Comparing actual and virtual movement in a play anywhere mobile AR location-based story

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ABSTRACT

New storytelling mediums are available to users through the digital technology present in modern mobile phones, presenting opportunities for increased personalisation and self-directed play. Many immersive experiences were unavailable during the COVID pandemic, highlighting a desire and demand for experiences that could be used close to home. Map Story 3 is a new immersive AR story app, designed to be used at a user's choice of location, bringing it closer in-line with the story, by overlaying interactive virtual content on top of the surroundings. A user study was conducted with two versions of Map Story 3, to investigate the differences between virtual movement in an AR location-based immersive experience, and actual movement involving walking between locations. The walking version scored significantly higher in relation to the majority of the immersion measures collected, suggesting the version where the user remained stationary currently offers significant barriers to immersion, when the objects were not displayed against congruous surroundings.

Keywords

Mobile Augmented Reality, Location Based Storytelling, User Immersion

INTRODUCTION

The rise of digital technology has provided opportunities for new storytelling mediums where the audience is offered a greater role in events. This includes observing them from various viewpoints, performing actions that influence the story direction as in various video games, or the ability to directly interact with physical objects and actors as in immersive theatre productions (Murray 1998) (MacIntyre and Bolter 2003) (Machon 2013). Recently, many site-specific experiences were forced to close due to the COVID pandemic. This led to the design of a storytelling app, specifically created for scientific study, to offer users an

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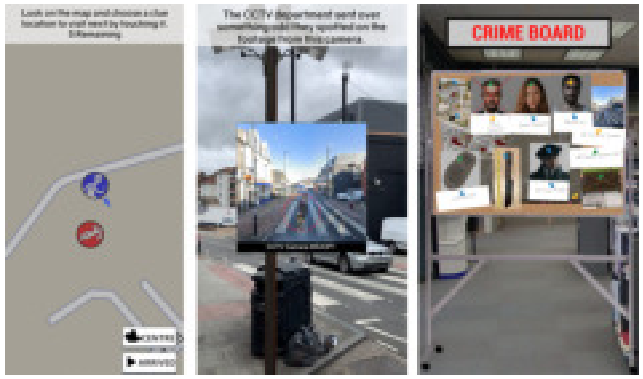


Figure 1: Images of Map Story 3 gameplay, where the user or a virtual agent is directed to nearby locations, placing and interacting with AR scenes, to build up a personalised clue board tied to a fictional story.

immersive story at their own choice of location, personalising the experience by incorporating aspects of the user's real world surroundings into the narrative. *Augmented Reality* (AR) was offered through a user's mobile phone, so a variety of different users could take part, and map locations could be brought closer in line with the story, by overlaying virtual objects. The story encouraged connections between the story world and the real world, whilst offering a variety of tasks as part of a pre-written story. Salen and Zimmerman's *immersive fallacy* has suggested that adults have a desire for immersion as long as there are not significant barriers to achieving it, with Murray suggesting that a balance of immersion, agency and transformation are important factors in maintaining engagement through stories told in new digital mediums (Tekinbaş and Zimmerman 2003) (Murray 1998).

Many location-based experiences take the form of guided story walks, which encourage a listener to make associations with local sights and people, and have grown in popularity with podcasts and the ease of downloading digital audio (Hardman 1983) (Klich 2017). However the pandemic has also demonstrated a desire to make immersive experiences available to those who are less able to leave their homes, as well as those less able to engage in physical activity. Niantic modified its popular AR games Pokémon GO and Harry Potter:Wizards Unite to better support playing the games at home. These changes were positively received, with social media campaigns trying to keep the changes after it was reported they would be ending (Ellis et al. 2020). The app created as part of this research aimed to compare users' responses to two versions of the same story that could be played at or near home, one that involved walking between local sites, with the other used primarily stationary at home. Deterding suggests encouraging the use of imagination is key to such experiences, with imagination arising from the story itself, the theming, the way the story is framed, and the user's opportunity for role-play (Deterding 2016). This connects to Walton's suggestion that immersion in art is maintained through the desire to ask *"what if"* questions about the people and situations depicted (Walton 1990). This idea has been extended to mixed reality through the suggestion that virtual objects may parallel the choice words used in a story, acting as props to guide the user to make sense of events and ask questions about the world presented (McDonnell and Wildman 2019). A user study with the app questions whether the virtual objects alone placed in a user's immediate vicinity in the stationary version of the app, may offer similar immersion to a walking version, where the virtual objects are overlaid at local sites selected to be part of the story from map data. Before outlining the user study, this paper looks at prior research in this area, as well as some of the technical aspects of the app, and the experience it offered.

Map Story 3 implements improvements from an iterative design process adopted through earlier iterations. This includes advanced controls and guidelines in the story where virtual objects should be placed, as well as a greater variety of tasks to perform with the different AR scenes. The later user study was intended to investigate the following questions:
RQ1. Will taking part in the stationary or walking versions of the app offer a significantly different user experience, as measured through a series of existing validated questionnaires?
RQ2. Which activities offered in relation to the placed AR content proved most popular, and did this vary between the version of the app where the user moved physically compared to the one incorporating virtual movement?
RQ3. Could any differences in immersion and engagement be observed through the details collected about the participants who took part in the user study?

RELATED WORK

Map Story 3 builds on previous research into real world pervasive experiences, often described as extending Huizinga's magic circle of play both spatially, socially and temporally (Oppermann and Slussareff 2016). The app also ties to research into location-based experiences that use GPS technology to incorporate game mechanics related to a user's position. Such experiences have developed from early real-world treasure hunts like Geocaching, to battling nearby players through SMS messages in Botfighters, as well as Blast Theory's projects to let real world and online players collaborate simultaneously (Montola et al. 2009) (Sotamaa 2002) (Flintham et al. 2003). The growth of smartphones containing various sensors offering data about a user and their surroundings, have led to the popularity of AR games like Pokémon GO. Here real world *Points Of Interest* in-game significance (Sifonis 2017). New AR features also no longer require physical markers as reference points, with *Simultaneous Localisation and Mapping* (SLAM), providing a machine vision markerless image tracking, through the camera view of an environment (Ketchell et al. 2019).

Immersive stories tied to real-world locations

Mobile phones provide access to information about a user's location through GPS, alongside online resources such as the Google Places API, that offers local place information. Niantic crowdsourced additional local information based on user submitted suggestions to build its private Portal Network (Laato et al. 2019). However, challenges remain in using the available information to create a story at a location. Attempts have been made to use *Artificial Intelligence* (AI) and *Natural Language Processing* (NLP) to turn the information about local POIs into a story, but even current AI struggles to offer a coherent narrative to match a human author's plots and believable characters (**kretschmer_meeting_2002**) (Budvytyte and Bukauskas 2006) (Stegeren and Theune 2018) (Mateas and Sengers 1999). There have also been attempts to transpose pre-written plots to different locations, by finding local equivalents for each location in the story, using machine learning. Challenges arise in terms of the changing atmosphere offered by each location and varying walking distances such an approach will bring (Ferreira et al. 2019) (Macvean et al. 2011). The current app aims to alleviate some of these issues by using overlaid virtual content through AR, to overlay specific features on a user's location, that are required by the story.

Some of the most successful location-based experiences have consisted of those for the heritage sector, designed to encourage new visitors. These experiences are often site-specific, connecting to the unique historical aspects of the location. Examples include REXplorer created to learn about the German town of Regensburg, alongside TimeWarp and SPIRIT that both incorporated AR (Ballagas et al. 2007) (Blum et al. 2012) (Packer et al. 2017). Studies involving a short video narrative iLand, suggested greater immersion and mental imagery occurred when a location closely matched or had a similar atmosphere to a story (Karapanos et al. 2012). However, barriers to immersion may occur from a location that offers many distractions, affecting a user's cognitive load, or as a result of the user feeling self consciousness (Shin et al. 2019). Such feelings can occur from being observed acting in a way the user worries might be perceived as childish, or acting out of the current *frame*, a term used by Goffman in relation to what behaviour is considered acceptable for a certain situation (Deterding 2018) (Wiseman et al. 2017). *The StoryPlaces Project* offered guidelines for location based stories through both pragmatic and aesthetic considerations, designed to help an audience be more open to the ideas presented (Packer et al. 2017).

Meaningful location based experiences

Location-based experiences are often studied alongside research into play, where the lack of a clearly isolated Huizinga's magic circle, can lead to issues arising from self consciousness, varying fitness, potential real world dangers and frustrations from identifying what actions to take (Walther 2011). Taking action has been related to generating meaning both positively and negatively, with people desiring to have actions available that will return them to a high hedonic state, as they might start to become bored, or alternatively experience moments of high anxiety (Merleau-Ponty and Landes 2012) (Apter 1989). Such real world experiences need to be designed with this in mind, given that each user will take their own unique path through such an experience. This has been described by Benford's trajectory model, where a user's trajectory will deviate from the designer's idealised path through the story (Benford et al. 2009). Encouraging the use of imagination is used in stories to fill in deliberately ambiguous details of a narrative, and enhance a reader's transportation to the world of the story (Bucher 2018). Additional meaning can be generated in location-based experiences through trying to connect it to the atmosphere of a location, as well as by encouraging individuals to infer their own relationships between the real and story worlds, tied to humans desire for making such connections (Boswijk et al. 2005) (Dansey 2008). Reid suggests *magic moments* provide a temporary high level of immersion through deliberate or coincidental moments of close similarity between the story and real worlds (Reid et al. 2005). Designing experiences with such ambiguity in mind can be key to their enjoyment, through offering this perceptual immersion specifically tied to a user's surroundings (Mcmahan 2003) (Gaver et al. 2003).

Measuring engagement and immersion

With the growth of mixed reality experiences, there has been various research tools validated for their suitability to measure user's engagement, positive and negative affect, usability, immersion, and sense of presence related to such experiences. There tends to be more resources designed for VR environments, arising from the unknown challenges when pervasive experiences are set in the real world, as well as some AR experiences where the user might be required to split their attention between a display device and the real world in order to maintain safety whilst navigating. The Pervasive GameFlow model suggests that Mihály Csíkszentmihályi's eight criteria for flow, are unlikely to be all fully met in such an experience, with pervasive experiences also often involving less clear goals, and so flow which is related to a balance between skill and challenge (Jegers and Wiberg 2006) (Brooks 2003). The *Augmented Reality Immersion* (ARI) questionnaire is one questionnaire made specifically to measure immersion in AR experiences, based on adapting Brown and Cairns three immersion level model, each successive level reached after removing further barriers to deeper immersion. The highest level of total immersion is directly related to the experience of both presence and flow, despite the previous suggestion that achieving flow might differ in such experiences (Georgiou and Kyza 2017).

Another approach adopted for stories told in new digital mediums, are questionnaires used to measure the extent of the user's transportation by a narrative in terms of their mental, story and emotional engagement. Transportation has been related to a sense of presence and feeling part of the story world. One such questionnaire is the *Narrative Transportation Scale* (NTS), that has been applied to stories in video media after its development for literary narratives, with the questions proving relevant to any type of story (Green and Brock 2000) (Karapanos et al. 2012). A further area of interest that has little prior research for AR, is how different users' experience might vary. This has proved a significant area of study tied to both *Reader Response Theory* for literary narratives, various player models in relation to video games, and with the *Immersive Tendency Questionnaire* (ITQ) in VR, that relates a user's immersive tendency with their sense of presence in a VR world (Green and Brock 2000) (Busselle and Bilandzic 2009) (Bartle and Philosophy Documentation Center 2007). Awareness of such user models has aided the personalisation of video games to maximise player enjoyment, though there is little research as to whether the ITQ or similar inventory might be applicable to AR experiences. Some replication studies have also suggested the relationship in VR might only hold in high presence situations (Witmer and Singer 1998) (Johns et al. 2000).

MAP STORY 3 DESIGN AND EXPERIENCE

This section outlines the design of the app as a research tool for location-based stories, to compare user immersion where AR is applied in different ways in relation to the same story. The mobile app was created in the Unity game engine with the AR features implemented through the ARFoundation plugin. This enabled the app to work on iPhones (6S or later) and the majority of non-lite Android devices, capable of supporting AR through the phone camera, implementing the SLAM algorithm to align virtual models. The linear story took the form of a murder mystery, given the investigation of a crime scene has parallels to an AR environment, where both involve selecting from available actions to reveal a hidden

Figure 2: In the walking study condition, the user walks between the target locations shown on a map after selecting a clue location. In the stationary condition a virtual agent walks between the locations following the *Mapbox API's* suggested walking route as shown in white, whilst the user remained stationary.

story (Sandvik 2010). On first starting the app, a local map was generated using the Mapbox API, and five nearby clue locations added to it. These were detected using the Google Places API, to find the most significant places or *Points of Interest* (POIs), within 250 metres of the user's starting position, with the closest one acting as the scene of the crime. Metadata about these locations provided additional information as well as allowing the rejection of inappropriate sites. Users of the app could select which clue location to visit next, with the ending taking place on a road close to their starting location, given such a preference was highlighted in previous iterations of the app.

Users were then introduced to the story and provided with instructions relevant to either the stationary or walking versions. In the stationary condition the user was asked to remain at a single location throughout the experience, successively overlaying all objects at this location, though allowing minimal physical movement for those who wished to move and inspect the objects. Here, a virtual agent was shown moving between the selected locations on the local map, the agent following the Mapbox API navigation tools walking route, as demonstrated in Figure 2. In the walking version of the app, the user was required to visit each real world location before placing a 3D model there in a suitable position tied to the objects location in the story. Positioning and rotation tools were provided to accurately align the objects, with gameplay in both versions of the app shown in Figure 3. The objects were placed in a pre-determined order matching the linear narrative.

After placing each model, a variety of tasks were offered required to progress the story. These involved both imagination tasks asking the user to imagine what events might have taken place around the AR scene, as in the case of a taped up bench, as well as interaction tasks that involved directly interacting with the objects, these tasks performed using the phone's touchscreen and accelerometer. Some tasks and identifying suitable map locations

Stationary Walking Stationary Walking

(a) (b)

Figure 3: Map Story 3 gameplay involving the waste skip object, (a) and the car model, (b). The left-hand image in both cases displays the stationary study condition with objects overlaid in at the user's immediate vicinity, with the right-hand image showing gameplay in the walking version.

involved further API calls, such as to Google's Nearest Road API to find an appropriate location along a road. The Google StreetView API was also used in relation to the CCTV camera object. Here a photo was downloaded and modified with an overlaid image of a suspect, to represent an image caught by a local CCTV camera at that map location. An example of some of the other tasks offered is shown in Figure 4, with the sequence of virtual objects placed as follows:

1. The crime scene.
2. A taped up bench.
3. A suspect's discarded evidence.
4. A street CCTV camera.
5. A rubbish skip.
6. A suspect's car.

After the user (or the virtual agent representing them) had visited a location and the user completed the interaction, evidence was added to a personalised clue board. This displayed the local map and real world names of clue locations, alongside any in-game photos the user had taken. As the user or the virtual agent moved between locations, further story was delivered through audio, encouraging the user to imagine who might have seen the victim and what events transpired. After the fifth location, users returned to a road close to the crime scene, where they were presented with an ending to the story, before being asked to complete questionnaires and offer any additional thoughts on their experience. The stationary version of the app would take around 25 minutes to complete, with the walking version lasting around 35 minutes due to the extra time taken to move between locations.

(a) (b)

Figure 4: Examples of some of the tasks performed during Map Story 3 after placing an object. At the bench (a), the user is asked to imagine what might have happened at the location and and who potentially witnessed the victim there. With the evidence object (b), the user is asked to collect the evidence revealing a footprint which is then scanned using their phone to make a cast.

Due to the risk a selected site might be inaccessible in the walking version, users were given a limited number of options to trigger the story to continue manually, instead of it triggering through their GPS position. In such cases, the user was asked to place the virtual object close to the intended target at a suitable position that fit with the story.

Map Story 3 data collection measures

Adopting questionnaires outlined in the earlier literature review, participants were asked to complete the *ARI* questionnaire on finishing the app, designed to measure their immersion in an AR experience, adapted from Brown and Cairns three immersion levels of engagement, engrossment and total immersion. Users also completed the *Narrative Transportation Scale* (NTS) connected to their emotional involvement, story immersion and mental imagery. The NTS has been adapted beyond literary narratives to measure the three types of immersion in various story media, as in the previously discussed location-based video narrative iLAND (Green and Brock 2000) (Karapanos et al. 2012).

On starting the experience, users completed a pre-questionnaire collecting their gender, age, previous experience of AR technology, enjoyment of walking for recreation and prior knowledge of the neighbourhood they had chosen to use the app. Users also completed the *Immersive Tendency Questionnaire* (ITQ), related to one's tendency to become involved, emotionally engaged and focus attention on an activity. The ITQ was validated through a relationship to user presence observed in VR experiences, and applied here as a preliminary investigation whether a user's immersive tendency might have a similar relationship to the immersion measures collected in AR (Witmer and Singer 1998). A question set was filled in after each clue location completed, with users asked to rate how easy it was to place and interact with the AR content, how much they enjoyed that section of the experience, and the degree to which they were keen to continue the story. This short question set was designed to limit the story interruption, whilst potentially revealing how users' opinion changed across the experience. On completion of the story, participants were also asked to rate their preferred top three AR locations visited. This offered a cross reference to the scores from each clue location, as well as providing useful insight into whether some virtual models or interactions were enjoyed more than others. Further data was collected from open feedback submitted through the app as well as from some users who agreed to take part in a 30 minute structured interview about their experience.

RESULTS

Participants

Participant recruitment for the app user study was done across various channels, including university mailing lists, social media, as well as the online study recruitment site, Prolific. In total 60 participants' data was retained for analysis (40 female, 19 male, 1 other gender identity), having completed the study in an appropriate manner based on a review of their data. 7 participants took part in an extended structured interview to provide additional feedback, these participants not coming from Prolific, due to its anonymity requirement. A breakdown of participant demographics is shown in Table 1, which demonstrates that the majority of those who took part were female, in a younger age group and with limited previous AR experience.

		Participant Count	
		Stationary	**Walking**
Gender	**Male**	10	9
	Female	19	21
	Other	1	0
Age	**18-29**	22	16
	30-39	5	9
	40+	3	5
Previous AR Experience	**Limited**	25	26
	Significant	5	4

Table 1: Demographics of the 60 participants who took part in the Map Story 3 user study in both the stationary and walking study conditions.

The questionnaire measures used were checked for internal consistency using Cronbach's alpha, which examines the uniformity of the question/item scores whose average produces users' rating for each measure. The results are shown in Table 2, demonstrating largely good internal reliability, though with values lower than 50% reported in the case of the *ITQ* tendency of a user to become involved in a new activity score, and the *NTS* story immersion scores. Both these questionnaires are not designed specifically for AR, which may have led to discrepancies in these factors.

Post experience measures of immersion and story engagement

Several of the NTS and ARI factors collected showed a departure from a normal distribution, a Shapiro-Wilk test used for this analysis. This affected the subsequent choice of statistical analysis used. A Levene test was used to test the homogeneity of variances between the two study conditions for each of the NTS and ARI factors. A significant difference was only

Measure	Scale reliability	Mean score and sd
ITQ Maintain Focus (6 items)	$\alpha = 0.75$	M = 5.34, SD = 0.79
ITQ Become Involved (5 items)	$\alpha = 0.48$	M = 4.82, SD = 0.82
ITQ Emotional Engagement (4 items)	$\alpha = 0.68$	M = 5.07, SD = 1.04
NTS Emotional Involvement (5 items)	$\alpha = 0.71$	M = 3.75, SD = 1.10
NTS Story Immersion (3 items)	$\alpha = 0.42$	M = 3.67, SD = 1.14
NTS Mental Immersion (2 items)	$\alpha = 0.82$	M = 4.92, SD = 1.47

Measure	Scale reliability	Mean score and sd
ARI Interest (4 items)	$\alpha = 0.82$	M = 5.64, SD = 1.12
ARI Usability (1 item)	α = N/A	M = 5.52, SD = 1.40
ARI Emotional Attachment (3 items)	$\alpha = 0.87$	M = 5.0, SD = 1.41
ARI Focused Attention (3 items)	$\alpha = 0.77$	M = 4.76, SD = 1.36
ARI Presence (4 items)	$\alpha = 0.85$	M = 3.84, SD = 1.51
ARI Flow (3 items)	$\alpha = 0.77$	M = 4.17, SD = 1.48

Table 2: Internal consistency of each of the study measures used across both study conditions.

observed in the case of the NTS mental immersion score, appearing more widely spread in the version where the user remained stationary ($F(1,58) = 4.1$, $\boldsymbol{p} = 0.047$). All user scores for each immersion factor are shown in the box plots in Figure 5.

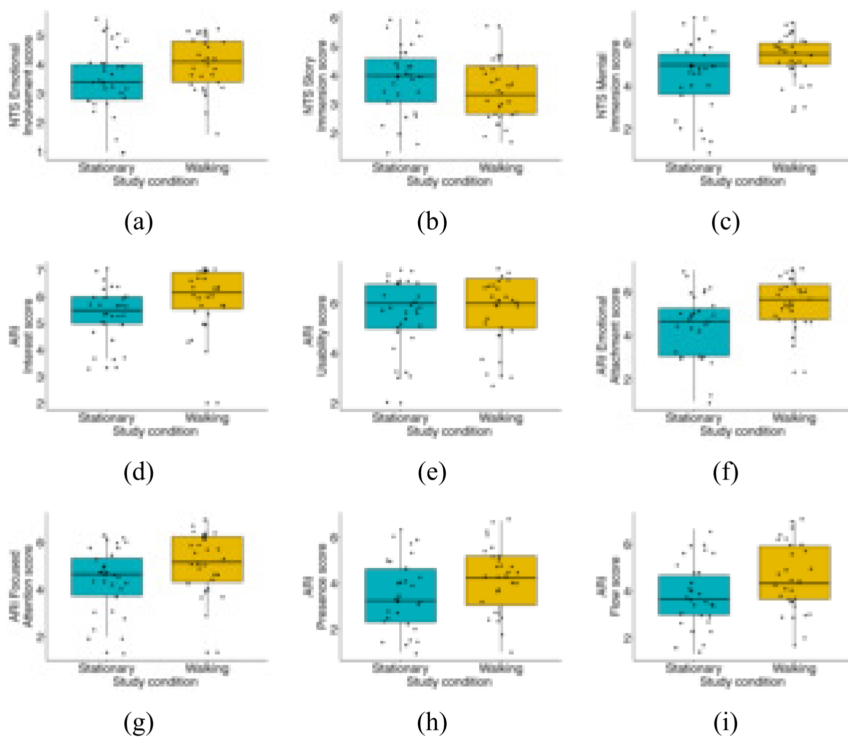
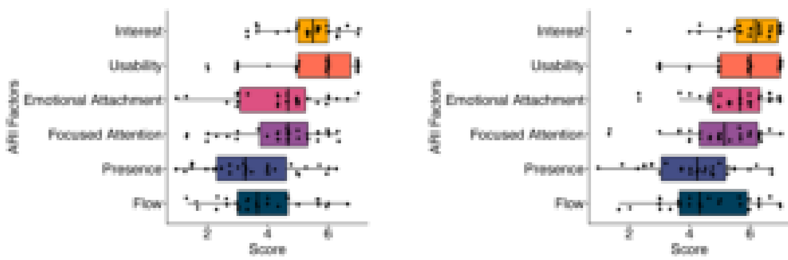


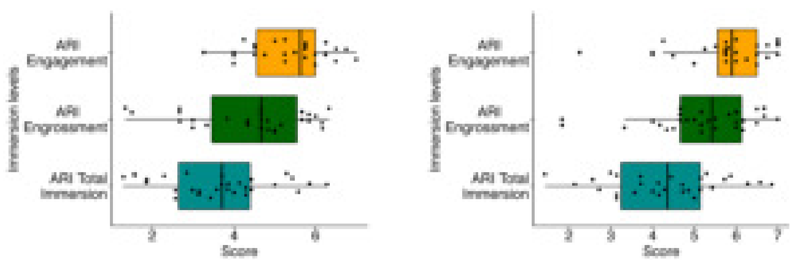
Figure 5: Participants NTS and ARI scores shown separately for the stationary and walking versions. NTS factors are (a) Emotional involvement, (b) Story immersion and (c) Mental immersion. ARI factors are (d) Interest, (e) Usability, (f) Emotional Attachment, (g) Focused Attention, (h) Presence and (i) Flow.

The ARI results are displayed by stationary or walking version in Figure 6, with the the six factors combined in pairs according to Brown and Cairns three levels of increasing immersion in Figure 7. Here the lowest level, engagement is calculated from users' interest and



(a) (b)

Figure 6: Participants ARI scores summarised separately for the stationary study condition (a), and the walking study condition (b).



(a) (b)

Figure 7: Brown and Cairns 3 levels of immersion shown separately for the stationary study condition (a), and the walking study condition (b). The levels are derived from the ARI factors as *Engagement* (interest and usability), *Engrossment* (emotional attachment and focus of attention) and *Total immersion* (presence and flow).

usability scores, up to the highest level of total immersion related to a user's presence and flow scores.

A Mann Whitney U test investigated the null hypothesis that randomly selected user ratings of each factor (NTS, ARI and ARI Brown and Cairns immersion levels) would not differ across the stationary and walking versions of the app. The results are shown in Table 3, and demonstrate that the walking version of the app was scored significantly higher than the stationary version in 5 out of the 9 measures checked, at a 5% significance level, including the engagement and engrossment immersion ratings.

Further investigating the three levels of immersion according to Brown and Cairns model in terms of engagement, engrossment and total immersion, a paired sample Wilcoxon rank sum test looked at how each user scored each of the three levels. This offered significant evidence that each participant tended to score each successively higher immersion level less than the previous one in both study conditions. This is shown in Table 4 and suggests the app was not successful in achieving the higher total immersion level associated with presence and flow.

Questionnaire measure	Effect, *r*	*p*-value
NTS emotional involvement	(0.24)	0.07
NTS story immersion	(0.17)	0.19
NTS mental immersion	0.26	**0.04***
ARI interest	0.32	**0.01***
ARI usability	(0.03)	0.84
ARI emotional attachment	0.38	**< 0.01***
ARI focus of attention	0.27	**0.04***
ARI presence	0.22	0.08
ARI flow	0.25	**0.05***
ARI engagement	0.28	**0.03***
ARI engrossment	0.34	**< 0.01***
ARI total immersion	(0.24)	0.06

Table 3: Results of a Mann Whitney U test comparing users NTS and ARI scores across the stationary and walking study conditions.

Measures Compared	Stationary		Walking	
	Effect *r*	*p*-value	Effect *r*	*p*-value
ARI Engagement - ARI Engrossment	0.71	**< 0.001***	0.53	**0.002***
ARI Engrossment - ARI Total Immersion	0.75	**< 0.001***	0.83	**< 0.001***

Table 4: Results of a paired sample Wilcoxon test comparing each user's 3 immersion level scores across the stationary and walking versions of the app.

Variation in participant experience

To investigate whether some aspects of the participants influenced their experience, users were asked to complete the three sections of the ITQ. They were also asked to rate the degree to which they enjoyed walking as a recreational activity, and the level to which they were familiar with the location where they were using the app. A Spearman rank correlation test (used due to the data deviating from a normal distribution) was used to look for any correlation between the three ITQ factors, and the post immersion and story engagement factors taken from the NTS and ARI questionnaires. The factors that showed evidence of a possible correlation in either the stationary or walking study conditions at a 5% significance level are shown in Table 5, with these dimensions further plotted for in Figure 8 together with a line of best fit. The ITQ dimension of a tendency to maintain focus, showed evidence of correlating with Brown and cairns engrossment and total immersion levels in both versions of the app. There was also evidence of a relationship with these immersion levels to one's enjoyment of walking as a recreational activity. However, this later result is affected by the limited number of participants in the walking condition who did not enjoy walking, suggesting that that individuals who do not enjoy walking made an active choice not to complete this version of the study.

A Mann Whitney U test looked whether participants appeared to rate any of the ARI and NTS factors differently according to their gender. Though limited by a bias towards female participants who took part in the study, no significant differences were evident at a 5% significance level. In terms of performing a suitable test for such variations across the different age groups who took part and their previous experience of similar AR experiences, unfortunately these tests were limited by the small number of participants who took part in older age groups and those with significant previous experience of AR technology.

User dimension	Immersion dimension	Stationary		Walking	
		rho	*p*-value	rho	*p*-value
ITQ Tendency to maintain focus	NTS Mental immersion	0.59	**< 0.001***	0.36	0.05
	ARI Engagement	0.44	**0.01***	0.21	0.27
	ARI Engrossment	0.57	**< 0.01***	0.48	**< 0.01***
	ARI Total immersion	0.53	**< 0.01***	0.57	**< 0.001***
Enjoy walking for recreation	NTS Story immersion	0.39	**0.03***	0.28	0.14
	ARI Engagement	0.15	0.41	0.65	**< 0.001***
	ARI Engrossment	0.27	0.14	0.45	**0.01***
	ARI Total immersion	0.41	**0.02***	0.32	0.08

Table 5: Results of the Spearman rank correlation tests that showed evidence of correlation between aspects of the users and their immersion ratings, across both the stationary and walking versions of the app.

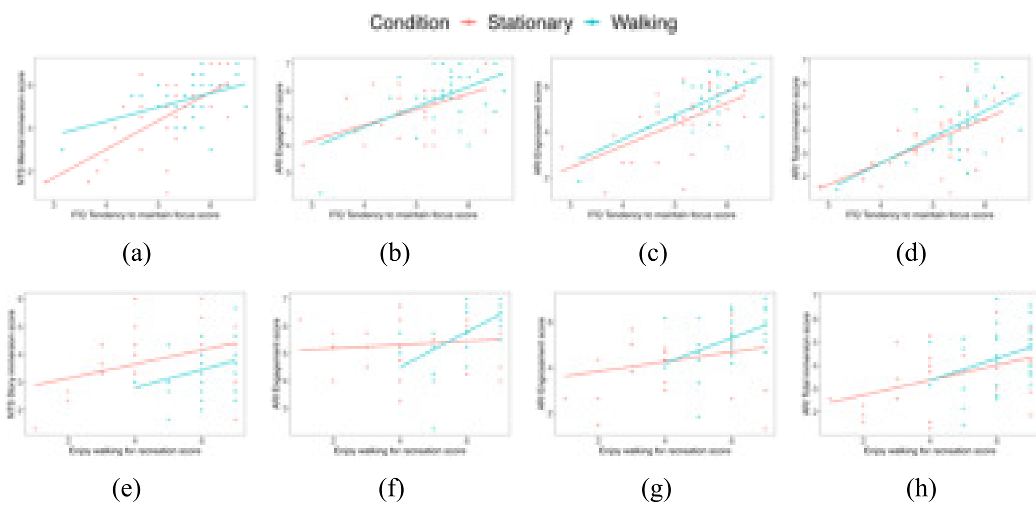


Figure 8: Best fit linear correlations of the ARI and NTS immersion factors that demonstrated evidence of a possible correlation with users' ITQ tendency to maintain focus score (a)-(d), and their enjoyment of walking as a recreational activity score (e)-(h).

Preference for particular object interactions

Map story 3 involved placing a series of AR scenes offering a variety of different interaction opportunities. As discussed earlier some involved asking the user to imagine a series of events playing out, whilst others required interacting with the virtual model on the phone's touchscreen, or through the phone's accelerometer. To investigate a preference for the different tasks, which were the same across both versions of the app, participants were asked to rate their first, second and third preferred interactions on completion of the story, as well as rating the usability and enjoyability of each object interaction before moving to the next clue location. Table 6 shows the counts of each users preferred object interactions in both study conditions.

A Chi-squared test was used to investigate evidence of a preference for any of the particular virtual objects placed and their required interactions, based on the null hypothesis that each choice was equally likely. In both versions of the app the crime scene and suspect's car proved to be more popular than the other objects (χ^2 = 13.6, ***p***-value = 0.02 - Stationary

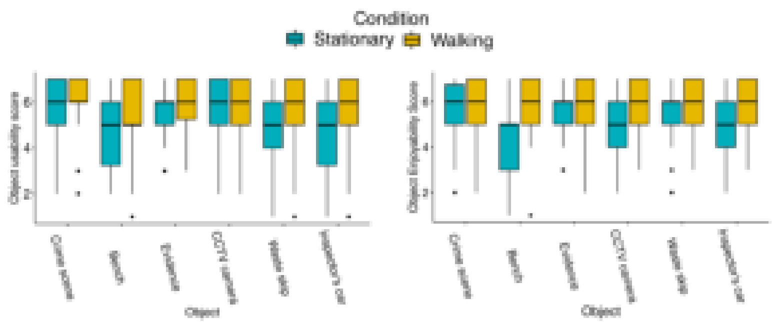
Object	Counts of preferred objects			
	1st Favourite	2nd Favourite	3rd Favourite	Placed in Top 3
Crime scene	11	4	4	19
Wooden bench	2	0	4	6
Suspect evidence	4	9	6	19
CCTV camera	3	1	4	8
Waste skip	2	8	6	16
Car	8	8	6	22

(a)

Object	Counts of preferred objects			
	1st Favourite	2nd Favourite	3rd Favourite	Placed in Top 3
Crime scene	12	7	2	21
Wooden bench	1	2	2	5
Suspect evidence	1	5	9	15
CCTV camera	1	4	6	11
Waste skip	3	4	8	15
Car	12	8	3	23

(b)

Table 6: Counts of user's top three preferred object interactions in both the stationary (a), and walking (b) versions of the Map Story 3 app.



(a) (b)

Figure 9: Each placed object's usability score (a), and enjoyability rating (b) for all users across both study conditions.

condition, and $\chi^2 = 30.0$, ***p***-value < 0.001 - Walking condition). These were always the first and last objects placed. Considering the counts across the top 3 preferences, the bench and CCTV objects were considered significantly less popular in the stationary version of the app (χ^2 = 14.1, ***p***-value = 0.01), whilst in the walking version only the bench object was deemed less popular (χ^2 = 14.4, ***p***-value = 0.01). Both the bench and CCTV camera asked the user to imagine a series of events playing out at the AR scene, whilst following a series of prompts. This approach appeared less engaging compared to interacting with the objects directly through the phones, though to less effect with the CCTV camera in the walking version.

The usability and enjoyability scores rated for each object in both study conditions are shown in Figure 9. A Mann Whitney U test was used to examine whether each of the six object scores was rated differently across the stationary and walking versions of the app. The results demonstrated no significant usability differences across the two conditions, though enjoyability was found to vary for two of the 6 objects at a 5% significance level, once again in relation to lower scores for the bench (r = 0.35, ***p***-value < 0.01) and CCTV camera (r = 0.26, ***p***-value = 0.04).

Users' desire to continue

Participants were also asked to rate their desire to continue the story before moving to the next clue location. Users ratings across the six story chapters (corresponding to the six objects and locations) are shown in Figure 10, for both the stationary and walking versions

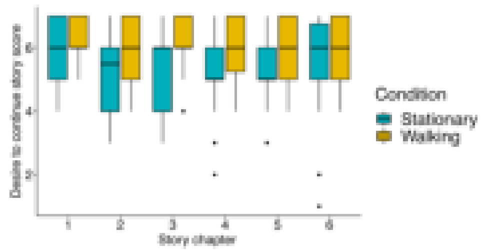


Figure 10: User's desire to continue rating after finishing each story chapter and object interaction in both the stationary and walking study conditions.

of the app. A Levene test only showed a significant variation in the spread of scores after the first story chapter (($F(1,58) = 5.6$, $\boldsymbol{p} = 0.02$), suggesting a greater number of users may have been less inclined to continue in the stationary version of the app. A Mann Whitney U test was also used to investigate if there was any difference in each chapter's scores across the two different versions of the app. The results are shown in Table 7 and suggest that users rated story chapters 2-4 significantly lower in the stationary version of the app compared to the walking version. This appears to show a drop in interest towards the middle of the story in the stationary study condition, which is not repeated in the walking version. This may be a consequence of the primarily imagination interactions not proving as engaging as previously demonstrated in relation to the bench and CCTV objects, or be tied to a loss of interest where the surroundings did not support the objects placed, which is discussed further in the next section.

Story chapter	Effect size, r	*p*-value
Chapter 1	N/A	0.26
Chapter 2	0.31	**0.02***
Chapter 3	0.31	**0.02***
Chapter 4	0.33	**0.01***
Chapter 5	N/A	0.11
Chapter 6	N/A	0.14

Table 7: Results of a Mann Whitney U test comparing user's desire to continue each story chapter scores across the stationary and walking study conditions.

DISCUSSION

Those who took part in a follow-up interview answered questions about their personal experience as well as covering issues related to the particular version of the app they completed. This data was combined with open feedback collected through the app for thematic analysis, identifying common threads such as the choice of story, the ease and enjoyment the AR, and the story's relationship to each map location. This forms part of the following discussion related to the two versions of the app, where a number of the immersion factors collected appeared to be rated higher in the walking version, suggesting an improved experience when the virtual objects were overlaid on relevant surroundings rather than just the users immediate vicinity. Further research is required to determine whether this a generic map may have produced the same results in the stationary version rather than one which was clearly the users own neighbourhood. The ARI usability score showed no difference between the versions, acting as a consistency check since the app was fundamentally the same across the two versions. The NTS story immersion also showed no significant variation, suggesting this measure might relate to how each user feels towards the particular story, over and above the way it was delivered. The stationary version of the app also showed greater variation in users' desire to continue, that appeared to drop significantly in the middle of the story. This could be related to the use of tasks for the middle chapters that asked users to imagine what story events occurred in relation to the AR scenes, which may have proved more challenging when the user's surroundings and lack of surrounding activity did not support the events described. In the case of the CCTV camera, a modified photo of the map location was shown, but principally only those in the walking version stood at the matching location, recognised the downloaded image and its relationship to their local area. This suggests one reason why this task was rated more positively in this version, as one participant in the walking condition commented at the time, *"I loved the CCTV picture of the suspect in the road"*. Feedback also suggested the walking version provided more opportunity for Reid's magic moments, generating meaning by connecting the story and user's surroundings, *"It was a nice moment when voice-over said watch for strange people and I looked up to see a large man walking a tiny dog"*.

Both versions of the app only suggested lower scores to Brown and Cairns higher immersion levels, with a number of participants reporting, *"at no point would I say I completely lost focus on the world around me"*. As stated in prior research through the Pervasive GameFlow model, the requirements for achieving presence and flow are likely to vary when simultaneously navigating the real world compared to being solely focused on an activity (Jegers and Wiberg 2006). This suggests there is room to develop new immersion questionnaires better tailored to quantifying user experiences in such activities. Partly arising from this being primarily made as a research tool, participants also left improvement suggestions including better aesthetic design, more detailed virtual scenes, and multiple tasks to complete at each map location, in order to create a deeper story world. Further suggestions included the ability to question the story suspects, and examine the evidence collected in greater detail. The story offered by the app was also a linear one, though AR storytelling in common with video games, has the potential to offer users the ability to take meaningful actions to offer unique paths through a story, which some users suggested was a current limitation, *"I didn't feel my actions had consequences, so it was more like watching than participating in the story"*.

In terms of different user experiences, there was evidence that the ITQ dimensions showed a relationship to Brown and Cairns three immersion levels, despite the questionnaire only previously being validated in respect of presence felt in a VR environment. Such a resource could be beneficial for AR in terms of offering improved personalisation. However, the applicability of the ITQ requires further investigation, due to the limited number of participants who expressed low ITQ scores in relation to some of its factors. Similarly, few participants who did not enjoy walking, signed up to use the walking version of the app. It is perhaps not unsurprising that this version appealed less to such individuals. A number of the walking participants also expressed feeling self conscious completing some activities in public places. This was shown in comments like, *"I looked a bit odd using my phone to play a game in the middle of everyone trying to walk round me"*. A couple of users also reported having to trigger a section of the story manually, where they couldn't reach the target location, such as when *”the crime scene was in a private car park which I couldn’t access”*. Specific issues with the stationary version of the app tied to the small size of the space where they were playing, *”the AR was hard to place because it was too large in relation to the space around me”*. Generally, comments feedback left was noticeably more positive in response to the walking version, with a number of users suggesting they hoped the app would be reworked into a publicly available product. This demonstrates that Whilst the stationary version offered an alternative to those less able or inclined to engage in a guided walk, it requires further improvement to offer a matching experience. Suggestions to try and offer this could involve using mobile VR to place objects against a virtual background, as a way to further investigate how reducing the discontinuity between the objects and their surroundings affects users’ immersion.

LIMITATIONS

The study with Map Story 3 was challenging from being conducted during the COVID pandemic. Challenges included the inability to observe participants taking part to provide additional insight, as well as participants using their own phones, that could lead to some performance variations from the use of different handsets and screen sizes. Whilst the variation offered by different locations is a primary goal of the app, it also risks confounding effects through varying distractions in the walking version, or if a attempts to use the app in too small a space in the stationary version. For this reason, guidelines were offered in this respect, with walking participants also presented with a limited number of opportunities to trigger the next part of the story manually, in cases where the target location may have been inaccessible. Being a research tool, the app had reduced quality of graphical, audio and voice acting presentation in relation to commercially available products, along with the use of a linear story that did not offer users significant agency in respect of making decisions. These are areas for future study in respect of the next iteration of the app, and their influence in offering deeper immersion. A few users commented that the sizes of some virtual objects did not appear correct, though since they were created at their correct physical dimensions, this perhaps highlights some additional issues around the depth perception of 3D objects for some users. A possible solution is the addition of a scaling tool for each object, in addition to the positioning and rotational ones provided.

The study had a limited number of participants of certain demographics, with a majority of young female participants with limited prior AR experience taking part. A larger, more varied sample size would have enabled additional statistical tests to be performed, potentially offering new insights. In terms of the questionnaires used there was also a preference for users that rated themselves highly across the ITQ factors, with a limited number of low scoring data points. A clear on-boarding tutorial might also have benefited the app to limit the novelty of the AR medium, though this was included seamlessly through the first object interaction that guided the user through a basic task of placing the crime scene model and taking several photos of it. However, there is the question whether these scores should be included if novelty may have played a factor. Both the first and last objects were rated as users’ favourites, which could be related to the raised narrative tension in both the story set up and reveal in a murder mystery. This highlights how such a study will inevitably pose some risks by the choice of story, that may appeal to some users more than others.

CONCLUSION

Map Story 3 successively offered an immersive experience that could be played almost anywhere, though with a user study demonstrating a difference between the stationary and walking versions, with the walking version scoring significantly higher in terms of the majority of the immersion and engagement factors collected. This suggests the virtual objects alone are not significant props to generate immersion in the story, when the background offered by the real surroundings do not support them. Given a desire that those less able or inclined to take part in a local walk might still be able to engage in the experience, an area of further study is whether similar immersion might be offered in the stationary version when the objects are placed against a relevant virtual environment, such as a 360 degree panorama. In this case the stationary version of the app would be adapted to offer mobile VR rather than AR. The app also demonstrated a preference for interactive tasks compared to purely imagination based ones, though the CCTV imagination focused task proved more popular when the user was stood at the matching location of a modified *Google StreetView* photo, so they could better identify a connection between it and their surroundings.

An AR medium also offers further potential for other storytelling opportunities, such as the ability to affect the story direction, which some users expressed a desire for. However, this might vary between users, similar to other differences reported like feelings of self consciousness performing some of the tasks in public spaces. The use of the ITQ showed promise in terms of identifying how different individuals might experience varying levels of immersion, though requires further exploration to fully investigate its effectiveness for AR experiences. This extends to selecting the most appropriate questionnaires for measuring user experience in location-based narratives including those that use AR. The ARI and NTS questionnaires appeared to offer congruent results, though there is scope to generate a single questionnaire that covers both the story engagement and immersion related to the different interaction opportunities offered by the AR content.

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