Space Pace: Method for Creating Augmented Reality Tours Based on 360 Videos

Timo Nummenmaa[1(✉)], Oğuz Buruk[1], Mila Bujić[1(✉)], Max Sjöblom[1], Jussi Holopainen[2], and Juho Hamari[1]

[1] Tampere University, Tampere, Finland
{timo.nummenmaa,oguz.buruk,mila.bujic,juho.hamari}@tuni.fi
[2] University of Lincoln, Lincoln, UK
jholopainen@lincoln.ac.uk

Abstract. In this paper, guidelines are presented for creating video-based guided tours that employ 360° video content and produce the feeling of augmented reality. The benefit of the approach presented in this paper is that it does not rely on heavy technological requirements but can be implemented by anyone with a consumer level camera capable of making 360° video recordings, in a variety of locations with low cost and modest technological prowess. Principle application areas are for example museum and city tours, wayfinding applications and crafted narrative experiences. The guidelines were derived via a pilot implementation of the tour experience, which was initially ideated using workshop methods. The evaluation of the pilot showed that the approach is promising as a new way to experience locations, and provides us with guidelines that can be classified as essential, recommended and needing consideration for developing and applied such technology. Our guidelines describe and specify a novel method of creating 360° video recordings using low-cost and readily available hardware. The method can be employed by a wide variety of actors to create services administering AR-like experiences in a cost and time effective manner.

Keywords: Augmented reality · 360° video · Mobile augmented reality · Guidelines · Design · Guided tour · Location-based services · Wayfinding · Navigational aids · Spatial cognition

1 Introduction

Traditionally, implementing an augmented reality application for a guided tour experience is a demanding process as it requires long implementation processes and expertise in fields such as coding or 3D modelling. It may also require specific applications, high-quality hardware and know-how by users to run the prepared content.

© ICST Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 2021
Published by Springer Nature Switzerland AG 2021. All Rights Reserved
A. Brooks et al. (Eds.): ArtsIT 2020, LNICST 367, pp. 119–138, 2021.
https://doi.org/10.1007/978-3-030-73426-8_7

However, with the advent of 360° cameras, location-based sensors, and mobile devices with high quality audio-visual outputs becoming mainstream consumer devices, the possibility for anyone to produce augmented-reality 360° content has become accessible. However, while this technology now exists in the hands of consumers and non-technology centred organizations, there has still been a lack of knowledge regarding the processes and methods to undertake such productions.

Therefore, in this paper, we propose the Space Pace method which is a low-cost and practical solution that will accelerate the process for preparing augmented 360° guided tours. Space Pace is a method that includes shooting a 360° video in a specific location or along a route with a guide who will lead the user in the exhibition area. By modifying the environment during the video production, video authors can add information to the target locations which may not be possible or feasible to display in real life and at the time of experiencing the exhibition area. The Space Pace method can be used in many kinds of use cases as it is usable by anyone and allows creating content which is realistic and quite close to genuine augmented reality applications. The guiding research question in this paper is:

How can we create widely accessible, easy to produce, but also engaging and informative location-based augmented guided tours?

To answer this question, in this study we illustrate the Space Pace method, supported by our report of a preliminary evaluation on its effectiveness as a guiding experience based on the iterative process and observations, interviews and video data of 12 participants. Finally, we present *Essential*, *Recommended* and *To be considered* design guidelines for creating 360° guiding videos that can provide the intended user experience. An overview of the study is presented in Fig. 1.

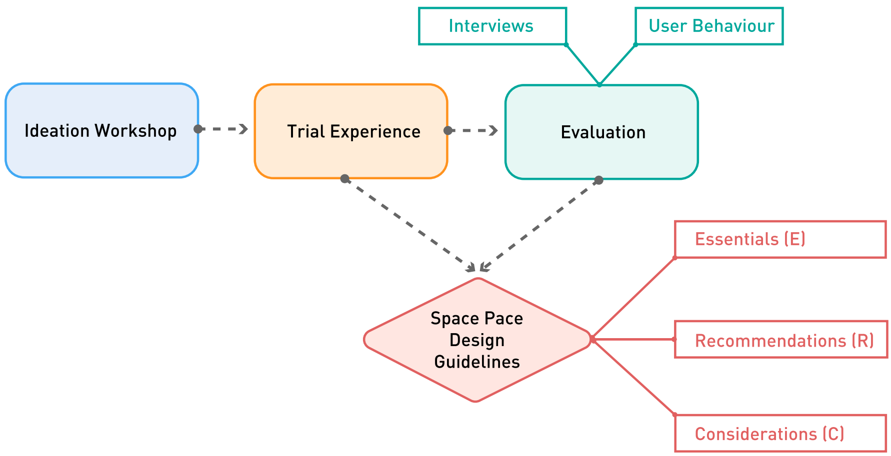

Fig. 1. Study overview

2 Related Work

The main inspiration for the project were video walks from artists Janet Cardiff and George Bures Miller [9]. In video walks, the user or users follow a video shown on a mobile phone, tablet, or other mobile device in the same location as it was shot, i.e. the users walk in the same place as if they were the camera that shot the video. The Cardiff and Miller video walks are exceptionally well produced and have high aesthetic and artistic values, providing a strikingly different *affective experience of space* [34].

Enhancing the experience of your immediate surroundings with technology has a long pre-digital history. Camera obscura, where an image is projected through small hole in a screen to a surface, can be regarded as one of the first such technologies. The principles were first mentioned in 5th century BCE in China and Ancient Greece, although the first documented uses of projecting to a screen can be traced to Al-Hazen's experiments in the 11th century [18]. Portable and more advanced versions came out in the 16th and 17th centuries culminating in magic lantern, widely attributed to Christiaan Huygens in mid-1600s. Magic lantern and other early projection techniques were used already early on to give the audience an otherworldly sense of presence through the projected images. Especially the genre of phantasmagoria with scary projections and convincing display of ghosts proved to be popular in 18th and 19th century [25].

Virtual tours have similarities to video walks as both provide a video based representation of an existing place. Virtual tours from early projects such as Movie Map [22] and Dudley Castle tour [8] to current web-based virtual tours for tourism and viewing real estate often assume that the user is stationary and somewhere else than the actual target location of the virtual tour. Video walks, however, emphasise the experience of walking [37] and how the actual bodily movement affects our sense of place [27]. Video walks aim at providing a different or reconfigured sense of the place where the user is already located.

Video walks are examples of indirect augmented reality [36], where the usual live camera view is replaced with a pre-captured panoramic view. A famous example of this approach is the augmented reality video guide for Casa Batlló in Barcelona [7,14]. Similar to many other indirect augmented reality applications the Casa Batlló video guide provides the augmented reality view from a static point of view in each of the locations in the tour. Space Pace, however, strongly encourage or even enforce movement through the place. Although one of our interests in this study is to understand how the users experience the "enforced" movement, we hope that some of the lessons learned can be applied to other indirect augmented reality use cases as well.

For wayfinding in an indoor environment, an indoor navigation solution such as SeeNav [28] provides navigation using an augmented reality application on a mobile device. Implementing an augmented reality indoor navigation application using services such as Mapbox [2] together with tools such as Unity [3] is also a possibility as demonstrated by Pavani [30] in an online tutorial. Both solutions describe different ways of obtaining the initial position of the user. In SeeNav, it is determined using an image captured by the user, with the tutorial by Pavani, special synchronization points are placed in the environment. While not specifically for on-location use, CityCompass [19] is a web technology based example of collaborative multi-user wayfinding using 360 video° worth mentioning.

Creating augmented and virtual reality guided experiences is becoming a prevalent application in the fields such as museum interaction. Those applications have a clear added value since they provide richer on-site experiences or extend the location-bound experiences to remote participants. Still, examples presented here, conventionally, require effort from both the creators and the users (i.e. downloading apps with a capable smart device that can run the them). Therefore, this study comes forward as a time and cost effective alternative to such methods by being be employed and experienced comparatively in an effortless way.

Some research that aims to guide the production 360° video has been conducted previously. However, the guidelines presented in this work differ in context from previous work that focuses on the creation of material to be experienced away from the filming location, with the user accessing the environment through various methods, such as head-mounted displays and projection technology (e.g. [20,32,33]).

3 Space Pace

The core idea of Space Pace is *the simple and efficient production of 360° video to be consumed using a mobile device, at the filming location, as an experience that evokes the feeling of augmented reality.* The Space Pace method was originally conceived in a design workshop and was developed further so that a trial experience could be created for testing with users.

3.1 Design Workshop

The initial aims of the workshop consisted of using a well-known cultural center (Kaapelitehdas in Helsinki, Finland) as a test bed for creating location specific augmented reality (AR) and internet of things (IoT) applications for different ways of engaging with the history and socio-cultural atmosphere of the venue. Play and playfulness were chosen as larger themes as they encourage engaging with the world and matters at hand in fundamentally liberating, engrossing, and inclusive ways [35], reflecting the values of the cultural center. The workshop lasted for three days.

The workshop was designed from start to be an intensive workshop for a small group. The final participants consisted of the two researchers mainly in charge of organizing workshop, an industry expert with previous AR app knowledge, an expert of the workshop location and a pioneer in mobile AR applications. The expert of the workshop location could not participate fully, but was able to intermittently contribute to the workshop.

The approach and aims in the workshop were closely aligned with playful design (e.g. [5,10,11,17]) both from the resulting artifact point of view and the methods and the attitude used in the workshop activities themselves. The aims of creating artifacts and interactions that elicit a playful mindset in the users are also similar to the ludic design or designing for Homo Ludens approaches [12].

The workshop was based on predetermined goals and constraints, but was designed to be dynamic and with a flexible timetable. However, a certain amount of time pressure was included in order to eventually progress from ideation to low tech prototypes. The focus of the actual workshop was on ideas, concepts and prototypes, similarly as in closely related dialogue-labs method [24].

The constraints for the workshop were based on the following factors: findings on the current state of AR applications, findings on the current state of smart space solutions, specific location related constraints, and findings from discussions with research project partners.

In addition to the authors' previous experiences with different design methods, a book named as *"Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions"* [15] was used as a guide in the selection of suitable methods for use in the research.

The three core methods that were chosen to be used in the workshop, and which affected preparation and material selection, were body-storming, re-enactment and user experience sketching. These three methods were selected because the participants were already familiar with them and they have been proven to be effective in ideation before. In addition to these core methods, brainstorming with video stimuli and VNA (verb-noun-adjective) cards [21] and PLEX (playful experiences) cards [23] ideation techniques were used. The process of ideation was based on context awareness and the usage of ideation tools. Workshop participants were introduced to the context first through a version of the guided tour of the premises, and later through an extensive review of related work video material. Additionally, the participants discussed challenges in designing for public places, such as designing for spectators [31], barriers for collaboration [16] and playful interactions between strangers [29]. Card based ideation tools VNA [21] and PLEX [23] were used to further excite the minds of the participants.

On the second day of the workshop, one low tech prototype was created in the form of a simple video walk experience, inspired by video walks by Cardiff and Miller [9]. This prototype was created to explore the idea and test out assumptions for creating presentable prototypes on the next day. On the final day of the workshop, a further developed version, now a 360° video walk, (see Fig. 2) created with the help of an artist working within the premises, was demonstrated along three other prototypes. The prototype was made up of two parts, a simulated tour which approached the artist's studio, and a view from the inside of the studio with the artist giving a short presentation. The video was created using a Ricoh Theta 360 camera. Approaching the studio was created similarly to the video prototype from the first day, but now using a 360 camera. In the in-studio video, the camera was static. This prototype later became Space Pace.

Fig. 2. Original 360° video walk prototype

3.2 Implementation of the Trial Experience

For a trial experience, we have iterated upon the initial workshop prototype in that the experience is started from scanning a QR code at the starting location, and crafted a video-guided 360° experience in a 26 m long corridor of University of Tampere. We decided to create a short video with a sufficiently easy to use and rather low-cost hardware so as to demonstrate the accessibility of Space Pace method and its reasonably priced development requirements. For this test, the Insta360 ONE camera was used [1]. First, two videos were recorded at different candidate locations. Comparing the two videos, the width of the corridor seemed more suitable in one of the videos and in that same one the corridor included colorful pillars and construction elements that showed promise in making it easier for users to perceive their real location in relation to the location of the guide in the 360°. The selected location was also easily accessible by test participants. The selection of location does not rule out the other location as a feasible location for using Space, as the choice was made to benefit the construction and execution of the trial. After the location was chosen, two recordings were used to plan the trial, and iterate on the approach.

Tour Script and the Execution. The tour implemented for pilot testing is composed of a single video that lasts for 1 min and 40 s. For the experience, a script was drafted that would include the following content: 1) At the beginning of the video, a tour guide greets the users and invites them to walk along through the corridor. 2) Along the way, the guide introduces and points to a coffee room, whose door is closed in the real world but open in the video. 3) After passing this point, he talks about several research posters hanged on the walls. In both of those moments, the guide keeps walking while introducing the information about the environment and does not stop. 4) Following introduction of the poster, the guide stops briefly in front of a classroom of which the interior can be seen through a window. However, similar to the meeting room in the previous spot, in the real life, the blinds on the window are closed while in the video version, they are open and a gameplay video of Bioshock Infinite [1] is being played. The guide here talks about the game briefly and then continues to walk through the corridor. 4) In the last section of the video, the guide stops again and points to the wall on which the three different posters of Rapture, a fictional underwater city in the first Bioshock Game[2], are hanged in the video version but not in the real world. 5) The tour ends with the guide taking a right turn in the corridor and informs the user that the tour ended.

The script of the video was as follows:

00:03 - Hello, I will be your tour guide today in this lovely corridor of the University of Tampere. So, let's don't lose so much time and get started. Follow me!

00:14 - On your left, you can see the coffee room where our colleagues can come together and relax when they become so bored of their work.

00:24 - Of course, other than the coffee, there some other enjoyments in that room [pointing to the table on which has ample amount of LEGO parts], which you can use while relaxing.

00:33 - This corridor hosts a lot of rooms for researchers and academics of University of Tampere, and also, of course, there is some great research here of which this poster [pointing to a poster on the right] is an example.

00:49 - Other than researcher rooms, there are also classrooms on this corridor. [Guide Stops] This one is really bright, spacious and colorful classroom. And in this screen, you can see Bioschock Infinite is played which is a great game.

01:02 - Let's keep going.

01:14 - [Guide Stops Again] Here is another important part in our tour. These are the Rapture Posters. Rapture is an under water city that you can go

[1] https://2k.com/en-US/game/bioshock-infinite/.
[2] https://2k.com/en-US/game/bioshock/.

and conduct your research and art, in the first game of Bioschock. So, maybe you can visit there after. Keep going!

01:31 - [Guide takes a right turn in the corridor]

01:35 - Here is the last spot of our tour.

The experience was created in such a way that with sufficient smartphone hardware users do not need to download any software to engage with the experience. The only limitation is support for 360° video in the YouTube app, and the ability to read QR codes. To begin the experience, a user would scan a QR code on the wall, and then start to follow a tour guide that seems to appear in front of the user on the screen of the mobile device, creating a feeling of AR.

Preparation Process. The workflow for the final trial experience was composed of: 1) Planning the tour, 2) recording the video, 3) exporting from the Insta360 ONE application, 4) uploading to YouTube, 5) creating a QR code using a QR code generator [13] and printing it on a page with the text "Scan me for a tour!", 6) attaching the page on the wall. Recording, exporting and uploading (phases 2–4) were all done directly on an iPhone X mobile device [4], with no need for using a computer for any post processing or editing. The video was recorded with the Insta360 ONE device connected to the mobile device used for recording, enabling the cameraman to see the video being recorded. When recording, the starting orientation of the camera was made to be such that the video would start oriented towards the QR code and tour guide when the video was opened. This would make the video start with the correct orientation when a user scans the QR code to start the video (see Fig. 3).

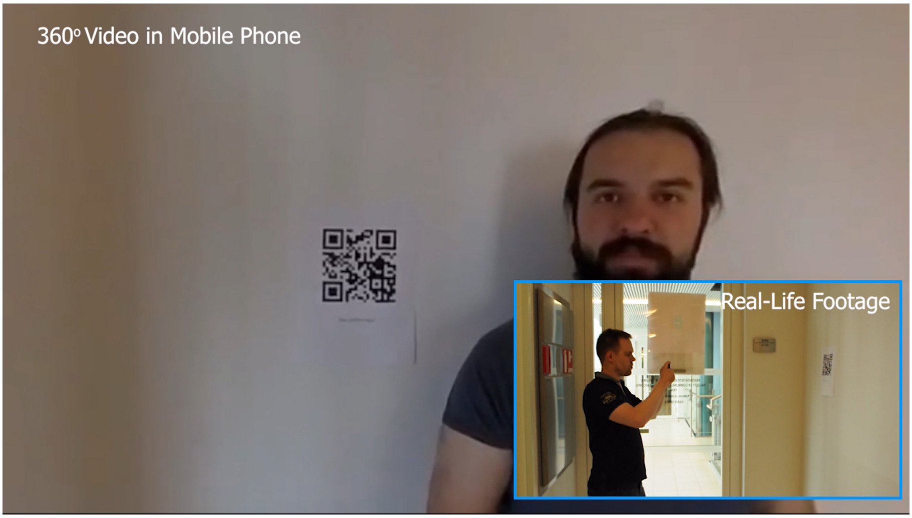

Fig. 3. Start of the tour (for illustration purposes, not a capture of experiment participants)

Out of this process, more generic instructions for the creation of Space Pace content were derived (Fig. 4).

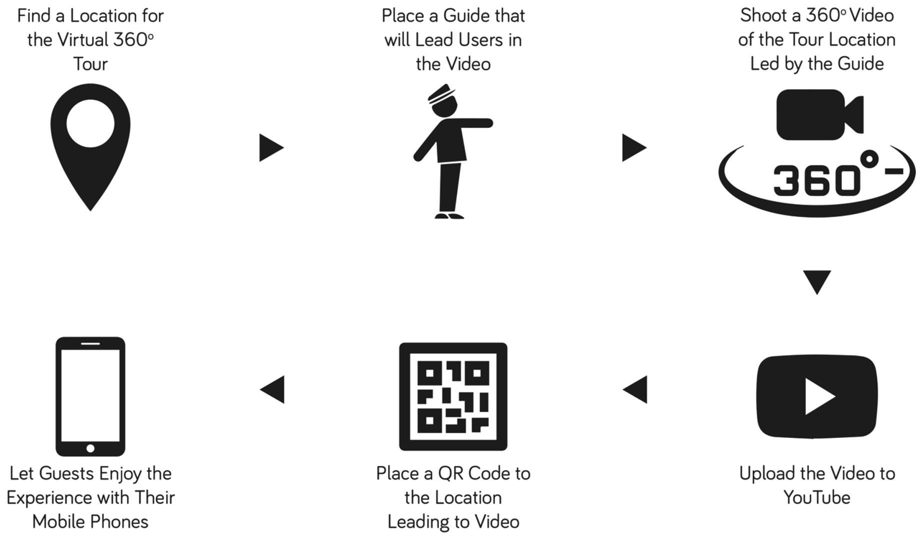

Fig. 4. Space Pace video publication process

4 User Testing and Evaluation

The pilot application of Space Pace was evaluated in a user test. This evaluation then served as grounds for developing Space Pace method guidelines.

A total of 12 participants were recruited at the scene for testing the created version of the Space Pace. It was a non-probability, convenience sample, composed of university students and employees. Participation was completely voluntary and it was explained to the participants how the collected data would be used in the research. No personal data was collected and no part of the study is directed at investigating the test subjects themselves or the test location. No video data with any identifying details of individuals was shared outside of the core researcher team and no such video is stored beyond the time-frame essential for the completion of this research. Under the guidelines of the Finnish National Board on Research Integrity, this research required no ethical approval.

Participants used an iPhone X mobile device to experience the 360° tour. The same device was used by all participants to reduce possible variability in results that would stem from factors not in the focus of the study. Additionally, it allowed us to collect the screen recordings from the tests, which we expected to provide valuable insight into how Space Pace was used. Apart from the mobile device, we also used a DSLR video camera to capture participants' behaviour during the tests. The camera was placed at the end of the corridor and was used to record each test in one take.

The data collected for this study consisted of both objective (screen and test recordings) and subjective reporting data (structured interviews). The screen recordings combined with an external camera view give us a detailed view of what the participant sees on the mobile phone in connection to their real world position and orientation. The interviews allow us to understand how the participants experienced the environment during the test and to gain additional insight. By using a mixed-method approach, we strengthened the validity of our findings when evaluating the strengths and weaknesses of this version of Space Pace.

Each participant started at the beginning of the corridor in front of a printed out QR code that was taped to the wall. They were instructed to point the phone's camera at the code, tap on the link, and turn the phone so that the video would play in full screen, landscape mode. These actions would prompt the video to play and researchers would then stay out of the sight until the very end. Finally, one researcher would conduct the structured interview that consisted of five questions (Table 1) immediately after the test was done.

Table 1. Post-experience interview questions

1. Please share two comments about the experience you just had
2. Can you remember what you saw in the coffee room?
3. Can you remember what you saw in the classroom?
4. What was the difference between the real-world classroom and the one in the mobile experience?
5. Can you remember what the posters were about and the colours they were?

4.1 Results

In the beginning of each interview, the participant was asked to share two free-form comments about the experience. The comments were predominantly positive and pertained to the novelty of Space Pace, as well as to how the experience was *fun* and *interesting* (e.g. Participant 7: "Funny and interesting. I didn't know what to expect, but it was like, well, a tour guide. Kind of like very easy to get the idea."). Two participants mentioned the possibility of "seeing behind closed doors" as a unique feature. The majority of negative comments were related to the maladjustment of participants' pacing relative to the video speed (e.g. Participant 6: "I would constantly notice that I walked too fast, and I was slightly ahead of where the video was and there was this feeling of disconnection when I could rotate the camera and see that I was a couple of meters ahead of where I was supposed to be and try to consciously slow down and pace myself more correctly").

With the structured section of the interview consisting of four questions (Table 1), we investigated participants' attention to both on-screen content and the physical surroundings. One participant's answers were discarded as they had not realized that it was a 360° video and had the mobile device pointed at the floor throughout the test. The rest of the answers were given either 1 or 0, depending on the participant's ability to recall the information. These findings are to some extent limited by the maladjusted pace speed, which prevented participants from seeing the physical location that was being described in Space Pace.

The first point of interest, the coffee room, was recalled by the least number of participants (2/11). This could perhaps be explained by the novelty of the experience and the time needed to get adjusted to the mechanics of Space Pace. On the other hand, around two thirds of participants were successful in recalling the classroom from Space Pace (7/11), as well as the difference between the real world one and that from the mobile experience (7/11). Finally, almost all of the participants recalled the posters from Space Pace (10/11), which might be contributed to the recency effect [26]. Moreover, as mentioned in the script, the guide kept walking while introducing the coffee room while he stopped in front of the classroom and posters. This difference might have also affected the results. Finally, only one participant recalled all of the points of interest.

The video data was analysed so that both the screen recording and the recording of each participant were viewed synchronously, side by side. This method ensured that both perspectives are considered at all times and in relation to each other. The analysis was conducted in such a way that occurrences of certain actions in the material were tallied. This was done by observing if an action that was previously identified to be of interest actually occurred in the recording(s) or not. The actions to examine in the videos were based on the script of the experience. This way of analysing the video proved effective and provided us with sufficient details to generate guidelines. We were especially interested in what participants do 1) at the start of the experience (turning towards the guide and starting walking) 2) regarding coffee room which has an open door in the video, but which is closed in real life 3) regarding the window which can be seen through in the video, but where the blinds are closed in real life, 4) regarding posters on the wall in the video that do not exist in the real word, 5) at the end of the tour. Additionally, we were interested in if the orientation of the participant and the device matched throughout the experience. These actions were divided into more atomic actions. The list of the final actions can be seen with the results in Table 2.

There are two specific things to note about the video analysis. Some participants walked past during the video camera in the corridor, and thus some final actions were not recorded for these participants. However, most actions that could not be seen in the video footage due to this problem took place in an area where certain actions (e.g. look at an item in the physical world) were impossible to do, and thus this is not a large issue regarding the validity of the results. Additionally, one participant did not realize that the video was a 360° recording and that it was possible to look in different directions. The participant pointed the mobile device towards the ground during the experiment.

Table 2. Aggregated data from the screen recordings and test recordings, in order of occurrence within experiment.

Observed action	% of participants
Turned away from the QR-code to face the corridor	100
Started walking as instructed by the guide	100
Was physically in front of coffee room when video showed it	100
Turned the phone to see the coffee room	50
Looked into the physical coffee room	16.7
Was physically in front of the classroom when the video showed it	50
Stopped when the guide stopped in front of the classroom	91.7
Turned the device to see inside the classroom	75
Was physically in front of the posters when the video showed them	50
Stopped when the guide stopped in front of the posters	83.3
Looked at posters	91.7
Looked at the physical wall where posters were supposed to be	58.3
Turned to see the cameraman (at any point during the experience)	50
Ended up at the correct ending point	50
Walked past the ending point	50
Orientation matched throughout the experience	100

5 Guidelines

In this section, we will present guidelines for shooting 360° guided tour videos that will successfully direct the user from one point to another while conveying the required information. Guidelines in this section are categorized in three pillars; (1) Essentials (E), (2) Recommendations (R) and (3) Considerations (C). Essential guidelines direct to points that should be applied to make the video work in the intended way. If these guidelines are not taken into consideration, there can be major problems in the user experience of the video such as disorientation or struggle to follow the conveyed information. Recommendations refer to issues that might be good to apply but can be modified according to content, context, location and users. These recommendations are created according to the user feedback and can be seen as potential solutions to some of the problems we faced. Considerations communicate points that caused or may cause obstacles according to our observations. However, we need to note that these conditions were not yet tested. Still, we see the benefit to cast light on these issues as points that need further clarification for making the Space Pace experience an optimal one. For example, we tested Space Pace in a narrow corridor and our consideration is that these guidelines may have to be modified if the video was prepared in a wider area which can be harder for users to follow visual cues in the real environment. We did not test Space Pace in a wider area, however our experience suggests that in wider environments, there might be other shortcomings that we did not observe in this test. See Tables 3, 4, 5 for the guidelines.

Table 3. Guidelines (Essentials)

Name	Guideline
Starting Orientation	The starting orientation of the user and the video should be the same. In this phase, both the video and the real environment should include similar visual cues so that the user can perceive the space easily. In our case, we used a poster with a QR code which assures the orientation of user and their device, as the user needs to point their device towards the code to read it. The same poster was also in the video that helped users to comprehend the starting orientation in the beginning. In our observations, we found that the orientation of the device and user matched for all of the participants
Guiding Orientation	In our initial tests, we tested different starting positions for the guide. It is important to render the guide visible in the first second and the guide should be present in the starting orientation of the video. If the guide is in another position, users may not be able to find her/him in case the sound or the subtitles are off. With the guide visible in the start of the video, all of the participants turned to follow the guide when the guide started to move out of the picture and along the corridor
Explicit Commands for Moving the User	A crucial point of the Space Pace experience is that the user is in the correct location and follows the guide in the right pace. The guide can stop or slow down for giving information and start walking or get faster after the information phase. In this moments, it is important to give commands such as "follow me" or express that we are in a phase of information giving. The guide should be expressive in talking and body language to make it easier for users to follow

Table 4. Guidelines (Recommendations)

Name	Guideline
Augmented content	Although having augmented content is one of the strong points of Space Pace experience, in some cases the initial need can only be having a guide in the scene. However, we observed that having content in the video that does not exist in the real world makes the experience more interesting and increases the surprise effect. It can also be confusing for some users, which should be taken into account in the design of the experience
Visible cameraman	Only half of the users pointed the mobile device at all towards the cameraman who shoots the video, and even if they did, they did not express complaints about it. Therefore, it may not be worth putting an extensive amount of effort into hiding the cameraman in the video
Size of the QR code	The starting location of the user can be influenced by changing the size of the QR code. The size of the QR code will guide the proximity of the user to the QR code. If the QR code is too small, the user will get closer and they may be confused if their starting view does not match the video. However, a sufficiently small code is not readable from afar, requiring the user to approach the code. Therefore, modifying the size of the QR code can help for orienting the user in the required location in the beginning
Instructions	We observed that users may not realize that they are looking at a 360° video and that they should be moving in the same pace as the video. A detailed instruction might work for a better experience which allows users to explore around by turning the phone in the beginning. By doing so, they can get accustomed to orientation and the required interaction style. This solution has the limitation of being an annoyance for proficient users

6 Discussion

During the iterative process from the first workshop prototype to the experience that was used for user tests, a sufficient implementation of our method was developed to produce data to confirm certain guidelines and to discover others.

One of the lessons learned already at the three-day workshop, where the initial concept of 360° video walking tours was ideated, was that the pace of

Table 5. Guidelines (Considerations)

Name	Guideline
Dynamic Pace	The pace of the video can change according to characteristic of the scene or the behaviour of the user. For example, pace is different while talking or showing an object compared to the state where the guide walks without attending anything else. Moreover, we also observe that the users who explore around with their phones were more successful to orient themselves to pace of the guide. Therefore, it might not be possible to standardize the walking pace in Space Pace videos. Instead, video authors can make sure to give required instructions in the beginning of the video to remind users to arrange their pace
Environmental Visual Cues	We chose an environment which does have different visual elements instead of a plain corridor. We wanted users to easily understand where they are when they look around. However, most of these visual elements were repetitive (such as poster boards or pillars) and half of the users who tested Space Pace faced problems to orient themselves in the environment. Therefore, it might be better to adorn the environment with visual elements which are not repetitive, standing out and existing both in video and real environment. In our tests, majority of users stopped when the guide stopped for giving information. In these phases, guide can refer to those elements to help users orient themselves according to the location in the video
Size of the Environment	In our case, the narrow corridor we used as a location helped users stay synchronized with the video, as they can only walk in one direction and it is easier to match the visual cues with the ones in the video. However, a wider space may require additional precautions to help users to stay oriented
Tutorial Requirement	As a first experience, it may not always be easy for users to arrange their pace to match it with the guide's pace, or understand how augmented content is different from the real environment. Therefore, a short separate sequence which will lead the user to a new QR code that starts the actual experience may help users to adapt to experience better. This short sequence may include some of the critical points such as exploration of an object in the environment and following the guide to adapt the pace of the video

the video must be a suitable walking pace for the person using the solution. In our solution, the speed of the tour guide was based on what is a comfortable speed to explain the surroundings, with slight pauses at certain spots. Half of the participants in the tests walked past the end point in the video, which might suggest that a faster pace should be employed. One other solution would be to set the pace to what can be observed as the walking pace of mobile phone users. Barkley and Lepp [6] have recorded the walking speed of people texting on their phone while walking, and the value from this study could be used in the design of a walking experience. However, the speed reported in the study is substantially faster than what can be considered as comfortable if one was to thoroughly absorb the surroundings, so the experience itself should then match the speed. Another way to approach the pacing issue would be to expect the users to first be unable to match their pace with the pace in the experience and to teach the users first how to pace themselves, either in the same experience or in a separate tutorial one. In some cases, cutting the video portions so that one video takes the user to a new QR code may help the user keep in sync with the surroundings, but could also prove cumbersome. We also should note that it may not be possible to reach a standardized pace for the whole experience since the speed can change according to the content (i.e. plain walking vs. information giving) or to the behaviour of the user (i.e. more exploration for the surroundings results in a slower speed). Therefore, we believe that the pace of the video should be considered and tailored according to specific use cases.

The mobile experience itself was fast to produce, only requiring two initial test videos before moving to produce the recording that would be used in our user test. The process of uploading the video was also fast, as no editing or heavy processing was required. Everything was doable directly on a mobile device up until the point when the QR code had to be created. The effort needed to produce the Space Pace experience compared to solutions where software needs to be developed, 3D models created, maps configured etc., can be considered to be significantly lower. It is also less time consuming and more affordable. However, if one would produce a heavily narrative based experience with, for example, props and costumes, the costs of this process would be affected.

There are limitations to this study that need to be addressed. The space where the tests took place was not a controlled laboratory environment. This means that the environment could change even during a test. A door could be opened by someone, a meeting could be taking palace in a space and there might be people walking in the corridor doing things like using a copy machine or just passing by. The changes in the environment state mostly affected the first stage of the experiment - the coffee room. There was a meeting taking place in this room during some of the tests. There was also some traffic in the corridor, but not so much that we would expect it to be an issue. These are also limitations that would affect real world implementations of this method, and thus may even bring a certain realism to our study.

Another limitation of the study was that due to convenience sampling, as most participants were already familiar with the corridor that was used in the study. We have to consider the possibility that this affects the way participants explored the area. While users' previous familiarity with the environment may also be the case in some implementations, it would not be the case in all possible contexts where Space Pace might be used. On the other hand, familiarity with the environment may also lead to the desire for exploration as the most of the content is known for the user. This can work towards the aims of this method since the video authors can adorn the environment for experienced users by placing other details to the outside of the centre of attraction which can be discovered in 360° video through careful exploration.

The language in the video was English and the guide was a non-native English speaker, while the majority of participants' mother tongue was Finnish. This may have slightly affected participants' experience, as understanding the content likely required additional focused attention than it would be the case with a Finnish-speaking guide. Finally, the limited number of participants, the brevity of the interview and the singular experience under study must also be taken into account. As such, the resulting guidelines, while already providing valuable insight, can be expanded and strengthened in the future.

7 Conclusions and Future Work

This study presented a novel way of creating 360° video guided tours using low-cost and readily available hardware. This method, titled Space Pace, mimics characteristics seen in augmented reality tours, using simpler hardware and more easily approachable methods that can be used by non-expert practitioners. We presented the Space Pace method through the creation process, consisting of a design workshop and iterative design that followed. We showed the method in action through a pilot user test with 12 participants and associated observations and interviews.

Based on the production and evaluation of the pilot study, we were able to construct a number of recommendations for others looking to produce similar fast and low-cost guided tours using 360° video. Along these, a number of questions were also raised that should be answered through further studies. One of the main questions still looking for an answer is the pace with which the video is filmed, and hence the pace with which the user is expected to progress. We need to explore the pace speed more thoroughly and how the environment where the 360° video walks take place should be taken into account when designing the experience. The size and shape of the space, as well as possible visual cues in the environment, are expected to be meaningful parameters that need to be taken into account in the design.

While the research has limitations, the methods and recommendations presented in this study can already be employed by a wide variety of both societal and industry actors to create services with clear added value. Examples of areas where these methods could be utilized with good results include museum tours, art exhibitions, and guided tours of large public spaces. The Space Pace method encompasses both the guidelines and procedures described in the paper, and will be expanded with future iterations.

Acknowledgements. This publication has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 833731, WEARTUAL, Academy of Finland decision 327352, and Business Finland decisions 5479/31/2017, 7488/31/2017 and 5654/31/2018.

References

1. Insta360 one - a camera crew in your hand, November 2019. https://www.insta360.com/product/insta360-one/. Accessed 7 Nov 2019
2. Mapbox, November 2019. https://www.mapbox.com/. Accessed 7 Nov 2019
3. Unity, November 2019. https://unity3d.com/. Accessed 7 Nov 2019
4. Apple: Iphone X, November 2019. https://www.apple.com/lae/iphone-x/. Accessed 7 Nov 2019
5. Arrasvuori, J., Boberg, M., Holopainen, J., Korhonen, H., Lucero, A., Montola, M.: Applying the PLEX framework in designing for playfulness. In: DPPI 2011, pp. 24:1–24:8. ACM, New York (2011). https://doi.org/10.1145/2347504.2347531. http://doi.acm.org/10.1145/2347504.2347531
6. Barkley, J.E., Lepp, A.: Cellular telephone use during free-living walking significantly reduces average walking speed. BMC Res. Notes **9**, 195 (2016). https://doi.org/10.1186/s13104-016-2001-y
7. Batlló, C.: All the information about your visit to casa Batlló, November 2019. https://www.casabatllo.es/en/visit/. Accessed 7 Nov 2019
8. Boland, P., Johnson, C.: Archaeology as computer visualization: virtual tours of Dudley Castle c. 1550. Br. Museum Occasional Pap. **114**, 227–233 (1996)
9. Cardiff, J., Miller, G.B.: Walks, November 2019. http://www.cardiffmiller.com/artworks/walks/index.html. Accessed 7 Nov 2019
10. Coulton, P.: Playful and gameful design for the internet of things. In: Nijholt, A. (ed.) More Playful User Interfaces: Interfaces that Invite Social and Physical Interaction, pp. 151–173. Gaming Media and Social Effects. Springer, Singapore (2015). https://doi.org/10.1007/978-981-287-546-4_7
11. Fernaeus, Y., Holopainen, J., Höök, K., Ivarsson, K., Karlsson, A., Lindley, S., Norlin, C. (eds.): Plei-Plei! PPP Company Ltd. (2012)
12. Gaver, W.: Homo ludens (subspecies politikos). In: Deterding, S., Walz, S.P. (eds.) The Gameful World: Approaches, Issues, Applications. MIT Press, Cambridge (2015)
13. QR Code Generator: Create your QR code for free, November 2019. https://www.qr-code-generator.com/. Accessed 7 Nov 2019
14. Gimeno, J., Portales, C., Coma, I., Fernandez, M., Martinez, B.: Combining traditional and indirect augmented reality for indoor crowded environments. A case study on the casa Batllo museum. Comput. Graph. **69**, 92–103 (2017)
15. Hanington, B., Martin, B.: Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions. Rockport Publishers, Beverly (2012)
16. Heinemann, T., Mitchell, R.: Breaching barriers to collaboration in public spaces. In: Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction, TEI 2014, pp. 213–220. ACM, New York (2013). https://doi.org/10.1145/2540930.2540951. http://doi.acm.org/10.1145/2540930.2540951
17. Holopainen, J., Stain, M.: Dissecting playfulness for practical design. In: The Gameful World: Approaches, Issues, Applications. MIT Press (2015)
18. Ihde, D.: Art precedes science: or did the camera obscura invent modern science. In: Instruments in Art and Science: On the Architectonics of Cultural Boundaries in the 17th Century, vol. 2, pp. 383–393 (2008)

19. Kallioniemi, P., Sharma, S., Turunen, M.: CityCompass: a collaborative online language learning application. In: Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work and Social Computing Companion, CSCW 2016 Companion, pp. 94–97. Association for Computing Machinery, New York (2016). https://doi.org/10.1145/2818052.2874334. https://doi.org/10.1145/2818052.2874334
20. Keskinen, T., et al.: The effect of camera height, actor behavior, and viewer position on the user experience of 360° videos. In: 2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), pp. 423–430 (2019)
21. Kultima, A., Niemelä, J., Paavilainen, J., Saarenpää, H.: Designing game idea generation games. In: Proceedings of the 2008 Conference on Future Play: Research, Play, Share, pp. 137–144. ACM (2008)
22. Lippman, A.: Movie-maps: an application of the optical videodisc to computer graphics. ACM SIGGRAPH Comput. Graph. **14**(3), 32–42 (1980)
23. Lucero, A., Arrasvuori, J.: PLEX cards: a source of inspiration when designing for playfulness. In: Proceedings of the 3rd International Conference on Fun and Games, Fun and Games 2010, Leuven, Belgium, pp. 28–37. ACM, New York (2010). https://doi.org/10.1145/1823818.1823821. http://doi.acm.org/10.1145/1823818.1823821
24. Lucero, A., Vaajakallio, K., Dalsgaard, P.: The dialogue-labs method: process, space and materials as structuring elements to spark dialogue in co-design events. CoDesign **8**(1), 1–23 (2012)
25. Mannoni, L., Brewster, B.: The phantasmagoria. Film History **8**(4), 390–415 (1996)
26. Murdock Jr., B.B.: The serial position effect of free recall. J. Exp. Psychol. **64**(5), 482 (1962)
27. Nedelkopoulou, E.: Walking out on our bodies participation as Ecstasis in Janet Cardiff's walks. Perform. Res. **16**(4), 117–123 (2011)
28. Noreikis, M., Xiao, Y., Ylä-Jääski, A.: SeeNav: seamless and energy-efficient indoor navigation using augmented reality. In: Proceedings of the on Thematic Workshops of ACM Multimedia 2017 (Thematic Workshops 2017), pp. 186–193. ACM, New York (2017). https://doi.org/10.1145/3126686.3126733
29. Paasovaara, S., Lucero, A., Olsson, T.: Outlining the design space of playful interactions between nearby strangers. In: Proceedings of the 20th International Academic MINDTREK Conference, pp. 216–225. ACM (2016)
30. Pavani, A.: Indoor navigation in AR with Unity - Points of interest, November 2019. https://blog.mapbox.com/indoor-navigation-in-ar-with-unity-6078afe9d958. Accessed 7 Nov 2019
31. Reeves, S.: Designing Interfaces in Public Settings: Understanding the Role of the Spectator in Human-Computer Interaction. Springer, London (2011). https://doi.org/10.1007/978-0-85729-265-0
32. Rothe, S., Kegeles, B., Hussmann, H.: Camera heights in cinematic virtual reality: how viewers perceive mismatches between camera and eye height. In: Proceedings of the 2019 ACM International Conference on Interactive Experiences for TV and Online Video, TVX 2019, pp. 25–34. Association for Computing Machinery, New York (2019). https://doi.org/10.1145/3317697.3323362. https://doi.org/10.1145/3317697.3323362
33. Saarinen, S., Mäkelä, V., Kallioniemi, P., Hakulinen, J., Turunen, M.: Guidelines for designing interactive omnidirectional video applications. In: Bernhaupt, R., Dalvi, G., Joshi, A., K. Balkrishan, D., O'Neill, J., Winckler, M. (eds.) INTERACT 2017. LNCS, vol. 10516, pp. 263–272. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-68059-0_17

34. Schaub, M.: The affective experience of space: Janet Cardiff and George Bures Miller. In: The Handbook of Sound and Image in Western Art, pp. 214–235 (2016)
35. Sicart, M.: Play Matters. MIT Press, Cambridge (2014)
36. Wither, J., Tsai, Y.T., Azuma, R.: Indirect augmented reality. Comput. Graph. **35**(4), 810–822 (2011)
37. Witmore, C.L.: Four archaeological engagements with place mediating bodily experience through peripatetic video. Vis. Anthropol. Rev. **20**(2), 57–72 (2004)