide, praising its simplicity and minimal design. Ten participants commented that AudioNear was easy to use and enjoyed the fact that all the necessary information was delivered discreetly and through audio, so they could focus on observing the environment. Nine participants found AudioNear ideal for free exploration. Six participants found the map-based navigation to be straight-forward and useful for route planning. Furthermore, four participants emphasised the guide's potential to become a group tool, that is, to create a shared experience for a group of tourists exploring together. On the other hand, seven participants found some audio tracks too long, while four participants did not like the fact that the tour did not offer any recommendations about which tourist sights are worth visiting and in what order. Two participants found the implementation of AR in AudioNear 'not impressive' (quoting user #7), expecting a more visual-based experience.

The interviews produced several valuable suggestions for the next version of AudioNear. The suggestions are mentioned according to their frequency of occurrence, in descending order:

- Adding recommended routes in the tourist's vicinity to allow AudioNear to offer a service like 'a sightseeing bus but on foot' (quoting user #3)
- Shortening audio tracks to a proposed duration of one minute
- Adding a ratings system for the sights
- Utilising voice commands to interact with the interface if more actions than controlling the audio track are needed
- Gamifying exploration by adding AR collectible game elements in the environment (Pokemon Go-like)

5 DISCUSSION

The design process of AudioNear used existing literature on related domains and related application contexts in order to synthesise the initial design concepts for creating a new tour experience in urban settings. Overall, AudioNear managed to address user needs and showed promising potential regarding future development. The user study indicated good usability, positive projections regarding the tour guide's real-world applicability and an altogether positive acceptance of the concept of audio AR for tourist purposes in urban environments. AudioNear enabled informative exploration of the sights, allowing users to plan their own tours based on their own personal criteria. Users found AudioNear to be easy to use, while interaction was straight-forward and content delivery was discreet. Therefore, we can say that, at this early stage, design suggestions DS1 and DS2 (Section 3.1) were satisfactorily addressed.

At the same time, we were able to gather valuable user feedback on future improvements through the used methodology. The integration of suggested content, that is, of recommended routes and sight ratings, is an important addition that will provide supplementary pre-tour material and further facilitate the users' decision-making process when planning their tours. Even though the current design of AudioNear addresses various types of tourists (Section 3.1, DS4), this addition would further support tourist types that seek structure in their travels; thus, it needs to be implemented under the *route planning/navigation* mode.

Based on the walkthrough's two-person user group interactions, there were positive indications that the system was able to foster shared, multi-user experiences. The design decisions made to fulfil the related suggestion (Section 3.1, DS3) seems to be on the right track; however, more research with larger groups of tourists utilising the audio AR tour guide is necessary, in order to reach solid conclusions about its performance.

During the interviews, two participants pointed out that the use of AR was not impressive. Indeed, the AR technology in AudioNear is implemented in a way that attempts not to evoke the 'wow' factor. When users think of AR, they may expect visually impressive applications focusing on the technology itself. In the AudioNear case, we approached augmentation as a cultural practice [25], placing the 'heart' of user activity in the environment, the sights and the cultural heritage of the place. That way, the essence of AR as a tool to meaningfully enhance reality is honoured [12].

Finally, even though the focus, at the current stage, is on the development of an effective and novel audio AR tour guide for urban tourism, the long-term goal is to learn more about what tourists expect and need from audio guides in urban environments, through empirical and iterative testing of several versions of the audio AR tour guide. The results of this process could lead to an audio AR-based design framework, which could then be of use for practitioners and researchers in this field. The framework would provide the main infrastructure for implementing audio AR-enabled tours with various cultural content (e.g. folk music [26], ambient collective city memories [29], etc.) and under various mobility settings (e.g. when on a bike or public transport).

6 CONCLUSION & FUTURE WORK

Overall, current work demonstrates that there is promising potential for audio AR to provide informative tourist services and engaging experiences. The design rationale described herein, the study results and the user feedback can lead to further design implications for researchers and designers in the field while contributing to the discussion around the potential of audio AR in tourism.

Future work will address users' suggestions, and additional usability, user experience and comparative studies (comparing AudioNear to regular mobile and mobile AR tour guides) with larger sample sizes will follow. The use of AudioNear will also be examined in the context of groups, focusing more on the shared experience it offers, as well as under other mobility settings, such as when using public transport bus and tram services to explore urban sites.

7 ACKNOWLEDGEMENTS

We would like to thank the study participants for their valuable feedback. The icons used in Fig. 4 were designed by Twitter (woman walking icon, under CC BY 3.0 license), Freepik (Eiffel tower icon), Smashicons (server and database icons), and DinosoftLabs (satellite icon) from Flaticon. This research is funded by the Norwegian Research Council through the Centre for Service Innovation.

REFERENCES

[1] Gregory Ashworth and Stephen J Page. 2011. Urban tourism research: Recent progress and current paradoxes. *Tourism Management* 32, 1 (2011), 1–15.
[2] Benjamin B. Bederson. 1995. Audio Augmented Reality: A Prototype Automated Tour Guide. In *Conference Companion on Human Factors in Computing Systems (CHI '95)*. ACM, 210–211.
[3] Randolph Bias. 1991. Interface-Walkthroughs: efficient collaborative testing. *IEEE Software* 8, 5 (1991), 94–95.
[4] John Brooke. 2013. SUS: A Retrospective. *Journal of Usability Studies* 8, 2 (2013), 29–40.
[5] John Brooke et al. 1996. SUS-A quick and dirty usability scale. *Usability Evaluation in Industry* 189, 194 (1996), 4–7.
[6] Ana Maria Caldeira and Elisabeth Kastenholz. 2017. Tourists' spatial behaviour in urban destinations: The effect of prior destination experience. *Journal of Vacation Marketing* (2017), 1–14.
[7] Erik Cohen. 1972. Toward a sociology of international tourism. *Social Research* (1972), 164–182.
[8] Erik Cohen. 1984. The sociology of tourism: approaches, issues, and findings. *Annual Review of Sociology* 10, 1 (1984), 373–392.
[9] Daniela D'Auria, Dario Di Mauro, Davide Maria Calandra, and Francesco Cutugno. 2015. A 3D Audio Augmented Reality System for a Cultural Heritage Management and Fruition. *Journal of Digital Information Management* 13, 4 (2015), 203–209.
[10] Steven Dow, Jaemin Lee, Christopher Oezbek, Blair Maclntyre, Jay David Bolter, and Maribeth Gandy. 2005. Exploring spatial narratives and mixed reality experiences in Oakland Cemetery. In *Proceedings of the ACM SIGCHI International Conference on Advances in Computer Entertainment Technology*. ACM, 51–60.
[11] Daisy XF Fan, Hanqin Qiu Zhang, Carson L Jenkins, and Pimtong Tavitiyaman. 2017. Tourist typology in social contact: An addition to existing theories. *Tourism Management* 60 (2017), 357–366.

[12] Hannes Gamper. 2014. *Enabling technologies for audio augmented reality systems.* Ph.D. Dissertation. Aalto University Doctoral Dissertations 39/2014.

[13] Ulrike Gretzel, Lina Zhong, and Chulmo Koo. 2016. Application of smart tourism to cities. *International Journal of Tourism Cities* 2, 2 (2016).

[14] Bruce Hayllar, Tony Griffin, and Deborah Edwards. 2010. *City Spaces-Tourist Places.* Routledge.

[15] Florian Heller and Jan Borchers. 2015. AudioScope: Smartphones As Directional Microphones in Mobile Audio Augmented Reality Systems. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems.* ACM, 949–952.

[16] Simon Holland, David R Morse, and Henrik Gedenryd. 2002. AudioGPS: Spatial audio navigation with a minimal attention interface. *Personal and Ubiquitous Computing* 6, 4 (2002), 253–259.

[17] Seppo E Iso-Ahola. 1980. *The social psychology of leisure and recreation.* WC Brown Co. Publishers.

[18] Anabel L Kečkeš and Igor Tomičić. 2017. Augmented Reality in Tourism - Research and Applications Overview. *Interdisciplinary Description of Complex Systems* 15, 2 (2017), 157–167.

[19] Philip Kortum and Claudia Ziegler Acemyan. 2013. How low can you go?: is the system usability scale range restricted? *Journal of Usability Studies* 9, 1 (2013), 14–24.

[20] Chris D Kounavis, Anna E Kasimati, and Efpraxia D Zamani. 2012. Enhancing the tourism experience through mobile augmented reality: Challenges and prospects. *International Journal of Engineering Business Management* 4 (2012), 10:1–10:6.

[21] Panos Kourouthanassis, Costas Boletsis, Cleopatra Bardaki, and Dimitra Chasanidou. 2015. Tourists responses to mobile augmented reality travel guides: The role of emotions on adoption behavior. *Pervasive and Mobile Computing* 18 (2015), 71–87.

[22] Panos E Kourouthanassis, Costas Boletsis, and George Lekakos. 2015. Demystifying the design of mobile augmented reality applications. *Multimedia Tools and Applications* 74, 3 (2015), 1045–1066.

[23] Steinar Kristoffersen and Fredrik Ljungberg. 1999. Designing interaction styles for a mobile use context. In *Proceedings of the International Symposium on Handheld and Ubiquitous Computing.* Springer, 281–288.

[24] Charlotte Magnusson, Konrad Tollmar, Stephen Brewster, Tapani Sarjakoski, Tiina Sarjakoski, and Samuel Roselier. 2009. Exploring future challenges for haptic, audio and visual interfaces for mobile maps and location based services. In *Proceedings of the 2nd International Workshop on Location and the Web.* ACM, 8:1–8:4.

[25] Lev Manovich. 2006. The poetics of augmented space. *Visual Communication* 5, 2 (2006), 219–240.

[26] Anna Michael and Costas Boletsis. 2017. A Tourism Model Shift for Historic Cities: Valorising the Musical Heritage through ICT. *e-Review of Tourism Research* ENTER 2017 Volume 8 Research Notes (2017), 1–6.

[27] Jason Pascoe, Nick Ryan, and David Morse. 2000. Using while moving: HCI issues in fieldwork environments. *ACM Transactions on Computer-Human Interaction (TOCHI)* 7, 3 (2000), 417–437.

[28] Solène Prince. 2017. Cohen's model of typologies of tourists. In *The SAGE International Encyclopedia of Travel and Tourism.* SAGE Publications, 280–282.

[29] Dimitrios Ringas, Eleni Christopoulou, and Michail Stefanidakis. 2011. CLIO: blending the collective memory with the urban landscape. In *Proceedings of the 10th International Conference on Mobile and Ubiquitous Multimedia.* ACM, 185–194.

[30] Christoph Stahl. 2007. The roaring navigator: a group guide for the zoo with shared auditory landmark display. In *Proceedings of the 9th International Conference on Human-Computer Interaction with Mobile Devices and Services.* ACM, 383–386.

[31] Delphine Szymczak, Kirsten Rassmus-Gröhn, Charlotte Magnusson, and Per-Olof Hedvall. 2012. A Real-world Study of an Audio-tactile Tourist Guide. In *Proceedings of the 14th International Conference on Human-Computer Interaction with Mobile Devices and Services.* ACM, 335–344.

[32] Thomas S Tullis and Jacqueline N Stetson. 2004. A comparison of questionnaires for assessing website usability. In *Proceedings of the Usability Professional Association Conference.* 1–12.

[33] Yolanda Vazquez-Alvarez, Ian Oakley, and Stephen A. Brewster. 2012. Auditory Display Design for Exploration in Mobile Audio-augmented Reality. *Personal and Ubiquitous Computing* 16, 8 (2012), 987–999.

[34] Z Yovcheva, D Buhalis, and C Gatzidis. 2012. Overview of smartphone augmented reality applications for tourism. *e-Review of Tourism Research* 10, 2 (2012), 63–66.

[35] Andreas Zimmermann and Andreas Lorenz. 2008. LISTEN: a user-adaptive audio-augmented museum guide. *User Modeling and User-Adapted Interaction* 18, 5 (2008), 389–416.