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Virtual Reality for Prototyping Service Journeys

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Abstract: The use of virtual elements for developing new service prototyping environments and more realistic simulations has been suggested as a way to optimise the service prototyping process. This work examines the application of virtual reality (VR) in prototyping service journeys and it hypothesises that VR can recreate service journeys in a highly immersive, agile, and inexpensive manner, thus allowing users to have a representative service experience and enabling service designers to extract high-quality user feedback. To that end, a new service prototyping method, called VR service walkthrough, is presented and evaluated through an empirical comparative study. A VR service walkthrough is a virtual simulation of a service journey, representing how the service unfolds over space and time. A comparative study between the VR service walkthrough method and an adapted service walkthrough method evaluates the application of both methods using a location-based audio tour guide service as a case study. Two user groups (each with 21 users) were used to evaluate both methods based on two factors: the user experience they offered and the subjective meaningfulness and quality of feedback they produced. Results show that the VR service walkthrough method gave a performance similar to that of the service walkthrough method. It was also able to communicate the service concept in an immersive way and foster constructive feedback.

Keywords: service design; service prototyping; service walkthrough; user experience; virtual reality

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1. Introduction

Service prototyping is a significant and integral part of service design. It aims to increase the designer's ability to empathise with intended users, customers and other stakeholders in the service [1,2]. A service prototype is 'a simulation of a service experience' [3], and an important service design tool for making services visible and helping to communicate service concepts at the early stages of the new service development process [4]. Service prototyping contributes to the service design process by (i) defining the service design problems to be solved, (ii) evaluating the usability and effectiveness of a service concept, and (iii) enabling collaboration between the different actors (e.g., users, stakeholders, service providers) [5,6]. To understand service experiences, service designers need to capture both physical and intangible service qualities. They should also portray the sequence of interactions that take place between the service provider and the service user, through service prototyping [7]. The most crucial factor in the service prototyping process is the ability to create a realistic sensation for the users and to immerse them in these service experiences [5,8].

The most prevalent kind of services are the ones that can be described as journeys [9]. Service journeys represent a chronological sequence of interactions between users and service providers, containing both physical and intangible qualities [9]. In order to present and evaluate a service journey and improve its design, the service must be understood as a whole service experience: all interactions or touchpoints with the user should be thought of holistically [10]. When understood and experienced holistically, as a whole sequence, service parts, service moments and touchpoints will reveal something about the service that cannot be accessed through the individual service constituents [7]. When it comes to prototyping service journeys, the main prototyping goal is to empathise with the targeted user group. For service designers, a number of challenges are posed by the necessity of following a holistic design approach and the need for the experiential, physical and intangible qualities of the service to be recreated with adequate precision [7,9,11]. A major prototyping issue lies with the significant design choices that need to be made during the early stages of the new service development process with regard to balancing the prototype's fidelity, development agility and cost: the target is the highest possible level of fidelity and agility at the lowest possible cost [7,11]. These choices concern the use of appropriate prototyping tools and methods that will enable the service prototype to immerse users in the whole service experience, empathise with them and ultimately extract useful and high-quality user feedback about the service experience [5,8].

2. Background and Research Motivation

A number of prototyping methods and tools can be used to prototype service journeys. At the conceptual level, tools like customer journey maps and service blueprints can describe the main interactions of a service journey; however, they are limited in their ability to recreate the experiential qualities of the service and relay information associated with service periods and interactions with users at touchpoints [8,12]. At a more practical level, methods like bodystorming, experience prototyping and service walkthroughs have been used to prototype service journeys. Bodystorming is an interaction design method, which is used in service design to evaluate service prototypes from an experiential point of view [5]. It enables the user to enact and role-play the service scenario in prototyping environments that resemble the intended use context [13–15]. Experience prototyping is an approach that attempts to understand the experience of interacting with an artefact, system or service [5,7,16]. This approach is similar to bodystorming in that it tries to replicate an existing situation or construct a new one, in which participants can understand in an embodied way what it feels like to interact with something [7]. However, these two methods have normally been used to focus on single touchpoints rather than to understand whole service experiences [5,7].

By contrast, the service walkthrough is an established service prototyping method specifically tailored for service journeys. This method is usually facilitated by service designers, allowing them to put themselves in the shoes of the users and, along with the targeted user or customer groups, to go through a physical representation of how the service journey unfolds over space and time [1,7]. In a service walkthrough, all stakeholders can take part in the service representation and understand the service by being physically and emotionally present in the situation of use. As a service prototyping method, the service walkthrough originates from a combination of experience prototyping, a pluralistic walkthrough and bodystorming. It offers a way to increase empathy with the potential customer group by going through the whole service and using props to represent certain actions [1,7]. Although the service walkthrough takes place in the real world, in the actual or a similar servicescape, it makes use of physical props and mock-ups, which makes it 'difficult to get the feel for how a customer journey would be experienced' when prototyping [7]. As a result, the use of multimedia is suggested as a way to further improve it [7].

The need for new service prototyping methods that can offer more realistic simulations has been reported and the use of virtual elements for developing new service prototyping environments has been suggested as a way to address the limitations of the conventional methods and to optimise the service prototyping process [5,8,17]. The need for realistic service representations has also been emphasised [7]. Virtual reality (VR) has the potential to overcome some of the current prototyping limitations by offering high-quality visual, audio and haptic simulations [8,18]. VR has already found broad application in engineering, industrial and product design for prototyping purposes [18,19]. Over the last few years, major changes in the VR technology field have taken place, which have allowed the development of low-cost, high-quality, immersive and collaborative 3D virtual environments, opening the way for the use of VR in service prototyping [8,11,20].

This work examines the application of VR in prototyping service journeys, hypothesising that VR can recreate service journeys in a highly immersive, agile and inexpensive manner, thus allowing users to have a representative service experience and enabling service designers to extract high-quality user feedback. To that end, a new service prototyping method, called *VR service walkthrough*, is presented and evaluated through an empirical comparative study. The method is inspired by the service walkthrough described by Arvola et al. [7] and it was first introduced in [21]. The VR service walkthrough focuses on prototyping service journeys by making use of VR environments and digital artefacts.

The following section (Section 3) presents the VR service walkthrough. Section 4 presents a service prototype case study, i.e., a mobile, location-based audio tour guide. In Section 5, this case study is examined by comparing the methods of the VR service walkthrough with the established service walkthrough method, adapted to utilise multimedia content (instead of physical props and mock-ups as described in [7]). Finally, the study results are presented (Section 6) and discussed (Section 7).

3. A VR-Based Prototyping Method for Service Journeys

A VR service walkthrough is a virtual simulation of a service journey, representing how the service unfolds over space and time. The method aims to facilitate the development and evaluation of medium-to-high fidelity service prototypes with distinct spatial elements and customer journeys, utilising fully immersive virtual technology [21]. The VR service walkthrough is facilitated by the service designer and involves actual service users and service stakeholders as prototype testers. The method allows designers to explore, evaluate and communicate service concepts in a holistic way, capturing the service as a whole. At the same time, it enables service users to immerse themselves in the virtual prototyping environment, interact with service components in virtual form and experience the service journey in VR [21].

The VR service walkthrough is based on the service walkthrough prototyping method, which adopted elements from experience prototyping, the pluralistic walkthrough and bodystorming [7]. Undoubtedly, these elements, along with the evaluation protocol, were also inherited by the VR service walkthrough in addition to the use of VR as the enabling technology of the method [21]. Pluralistic walkthroughs provide the protocol and the interaction components of the main process, allowing the exploration of the prototype by the user. Bodystorming is a necessary element of the process, although the fact that the VR service walkthrough can potentially reach high levels of fidelity may minimise the need for role playing [21]. Experience prototyping, however, is the focus of the new VR service walkthrough method as the ability to prototype and capture the experience of interacting with a service is crucial, especially when this experience is mediated by VR, thus creating a fully immersive, simulated and situated experience [21].

The VR service walkthrough method is designed to enable medium-to-high fidelity prototyping as well as to be effective in terms of development agility and cost. The VR service walkthrough, due to its technical nature, targets agile development and on-the-fly adjustment of the service components, based on the service user's feedback, so that more observations and conclusions can be drawn from the service prototyping session [21]. At the same time, the development cost of the prototyped services should be affordable, ranging from low-to-medium cost, depending on the chosen hardware and the simulated scenario. The use of high-quality VR headsets, like the HTC Vive or the Oculus Rift and the development of customised, detailed graphic environments can be costly, although the use of smartphone-based headsets (e.g., Google Cardboard) and commercial off-the-shelf (COTS) applications can minimise the cost significantly [21].

In order to evaluate the service experience coming from the VR service walkthrough method, a comparative study was carried out using a location-based audio tour guide service as a case study.

4. The Case: Location-Based Audio Tour Guide Services

As tourism is a service-intensive industry dependent on the quality of customer service experiences and customer journeys, service prototyping has found many applications in evaluating tourism services [22–24]. This section introduces a case study built on the development of a mobile, location-based audio tour guide service for the city of Oslo, Norway.

The qualities of location-based audio guide services for tourism have been researched in the past both in indoor settings (e.g., museums) and confined outdoor spaces (e.g., zoos), with promising potential [25–29]. However, there is a need for further research on new location-based audio guide services that enable tourists to freely explore open, outdoor urban environments in a culturally informative way while also supporting social interaction and shared experiences [30–33].

4.1. Service Concept

A mobile tour guide service for the city of Oslo, namely AudioNear, was designed at SINTEF Digital, using location-based audio to enable tourists to navigate on foot and explore outdoor tourist sights by providing on-the-go, speech-based auditory information about various sites (buildings, landmarks, monuments, etc.) located in the vicinity [30]. AudioNear was designed to support two functionalities: *exploration* and *route planning/navigation*. 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 starts playing with various pieces of information about that place (Figure 1). Users can control the audio track playback with the headphones' mic button so that interacting with the guide's graphical interface is not necessary when moving about. 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 the map to locate the nearest sights, choose the ones they want to visit, based on the information provided, and navigate towards them. The design of the AudioNear service utilises the existing literature on related domains and related application contexts in order to synthesise the starting material and the initial design concepts for creating a new tour experience in an urban setting [30].

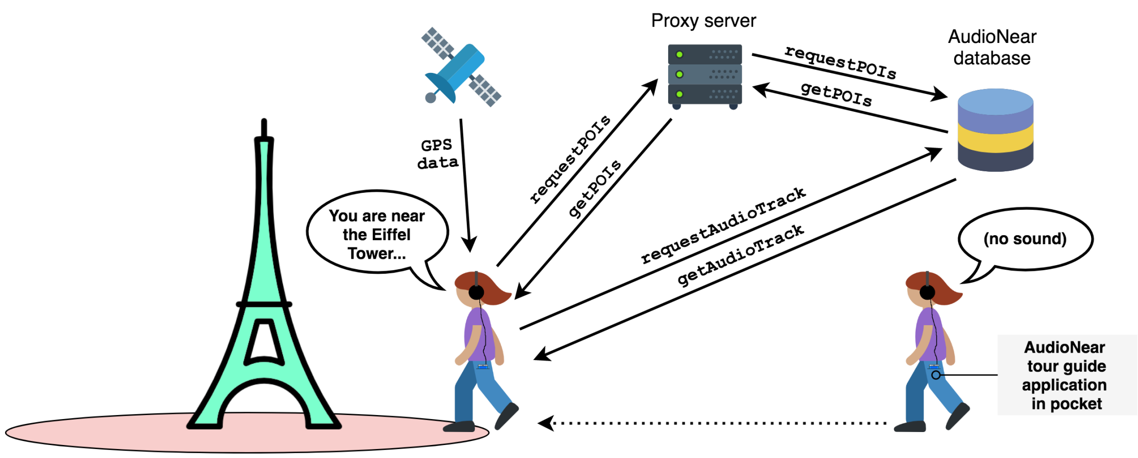

Figure 1. The designed architecture for the location-based audio tour guide, describing its radius-activated functionality for a user entering a tourist sight's radius.

4.2. Design Rationale

The main design goal of the service is to enable tourists to explore tourist sites and get all the site-related, tourist information at one time and in one place so that they can 'interpret' the environment and find out more about the cultural heritage of the place that is being visited [30,32,34,35]. At the same time, this information should be delivered in an unobtrusive and undisruptive way so that tourists can focus on their surroundings; therefore, minimising the distraction coming from the interaction with their mobile devices is important [29,32,34,36]. Auditory information and minimal-attention interfaces can offer a promising alternative to graphical user interfaces, accomplishing eyes-free interaction and minimised distraction [37–40]. For AudioNear, the use of location-based auditory content was chosen as an appropriate way to accomplish the main design goal. A number of important design decisions were also made to develop a minimal-attention interface and further minimise distraction [30]. More specifically, AudioNear was designed to work right out of the box upon launch, without requiring extra user information or further adjustments. Interaction with the audio tracks was designed to take place through the headphones' mic button (tap button once to pause/stop playing track, tap button twice to replay track) so that the user would not need to interact with the mobile device. The audio tracks were designed to be short and concise, and no sound was produced when the user was outside the radius of a sight. As a result, the user could still pay attention to external, environmental sounds while exploring (Figure 1).

In addition, the way the service content is delivered should satisfy the needs of different tourist types and address different styles of experiencing a new environment as a tourist [29,30,41,42]. AudioNear was designed to support two functionalities, as described in Section 4.1: (1) as service users explore the city, auditory information is presented to them based on their location, and (2) service users can check the map of the tour guide to locate the nearest point of interest and move towards it. These two functionalities are designed to serve both those users who prefer unstructured touring experiences, i.e., to explore a tourist site based entirely on what they see and like, and those users who need structure and planning for their tours. After launching the app, the user does not need to check the smartphone again unless he/she wants to locate and navigate to the nearest point of interest through the service's map functionality [21,30].

Finally, another design goal was to implement a robust spatial activation method for the audio tracks that would also support shared, multi-user tour experiences [30]. The tour guide service should create a shared auditory and social experience and operate uniformly for users moving in groups (e.g., families) [25,29]. To fulfil this requirement and avoid being bound by specific hardware (e.g., headphones for directional audio), a radius-based approach was taken which defines activation zones in close proximity to particular tourist sights (Figure 1). This design concept allows for the automatic triggering of the audio track when a user is inside the radius of a tourist sight, while a group of users moving together will receive the same auditory information at the exact same time when in radius, thus creating a shared auditory experience [27,29].

4.3. Service Prototype's Characteristics

Following the conceptualisation and design of the service, the implementation of a prototype was necessary in order to communicate the service concept, evaluate its functionality and get useful feedback from service users. The service prototype had to recreate the whole user journey in a way that communicated the service concept and conveyed the service experience.

Sixteen sights in the Oslo city area were chosen for inclusion in the prototype version of the service. The radius values of these sights ranged between 25 and 65 m and were strategically and manually placed for each sight so that they only referenced areas where the sight was clearly visible.

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 the users that they had entered a sight's radius and that speech-based auditory information was about to start. This was followed by a three-second pause before the speech-based track started with the words: 'You are near <name of tourist sight>'. The duration of the tracks was between 65 and 90 s in order to present distinct values and allow the investigation of user preferences for track duration. The tracks were encoded and compressed into MP3 format to reduce their file size.

In this case study, two service prototypes for a service journey were implemented and evaluated: one using the VR service walkthrough method and the other using the service walkthrough method, adapted for the use of multimedia content.

4.4. Service Prototyping with the VR Service Walkthrough Method

A VR service walkthrough was used to prototype the AudioNear tour guide service. The current implementation of the VR service walkthrough method used a medium-fidelity prototype of the service journey. It was relatively inexpensive with regard to man-hours and equipment costs.

Google Street View VR was used to enable the service user to virtually navigate the city of Oslo. It provided the user location to trigger the respective audio track when the user was in the radius of a point of interest. The map functionality of the service was facilitated by Google Maps, enabling the user to get a map overview of the surroundings and the places of interests in the area. VR hardware consisted of an Android smartphone, a generic VR headset and a wireless mouse for interaction/navigation purposes. The service user also wore headphones (Figure 2). Ambient sound effects (i.e., people walking in the street) were also added to give more realism to the scene for immersion purposes [21].

Figure 2. (**Left**): Conducting the VR service walkthrough with the service designer "accompanying" the service user. (**Right**): A screenshot of the user's VR view.

At this stage, the walkthrough involved one user per session, focusing on individual feedback. The service user had the opportunity to virtually visit several monuments in the city of Oslo and to listen to historical information about them when he/she was located in their vicinity. At any time, the user could check the VR map, locate the nearest place of interest and navigate there [21].

The service designer moderated the VR service walkthrough session, 'accompanying' the users in the virtual tour by observing their service journeys via screen and audio mirroring. While navigating, the user was free to make comments and express thoughts and opinions on the service to the service designer and to describe the whole experience. The service designer documented user feedback and followed up on the user's remarks, always in an investigative, discreet and unobtrusive way without disturbing the flow or distracting the user [21]. With regard to pausing or not pausing the walkthrough session to collect user feedback [10], the VR service walkthrough adopted a middle strategy. The designer identified specific use periods where no points of interest existed in the vicinity and where the service was less intense and demanding from a cognitive perspective. These periods allowed for short discussions, questions and follow-up on the user's remarks without breaking immersion for the user [21].

4.5. Service Prototyping with the Service Walkthrough Method

The service walkthrough method was also used to prototype the AudioNear tour guide service. The current implementation of the service walkthrough method was adapted for multimedia content—as suggested by [7]—and, more specifically, a mobile app prototype in order to better demonstrate the main service functionality and to provide a high-fidelity prototyping experience. Naturally, this implementation demanded several man-hours for interface design and app development purposes.

The AudioNear mobile app was written in PHP and MySQL, using the AR Layar API. (https://www.layar.com) The Layar platform enabled the development of the planned location-based, radius-activated audio experience, with map-based navigation (Figure 3). The prototype was developed as a web-based application, using a 4G broadband connection [30].

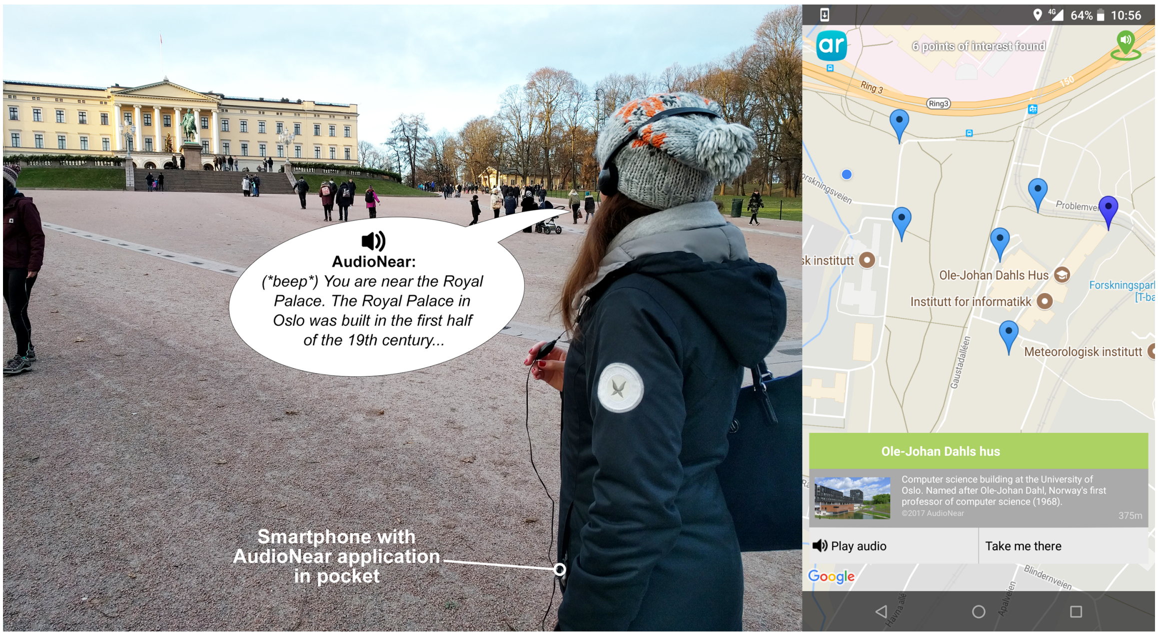

Figure 3. (**Left**): The user utilises AudioNear to explore Oslo during a service walkthrough. When the user approaches a landmark, an audio track with cultural information begins to play. (**Right**): A screenshot of the map from the AudioNear app.

At the beginning of the service walkthrough session, users were given a basic description of the tour guide's functionality. An Android smartphone and headphones were provided for running the application. Users then launched the AudioNear app and examined the map of tourist sights. Participants were completely in charge of the service walkthrough's route planning and navigation. Next, the author (who was also the service designer and developer) took part in a service walkthrough, accompanying each participant while they were exploring the area and experiencing the service prototype (Figure 3). 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 interaction with the tour guide and discussing its usability [30].

5. Evaluation Study

A comparative study of the two service prototyping methods, i.e., the VR service walkthrough and the adapted service walkthrough methods, took place to evaluate their application in the location-based audio tour guide service case study. In the context of this study, the VR service walkthrough was designed to be compared against the extreme case of a highly performing method, i.e., a prototyping method based on the real world and using a high-fidelity prototype. The service walkthrough method was adapted for this purpose. The adapted version used multimedia content (audio files, photos, digital map, location-based system, et al.) whose delivery through a mobile app took place as intended in the final service. In addition, the entire prototyping session took place outside, in the real service environment.

The main hypothesis of the study was that the immersive, engaging and experiential qualities of VR would increase the performance and outcome of a 'quick and dirty' implementation of a medium-fidelity prototype when a structured prototyping process is in place. When it comes to prototyping service journeys, a further hypothesis was that this VR-based method, together with a medium-fidelity prototype, would successfully communicate the service concept and offer an engaging user experience, similar to what can be achieved by a conventional prototyping method using a high-fidelity prototype.

As stated in Section 1, prototyping methods aim at communicating the service concept and recreating the experiential qualities of the service journey in the best way possible. As a result, the evaluation of the two prototyping methods was based on two factors. As the experiential qualities of the prototyping process are crucial in the quest to simulate the service experience, the first factor was a direct evaluation measure of the two methods by examining the user experience they offered [3,5,8]. A user experience questionnaire was administered to evaluate this factor. As user feedback can be indicative of how well the service concept is communicated and understood through the prototyping process, the second factor was an indirect evaluation measure of the two methods through the subjective meaningfulness and quality of feedback produced for the audio tour guide service [7,21]. This factor was investigated by carrying out a semi-structured interview.

The study followed a between-group design, with users of group A experiencing service prototyping with the VR service walkthrough method and users of group B using the service walkthrough method, as described in Sections 4.4 and 4.5. Participants were assigned to the groups based on block randomisation with equal sample sizes. A 10-minute trial session for users of both groups was conducted, allowing them to test the prototypes before the walkthroughs, in order to familiarise themselves with the interaction methods and to minimise any technological 'wow' factor that could potentially affect user feedback. Six sights surrounding the research institute where the study was conducted were chosen as points of interest for user exploration, both in VR and real life, during the two prototyping sessions. The six sights were chosen so that users of both groups would be able to experience touring the same area and so that the duration of the walkthroughs would be adequate for presenting the service concept with both methods. The sessions of exploring these six sights would last between 25 and 35 min, based on pilot testing.

5.1. Measures

The comparative study used the Game Experience Questionnaire (GEQ) [43] and a semi-structured interview. The GEQ is a user experience questionnaire that has been used in several application fields (gaming, location-based apps, VR, et al.) because of its ability to cover a wide range of experiential factors with good reliability [44–51]. In this study, the experiential components of competence, sensory and imaginative immersion, flow, tension, challenge, and negative and positive affect (from the In-Game version of the GEQ) were considered to be relevant and useful for the evaluation of both methods. The questionnaire asked the user to indicate how he/she felt during the prototyping process based on a series of statements. The GEQ questionnaire contained 14 statements (e.g., 'I forgot everything around me'), rated on a five-point intensity scale ranging from 0 ('not at all') to 4 ('extremely').

The semi-structured interview collected participants' comments on three topics, expressed as questions: (1) what they liked about the service, (2) what they did not like about the service, and (3) what they suggested for improving the service. The researcher was able to follow up on the participants' comments until each topic was covered.

5.2. Process

The study process took place as follows. First, study consent and demographics were collected. Each participant was randomly assigned to one of the two experimental groups. The service prototyping session then took place, making use either of the VR service walkthrough or the service walkthrough method, depending on the participants' experimental group. A 10-min trial took place before the main session. Afterwards, the semi-structured interview was administered to collect user feedback on the service. Finally, user experience from both prototyping methods was measured using the Game Experience Questionnaire [43].

Pilot testing of the process took place to examine its feasibility, its duration and the prototyping session's ability to adequately present the service content in this time frame. The total duration of the study process was estimated to be 60 to 75 min.

5.3. Statistical Analysis

All data was analysed using the Statistical Package for Social Sciences (SPSS) version 25. Descriptive analysis was used to depict the demographic data of the participants. The non-parametric Mann-Whitney U test was used to compare differences between the two independent groups. The significance level was set at $p < 0.05$. Open coding was used to identify and organise the participants' comments from the interviews.

6. Results

Forty-two participants were assigned to the two experimental groups: group A (N_A = 21, mean age: 30.29, SD: 4.23, male/female: 12/9) used the VR service walkthrough method and group B (N_B = 21, mean age: 28.76, SD: 3.66, male/female: 14/7) used the service walkthrough method. All participants had previously used personal tour guides, such as travel books or mobile applications, at least once before in their trips. All six sights in the area were visited by the participants, with a tour duration of between 25 and 34 min (mean duration: 29.62, SD: 2.09) for group A and between 26 and 36 min (mean duration: 31.1, SD: 2.93) for group B. Five participants from group A were novice VR users, twelve were moderately experienced, having used VR applications in the past, and four were very experienced, actively using VR applications and owning VR systems. All participants from both groups successfully completed the sessions.

Figure 4 displays the values from the GEQ questionnaire and Table 1 shows an analysis of results using the Mann-Whitney U test. The results revealed that the service walkthrough achieved higher values in all GEQ components. However, the differences between the two methods had statistical significance only for the competence value, with a mean rank spatial score of 17.31 for the VR service walkthrough and 25.69 for the service walkthrough (Z = −2.331, p = 0.020). The service walkthrough performed better for tension, challenge and positive affect, in particular. However, this did not reach statistical significance (Table 1).

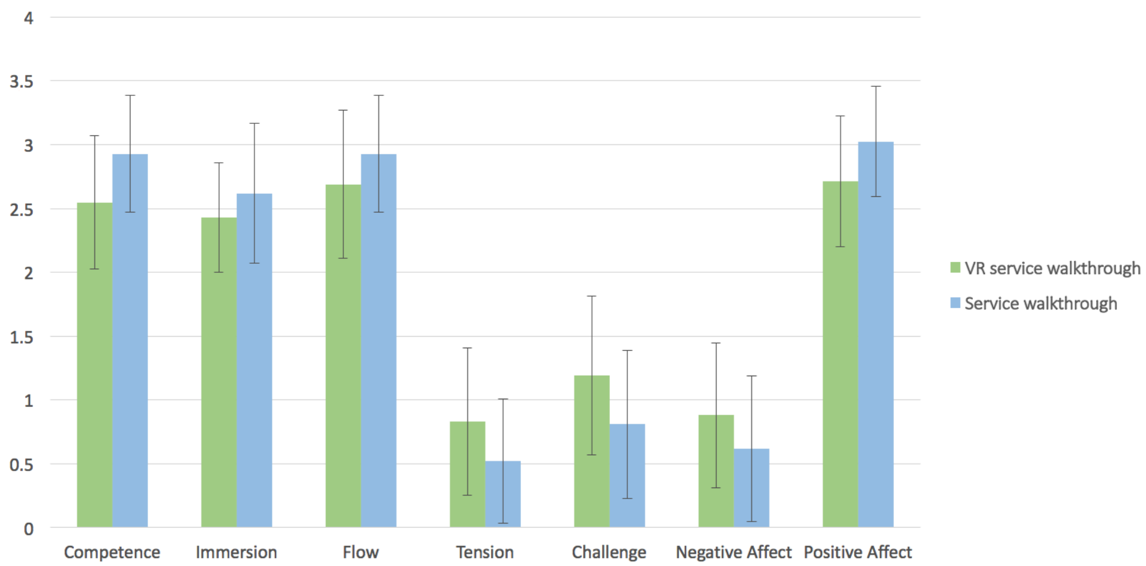

Figure 4. Mean GEQ values (with standard deviation bars) across seven experiential dimensions.

Table 1. The results of the Mann-Whitney U test for the examined methods.

GEQ Components	Mean Rank VR Service Walkthrough	Mean Rank Service walkthrough	Z	Sig. (2-Tailed) *
Competence	17.31	25.69	−2.331	0.020
Immersion	19.29	23.71	−1.249	0.212
Flow	19.10	23.90	−1.320	0.187
Tension	24.69	18.31	−1.757	0.079
Challenge	25.00	18.00	−1.915	0.056
Negative Affect	24.17	18.83	−1.453	0.146
Positive Affect	18.19	24.81	−1.868	0.062

* Significance level: $p < 0.05$.

Table 2 shows the results of the qualitative analysis of the interview comments together with the frequency of their occurrence. Positive comments highlighted the simple interaction with the tour guide, the usefulness of auditory information, the suitability of the service for a free exploration of open spaces and its use in larger user groups (e.g., families, groups of tourists, et al.). Negative remarks focused on the duration of the audio tracks and the fact that the service could do with more structure by offering suggested, predefined routes. Comments included several suggestions for improvement, such as adding suggested, pre-defined routes, gamification elements (e.g., collecting location-based badges like Foursquare or digital objects like Pokémon GO), user ratings for sights, voice commands for manipulating the audio tracks and 3D/spatial audio for creating the impression that the sound of a virtual source emanated from a certain position in the physical space. One participant also suggested the use of location-based advertisements for businesses in the user's vicinity, implemented as short individual audio tracks.

Table 2. The users' comments as collected from the interview sessions.

	Interview Comments	Group A VR Service Walkthrough	Group B Service Walkthrough
P	The tour guide is simple and easy-to-use	16	18
P	Auditory information allow to focus on surroundings	13	16
P	The tour service is suitable for free exploration	11	15
P	The tour guide is suitable for user groups	1	9
N	Some audio tracks were too long	17	16
N	The tour guide did not provide suggested routes	12	14
S	The tour guide could suggest specific routes	12	15
S	The tour service could be gamified	9	9
S	The tour service could feature location-based ads	-	1
S	The tour guide could feature sights' user ratings	3	9
S	The tour guide could utilise voice commands	2	6
S	The tour guide could use 3D audio	7	6

* P: Positive comment, N: Negative comment, S: Suggestion.

7. Discussion

The use of both the GEQ questionnaire and the semi-structured interview allowed for the discovery, verification and documentation of significant experiential and practical issues. The GEQ questionnaire provided a general overview of each method's experiential performance, whereas the interview shed more light on how well the service was understood. This tourism-related case study and the audio tour guide service provided an ideal testbed to evaluate the performance of both methods for prototyping service journeys. Users were engaged by the AudioNear tour guide service, interacting with the prototypes and providing feedback about them. In addition, user suggestions shed more light on further development of the service, raising and addressing important design issues (e.g., adding routes, shortening the audio tracks, gamifying the service).

At first glance, the GEQ results indicated that the service walkthrough method with multimedia content received higher values than the VR service walkthrough method. Indeed, the GEQ revealed differences in experiential values in favour of the service walkthrough method. However, only the competence dimension showed a statistically significant difference. At the same time, the VR service walkthrough demonstrated a satisfying GEQ performance overall. GEQ results revealed higher values for positive feelings than negative ones, demonstrating that the method offered a pleasant experience. Flow and immersion reached moderate to high levels, showing that users were focused on the process and that VR managed to construct an immersive experience close to the real-world one (as implemented in the service walkthrough method). Based on the competence and challenge values, the evaluation also suggested that users may find use of the VR method somewhat demanding. As shown in a previous study [21], VR interaction can be challenging for novice users. The VR service walkthrough immersion may come at a cost, especially to those who are not familiar with VR. Although people will become more and more familiar with VR with the passage of time, its intense immersive characteristics may be an obstacle for the novice VR user of the VR service walkthrough method.

Interview comments about the service were used as an indirect measure of how well the service concept was communicated. This comparison was exploratory in nature, working as an attempt to document which topics were addressed by both groups, the differences between the groups and what these differences may mean for the different methods. The interview results showed that almost all feedback topics raised by group B were also covered by group A, even if at different frequencies. Positive comments about the suitability of the tour guide for groups of users was the only response that demonstrated a considerable frequency difference between the two groups. The comment was made only once in group A (VR service walkthrough), perhaps meaning that this method was unable to demonstrate the multi-user capabilities of the concept. This result may suggest that the service designer being present in the real world, accompanying the users by mirroring their virtual actions, and users being present in the virtual world may disrupt the communication of a multi-user experience, such as the one that took place during the service walkthrough session. Although the specific implementation may be suitable for recreating single-user experiences, in the case of communicating multi-user service concepts, the VR service walkthrough method may benefit from having all users (regular users, service designer, developer and other participating stakeholders) present inside the virtual environment, thus creating a virtual, multi-user experience.

The main observation to be made about the results of the comparative study is that the VR service walkthrough method with a medium-fidelity prototype had a similar performance to that of the multimedia service walkthrough method using a high-fidelity prototype. In this case, the actual comparison was between the immersive qualities of VR and a superior implementation (regarding cost and fidelity) for prototyping service journeys. In the end, results suggest that these VR qualities managed to boost the prototyping performance of a medium-fidelity prototype. The structured VR service walkthrough method communicated the service concept and recreated the service experience to a high degree. Although there is always a proportional relationship between prototyping costs and prototype fidelity, VR's immersive qualities can potentially disrupt this balance in favour of the service designer, thus achieving more with less.

However, it should also be noted that this efficiency is achieved on a case-specific basis, meaning that services with different characteristics and prototyping resources (i.e., available budget and time) may require a different balance between cost and fidelity when it comes to VR-based prototyping. Nowadays, there are many tools available for the development of VR environments, such as 360-degree videos, COTS applications (e.g., Google Street View VR), VR sandboxes (e.g., ModBox) and VR development platforms (e.g., Unity), as well as various low- and high-cost VR headsets (e.g., Google Cardboard, HTC Vive, Oculus Rift, et al.). The choice of the appropriate tools, their utilisation for prototyping purposes and the overall cost-benefit evaluation and decision about using the VR service walkthrough method is a case-specific process and an important task for the service prototyping team. It should also be stressed that the VR service walkthrough addresses certain service prototyping conditions and covers a specific range of services. The VR service walkthrough targets the representation of service journeys and attempts to capture the sequences of mediated interactions between service provider and customer in a service prototype. Tourism and travel services are strongly temporal and sequential in nature, involving a series of interactions. As a result, the proposed service prototyping method could find a wide application in that field or similar fields with those characteristics. This would optimise the trade-off between prototype fidelity and cost while providing a viable way for service designers to empathise with target groups.

Finally, the current work has certain limitations. First, the study was limited by its moderate sample size. In addition, the VR service walkthrough was compared against an adapted high-performance prototyping method. In order to cover the 'prototyping fidelity' scale more extensively and to present the VR-enabled method in a more concrete way, additional comparisons against other prototyping methods with potentially lower performance should be carried out, e.g., by using a traditional service walkthrough with props and mock-ups [7].

8. Conclusions

This work introduced and evaluated a prototyping method for service design that applies the service walkthrough concept in fully immersive VR settings. The method addresses service journeys and aims at enabling the service designer to increase empathy with the potential customer group through optimising the service prototyping process to create more immersive and engaging service-simulated environments.

The case study on tourism and the comparative study against an established prototyping method using a high-fidelity prototype proved to be ideal tools for evaluating the VR service walkthrough method and documenting its strengths and weaknesses. The study results show that this method can communicate the service concept in an engaging and immersive way and can foster constructive feedback. However, the method may present some interaction challenges and may not fully support multi-user experiences, thus needing further technical adjustment. Overall, the VR service walkthrough method performed satisfactorily using its immersive VR qualities to advance the prototyping performance of a medium-fidelity prototype.

The current work and the introduction of VR service walkthrough provide the opportunity for organisations, businesses, designers, and researchers to reproduce and further advance the method. Hopefully, this work will further contribute to the discussion around the potential of VR in service design, which, until recently, was an under-researched field [8,11,21].

Future work will address the aforementioned technical issues. In addition, more case studies are necessary in order to further document the method's efficiency in the same or similar fields. At the same time, additional case studies will also contribute by exploring various service scenarios and technical VR implementations that may differentiate the application of this method. This will help enable the formulation of robust guidelines for the method's application in various settings.

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References

1. Blomkvist, J.; Bode, A. Using Service Walkthroughs to Co-Create Whole Service Experiences. In Proceedings of the International Service Innovation Design Conference, Tainan, Taiwan, 22–24 October 2012; Volume 3, pp. 1–7.
2. Miettinen, S. Service Prototyping in Action. *Touchpoint J.* **2011**, *3*, 2.

3. Stickdorn, M.; Schneider, J. *This is Service Design Thinking: Basics, Tools, Cases*; Wiley: Hoboken, NJ, USA, 2012.
4. Blomkvist, J.; Holmlid, S. Existing Prototyping Perspectives: Considerations for Service Design. In Proceedings of the Nordic Design Research Conference, Helsinki, Finland, 29–31 May 2011; pp. 1–10.
5. Simo, R.; Miettinen, S.; Kuure, E.; Lindström, A. A laboratory concept for service prototyping-Service Innovation Corner (SINCO). In Proceedings of the ServDes. 2012: Service Design and Innovation Conference, Espoo, Finland, 8–10 February 2012; Linköping University Electronic Press: Linköping, Sweden, 2013; pp. 229–241.
6. Chasanidou, D.; Karahasanovic, A. Open Service Innovation Platforms and Experience. In Proceedings of the ServDes. 2014: Service Design and Innovation Conference, Lancaster, UK, 9–11 April 2014; Linköping University Electronic Press: Linköping, Sweden, 2014; pp. 440–445.
7. Arvola, M.; Blomkvist, J.; Holmlid, S.; Pezone, G. A service walkthrough in Astrid Lindgren's footsteps. In Proceedings of the ServDes. 2012: Service Design and Innovation Conference, Espoo, Finland, 8–10 February 2012; Linköping University Electronic Press: Linköping, Sweden, 2012; pp. 21–29.
8. Jung Bae, D.; Seong Leem, C. A visual interactive method for service prototyping. *Manag. Serv. Qual.* **2014**, *24*, 339–362.
9. Blomkvist, J.; Åberg, J.; Holmlid, S. Service walkthroughs to support service development. In Proceedings of the ServDes. 2012: Service Design and Innovation Conference, Espoo, Finland, 8–10 February 2012; Linköping University Electronic Press: Linköping, Sweden, 2013; pp. 43–52.
10. Blomkvist, J.; Arvola, M. Pausing or not? Examining the service walkthrough technique. In Proceedings of the 28th International BCS Human Computer Interaction Conference, Southport, UK, 9–12 September 2014; pp. 171–176.
11. Boletsis, C.; Karahasanovic, A.; Fjuk, A. Virtual Bodystorming: Utilizing Virtual Reality for Prototyping in Service Design. In Proceedings of the International Conference on Augmented Reality, Virtual Reality and Computer Graphics, Ugento, Italy, 12–15 June 2017; Springer: Berlin, Germany, 2017; pp. 279–288.
12. Holmlid, S.; Evenson, S. Prototyping and enacting services: Lessons learned from human-centered methods. In Proceedings of the 10th Quality in Services conference, Orlando, FL, USA, 14–17 June 2007; Volume 10.
13. Burns, C.; Dishman, E.; Verplank, W.; Lassiter, B. Actors, Hairdos & Videotape-Informance Design. In *Conference Companion on Human Factors in Computing Systems*; ACM: New York, NY, USA, 1994; pp. 119–120.
14. Oulasvirta, A.; Kurvinen, E.; Kankainen, T. Understanding Contexts by Being There: Case Studies in Bodystorming. *Pers. Ubiquitous Comput.* **2003**, *7*, 125–134.
15. Schleicher, D.; Jones, P.; Kachur, O. Bodystorming As Embodied Designing. *Interactions* **2010**, *17*, 47–51.
16. Buchenau, M.; Suri, J.F. Experience Prototyping. In Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, Brooklyn, NY, USA, 17–19 August 2000; pp. 424–433.
17. Meiren, T.; Burger, T. Testing of service concepts. *Serv. Ind. J.* **2010**, *30*, 621–632.
18. Seth, A.; Vance, J.M.; Oliver, J.H. Virtual reality for assembly methods prototyping: a review. *Virtual Real.* **2011**, *15*, 5–20.
19. De Sa, A.G.; Zachmann, G. Virtual reality as a tool for verification of assembly and maintenance processes. *Comput. Graph.* **1999**, *23*, 389–403.
20. Koutsabasis, P.; Vosinakis, S.; Malisova, K.; Paparounas, N. On the value of virtual worlds for collaborative design. *Des. Stud.* **2012**, *33*, 357–390.
21. Boletsis, C. VR Service Walkthrough: A Virtual Reality-based Method for Service Prototyping. In Proceedings of the ServDes. 2018: Service Design and Innovation Conference, Milan, Italy, 18–20 June 2018.
22. Stickdorn, M.; Zehrer, A. Service design in tourism: Customer experience driven destination management. In Proceedings of the 1st Nordic Conference on Service Design and Service Innovation, Oslo, Norway, 24–26 November 2009; pp. 1–16.
23. Stickdorn, M.; Schneider, J. myServiceFellow: gaining genuine customer insights. In Proceedings of the 1st Nordic Conference on Service Design and Service Innovation, Oslo, Norway, 24–26 November 2009; pp. 1–3.
24. Stickdorn, M.; Zehrer, A. Service Design for tourism SMEs-The concept of service design and its application on the Alpine Zoo in Innsbruck, Austria. In Proceedings of the ServDes. 2010: Service Design and Innovation Conference, Linköping, Sweden, 1–3 December 2012; Linköping University Electronic Press: Linköping, Sweden, 2012; pp. 147–148.

25. Bederson, B.B. Audio augmented reality: a prototype automated tour guide. In *Conference Companion on Human Factors in Computing Systems*; ACM: New York, NY, USA, 1995; pp. 210–211.
26. D'Auria, D.; Di Mauro, D.; Calandra, D.M.; Cutugno, F. A 3D Audio Augmented Reality System for a Cultural Heritage Management and Fruition. *J. Dig. Inf. Manag.* **2015**, *13*, doi:10.13140/RG.2.1.2171.9520.
27. Vazquez-Alvarez, Y.; Oakley, I.; Brewster, S.A. Auditory Display Design for Exploration in Mobile Audio-augmented Reality. *Pers. Ubiquitous Comput.* **2012**, *16*, 987–999.
28. Wei, S.; Ren, G.; O'Neill, E. Haptic and audio displays for augmented reality tourism applications. In Proceedings of the 2014 IEEE Haptics Symposium (HAPTICS), Houston, TX, USA, 23–26 February 2014; pp. 485–488.
29. Stahl, C. 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, Singapore, 11–14 September 2007; pp. 383–386.
30. Boletsis, C.; Chasanidou, D. Smart Tourism in Cities: Exploring Urban Destinations with Audio Augmented Reality. In Proceedings of the 11th Pervasive Technologies Related to Assistive Environments Conference, Corfu, Greece, 26–29 June 2018.
31. Kečkeš, A.L.; Tomičić, I. Augmented Reality in Tourism - Research and Applications Overview. *Interdiscip. Descr. Complex Syst.* **2017**, *15*, 157–167.
32. Yovcheva, Z.; Buhalis, D.; Gatzidis, C. Overview of smartphone augmented reality applications for tourism. *e-Rev. Tour. Res.* **2012**, *10*, 63–66.
33. Iso-Ahola, S.E. *The Social Psychology of Leisure and Recreation*; WC Brown Co. Publishers: Dubuque, IA, USA, 1980.
34. Kourouthanassis, P.; Boletsis, C.; Bardaki, C.; Chasanidou, D. Tourists responses to mobile augmented reality travel guides: The role of emotions on adoption behavior. *Pervasive Mob. Comput.* **2015**, *18*, 71–87.
35. Kourouthanassis, P.E.; Boletsis, C.; Lekakos, G. Demystifying the design of mobile augmented reality applications. *Multimed. Tools Appl.* **2015**, *74*, 1045–1066.
36. Magnusson, C.; Tollmar, K.; Brewster, S.; Sarjakoski, T.; Sarjakoski, T.; Roselier, S. 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, Boston, MA, USA, 4 April 2009; pp. 8:1–8:4.
37. Gamper, H. Enabling Technologies for Audio Augmented Reality Systems. Ph.D. Thesis, Aalto University, Helsinki, Finland, 2014.
38. Heller, F.; Borchers, J. 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, Seoul, Korea, 18–23 April 2015; pp. 949–952.
39. Pascoe, J.; Ryan, N.; Morse, D. Using while moving: HCI issues in fieldwork environments. *ACM Trans. Comput.-Hum. Interact.* **2000**, *7*, 417–437.
40. Holland, S.; Morse, D.R.; Gedenryd, H. AudioGPS: Spatial audio navigation with a minimal attention interface. *Pers. Ubiquitous Comput.* **2002**, *6*, 253–259.
41. Cohen, E. The sociology of tourism: approaches, issues, and findings. *Annu. Rev. Sociol.* **1984**, *10*, 373–392.
42. Cohen, E. Toward a sociology of international tourism. *Soc. Res.* **1972**, 164–182.
43. IJsselsteijn, W.; De Kort, Y.; Poels, K. *The Game Experience Questionnaire*; Technische Universiteit Eindhoven: Eindhoven, The Netherlands, 2013.
44. Lee, G.A.; Dunser, A.; Nassani, A.; Billinghurst, M. Antarcticar: An outdoor ar experience of a virtual tour to antarctica. In Proceedings of the IEEE International Symposium on Mixed and Augmented Reality-Arts, Media, and Humanities, Adelaide, Australia, 1–4 October 2013; pp. 29–38.
45. Meijer, F.; Geudeke, B.L.; Van den Broek, E.L. Navigating through virtual environments: Visual realism improves spatial cognition. *CyberPsychol. Behav.* **2009**, *12*, 517–521.
46. Nabioyuni, M.; Bowman, D.A. An evaluation of the effects of hyper-natural components of interaction fidelity on locomotion performance in virtual reality. In Proceedings of the 25th International Conference on Artificial Reality and Telexistence and 20th Eurographics Symposium on Virtual Environments, Eurographics Association, Kyoto, Japan, 28–30 October 2015; pp. 167–174.
47. Nacke, L.E.; Grimshaw, M.N.; Lindley, C.A. More than a feeling: Measurement of sonic user experience and psychophysiology in a first-person shooter game. *Interact. Comput.* **2010**, *22*, 336–343.
48. Proffitt, R.; Lange, B.; Chen, C.; Winstein, C. A Comparison of Older Adults' Subjective Experiences with Virtual and Real Environments During Dynamic Balance Activities. *J. Aging Phys. Act.* **2015**, *23*, 24–33.

49. Nacke, L.; Lindley, C. Boredom, Immersion, Flow: A pilot study investigating player experience. In Proceedings of the IADIS International Conference Gaming 2008: Design for Engaging Experience and Social Interaction, Amsterdam, The Netherlands, 25–28 July 2008.
50. Nacke, L.; Lindley, C.A. Flow and immersion in first-person shooters: measuring the player's gameplay experience. In Proceedings of the 2008 Conference on Future Play: Research, Play, Share, Toronto, ON, Canada, 3–5 November 2008; pp. 81–88.
51. Lee, G.A.; Dünser, A.; Kim, S.; Billinghurst, M. CityViewAR: A mobile outdoor AR application for city visualization. In Proceedings of the IEEE International Symposium on Mixed and Augmented Reality, Atlanta, GA, USA, 5–8 November 2012; pp. 57–64.