Creating Immersive Play Anywhere Location-Based Storytelling Using Mobile AR

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Abstract. Map Story is an Augmented Reality (AR) location-based storytelling app for smartphones, that directs users to nearby real-world locations whilst following a new story. Some of the locations are augmented with virtual content visible on users phones, in order to bring the locations closer in line with those described in the story. In addition to developing the app, a preliminary user study is described, with participants using the app at their own choice of starting location, with data collected through a combination of in-app feedback and questionnaires, alongside post interviews with a selection of those who took part. As well as developing guidelines for such an experience, there is evidence that the real sites visited were reported as being a closer match to the story events, and more believable in terms of the story events playing out there than the AR locations, but with the AR sites potentially beneficial in encouraging a greater focus on the story.

Keywords: Location-based storytelling · Augmented reality · User experience

1 Introduction

Digital story experiences including some immersive theatre productions and escape rooms have grown in popularity in recent years, though are often site specific, since it is easier to connect a narrative to the features and layout of a known location, rather than one which cannot be guaranteed to contain all the elements required for the story. This often limits these experiences to having short runs for a limited audience, due to the cost of props, actors and orchestration [35]. This research aims to develop a location based story experience that can be experienced anywhere using the technology in a personal smartphone. To bring a user's location closer in line with that described in the story, the app makes use of Augmented Reality (AR), allowing virtual content to be overlaid on the real world and combined with a camera view, visible on the display of the mobile phone. The public have largely been put off by the discomfort and

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cost of current AR headsets, so mobile AR still provides various opportunities to discover how AR can enrich a user experience [4,27].

Providing an engaging experience at an unknown location is challenging, given that makers of site specific experiences often emphasise a location's unique atmosphere to aid both seamless and ethical design, sometimes providing insight into the area [13,34,37]. AR is adopted here as an approach to solving some of the unknown aspects of a location, with the added advantage that a blended AR environment offers unique opportunities for agency and immersion that can potentially feel more authentic than a purely virtual environment [32,44]. Immersion is a commonly used subjective measure to gauge the quality of a mixed reality experience, with varying definitions existing in AR and Virtual Reality (VR), given that being fully sensory immersed and present in the environment is often desired in VR, whilst in AR a user will need to retain some awareness of their real surroundings, such as for safety reasons [39].

The research described produced the app Map Story, which aims to provide a solo interactive story at a location of the user's choosing, through a suitable iOS or Android mobile phone. Mobile AR enables the user to both discover hidden items at real-world locations to progress the story, as well to overlay buildings and other features referenced in the story on top of the user's real-world surroundings, when no real-world equivalent exists. The app incorporates GPS to locate the user, identifying suitable story locations or *Points Of Interest* (POIs) through the Mapbox API. A preliminary user study was conducted using the app, where participants were asked to submit feedback whilst taking part in terms of a pre-questionnaire, a short questionnaire completed at each POI site visited, and a post immersion questionnaire, where they could also supply additional thoughts and comments. The open feedback collected was analysed alongside post interviews with some of those who took part, in order to gain a deeper understanding of the benefits and limitations of the current app, in relation to its use of AR content alongside real-world locations.

The feedback are also aims to identify the challenges posed by real-world distractions to discover how Map Story might be improved. A further area investigated is how different users responded to the experience. This has been studied in video games in terms of player models, in VR with Witmer and Singer's *Immersive Tendency Questionnaire* (ITQ), and in literary narratives using *Reader Response Theory* [5,9,17,51]. However, little prior research exists in relation to AR, so the preliminary approach adopted here compares a subset of the *Big-5 Personality Inventory* in relation to users reported immersion [20]. This personality questionnaire has previously been applied in related fields, such as to adapt a video game narrative based on players' interests [10]. Another factor considered is the amount of walking users might be willing to do, particularly for those without a predilection to it as a pastime. Popular apps like *Zombies Run!* (2012) also offered a story alongside localisation features, but this app was promoted as an exercise tool, whilst Map Story is designed primarily to offer an immersive story experience [21].

2 Related Work

Location-based experiences have grown with the improved sensors found in modern smartphones. GPS gave rise to early experiences such *Geocaching* (2000) treasure hunts and work by Blast theory, such as *Can You See Me Now* (2006) [14]. AR has also been used in heritage projects such *The SPIRIT project* (2001), encouraging new types of visitors by connecting tour sites to an overarching narrative [42]. The inaccuracy of GPS requiring the use of physical markers, alongside faster battery drain were commonly reported issues in such experiences. However modern AR libraries include *Simultaneous Localisation and Mapping* (SLAM), a machine vision algorithm that can accurately align content to the real world without the need for physical markers, whilst phones collect ever more data about the user and their location, giving the potential for greater personalisation of experiences and new opportunities to immerse users [1,18,23].

Location-based experiences aim to generate perceptual immersion though the events closely relating to the user's surroundings, with popular AR game *Pokémon Go* (2016) also demonstrating how real-world locations can gain new significance as a result of the virtual content discovered there [2,30,41]. Research into location-based storytelling has highlighted the benefits in creating moments of ambiguity, such that the user might implicate passers-by in the experience, tied to what Reid refers to as *magic moments* [36]. These result in high immersion when the user perceives a suitably close match between the fictional events and their real surroundings. Karapanos et al. similarly found that watching a short video narrative in the real location corresponding to the narrative offered greater immersion and mental imagery, compared to one where the surroundings did not match or have a similar atmosphere [22]. Artificial Intelligence (AI) and Natural Language Processing (NLP) have been used to try and connect the available information about an area to generate a story, though such approaches have often struggled to make the story engaging and coherent [8,47]. A further approach is to transpose a site-specific experience to new locations by finding suitable equivalents for each POI visited, though this is challenging without varying the amount of walking and atmosphere offered by each location [12,28].

Benford describes a framework for considering mixed reality experiences in terms of a participant's *trajectory* through it, considering how the different spaces involved, use of time, roles and interfaces forming the experience must all be carefully balanced [6]. The designer will have imagined an ideal *canonical* trajectory through an experience, with different users deviating from this, and unknown locations providing greater opportunity for variation, through the cognitive load required to navigate them, as well as considering what behaviour might be appropriate in a particular location, tied to Goffman's concept of *frames* [11,40]. Acting outside of the appropriate frame might cause the user to temporarily disengage from an experience through feeling awkward and self conscious [25,50]. The *The StoryPlaces Project* (2017) outlined a series of aesthetic and pragmatic considerations for designing location-based experiences, including aspects related to walking, safety and how locations may change over time [33].

Murray suggested narrative experiences in any new medium must balance user immersion, agency and transformation [31]. This suggests a potential future direction for this research. Offering increased agency can be related to video game research where the designer offers a world for the user to explore, with the hope the immersion offered means they will not be too drawn to the systems limitations [45]. In the storytelling game *Façade* (2005), taking an active role was found to lead to higher satisfaction, presence and enjoyment, though this was also linked to the game's believable characters and story [38,49]. Jane McGonigal suggests rewards in immersive experiences come from being encouraged to act beyond normal habits and engage with a space and those within it [29]. This parallels research into immersive theatre, suggesting audience members enjoy the added opportunities for sensory interaction, whilst also connecting to a narcissistic desire that the events directly relate to them [3,26].

3 Map Story Design and Procedure

Map Story was made in Unity with the AR features implemented using the ARFoundation plugin, incorporating ARKit for iOS and ARCore for Android, with SLAM positioning to align virtual objects in the real world. This enabled the app to work on iPhones 6s and later and non-lite Android handsets, though SLAM is ineffective in low ambient light levels, so users were asked to only use the app during daylight hours. Map Story also incorporated a bespoke narrative, that directed the user to six sites around their local neighbourhood, whilst attempting to locate a missing fictional character. Each of the six sites chosen were selected as places that would have a strong possibility of existing in the user's real vicinity, such as a public house, school and a church. Users would be guided to the real location in cases where it existed (*real sites*), alternatively visiting a suitable location that could be overlaid with a 3D model of the site described when no real version existed close by (*AR sites*).

On first starting the app, it would connect to the Mapbox API having located the user via GPS, and search for the six real world story sites close to their position. An error screen was presented if Mapbox could not detect any of the six requested sites in an approximate half mile radius around their position, offering the suggestion to try loading the app elsewhere. In cases where some of the six sites could not be found in the designated play area, users would then visit a mixture of real and AR sites. The AR sites would involve the user being guided to a suitable location to overlay a virtual model of the relevant site on top of their real-world surroundings using their phone camera, with the combined AR scene then visible on their phone display. Appropriate real-world locations chosen to place the AR sites varied between empty green spaces, street corners, or on top of other buildings. Additionally some of the real sites were swapped with AR ones in order that the total number of real and AR sites visited was kept roughly equal across the study. After selecting the six sites, an algorithm calculated a route between them and the user's starting position to minimise the total distance walked, this requirement adding a restriction on the story's

design to allow the six sites to be visited in any order. A real-time walking route to the next site was displayed on the in-app map provided.

Additional story was delivered to the user whilst walking to the next site, with CereVoice's *Text To Speech* (TTS) software converting all in-game text to audio, such that the app could be used hands free whilst walking. These story sections encouraged the user to look around, aiming to encourage Reid's magic moments, when an aspect of the story closely resembled the real world. On arriving at a designated AR site, users would be instructed to hold up their phones to overlay a virtual model on their surroundings. Once placed, events would then proceed the same as at the real sites, where users would search for a lost diary page containing new story details and backstory, this virtual diary page appearing in relation to the phone's accelerometer movement, with a large AR marker appearing if users had not found the page after a short time. On picking up the diary page by touching it on the screen, additional story would be revealed before directing the user to the next site. These stages of gameplay at each story site are shown in Fig. 1.

(a) (b) (c)

Fig. 1. Map Story gameplay. Users visit real world locations marked on a local map, some of which are augmented with a virtual model (a). At each location the user must locate a hidden diary page (b) to uncover new story details (c).

The app was refined after pilot testing, which included reducing the number of sites visited from nine to six, to reduce the length of the experience and amount of walking. An option to skip a story site was also introduced in case the user might not want to visit a suggested location, or it was inaccessible or too far away. Participants also raised concerns about the length of the questionnaires completed at each location, so the measures used were refined as described in Sect. 4.

3.1 Map Story Storyline

Map Story incorporates a new fictional narrative where a user is contacted to complete a questionnaire about themselves (actually the extroversion and openness sections of the Big-5 Personality Inventory) and then mysteriously receives a mobile phone in the post (in reality the user using their own phone). The phone received connects to the story of a local scientist who has gone missing, and the user is invited to visit the last six places the missing woman went, which are marked on a map displayed on the phone. The story places the user as a main character in the narrative alongside the missing scientist, and allows the six map locations to be visited in any order, based on minimising the walk between them. Clues to the overarching mystery are revealed through discarded diary pages discovered at each location, as well as through additional story presented as audio whilst walking. After visiting all six sites, the user is led to an open green area (such as a park), where they discover an AR portal they can walk through, to emerge in a fully virtual world visible on their phone screen. Here they finally catch up with the character they have been tracking, who had discovered a way to travel to this parallel version of the user's neighbourhood as shown in Fig. 2.

Fig. 2. Walking through the AR portal at the ending of Map Story.

4 Measures

After Map Story was built and refined through pilot testing, a short user study was conducted. Data was collected through the app by means of pre-questionnaire, a short series of questions repeated after visiting each real or AR story site, and a final post questionnaire. The pre-questionnaire asked users their age, gender, prior experience of AR technology and immersive experiences, as well as the extroversion and openness to new experience sections of the *NEO-FFI-3 Big-5 Personality Inventory* (BFI), these particular dimensions selected as particularly relevant to adopting a novel technology in public, where social play also poses a risk of embarrassment [11]. This formed a first investigation of their effectiveness in identifying different player types, given AR lacks a bespoke tool like the ITQ for VR, that identifies a relationship between a user's immersive tendency and their sense of presence in a VR world [51]. The post questionnaire adopted immersion measures from the *Augmented Reality Immersion* (ARI) questionnaire [15]. This questionnaire is based on Brown and Cairns immersion model incorporating three increasing levels of immersion as successive barriers to deeper immersion are removed. These three levels are further divided into two sub-categories as follows [7]:

1. **Engagement** - Interest and Usability.
2. **Engrossment** - Emotional Attachment and Focus of Attention.
3. **Total immersion** - Presence and Flow.

To provide a quantitative measure of the differences between the real and AR sites visited, participants were asked to rate six statements at each site visited before walking to the next location. The limited question set aimed to prevent a significant interruption in the story, and related to the following:

1. The match of the site visited relative to the one described.
2. The user's focus on the story whilst at the site.
3. Being able to imagine the story events playing out at the site.
4. The user's interest in continuing the story.
5. The usability issues experienced at the site.
6. The story being the user's primary intent (tied to being in a flow state).

Users could also provide their thoughts through the app about each real and AR site visited, as well as on completion of the story. Participants were also invited to take part in a structured interview about their experience which was transcripted and analysed alongside all open feedback. Map Story was also presented as part of a location-based experience workshop, to the Queen Mary, University of London English and Drama department, with this discussion also contributing additional feedback.

5 Results

5.1 Participants

Map Story was downloaded a total of 95 times for Android and 43 times for iOS. Data was only retained from those who successfully completed the experience and visited at least 4 out of 6 of their suggested story sites, given the in-app option to skip any locations that might not be easily accessible. This left 23 completed sets of user questionnaires (15 male, 6 female and 2 of unspecified gender). The participant demographics are shown in Table 1 along with the total number of real and AR sites visited across the study (58 real, 57 AR and 23 skipped), demonstrating the algorithm used was effective in equalling the number of real and AR sites visited, though still with a significant number of sites skipped. In addition twelve participants agreed to take part in a post interview providing more detail about their experience at both the real and AR sites visited, from their choice of location to use the app.

Table 1. Demographics of the 23 participants who took part in the Map Story user study (left) and a breakdown of all real and AR sites visited (right).

		Participant count
Gender	Male	15
	Female	6
	Other	2
Age	18–29	9
	30–39	8
	40–49	5
	50+	1
Previous AR Experience	Limited	17
	Appreciable	6
Previous immersive Theatre experience	Limited	10
	Appreciable	13

Site name	Site count	
	Real	AR
School	12	7
Public house	12	8
Church	10	9
Pond/Lake	6	15
House	10	6
Shop	8	12
Skipped sites	23	

The data collected was checked for internal consistency using Cronbach's alpha, with the results shown in Table 2, demonstrating good internal reliability in most cases, though with a slightly lower value in the emotional attachment dimension of the ARI questionnaire. The results for this dimension are still reported, though it is worthy of further discussion whether the questions may have generated confusion, or have been influenced by external distractions given

Table 2. Internal consistency of each of the study measures used.

Measure	Scale reliability	Mean score and sd
Big-5 extroversion (8 items)	$\alpha = 0.84$	M = 3.11, SD = 0.61
Big-5 openness (10 items)	$\alpha = 0.88$	M = 3.85, SD = 0.68
ARI interest (4 items)	$\alpha = 0.87$	M = 5.75, SD = 0.97
ARI usability (4 items)	$\alpha = 0.85$	M = 5.88, SD = 0.94
ARI emotional attachment (3 items)	$\alpha = 0.42$	M = 5.07, SD = 0.82
ARI focused attention (3 items)	$\alpha = 0.63$	M = 4.68, SD = 1.13
ARI presence (4 items)	$\alpha = 0.71$	M = 3.43, SD = 1.05
ARI flow (3 items)	$\alpha = 0.71$	M = 3.68, SD = 1.25

their completion in public. Additionally, a number of the measures showed a departure from a normal distribution after conducting a Shapiro-Wilk test. This influenced the choice of statistical analysis techniques used.

5.2 Immersion Relative to the Proportion of Different Sites Visited

The ARI immersion scores reported by each participant were correlated against the proportion of real and AR sites that each participant visited (each participant visiting a mixture of at least 4 real and/or AR sites). A Spearman rank correlation test was used due to the data deviating from a bivariate normal distribution, with a medium size positive correlation only suggested in terms of users' focus of attention and the proportion of AR sites visited (rho = 0.41, $\boldsymbol{p} = 0.049$). An equivalent negative correlation for users' focus of attention score with the proportion of real sites visited was partially support by the correlation factor (rho = -0.38), though not significant at a 5% significance level ($\boldsymbol{p} = 0.07$). However, with the limited sample size and resulting errors, this is suggested as a worthwhile area for further investigation.

Figure 3 displays the 6 ARI dimension scores across all participants, as well as the grouped scores according to Brown and Cairns 3 levels of increasing immersion. This provides evidence that the app was only effective in promoting the lowest level of immersion in terms of user engagement. A paired Wilcoxon signed rank test suggests each user's engrossment score was significantly lower than their engagement score ($r = 0.82$, $\boldsymbol{p} < 0.001$), and similarly their total immersion score was less than their engrossment score ($r = 0.87$, $\boldsymbol{p} < 0.001$). In this model the highest levels of immersion relate to a user experiencing both a sense of presence that they are part of the AR environment, alongside a sense of flow, related to an optimal experience.

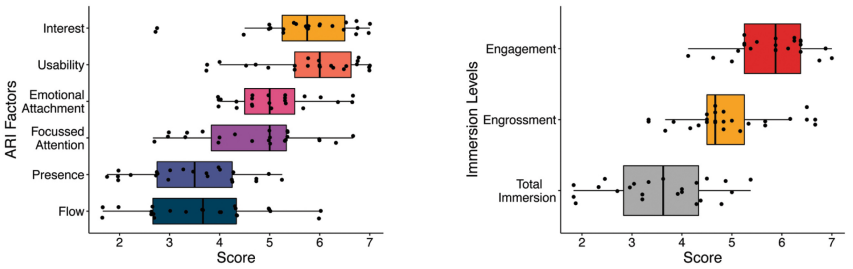

Fig. 3. The 6 ARI dimension scores for all participants (a), also summarised in terms of Brown and Cairns 3 increasing levels of immersion (b).

5.3 Ratings for Real and AR Sites

Six statements were rated to investigate differences between the two types of site, whether real or AR. Based on the null hypothesis that the responses were the same at each site, a Wilcoxon rank sum test was applied (the responses not being normally distributed) comparing the median scores for the sites visited. The scores for each of the six statements at the 58 real and 57 AR sites visited are shown in the box plots in Fig. 4 and suggest the null hypothesis is not valid for three of the statements at a 5% significance level ($\boldsymbol{p} < 0.05$). The relevant statements are how well the site matched the one described in the story ($r = 0.51$, $\boldsymbol{p} < 0.001$), how real the site felt in relation to the story events ($r = 0.27$, $\boldsymbol{p} < 0.001$), both of which demonstrate a higher score in the case of the real sites,

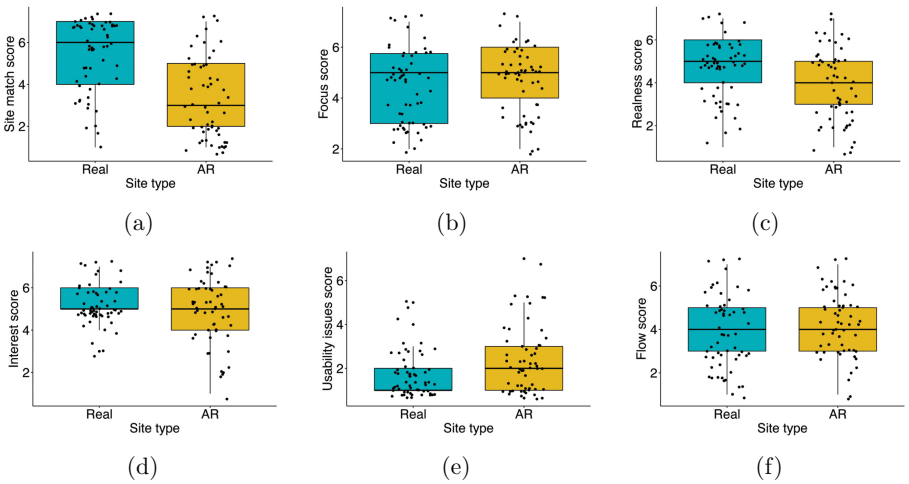

Fig. 4. Box plots showing the six statement ratings at the 58 real and 57 AR sites visited across the study. Each statement refers to the following aspects of the site (a) Site match, (b) User's focus, (c) Realness of events, (d) User interest, (e) Usability issues, (f) User's sense of flow.

though with only a medium effect size in terms of the site match. Additionally the score for usability difficulties was suggested as having a higher median value for the AR sites ($r = 0.21$ $\boldsymbol{p} = 0.03$) though with a relatively small effect size. An equivalent result was obtained considering the mean responses to each of the six statements averaged across the real and AR sites visited by each participant. This comparison was calculated for verification purposes and the same three statements showed a significant difference comparing the real and AR sites.

A non-parametric Kruskal-Wallis rank sum test found no significant difference in user responses across the six different AR sites. This indicates no preference towards any 3D models used as AR overlays. However, the test is limited by the small number of data points for each AR site, and is reported for guidance only.

5.4 Varying Immersion for Different Users

A Spearman rank correlation test was used to look for evidence of a correlation between each ARI factor and each participant's reported extroversion and openness BFI scores, with a null hypothesis based on there being no relationship. This null hypothesis was supported by the results with no evidence of a correlation between any of the ARI dimensions and personality factors ($\boldsymbol{p} > 0.05$ in all cases). The same result was confirmed in relation to each user's average scores across the AR and real sites they visited, with the six statements rated at each site showing no evidence of a correlation to their reported extroversion and openness scores. The six ARI dimension scores were further investigated for differences according to users gender or previous experience of AR and immersive theatre, by means of an unpaired Wilcoxon rank sum test. This test was limited by the number of users in each group, but again did not provide any evidence of a showing a significant difference in score at a 5% significance level.

5.5 Varying Immersion Based on Distance Walked Between Sites

The six statements completed at each site were also compared against the distance traversed to reach the site. Using a Spearman rank correlation test evidence for a small positive correlation (rho = 0.29, $\boldsymbol{p} = 0.03$) was only detected in respect of how well the real sites matched the story, suggesting the possibility that a close match might offer a small reward for walking to the real site for some users. This is discussed further in the following section where the open feedback received offers an alternative picture based on the amount of walking involved.

6 Discussion

User feedback suggested Map Story was largely successful in its first aim to create a mobile AR story app that could be used almost anywhere, though identifying some areas for improvement, such as the limited number of available sites at certain map coordinates. This was primarily a result of the map API

used, which also resulted in excess walking between some sites (>250 m), that led to some users not completing the experience citing, *"many locations were too far apart"*, and providing less data points for these longer walking distances as a result. Feedback also highlighted that users expect such an experience to finish back at their starting location unless notified otherwise in advance. The higher ARI focus of attention score for AR sites was supported by some user feedback, *"the AR elements definitely make it more engaging"*, tied to being offered something new in cases where users knew their neighbourhood well. This has been also been suggested as one contributing factor why Niantic's *Harry Potter:Wizards Unite* (2019) did not perform as well as their previous game Pokémon Go. Both games used the same POIs, with their familiarity potentially offering less incentive to play [24]. With Map Story one user commented, *"I felt knowing the local area well made to harder to think about it in terms of the new story"*, though they do not elaborate if the AR features made the task easier in this respect. The real sites scored higher in terms of matching the story, with most issues around them tied to the map data being out of date. Issues with the AR sites primarily related to the 3D model being overlaid awkwardly on top of the real world, providing a greater barrier to immersion. Users also reported the AR could have been used more effectively such as through offering greater interaction, *"I feel the AR could have fed way more into the story and given more chances to lose ourselves in the world"*. A couple of users also assumed they had been lead to the wrong location when they knew a real site equivalent existed nearby, causing confused at the request to place an AR scene. In this respect the AR markers used to let participants know they were searching in the right place for a diary page did not break immersion, but were cited as a comforting feature to let someone know they were looking in the correct place.

Feedback also suggested that the app was only successful in encouraging deeper immersion at particular moments, tied to Reid's magic moments where an aspect of the story temporarily paralleled something in the real world environment, *"a driver asked directions to the church which turned out to be the next location to visit"*. Passing by a real school provided an opportunity for magic moments, but several participants reported feeling uncomfortable using their phones near to where children were playing, raising an important ethical consideration for designing an app used in public spaces. Even when story events did not match the real world, some users demonstrated their desire for immersion in making the inconsistencies fit, *"not sure this pub operates anymore, it somehow matches the eeriness of the story"*. Encouraging deeper levels of immersion and engagement might come from offering increased agency and interaction with the virtual content. However, there are also questions around the suitability of quantifying experience using the standard models of presence and flow adapted to the ARI questionnaire's levels of immersion in Brown and Cairns model. The Pervasive GameFlow model devised for research into pervasive experiences, highlights the need to adjust the standard criteria for flow to occur in such cases, given players will inevitably report a greater awareness of their surroundings, which often also leads to greater focus on their personal intentions [19].

The story used in Map Story specifically allowed several real-world locations to be visited in any order, which by design led to it being experienced as mysterious and at times ambiguous. This was divisive, with some users enjoying the suspense and replaying audio tracks several times to listen for hidden clues, whilst others reported that it left them unsure of the main character's motivations. As a result whilst many reported enjoying the ending, others felt they were surprised when it did not match their interpretation of the events. This highlights the importance in developing a tool to identify user types in such AR experiences, which was not supported through the two dimensions of the Big-5 model adopted here. Additional suggestions for improving the app included a desire for improved visuals, as well as additional audio whilst walking, alongside audio cues to let users know they had arrived at the target location when using the app hands free. Additional audio narration would also benefit the chance of creating further magic moments by encouraging users to connect the story with their environment. The use of the TTS audio was generally well received, though a few participants found the voice distracting and slightly robotic, desiring a human narration. Several users also hoped that the personality questionnaire completed might have further personalised the experience. This is an ongoing research area with previous studies reporting its potential positive effect on user immersion [16,43,48].

7 Limitations and Future Work

The user study was carried out whilst there were ongoing Covid-19 pandemic restrictions regarding outside exercise. Despite the app offering a solo immersive story experience, this still had an effect on participant recruitment as demonstrated by the small sample size. This made some of the desired quantitative analysis impractical due to the limited number of participants of different age groups or with significant previous experience of using AR, and is why a more extensive qualitative analysis involving user post interviews was performed alongside the quantitative findings, to confirm the efficacy of the results. The restrictions also limited the ability to observe participants taking part, in order to see how different users reacted to using the AR app in public spaces.

Users took part using their own phones at their own choice of location. Whilst the app performed similarly on a range of handsets it was tested on, some variation in experience might be expected in relation to the screen size and the particular Android or iOS model used. The variety of locations poses the largest confounding variable given the variation in passers by, distractions, atmosphere and spacing of the story sites. There is an argument that the app is designed specifically for this purpose, and so should be tested *in the wild* as opposed to a lab environment, though the effect is evident in some users' scores and feedback, *"the area was very busy which made the experience less engaging"*. The choice of story poses another potential confounding variable given the range of users taking part. Collecting data primarily through the app added a challenge to confirm that all data retained was from those who completed the study appropriately.

To this end data was only kept from those who visited at least four out of six of the suggested story sites, the skip feature implemented after pilot testing given the risk of the map API referencing outdated map information. This limit on the data kept prevented users' data being retained who did not engage in a significant walk around their neighbourhood using the app. A further limitation was that users were only given a single opportunity to place the AR sites through their phones, which risked the virtual models being overlaid awkwardly on the real world. This is a key requirement for future iterations of the app, that users be given the opportunity to re-position any overlaid AR content before deciding its final location is appropriate. Salen and Zimmerman's *immersive fallacy* states that participants are aware their belief in the story world is voluntary, and will want to aid generating immersion, such as through helping to more seamlessly overlap the story world with the real world [29,46].

8 Conclusion

Map Story was largely successful in providing a real-world story that could be experienced anywhere through the addition of AR elements. Evidence for the benefits of such an approach are suggested through users' increased focus of attention on the story. It was suggested this offers a greater opportunity for a novel experience when the user is already familiar with their local area. Challenges arise around AR risking greater usability issues, as well as a user accepting the story events in relation to the virtual elements. The use of AR markers demonstrated benefits in comforting users, by letting them know that they were at the correct location, though more freedom to align virtual content relative to the real world is required for further iterations of the app, with evidence that the increased agency offered would help to enhance immersion rather than detract from it.

The BFI personality measures used did not show a relationship with users reported immersion levels, in spite of user feedback demonstrating several differences in opinion regarding the app. Personalising such an experience based on users' preferences is a worthwhile goal for AR experiences, though challenging due to the lack of specific tools for analysing AR experiences. As an example, excessive walking was found to be a deterrent to immersion for some users, though this could be controlled through a map API with a greater number of labelled map sites, or users might be encouraged to walk further through offering additional story content. A further improvement is that users desired to finish the app close to their starting point unless a different end location was notified in advance. The occurrence of magic moments did offer moments of high immersion, with the role AR might play in aiding the creation of such moments a further consideration for the next iteration of the app. AR needs to be used appropriately, as was deemed unnecessary or confusing when a similar real world equivalent existed nearby. However it was also shown to offer benefits in terms of a new experience in a possibly familiar location, as well as offering the potential for new opportunities for interaction in the story events, as proposed for a future revision of Map Story in the hope it can offer a more immersive user experience.

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