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作者/Author: Jiun-Jhy Her

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Encouraging a Sense of Object Presence by Context Correspondence in Non-immersive Augmented Reality

Jiun-Jhy Her

Department of Digital Media and Education Industry, National Taitung University, Taiwan, jiunjhy@nttu.edu.tw

ABSTRACT

The goal of this study is to encourage meaningful non-immersive augmented reality (non-iAR) experience. A sense of presence (SoP) is deemed instrumental to a meaningful interactive digital reality experience. Nevertheless, in contrast to SoP, a sense of object presence (SoOP) is more pertinent for ascertaining non-iAR experience, as it concerns the connection of users with visual cues and the physical setting to access the theme content. However, there is a paucity of research on SoOP regarding non-iAR interactions. Relevant studies emphasize a feeling of ‘being there’ in the interactive process and indicate that visual realism is the main factor affecting SoP for users; studies often associate such experience to immersion. This present study argues that correspondence between visual cues and the physical setting is the primary factor influencing SoOP, which is equivalent to neither visual realism nor immersion. This argument was attested via examinations of three case studies of non-iAR apps in a museum and a university campus in Taiwan: *Time Corridor*, *AR Book*, and *D Zone*. Since the three apps were by nature conceptually related to physical places, Tim Cresswell’s (2009) tripartite component of understanding place (materiality, practice, and meaning) was adopted for integration with visual cues and the physical setting; the two key elements constitute context correspondence to analyze the three apps through mixed research methods: qualitative evaluation and statistical analysis. The result of the analysis shows that *AR Book* has the best agreement on the affordance to facilitate understanding and navigation of the theme content. *Time Corridor*, in contrast, has the lowest agreement. The findings inform the central assertion of the current study: context correspondence is key to encouraging SoOP in non-iAR interactions, which facilitates meaningful non-iAR experience.

Keywords: Context Correspondence, Sense of Object Presence, Non-Immersive Augmented Reality, Visual Experience, Location-based Media.

1. Introduction

This research argues that instead of emphasizing ‘being there’ or ‘realness’ (Weber et al., 2021), correspondence between visual cues and the physical setting is more significant in encouraging a sense of object presence (SoOP) that facilitates meaningful non-immersive augmented reality (non-iAR) experiences. The concept of context correspondence proposed in this study is comprised of two key elements: visual cues and the physical setting. The correspondence between these two elements has a decisive influence on the occurrence of SoOP in non-iAR interaction. The experience of presence is deemed pivotal to encouraging natural, immediate, direct, real, and enjoyable interaction in immersive virtual environments (Chan & Weng, 2005) as well as in other types of digital reality. Thus, it is important to explore “what presence is, what encourages and discourages it in users, and its effects” (Lombard & Ditton, 1997, p. 2). Relevant studies mainly classify presence as a sense of ‘being there’ and an illusion of non-mediation,

which also suggests that the sense of presence (SoP) is interwoven with visual realism and immersion (Steptoe et al., 2014; Regenbrecht & Schubert, 2021; Weber et al., 2021). Minimizing the difference between the real and the virtual can be useful for inducing SoP in augmented reality (AR) (Slater, 2003; Bimber & Raskar, 2005; Choi, Kim & Kim, 2019). However, realistic presentation and the feeling of ‘being there’ should not be the ultimate goal, because not all AR themes and applications are suited to these two conditions in the physical settings. Recently, Choi et al. (2019) examined four different display configurations of AR (phone AR, cardboard, optical see-through display, and head-mounted device), noting that the occurrence of ‘being there’ (immersion) in phone AR is rare. Along with this rationale, visual cues in AR need not necessarily emphasize ‘being there’ and realness.

This current study began with an examination of whether a definitive causal relationship exists between SoP, visual realism, and immersion. An in-depth contextual review revealed that studies

in which SoP has been ascertained were mainly conducted in the domain of immersive digital interaction, in particular on immersive virtual environments (Bommel, 2017; Regenbrecht & Schubert, 2021). Namely, concepts developed in the literature cannot be strictly applied to AR (Krüger, 2018), including non-iAR, illustrating a research concern that has long been neglected. A lack of research does not imply that SoP does not exist in AR interactions; nevertheless, an extension of it to SoOP is more pertinent to accommodate its affordance for ascertaining non-iAR experiences (Krüger, 2018; Choi et al., 2019; Genay et al., 2021). Chan and Weng (2005) and Choi et al. (2019) show that when initiating a study on SoP, it is critical to focus on a specific type of technology. Although the rapid development of digital reality technologies (i.e., non-iAR, AR, virtual reality (VR), mixed reality, and extended reality) in the past two decades has resulted in these technologies sharing certain forms of presentation, they can still be distinguished in terms of the mediating configurations, such as devices, presentations of digital content, and participants' perception and response. Identifying these characteristics is essential to examining the experience of presence. Non-iAR is more commonly associated with mobile devices (e.g., smartphones and tablets) than are its counterpart technologies. The mobility of these devices enables the presentation of virtual information at a specific geographical space, which constitutes a feature of location-based media (Rieser & Clark, 2013; Evans & Saker, 2017; Silva, 2017).

Through examinations of relationships between SoP, immersion, realism, and characteristics of SoP in non-iAR, the affordance of SoOP in ascertaining non-iAR experience has emerged; investigation of how to encourage SoOP during non-iAR interactions makes manifest visual cues and the physical setting, the key elements which constitute context correspondence. By integrating Tim Cresswell's (2009) tripartite components of understanding place (*materiality, practice, and meaning*) with visual cues and the physical setting, an analytical framework has been established (Figure 9) that facilitates an analysis of three case studies of three non-iAR apps in a museum and a university campus in Taiwan. The analysis was conducted on the basis of qualitative evaluations, and the findings are supported by statistical analysis (Tables 2, 3, and 4). To observe how the three AR apps were used in natural settings, and how the occurrence of SoOP affected the understanding of the research participants (Denzin 1994; Nurani 2008; Evans 2015) regarding the interaction content, the current author and two research assistants conducted nonparticipant observation in-situ and

small group interviews. The mixed research strategy enables triangulation (Denzin 2009; Johnson et al. 2017), and illustrates how and whether context correspondence—the integration of visual cues and the physical setting—influences the development of SoOP in the process of non-iAR use.

2. Literature Review

2.1 SoP, Immersion, and Realism

Due to the multiple modalities involved, ambiguous concepts about SoP and immersion make it difficult to find clear distinctions (Sajjadi, 2020). A sense of 'being there' and an illusion of non-mediation are predominately defined as essential characteristics for both SoP and immersion (Weibel & Wissmath, 2011; Steptoe et al., 2014; Regenbrecht & Schubert, 2021). However, this definition leads to confusion and even contradiction. Numerous studies indicate that SoP is an indefinable term, as it is often used in tandem with immersion (Calleja, 2014; Skarbez et al., 2017; Michailidis et al., 2018).

Instead of presenting an exhaustive list, this section discusses two distinct views by Slater (2003) and Weibel and Wissmath (2011) to ascertain SoP from a different context. Slater (2003) makes use of individuals' perception of music in a theater to distinguish between presence and immersion; people acknowledge their physical presence in the theater while hearing emotive music, but find it difficult to immerse themselves when the music is uninteresting. Slater suggests that presence and immersion represent objective and subjective conditions. Weibel and Wissmath (2011) demonstrate that presence and flow are different in form: presence develops from a computer medium, whereas flow typically emerges when performing physical activities. They claim that (spatial) presence and flow are conceptual elements that constitute immersion. Slater's (2003) perspective emerges from one's perception of music, and Weibel and Wissmath's (2011) notion derives from their research on a computer game; the sources of their findings are distinct from the majority of theories established based on studies of virtual environments. This short discussion shows that SoP is not necessarily a state of immersion, but instead can be an objective condition to immersion. In addition to immersion, realness is often related to occurrences of SoP (Choi, et al., 2019; Regenbrecht & Schubert, 2021; Weber et al., 2021). Indeed, visual realism can be useful for encouraging SoP but is not always required, because unrealistic visual outputs can also induce SoP. Waterworth et al. (2010) note that in

social virtual environments, individuals commonly perceive themselves as an unrealistic third person (avatar). Lombard and Ditton (1997) observe this also, defining the condition as 'social realism', which is not equivalent to visual realism.

This section examines whether causations exist between SoP, immersion, and realism. The results suggest that even if a visual cue is presented in an unrealistic manner, SoP can still manifest. Furthermore, although SoP is not synonymous with immersion and the perception of realism, correlation among the three may be inevitable because of their homology. However, Slater (2003, p.1) states: "If researchers are talking about different things, then there is no point arguing." A study of presence, immersion and usability in mobile AR conducted by Choi et al. (2019) reflects this view, in which they distinguish different display configurations of AR before implementing analysis. Accordingly, before attempting to elucidate these terms to inform research outcomes, researchers must determine the scope of their studies according to factors such as media form, amount of digital content, and participants' perception and responses, because such factors can significantly affect the results of a study.

2.2 SoP and SoOP in Non-iAR

Although not as commonly discussed as immersive systems, SoP is considered to exist in non-iAR. More than a decade ago, Goldiez and Dawson (2004) explored whether SoP can occur in AR systems, and concluded that it does. Nevertheless, despite numerous investigations into presence and immersion in VR and immersive AR, few studies address the influence of SoP in non-iAR, in which even less is understood regarding SoOP. This current section investigates two fundamental questions: (1) What is non-iAR? and (2) What are the characteristics of SoOP in non-iAR?

2.2.1 What is non-iAR?

Non-immersive systems such as non-iAR are typically used in mobile devices to interact with non-isolated digital content while enabling users to receive environmental information in real time. This is in contrast to immersive systems, which are typically used alongside wearable devices such as head-mounted displays (HMD) for VR, and whose users are surrounded by digital elements in these systems, while users' senses are generally disconnected from the external environment during interaction (Bolter & Grusin, 2000; Cipresso et al., 2018; Tsyktor, 2019). Although seemingly clear distinctions exist between non-immersive and immersive

systems, there is still a gray area between them. This ambiguity may be attributable to the interwoven nature of AR and VR (Goldiez & Dawson, 2004; Tang et al., 2004). In 1968, Ivan Sutherland first realized AR in an HMD configuration. Since then, VR and AR have developed in parallel. As mentioned above, immersion is typically the desired result of using wearable devices. However, with the continuous advancement of digital reality technologies in terms of both content presentation and hardware sophistication, the boundary between immersive and non-immersive systems has shifted constantly. In addition to the types of hardware used, the extent of virtual information generated and perceived by users is also critical to distinguishing the two systems. As indicated by Bolter and Grusin (2000), the 'separation' between the virtual and the physical is the key consideration. Wu et al. (2013) define light and heavy AR, and claim that the amount of virtual information provided to users influences whether immersion has been attained (e.g., light AR refers to the status in which users perceive a large amount of information from the physical materials interacted with in the real world). The discussion suggests that the type of device employed is not the sole determinant distinguishing immersive and non-immersive AR, because the state of the user's experiences is co-affected by the extent of the virtual sources and the environment constructed being presented to them. It is indeed an ongoing innovation in digital reality technology that has to some extent resulted in the difficulty of defining AR and its digital counterpart. From a practical perspective, the current study defines non-iAR in terms of non-wearable mobile AR devices that do not isolate the experiences of the user from the real world, and the context-relevant digital information that is provided to the user.

2.2.2 Characteristics of SoOP in non-iAR

In the examination of SoOP based on its SoP root, relevant studies explore the characteristics in each different research context; this is also viable for ascertaining SoOP in non-iAR. Slater et al. (1998) define two types of presence: subjective and behavioral. Subjective presence is the psychological type of presence in which users perceive the feeling of 'being there', whereas behavioral presence is the physical type of presence in which users exhibit an observable response to stimuli. Sheridan (1992) defines three types of presence: self, physical, and social. In self-presence, people believe they are playing a role in the virtual environment, and a relationship is observed between self and the virtual context, which is also an extension of the

state of ‘being there.’ In physical presence, users in virtual environments affect the states of virtual objects, and vice versa. In social presence, users connect and interact with other users or agents in the virtual setting. This concept of social presence enables an extension of SoP to SoOP from a predominant definition of immersion and the sense of ‘being there’ to the salience of a person to association with a virtual object. Stevens and Jerrams-Smith (2001) address SoOP, which is “the subjective experience that a particular object exists in a user’s environment, even when that object does not.” Billinghurst and Henrysson (2006) note that SoOP represents the feeling that a virtual object is part of the real world, highlighting the connection between users and the digital content to facilitate interactions. Choi et al. (2019) state that the object presence refers to the extent of virtual augmentation that is felt to be natural and harmonious as a part of the real world. These discussions suggest that SoOP can be regarded as an extension of the predominant concept of SoP, whereas the latter is more applicable for the assessment of non-immersive interactions (Krüger, 2018). Goldiez and Dawson (2004) state that AR systems that produce strong sensations of presence should positively influence people’s experiences. They also mention that SoP can be strengthened when visual elements assist users to complete specified tasks in the AR environment. Baños et al. (2004) suggest that investigations of presence must surpass the scope of immersion and the sense of being there. Accordingly, SoOP assumes its critical role in the context of non-iAR research and practice. Steptoe et al. (2014, p.214) assert that “AR grounds interaction within the local physical environment, so any suitable definition of presence as applied to immersive AR must emphasize the ‘seamless integration’ of virtual content with the physical setting.” This perspective is also crucial to non-iAR; in particular, seamless integration is cognate with the core principle of context correspondence.

3. Context Correspondence

This study argues that correspondence between visual content and the physical setting is essential for encouraging SoOP in non-iAR interactions. Genay et al. (2021) elucidate how the coherence of virtual and real objects affects user experience via a see-through display in a mixed reality setting. Slater (2003, p. 4) states that “presence arises from an appropriate conjunction of human perceptions,” which applies to SoOP. In their discussion of presence in AR and mixed reality, MacIntyre et al. (2004, p.42) state the following: “All media

technologies should be able to leverage and extend the aura of a place or object for a person.” Rather than emphasizing realism or immersion, the aforementioned discussions underline the core principle of context correspondence.

The *Black and Blue Cosmos* series (Figure 1), an AR work, was created based around the theme of an indigenous festival (the Amis Music Festival 2019) in Taitung, Taiwan by Chen Pu, a Taiwanese artist. This AR work reflects SoOP and how it is encouraged by the context correspondence; when a user scans the octagonal star stickers on his/her arm with a hand phone, virtual flowers appear to grow onscreen. In this non-iAR application, a virtual yellow flower is presented as a cartoon-like image. Although its presentation is inconsistent with the surrounding environment, its style and vivid colors correspond to and complement the festival’s ethos and subject matter.



Figure 1. *Black and Blue Cosmos* at Amis Music Festival

The effectiveness of a digital reality system depends on its ability to integrate seamlessly into user environments and enable users to experience natural interactions, thereby reducing the sense of violation that can occur when using AR (Steptoe et al., 2014; Genay et al., 2021). *Black and Blue Cosmos* (Figure 1) exemplifies the seamless integration of a virtual element to the theme of the event, which manifests the concept of context correspondence. In non-iAR, strong SoOP may be induced when virtual and real content are effectively integrated to form a perceptually unified environment (Steptoe et al., 2014). In contrast, if only visual realism is emphasized, a loss of focus on the theme may result, further causing the user to lose interest and motivation for in-depth exploration and resulting in a failure to achieve interactive goals. Kaptelinin (1996) suggests that the core issues pertaining to human activity in human–computer interaction can all be defined as instances of ‘optimal integration.’ The following sub-sections discuss rationales behind the establishment of visual cues and the physical

setting; the correspondence between these two key elements can be seen as a form of optimal integration that encourages SoOP and thus meaningful interactions in non-iAR.

3.1 Visual Cues

By compositing rendered images from a handheld device, AR can superimpose images onto the real world (Silva, 2017). This underlines visual cues, a fundamental element for experiencing AR. Jeřábek, Rambousek, and Wildová (2014) indicate that visual perception is a prerequisite for AR to function. In an AR environment, visual stimulus is a key factor for encouraging SoP (Regenbrecht & Schubert, 2021); in non-iAR, SoOP is rather self-evident. Generally, when a user is receiving messages using all five senses, visual cues are the largest source of information for perceiving the surrounding environment (Damianova, 2015). The same condition applies when using mobile devices (Liao, 2019); users become increasingly dependent on visual information (Liu, 2019).

Nevertheless, this does not suggest that the intensity of visual realism dominates experiences that affect SoOP in non-iAR interactions. This current study argues that presenting visual cues in a visually realistic form is not always necessary. The trend toward presentation of visual realism via various digital platforms may be partly attributable to the rapid evolution of computer algorithms that have considerably improved both the perceptual realism and quality of digital content. Kort and IJsselsteijn (2006) indicate that media content is advancing relentlessly toward hyperrealism. Although a sophisticated media experience is vital to improving the sensory experience, intensity does not correspond to quality (IJsselsteijn, 2003). Thus, the breadth and depth of user perceptions during interactive experiences are not equivalent to the extent to which the virtual content manifests realism.

Bowman and McMahan (2007) suggest the same: namely, that interaction which occurs through more virtually real elements within an environment does not necessarily increase the level of immersion. Likewise, SoOP in non-AR is induced not only by a high level of visual realism, but also via the individual's personal experience and knowledge (Waterworth et al., 2010). The connection with this individual's experience to the theme of the interaction via visual perception is the essence of visual cue correspondence. Marsh (2003) proposes the concept of "an antidote to disruption," which mirrors the concept of the correspondence. For Marsh, 'disruption' refers not only to visual experience, but also to the manifestation of

virtual images in a physical place through the use of digitally mediating technologies. Given adequate visual stimulus, user attention is not disrupted but encouraged.

3.2 Physical Setting

Spatial presence in non-iAR is greater than that in VR, which is consistent with the understanding that AR is a locative medium (Acker, 2017). This unique feature distinguishes non-iAR from its digital counterparts and serves as a foundation for the concept of the physical setting. Non-iAR users do not leave the space they occupy, thus maintaining their SoP in the non-synthetic world (Baus and Bouchard, 2014). Places, backgrounds, and physical media in this non-synthetic world can all serve as a base for non-iAR visual display. Therefore, this base should not be restricted to a place; indeed, it can be extended to other physical materials. Accordingly, the current study refers to these physical materials collectively as the physical setting, a broader term which can refer to a physical nature containing objects such as places, books, tables, or even body parts (see, for example, Figure 1) that provide a base for presenting the AR content.

However, emphasizing such locative or physical nature does not organically result in meaningful interaction. Physical setting correspondence enables visual cues to assume a "place-bound identity" (Kwon, 2002). With an appropriate arrangement of the physical setting, SoOP can emerge when connected with visual cues, which furnish users with access to interactive situations and engender meaningful connections. Kwon (ibid) examines the relationships between subject, object, and location in her study of site specificity. She asserts that a suitable arrangement of object, location, and theme should be adopted to reflect the unique story and meaning. This idea coevolved with site-specific art that considers the site an actual place, where the artwork embodies that place only. In this regard, locative media in non-iAR share the same genealogy with site-specific art. An appropriate arrangement of the physical setting enables virtual cues to convey information effectively. Non-iAR is a medium, and images should be displayed through non-iAR in a specific physical setting. However, this physical setting cannot simply to be regarded as a backdrop (Azuma, 2016). Real events triggered by AR must adhere to the relationship between virtual objects and the physical setting.

Heeter (2003, p. 335) states that "sensory realism is certainly an important influence on presence, but there is more to the story." The physical setting is often associated with a

self-evident story which in particular emerges when visual cues connect with the place or media and theme via non-iAR. IJsslesteijn (2003, p. 38) states that “the basic appeal of media still lies in its content, the storyline, the ideas and emotions that are being communicated.” To advocate three AR content design strategies—reinforcing, reskinning, and remembering—Azuma (2016) illustrates a case study (illustrating the reinforcement strategy) of an AR project related to the Twin Towers lost in the September 11 attacks. The creator, Brian August, adopted a non-photorealistic approach to depicting the Twin Towers. The work is noteworthy in the discussed context because it mirrors a message about the buildings: although they no longer exist, they can be re-embodied in AR, enabling users to experience the buildings as they were and remember the tragic events surrounding their destruction. This case again reflects the core principle of the current study—the correspondence between visual cues and the physical setting in non-iAR.

3.3 Summary

Visual cues and the physical setting are not opposite but are mutually interrelated with respect to the influences of SoOP in non-iAR context. The visual stimulus in current AR applications remains the key factor influencing users’ experience (Liao, 2019; Damianova, 2015). The physical setting refers to various physical materials. Weibel and Wissmath (2011) assert that in addition to helping users access interactive content, SoP increases attention and flow, suggesting that presence is also a means of accessing AR content. In a discussion about flow experience, Csikszentmihályi and Csikszentmihályi (1988) use tennis as an analogy, arguing that two opponents enjoy playing with each other more when their skill levels are similar, enabling them to cope with challenges presented by their opponent. This analogy reflects the argument of the current study, namely, that appropriate arrangement of virtual and physical elements encourages SoOP. Analyzing causation among SoP, immersion, and realism in the context of non-iAR helps to identify SoOP (an extension of SoP) and the characteristics of SoOP in non-iAR; the preceding discussions inform the basic principle of context correspondence. With regard to visual cues, Lombard and Ditton (1997) offer a fairly complete classification of the visual display characteristics of AR. This classification increases continuously along with the development of the technology (Slater, 2003; Gorini et al. 2011; Azuma, 2016); elimination of frame and naturalness (Tang, Biocca & Lim 2004; Choi et al., 2019); seamlessness,

transparency, naturalness, consistency, realness, and continuity (Marsh, 2003; Regenbrecht & Schubert, 2021); and seamless integration and perceptual unification (Steptoe, Julier and Steed 2014). The elements of the physical setting include content (Waterworth et al., 2010), story (Nóbrega et al., 2017; Frith & Richter, 2021), and locative media (Rieser & Clark, 2013; Evans & Saker, 2017; Acker, 2017; Silva, 2017). Although the composition of the physical setting does not have elements as broad as those for visual cues, they are both key considerations influencing the occurrence of SoOP. The following sections elucidate how the two key elements are used in the examinations of the three case studies.

4. Case Studies

Three non-iAR apps compatible with the physical environment or medium were used for case studies. Each app was made with edutainment objectives that enable the author to assess whether users grasped the content of the interaction and how they responded to the integration of visual cues and the physical setting. The research process allows for evaluation of the interplay between non-iAR interaction and the development of SoOP. Table 1 shows the elements of visual cues and the physical setting comprised in the three apps.

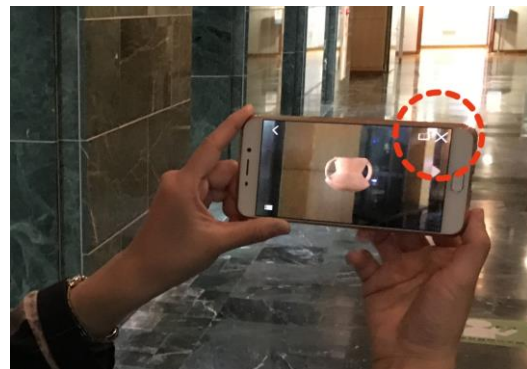


Figure 2. Participant testing *Time Corridor* AR app

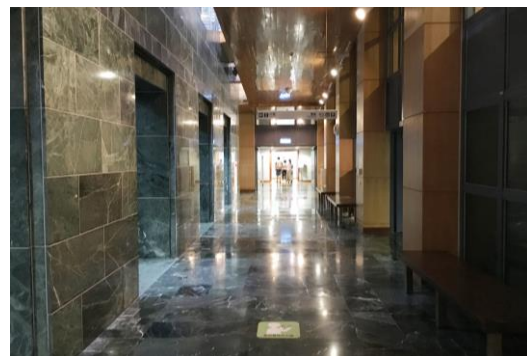


Figure 3. Minimalist museum lobby; physical setting for *Time Corridor* AR app

The first case study involves *Time Corridor*, an AR app (Figure 2) which displays twelve visual

realistic 3D virtual pottery specimens dating from the early Neolithic to the Iron Age at a lobby in the National Museum of Prehistory, Taitung, Taiwan. To download the app, visitors first scan a quick response code using a mobile device. After installing the app, visitors point the camera on their mobile device toward optimal locations, which enables the virtual pottery to be viewed in the lobby (Figures 2 and 3). The visitors rotate the onscreen virtual pottery via interactive 360° view to observe pottery details such as textures and patterns. A help button (red circle; Figure 2) is also provided onscreen to enable visitors to access the museum's catalog system for additional information about each specimen. In addition, to help visitors get the best views, floor labels are provided for displaying pottery from different eras (see an example; Figure 4).



Figure 4. Floor label indicating location for best view of pottery

The second case study, *Where Mountains Meet the Sea: Decoding the Identity of the Prehistoric Jade Frog and the Birth of Taiwan*, is an AR picture book also published by the National Museum of Prehistory (*AR Book*; Figures 5 and 6). *AR Book* contains abundant illustration and narrative (text) elements, which are divided into three parts: animated 3D graphics, puzzles, and pottery coloring. The animated 3D graphics are subdivided into three units: Tectonic Plate Movement, Birth of Taiwan, and Zuoqhen Fauna, containing rich geographical and cultural information. As the animated 3D graphics part comprises more content for viewing through non-iAR, a comparative analysis was conducted on this part only. Readers use a mobile device to scan the QR code in the picture book to download an app and then scan the pictures in each unit to access a series of interactive reading activities. When the animated 3D graphics (e.g., tectonic plate movement, lava flowing from volcanoes, landslides; Figure 6) appear on the mobile device, readers use the AR and virtual help buttons to further explore the content of each unit.



Figure 5. Participants testing *AR Book*

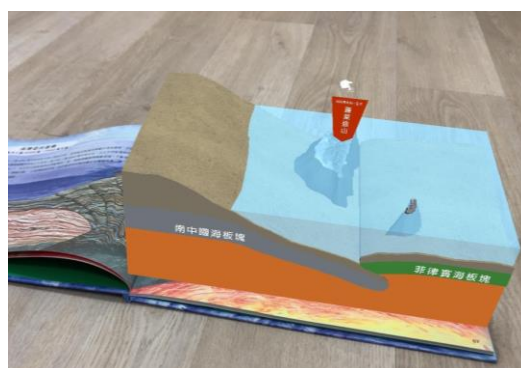


Figure 6. AR-animated 3D graphic showing tectonic plate movement

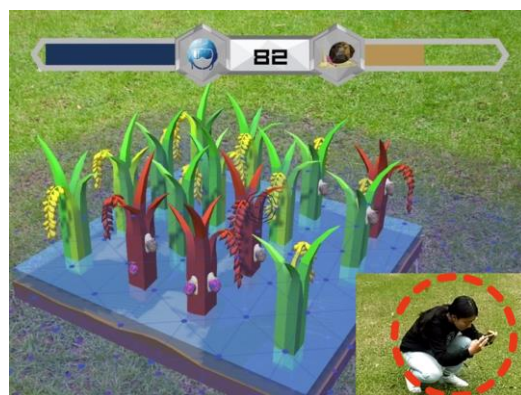


Figure 7. Apple snail level of *D Zone*

D Zone (Figures 7 and 8), the third case study, was created by three fourth-year undergraduate students enrolled in the digital media design course at National Taitung University, Taiwan. AR simultaneous localization and mapping (SLAM) technology was employed to create this game. The objective of the game was to highlight an ecological concern, namely the need to help repopulate indigenous species in their habitats. Three invasive species—the mole fish, apple snail, and fire ant—are represented in the three respective levels of the game. Players use a mobile device to scan the surrounding environment to reveal game content (red circle;

Figure 7). In the fire ant level (Figure 8), the game depicts methods to eliminate fire ants, including sealing anthill entrances, pouring gasoline on anthills, and burning anthills with a flame gun. In the apple snail level (Figure 7), players remove apple snails using a virtual 3D hand to prevent the snails from destroying rice plants. The designers stated that the game characters, objects, and scenes were designed as 3D cartoon-like style to induce players' affinity for the game and their motivation to play it.



Figure 8. Fire ant level of *D Zone*

Table 1. Visual cue and physical setting elements comprised in three apps.

App	Visual cues	Physical setting
<i>Time Corridor</i>	<ul style="list-style-type: none"> - Twelve virtual pottery specimens - Help buttons 	<ul style="list-style-type: none"> - Minimalist museum lobby - Floor labels
<i>AR Book</i>	<ul style="list-style-type: none"> - 2D illustrations - Animated 3D graphics - Text 	- Picture book
<i>D Zone</i>	<ul style="list-style-type: none"> - 3D cartoon-like game characters, objects, and scenes 	Unspecified game space

5. Methods

Mixing methods yields more comprehensive evidence giving a better understanding of the research problem (Jogulu & Pansiri, 2011). The three case studies were conducted based on an ethnographic approach involving nonparticipant observation, questionnaires, and interviews. The findings are further assessed by statistical analysis through a one-way repeated measures ANOVA with a Bonferroni correction as a post hoc test (Table 3 and 4). The assessment focused

on the occurrence of SoOP in non-iAR uses in a real life context, which is affected by correspondence or non-correspondence between visual cues and the physical setting. It was crucial to observe how participants used the apps in a natural setting (Denzin 1994; Nurani 2008; Evans 2015), and how those uses influenced the research participants' motivation to explore the content of the interactions. The current author and two research assistants (the research team) cooperated to observe the participants' behaviors in naturally occurring situations.

5.1 Participants and Grouping

A total of 27 first-year undergraduate students enrolled in the digital media design course at National Taitung University participated in the study. These 27 students, the core sample (Jeffrey & Troman 2004) recruited from a 34-student class, were novices in the area of digital media and had no experience designing AR apps. Their consent to participating in research activities was granted prior to the research. Morgan (2012) advocates the advantage of 2- to 3-person interviews, as they enable the researcher to hear more from each individual participant. To encourage diverse opinions in group discussions, many researchers support a minimum of three to four participants in small group interviews (Morgan 1996; Rabiee 2004; Krueger & Casey 2014). Accordingly, the students were divided into nine groups of three. The current author and the two research assistants each followed three groups of students to observe their behavior while using AR apps in situ (i.e., the National Museum of Prehistory and the university campus), and to corroborate their responses throughout the studies.

5.2 Analytical Framework

Tim Cresswell (2009) discusses place-based experience which evolves by three mutually constituted components: *materiality* (the material structures of place), *meaning* (the meanings that are associated or endowed with place), and *practice* (the things that people do that are related to the meanings that places might have). By adopting the three components and conducting studies of three location-based social networking applications, Wilken and Humphreys (2020) notes that "the material experience [...] is made by people doing things according to the place-based meanings they might wish these services to evoke." According to Cresswell (ibid), people doing things through a certain form or modality (practice) and media (*materiality*) enables the occurrence of material experiences (*meaning*). Wilken and Humphreys (ibid) also indicates that the meanings of place

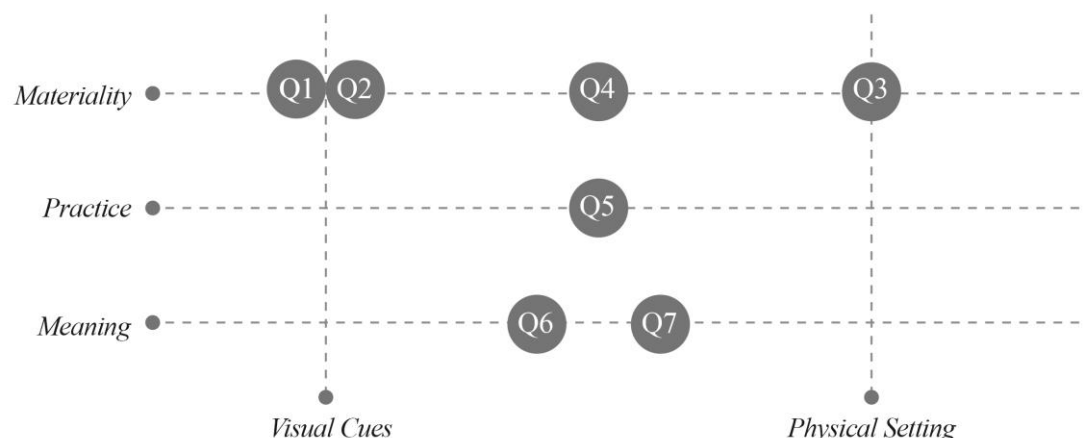


Figure 9. Illustration of how the analytical framework is formed by integrating Cresswell's (2009) tripartite components with visual cues and the physical setting

are constantly enacted and negotiated across multiple level of media engagement. The three case studies presented in this study are by nature conceptually related to physical places, making the integration of Cresswell's (2009) tripartite components and visual cues and the physical setting adequate for assessing participants' non-iAR experiences.

Based on this integration, an analytical framework has been established from which seven research questions derive (see Table 2, Questionnaire item). To illustrate the rationale behind the analytical framework, the seven questions are indicated by sequential labels from Q1 to Q7, presented in Figure 9 and Tables 2 and 3, and referenced in the following sections. As Q1, Q2, and Q3 concern the coherence between the visual responses and the physical setting, they are associated with visual cues and the physical setting, respectively, intersecting *materiality*. As Q4 comprises multiple elements, it is placed between the two key elements on *materiality*. Since Q5 involves the uses of each app, it is associated with *practice*. To ascertain whether participants grasp the content, Q6 and Q7 are associated with *meaning*. Via these seven questions, the analytical framework practically assesses whether the participants developed SoOP; namely, whether the participants sensed that virtual objects cohered with the real world settings that facilitated the connection between them and the digital content, and further yielded meaningful interactive experiences.

To understand how and whether context correspondence in the form of visual cues and the physical setting influences the occurrence of SoOP during the use of the three apps, nonparticipant observations were first conducted in each testing phase by the research team. The seven questions were posed in questionnaire form and during the interviews. Immediately

after testing an AR app, the current author explained the seven research questions to ensure the participants understood the questions. Each participant then completed a 5-point Likert scale questionnaire (from Strongly agree, Agree, Neutral, Disagree, to Strongly disagree). Then, to collect their qualitative opinions, the participants were interviewed in groups of three within a week by the author. The interviews, the participants' responses from testing the apps, and the observations made by the research team constitute multiple triangulation (Gray & Malins 2004; Evans 2015), which enables the elaboration of the concept of context correspondence and to what extent visual cues and the physical setting co-effect the manifestation of SoOP.

5.3 Qualitative Evaluation

Participants exhibited more doubt and hesitation when operating *Time Corridor* than when testing *AR Book*. Initially, this result was thought to be a game-like reaction caused by curiosity in searching for hidden virtual pottery through the AR app in the museum lobby. However, the questionnaire and interview results revealed that the virtual pottery against an unmatched space layout—a minimalist lobby (Figure 3)—attributed to non-correspondence due to the low correlation between the virtual objects and the space, although the former were made visually real. Moreover, the rendering characteristics (e.g., materials, textures, and lighting) on the virtual pottery were nearly identical, making it difficult to distinguish their dating from different ages.

Participant ST06 said, "I could not figure out why the pottery was displayed in this place." Participant ST021 answered, "I did not know where to point my camera for the image to appear." Another participant

(ST026) asked, “Does each piece of ancient pottery represent a different age? We tried it a few times and they all look similar.”

This non-correspondence decreased the motivation of the participants in terms of further exploration of the space and testing the functions of the app. On Q6, 48.1% and 25.9% checked Disagree and Strongly disagree. Although 7.4% indicated that they would like to further explore the theme through the app, this was due to the AR interactive 360° view: the participants reported that they planned to use this technology in a future project. On Q5, although 77.8% reported that the AR interactive 360° view was interesting, none of the students viewed all twelve pottery specimens. Moreover, the majority of the participants reported they did not use the help button (red circle; Figure 2) to access pottery descriptions; many did not even notice this option. The outcome of non-correspondence is also reflected by Q2, revealing that the onscreen visual cues (i.e., the virtual pottery and the help button) did not result in affordance to help participants to explore the theme content.

By contrast, when testing *AR Book*, participants were more active and positive, discussing with other group members how to capture the recognition image and achieve the optimal display angle for the visual content. Of the participants, 85.1% indicated that the animated 3D graphics were useful (Q5), helping them to view and learn about dynamic geographical phenomena. Also, 62.9% (Q3) and 66.7% (Q4) checked Agree for the overall integration of virtual images, the physical setting, and the theme, and responded that the correspondence between these elements helped them to access the interactive content. The findings show that coherence with these elements is crucial to encouraging SoOP and further exploration.

Participant SB014 stated, “I learned that Taiwan was formed by plate tectonic processes involving the Philippine Sea plate and the Eurasian plate. My classmates and I discussed visiting Yuli to see the plates in person.” (Yuli is a town in southeast Taiwan at the boundary between the two plates.) Participant SB025 said, “We were intrigued by the static pictures that seemed to come to life when we placed our phone on top of the pictures. We tried the [interactive] buttons several times to see the different animations”. Another participant (SB23) said, “While testing the app, my classmates and I tried to figure out how the animated 3D

graphics were made and presented onscreen.”

After testing *Time Corridor* and *AR Book*, a museum tour guide asked questions about exploring the museum through the two apps, and offered three copies of the picture book as prizes to the participants who answered the most questions correctly. On Q6 to *AR Book*, 48.1% (Agree) and 22.2% (Strongly Agree) reported that they would like to further explore the interactive content through the app. The interview quotes below reflect the findings and demonstrate how the correspondence between visual content and the physical setting effects not only the understanding of theme content but also user behavior, such as motivating them to explore the know-how behind the theme context.

Participant SB09, who received one of the books, said, “I would like to take this AR picture book home for my younger brother.” Participant SB24 also obtained a copy and responded, “Perhaps we could do a project similar to this.”

The participants tested the *D Zone* app at a place chosen by the app designers: a lawn at the university campus (Figures 7 and 8). Since the app adopted AR SLAM technology, participants only needed to scan their surroundings with a smartphone to begin the game; thus, the game could actually be played anywhere. Nevertheless, this unspecified game space is a factor that caused non-correspondence between the visual cues and the physical setting. Although starting the game was easy, the locative media feature of AR could not be harnessed; this detracted from the meaning of the visual cues and reduced the clarity of the AR interaction objective. The purpose of this game was thus not achieved, resulting in counterproductive experiences, and leading to more questions. Of the participants, 59.2% (Q2) and 62.9% (Q4) reported that they did not grasp the content or objective of the game; many even questioned the methods used to eliminate the three invasive species. In addition, 74% checked Disagree on Q3, as they were confused about the correlation between the space nature and the game theme.

Participant SD08 did not directly respond to Q4 but questioned, “Is it true that people really burn fire ants using flame guns? [...]. Are the apple snails the same as those I sometimes see at the roadside?” Another participant (SD013) commented and inquired: “The 3D models of rice plants and snails are cute, but in the real world, do farmers catch apple snails by hand?” Moreover, participant SD014 said “I assume walking around with a mobile

Table 2. Questionnaire results from 27 student participants about evaluation of three apps, by percentage according to 5-point Likert scale questions from top: Strongly agree to bottom: Strongly disagree.

Questionnaire item	<i>Time Corridor</i>	<i>AR Book</i>	<i>D Zone</i>
Q1. Do the image elements displayed onscreen facilitate navigation of the content?	0 0 0 44.4% 55.5%	7.4% 59.2% 33.3% 0 0	0 7.4% 55.5% 25.9% 11.1%
Q2. Do the image elements displayed onscreen facilitate understanding of the content?	0 0 0 59.2% 40.7%	7.4% 59.2% 33.3% 0 0	0 0 11.3% 59.2% 29.6%
Q3. Do you observe a correlation between space or medium and theme?	0 0 25.9% 25.9% 48.1%	18.5% 62.9% 18.5% 0 0	0 0 7.4% 74% 18.5%
Q4. Does the integration of images and space or medium facilitate understanding of the content?	0 0 0 18.5% 81.5%	14.8% 66.7% 18.5% 0 0	0 0 7.4% 62.9% 29.6%
Q5. What function of this app do you find most useful, interesting, or neither?	Interactive 360° view 77.8%	Animated 3D graphics 85.1%	AR simultaneous localization and mapping technology (SLAM) 29.6%
Q6. I would like to further explore the theme through the app.	0 7.4% 18.5% 48.1% 25.9%	22.2% 48.1% 29.6% 0 0	0 0 29.6% 44.4% 25.9%
Q7. Did you sense a feeling of immersion during the test of the app?	0 0 0 81.5% 18.5%	0 0 0 77.8% 22.2%	0 0 0 81.5% 18.5%

phone is no different from sitting in a classroom. Isn't it more convenient to just test the app in the classroom?"

In the results of the three case studies, neither visual realism nor immersion demonstrate the affordance of the visual cues and the physical setting used in ascertaining SoOP in non-iAR. In *Time Corridor*, no participants viewed all twelve virtual pottery specimens, which can be attributed to non-correspondence, as the minimalist lobby of the museum did not match the theme of the early Neolithic to the Iron Age, which indirectly caused participants to confuse the ages of the virtual pottery specimens even though they were made to appear visually real. In addition, although 25.9% checked Neutral on Q3 (regarding perception of the correlation between space and theme), participants reported that this was because of their awareness of being in a museum environment. Overall, the participants were unable to correlate the displays of the virtual pottery specimens and their relationship to the space despite the information supplied, which further decreased the participants' motivation to explore the additional content. By contrast, in *AR Book*, the animated 3D graphics presented onscreen and the 2D illustrations in the book were neither visually real nor did they employ identical styles; however, they mutually corresponded. The majority of participants reported that the integration of 3D animated graphics (e.g., moving plate tectonics, lava flowing from volcanoes, landslides) rendered onscreen along with 2D illustrations in the picture book facilitated accessing of the theme content and encouraged further exploration (Q4 and Q6). Although the current study focuses only on the animated 3D graphics part, several participants

expressed interest in additional field visits and had tested the other two AR games (puzzles and coloring activity). One participant even reported she would like to bring *AR Book* home to her younger brother. Some expressed interest in visiting the places in person. In *D Zone*, overall, participants expressed approval of the design of the 3D cartoon-like game objects, and checked Neutral (55.5%; Q1); a few even marked Agree (7.4%; Q1). These responses, again show that visual realism is not a prerequisite for SoOP in non-iAR. However, the game design did not consider the locative media feature of non-iAR; since the relationship between visual cues and the physical setting was not carefully arranged, participants were left with doubts. Moreover, participants questioned the differences between apple snails (an invasive species) and ordinary snails and the correct way to eliminate apple snails. They also questioned the need to test the app on a lawn at the university campus. These results indicate that the corresponding objective was not realized. Table 2 shows how the participants responded to the seven questions after testing the three apps that enables inference about whether co-influence of visual and physical elements facilitated access to the interaction content. These findings are further attested by inferential statistical analyses.

5.4 Statistical Analysis and Discussion

A one-way repeated measures ANOVA with a Bonferroni correction as a post hoc test was conducted on each question to test the differences of responses on the three apps, but the qualitative question Q5 was excluded. Table 3 shows comparative results to the levels of context correspondence between the three apps.

Table 3. Results of one-way repeated measures ANOVA to three case studies by questionnaire results from Q1 to Q4 and Q6 to Q7

Questionnaire item	F (2, 52)	p	η^2	Post hoc tests (Bonferroni correction)
Q1	301.04	.000	.920	2>1, 2>3, 3>1
Q2	592.18	.000	.958	2>1, 2>3, 3>1
Q3	275.17	.000	.914	2>1, 2>3
Q4	590.81	.000	.958	2>1, 2>3, 3>1
Q6	543.66	.000	.954	2>1, 2>3
Q7	1.03	.320	.380	n.s.

1: *Time Corridor*, 2: *AR Book*, 3: *D Zone*, n.s.: not significant

The results show that *AR Book* achieved statistical significance in Q1, Q2, and Q4. It has the best agreement on the affordance to facilitate understanding and navigation of the thematic content through visual elements and their integration with the physical settings. In contrast, *Time Corridor* has the lowest agreement. *AR Book* also has the best agreement on Q3 and Q6; the two questions correspondingly assessed the co-presence of visual cues and the physical setting reflecting themes of interaction, and whether this co-presence achieved context correspondence that affected the participants' motivation to further explore the theme content. Moreover, to provide an in-depth view of why Q7 achieves no significance, Table 4 further delineates descriptive statistics of Q7; the result shows a very low level of feeling of immersion during the test of all three apps, which reflects the aforementioned discussion that immersion may not be an essential condition for encouraging meaningful experience in the non-iAR realm (Sheller & Rendon, 2017; Choi et al., 2019).

Table 4. Descriptive Q7 statistics

<i>App</i>	<i>Mean</i>	<i>SD</i>	<i>N</i>
<i>Time Corridor</i>	1.81	.396	27
<i>AR Book</i>	1.78	.424	27
<i>D Zone</i>	1.82	.396	27

6. Conclusion and Suggestions

Discussions of SoOP inevitably spill over to include SoP. However, unlike SoP, which emphasizes the feeling of 'being there,' SoOP concerns the feeling that a virtual object is coherent with the real world, drawing attention to the connection between users and visual cues as a means to facilitate access to the theme content. The interrelated nature of visual cues and the physical setting constitutes context correspondence. Table 3 shows that a higher level of correspondence between the two elements encourages SoOP in non-iAR. The findings from the qualitative evaluation also suggest that the main role of SoOP in AR is not only to enable users to experience AR in-depth and understand a specific subject, but may also motivate users to conduct further exploration, including field visits. Feedback from one participant (SB14) supports this observation. This again informs a crucial role of SoOP in

non-iAR interactions: sufficiently powerful AR experience can motivate users to change their beliefs and behaviors (Azuma, 2016). Marsh (2003, p. 86) argues that "all experiences occurring in unfolding events, episodes, the 'big picture' of a scenario that are, or have been, witnessed or evoked in users interacting with mediated environments." In the domain of digital reality, more specifically non-iAR, SoOP gradually unfolds during an interactive process, in which the key is in the appropriate arrangement of the media, namely, the presentation of visual and physical elements. Numerous studies suggest that SoP is largely initiated by VR or immersive AR. Although findings from these studies do not directly apply to the current research, they are fundamental for discussing SoOP in non-iAR and the establishment of context correspondence. As development of AR, VR, and digital reality technologies continues, further research in the field is required to stay abreast of this progress. The three case studies reported here serve as conduits for the examination of SoOP in an unfolding process of non-iAR interaction in different modalities, themes, and settings, which enriches the findings of the current research that facilitate the generalizability and transferability of the findings to other relevant research. The central assertion of the current study (i.e., that correspondence is a key concept for encouraging SoOP in non-iAR) will hopefully provide users with more satisfactory experiences in non-iAR and enable designers to achieve their design goals fully and more effectively.

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