Embedded AR Storytelling Supports Active Indexing at Historical Places

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Fig. 1. We tested two AR narration styles, passive, informative versus an interactive moral dilemma, on their supporting effect on *active indexing* at two cultural heritage sites of daily use, (left) FB and (right) GEP.

Embedded interfaces support *active indexing*, the process of making sense of the experienced. While this supports the creation of meaningful relationships, findings are limited on how it could support sustaining the significance of historical places. We selected two historical places of daily use and developed two AR apps for each. The apps aimed at fostering participants' indexing and meaningful connection to the places by presenting their history. One app offered passive, informative content. The other displayed an interactive, moral dilemma emphasizing the places' social values. We tested the apps in two between-subjects studies with N=42 participants in total. We explored how participants ' historical understanding can be improved by embedding our interfaces on five levels (spatially, physically, contextually, historically, and morally). We found that the morally embedded AR stories supported *active indexing* stronger than the passive ones and argued that they could foster meaningful relationships between users and historical places.

CCS Concepts: • **Human-centered computing** → **Empirical studies in ubiquitous and mobile computing**; **Ubiquitous computing**.

Additional Key Words and Phrases: Cultural Heritage, Embedded AR, Moral Dilemma, AR Storytelling

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1 INTRODUCTION

Cultural heritage sites serve as society's living memory [5, 58]. They incorporate strong cultural meaning and significance, building upon complex compositions of tangible and intangible values [49, 76]. Such locations and their significance can be sustained by emphasizing their historical, architectural qualities, and social value. The latter connects

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their meaning to contemporary needs and situations [48], which further increases users' attachment to the place [9]. However, this presents the following two challenges: 1) The meaning and significance often go unnoticed because there is not enough available and accessible information onsite [56]. 2) The information presented lacks personal relevance, which is integral to long-time learning. Technology to enhance historical sites should therefore aim to provide accessible, meaningful, and personally relevant experiences.

The process of making sense of and to create meaningful connections to something by embedding technology in a specific context [67] is called *active indexing* [8, 41, 67]. This process enables users to draw personally relevant and general connections through active and purposeful exploration of one's environment through embedded interfaces [8, 41]. Hornecker distinguishes between *spatio-contextually embedded* interfaces that set objects and location into a logical spatial relation [42, 91] (e.g. an information sign next to an exhibition piece), and *physically embedded interfaces* that are either physically represented or somehow physically anchored in the real world (e.g., a statue representing a local hero and their story [21, 27, 41]).

However, historical places also embody part of one's personal history and relate to personal attitudes and moral values due to their historical significance. Memorials, for example, remind people of what happened in the past to prevent history from being repeated. The relation of values to learning about history has been explored in the learning sciences [34, 72], but relatively little work addressed historical places and their meaning. We hence aim to explore the question of whether and how embedded interfaces can support *active indexing* regarding moral values.

To approach this question, we selected two historical landmarks that are also contemporary public places of daily use. The first, abbreviated GEP for Georg-Elser Place, Munich, below, was built to remind visitors of a local hero's civil courage during world war II. The other, called FB for Airport Fürstenfeldbruck below, commemorates a violent hostage-taking motivated by racist ideology at an airbase in the 20th century. We developed four different Augmented Reality (AR) applications, two for each place, and compared them in two between-subject studies with N=42 participants in total (22 participants at GEP, 20 at FB). The AR was designed to include the same amount of historical facts. For both places, we provided two narration styles, one being informative, only showing textual overlays and visual information embedded in the environment further referred to as the *informative* app. The other app allowed the user to make decisions and interact with the content. Both designs are common practice in AR content design [29] and also well-established in Urban Interaction Design (UIxD) [20, 51, 53] and architectural heritage [23, 45, 83]. Our motivation to compare the content narration is based on prior findings in the context of teaching historical significance [34, 72, 75]. These show that emotionally engaging, empathetic storytelling, which allows drawing meaningful connections to one's personal life, results in better learning and understanding than pure fact presentation. We hence decided to present the active interaction in the form of a moral dilemma. A moral dilemma requires users to make a morally challenging decision between two conflicting alternatives [14, 31, 82]. By having to decide for one, the user has to violate the other moral norm. [59] Moral dilemmas are known to trigger emotional arousal [14] and hence may cause behavior change [82]. In relation to learning about a place's historical significance, moral dilemmas support the understanding of historical actions and reasoning and allow to draw connection to today [47, 63]. We further refer to this rather active app as the *dilemma* app. The goal of our studies was to explore how to approach and support *active indexing* through embedded interfaces in the wild to sustain their historical significance at both target environments. This resulted in the following two concrete research questions:

R1 How can we foster active indexing at historical, public places of daily use through embedded AR?

R2 What influence do morally embedded versus informative AR narration styles have on the active indexing process?

With our approach of exploring *active indexing* at historical places of daily use, we explore simultaneously how different levels of embeddedness can foster users' understanding of a places' historical significance and support the creation of a meaningful user-place relationship. Our results show that morally embedded AR content has a stronger effect on users' active indexing compared to passive, informative apps. It can increase active indexing activities beyond the spatial and temporal study contexts.

2 RELATED WORK

Prior work explored *active indexing* strategies in education [34, 72, 75], museum exhibitions [4, 6, 16, 40–42, 72, 91] and for public user-place relationships [38, 53, 70, 81]. In each context, authors presented location-based solutions that leave room for spatial and contextual exploration [40, 53, 70, 81, 91]. We will introduce current *active indexing* strategies and their effect on creating meaningful relationships and understanding based on prior work in UIxD and cultural heritage. In addition, we will have a closer look at affective narration styles that should enhance *active indexing*.

2.1 Active Indexing in History Education

In history education, one strategy to teach historical facts and events is to create a relation to current events [75]. A relevant approach to achieve this considers the information's narrative style [4, 94]. For example, Bartelds et al. [34], and Savenije and Bruijn [72] noticed a positive and facilitated learning effect when stories appealed to students' emotions. It enabled them to feel *historical empathy*, which is the creation of meaningful relationships between historical figures, their histories, and the museum visitors through factual information presented from a personal perspective [26, 72]. In line with this, Brooks [11] and Seixas [75] found that understanding the presented facts and stories beyond their epoch means understanding the historical significance of an event and helps to identify who we are in comparison to people from the past.

Within HCI, Hoellerer et al. [38] created so-called *situated documentaries* using AR technology and coordinated displays to educate visitors of a university campus' historical events already in the 1990s. Although this work was never formally evaluated, it already showed the potential such a spatially and contextually embedded interactive representation could have for historical awareness. Other work also applied situated, and spatially contextualized learning, aiming to support *active indexing* [16, 22, 40]. It links *social relations, cultural history, and spatial conditions*, to enable an embedded learning experience [35, 66]. In comparison, Hornecker created a spatial contextualization through careful positioning of the so-called *jurascope* AR prototype in direct sight to a museum's exhibition piece. Thus, it created a meaningful connection between both objects [40]. Lastly, Ciolfi and McLoughlin [16] distributed augmented cues over the whole premises of a living history museum context, which incorporated audio tracks of personal stories from former inhabitants that could induce strong emotions. Through their approach, the interfaces were *spatially, physically, contextually, and socially embedded*, which fostered users' engagement and empathy. These examples show the importance of *affective narration* in history education for *active indexing*.

2.2 Moral Dilemmas

A widely used strategy to create a strong emotional effect for video game players is moral dilemmas. According to prior work, they increase player engagement and evoke meaningful playing experiences [19, 37, 74]. In Iten et al. [44], authors explored decision-making characteristics to create meaningful player experiences. They identified three influencing themes: the consequence of the interaction, the social connection to players and non-players, and the player's moral values. Furthermore, Schrier [74] compared the effect of written versus played ethical dilemmas in a video game on

ethical thinking. One of their results showed that participants who were regularly playing the dilemma considered long-term effects and indirect outcomes more in their decision-making than participants reading the paper version. This illustrates that the choice of media has a relevant impact on the understanding of connections and the creation of meaning. Besides the gaming context, moral dilemmas are also used to educate and reflect about social and moral values that can lead to behavioral changes [43, 85, 86, 90]. In the context of social values, e.g., Taylor and Taylor [85] confirmed that ethical dilemmas incorporate the advantages of fostering greater social responsibility and critical reflection, which would allow a more objectified evaluation and decision-making. Thus, moral dilemmas provided by media content can create strong emotions that influence interpretation, inductive learning abilities, and decision-making [14, 15, 39, 44].

Moral dilemmas can be tailored to a certain context by considering moral foundation theory [31]. This theory includes five counter domains of moral intuitions that are the root of decisions in moral dilemmas [78]: 1) care versus harm, 2) fairness versus cheating, 3) loyalty versus betrayal, 4) authority or respect versus subversion, and 5) purity or sanctity versus degradation. Christensen et al. [14] identified four main factors that should be specified when designing the storyline of moral dilemma: 1) Personal or impersonal: Is the action conducted by the reader personally, or do they decide about someone else's actions? 2) Benefit recipient: does the action provide a personal benefit or not? 3) Evitability: Is the dilemma avoidable or inevitable? And 4) Intentionality: Is the caused harm intentional or due to collateral damage? We used these criteria to design two moral dilemmas for our studies.

2.3 Meaning and Sense of Places

Prior research relates meaningful user-place relationships to the concept of place attachment [9, 30, 68], which consists of place-identity (how much a person identifies with a place) and place-dependence (how much a place satisfies a person's needs in comparison to other places) [9]. It contributes to a person's well-being and to the feeling of ownership and responsibility toward a place [2, 12, 69]. In turn, this can influence the place-protection and -preservation [77]. To increase place attachment, prior research explored a variety of spatially embedded installations. For example, Farnham et al. [28] asked users to share their onsite experiences on a public screen placed at the location. Thus, they increased users' feeling of connectedness to the place through shared social experiences. Prior work by Kostopoulou et al. [53] and Lehto et al. [61] used location-based AR to revive historical places and visitors' understanding and attachment to them. Both emphasized the importance of spatially embedded cues and the user experience onsite. However, research on fostering meaningful user-place relationships is still scarce within the HCI community, with a growing need to comprehend it [3, 80] and how *active indexing* might foster it.

2.4 Summary

Prior work showed that *active indexing* can foster understanding and meaningful relationships [16, 41, 91]. Particularly in educational history [34, 72] and video game research [19, 37, 74], findings report on greater learning effects and understanding when the content addressed participants' emotions, for which moral dilemmas are already used. However, considering the process of fostering meaningful user-place relationships, HCI research is still limited regarding strategies in general [3, 80], including the role of active indexing and the influence of user's emotion in this context.

3 AR PROTOTYPES AND STUDIES

In order to explore *active indexing* strategies, we built four AR prototypes, two for each location, comparing the two AR narration styles, *informative* and moral *dilemma*, and their effect on fostering *active indexing* and the creation of *meaningful user-place relationships*. Each AR scene included the same number of historical facts. We decided to use

AR apps on mobile phones, one handheld, one physically embedded, which has become an established technology in urban, architectural heritage interaction, and interactive museum exhibits, and which is known to be easy and quick to use [7, 40, 46, 60, 84].

3.1 AR Scenes and Dilemmas

We prepared one informative AR application per place that presented textual information and images to our participants about the respective historical event. Compared to the interactive apps, the informative apps had no continuous storyline between the different information points. The dilemma apps' structure was based on prior work by Graham et al. [31] considering the moral foundation theory and by Christensen et al. [14] for the details on how to design moral dilemmas. Table 1 provides an overview of the dilemmas' characteristics and how we transferred them into our stories. Additionally, we addressed the reader with "you" and used a classic dilemma structure. The structure includes an introduction that sets the reader's expectations and presents an understandable, difficult situation. It follows the possible action choices and the consequences that either option has. Lastly, a personally addressed question confronts the reader with the moral dilemma and decision-making.

Table 1. Designing a moral dilemma: Requirements derived from psychology literature, translated into our story designs.

Reference	Feature	GEP	FB
Graham et al. [31]	Moral intuition	care versus harm	care versus harm
Christensen et al. [14]	Personal or impersonal	personal	personal
	Benefit recipient	yes - risk of dying	no - risking other people's lifes
	Evitability	inevitable	inevitable
	Intentionality	intentionally	intentionally

Thereafter, we will briefly outline both moral dilemmas. The actual descriptions given to participants were more extensive and complied with the technical conditions above. Participants did not have to make a decision at either place but were all confronted with the question to decide between two important moral values. At both places, participants clicked through a communication with another character who introduces them to the respective scene and problem. The storyline of the *moral dilemma* at GEP put participants in the perspective of a chief commissioner who had received notice of a bomb threat to kill Adolf Hitler. The assassin was captured onsite, but the bomb could not be found. As an explosion would kill at least eight people, the participants had to decide whether to inflict brute force on the assassin personally or not. Figure 2 shows the physical prototype and AR scenes from both apps, informative and dilemma.

(a) (b) (c)

Fig. 2. Prototype at GEP: a) The spatially embedded stationary prototype. b) The informative augmentation versus c) the augmentation showing the dilemma scenario.

In comparison, the *moral dilemma* at FB confronted participants with a hostage situation, in which seven athletes of an Israeli sports team were taken hostage with the help of Neo-Nazis. Besides that, the participants were put into the police officer's perspective responsible for freeing the hostages. The participants had to choose between killing one of their colleagues to free the hostages or risk letting everyone die (see Figure 3).

3.2 Study Design

We conducted two field studies at the identified places. Both are still in daily use, and while GEP is located in an inner-city area, FB is located in the outskirts. Both are commemorating historical events of current moral relevance, addressing civil courage (GEP) and racism (FB). We selected those two places as there is little information about the events at neither place. Testing two AR apps at either location, half the participants tested the *informative*, the other half the *dilemma* app (between-subjects design). The study included three surveys at different points in time, before (PRE), immediately after (POST), and about two weeks after (FOLLOW-UP) the onsite interaction experience.

3.2.1 Technical and Spatial Setup. We implemented the AR apps for GEP in Unity, version 2019.4.15f1 using android build support and the vuforia engine, version 8.5.9, and for FB in Unity 2020.3.4f1 and the Vuforia Engine 9.8.5, both on Google Pixel 3 phones. Additionally, we installed physical components at each location: At GEP, we integrated the phone in a stationary, physical telescope-like prototype as presented in Figure 2. On initialization, all AR objects were positioned relative to the camera within a 140° angle. Participants could interact with the app by either pushing the whole telescope forward to select something or turning it about 180° from left to right to return to a prior scene within the scenario. In comparison, we used a mobile setup at FB. Participants could move around and use the space holding the phone in their hands. They activated the content by moving around the place and by hovering the camera over pre-defined anchor points with differently shaped, white-colored spots made of wallpaper (see Figure 3). We embedded them to connect the digital components with the physical place. Users, for example, followed the white lines to find the spatially distributed AR content. The objects' positioning was relative to the initial camera position. We physically indicated the starting position in the real environment.

3.2.2 Recruitment and Participants. Our study explored how and if *active indexing* can support the creation of meaningful relationships to historical places of *daily use*. Thus, we recruited locals that lived within a 3-mile radius via local notice boards and personal contacts. At GEP, we tested with a total of 22 participants (m = 5, f = 17) and with 12 men and eight women at FB (a total of N=20). We received a total of 42 completed follow-up questionnaires, 22/22 from GEP and 20/20 from FB. After completion, participants were reimbursed with either a 15€ Amazon or local business voucher. The study received ethical approval from our faculty's ethics board (EK-MIS-2021-054) for the study design and content.

3.2.3 Questionnaires and Measures. We used the sosci survey online tool [1] for polling participants, in which they could identify themselves with their personalized study ID. We collected the demographic data (gender, age, education degree, occupation) and the participants' prior experience with the respective place in the PRE testing. To do so, we used questions from the *experience use history* questionnaire [24, 33] (e.g.,: time previously spent at location). In all surveys, we further tested participants' knowledge regarding the places' history to track the learning effect based on the study participation, with the help of recall questions and multiple-choice transfer questions (cf. [13, 55, 95]). The FOLLOW-UP also assessed participants' perceptions of the physical and digital set-up, its comprehensibility, and the

[1] https://www.soscisurvey.de/, last accessed December 2021

(a) (b) (c)

Fig. 3. Prototype at FB: a) One of three spatially-embedded physical prototype parts. b) The informative augmentation versus c) the augmentation showing the dilemma scenario.

extent to which the experience triggered further reflection and social communication beyond the study setting. These aspects were evaluated using both five-point Likert scale items and open-ended questions.

To evaluate the (1) emotional effects, (2) place attachment, and (3) enjoyment of the AR experience, we used the complete iPANAS [10, 50, 87], the APAS [9, 30] and the User Acceptance Model for Hedonic Information Systems [89][2].

Since we were only interested in the participants' meaningful user-place relationship and thus the *place identity*, we did not include the APAS questions regarding *place dependence* which are concerned with the practical and functional meaning of a place (e.g., a supermarket).

We evaluated the collected data in R (version 1.2.5033; packages: readxl[93], tidyverse[92], tidylog[25], apa[32], afex[79], ggsignif[17], emmeans[62]) and two of the authors independently coded participants' feedback to the open-ended questions by looking for common themes and behaviors. Evaluating the questionnaire results, we computed a mixed model ANOVA on percent correct for the knowledge questions and on the place identity scores between-subjects per location and app using the Greenhouse-Geisser correction.

3.2.4 Procedure in Both Places. We conducted a pilot study at each location first. The main studies were conducted over two weeks in parallel. In both field studies, we followed the same procedure. We provided participants with the study information and data privacy regulation according to GDPR. This was followed by an introduction to our hygiene concept considering national health regulations[3]. Each participant confirmed their consent to the data regulation and the hygiene rules. Afterward, they filled out the first survey (PRE). At the beginning of the main part of the study, we asked participants to familiarize themselves with the app. When they felt comfortable, they entered the main scene. Depending on the app type, participants either interacted with the informative or the dilemma app. Immediately after the interaction, we asked them to report on their individual experience by filling out the second questionnaire (POST). About two weeks later, participants completed the FOLLOW-UP questionnaire remotely.

4 RESULTS

Below, we will focus on the main findings of our studies. All (N=42) participants completed the study. The majority were students with an average age of 26 years (SD=8.4). At GEP, all but two of the 22 participants had spent between 10 min. and three hours during their average visits onsite before. In comparison, all but one FB participant had spent

[2]We adapted the User Acceptance Model to our context; e.g., "I can decide more quickly and more easily which movie I want to go see than in the past" –> "I can decide more quickly and more easily what I want to go see at the place than in the past."
[3]The study took place during the first year of the Corona pandemic. Rules included the disinfection of devices after each participant, keeping a 1,5 m distance at all times, and asking participants to sanitize their hands before the interaction.

between 15 min. and four hours at the location. All participants reported that they overall enjoyed interacting with the respective app and that they would like to reuse it. This validates that all apps worked similarly well for participants with only minor differences, allowing to compare the remaining results across apps. This further reflects in the knowledge questions' results, in which the learning effect was relatively balanced among conditions between before and after the interaction. At FB, participants showed a small, non-significant, but persistent learning effect after the interaction immediately after and in the follow-up survey (see Figure 4). In comparison, GEP participants' knowledge increased significantly for both apps. We only found a significant main effect for measurement point, $F(1.72, 65.24) = 38.03$,, $p < .001$, $\eta_p^2 = .50$, an interaction of Location and Measurement point, $F(1.72, 65.24) = 6.81$, $p = .003$, $\eta_p^2 = .15$ and an interaction of app and location, $F(1, 38) = 4.76$, $p = .035$, $\eta_p^2 = .11$.

4.1 Physical, Spatial and Contextual Connections

Overall, the relation between the physical prototypes and the spatial context made sense to participants at both locations. They also estimated that each would have caught their attention independently from the study. However, they neither understood the physically-embedded prototypes before the interaction, e.g., *"Upon arrival, I only noticed the markings as garbage. The markings then made sense as part of the AR, and their meaning was clear to me afterward." (P13, FB).*

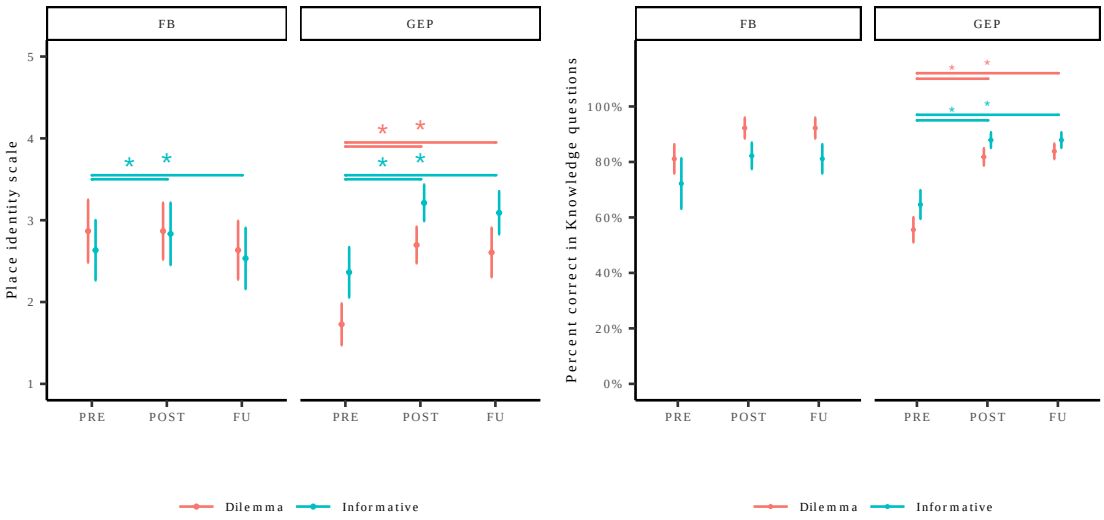
In comparison, participants assessed the connection between the AR content and the spatial context as clear for all apps. Participants appreciated the novel in situ interaction possibility, the shared information, and the presentation styles at both places. They further liked the design choice of using a telescope-like prototype at GEP. It would directly indicate that there is something to look and search for: *"The construction resembled binoculars and it, therefore, made sense to look through it and at certain things at the place." (P15, GEP).* However, two also criticized that the place could have been more actively integrated into the scenario. In turn, the physical floor markings at FB supported a good spatial-contextualized connection between the app and the former airbase: *"The floor marking was placed very cleverly so that you always had a view on the airbase while using the app. In addition, my interest was greatly increased by using the images in the app." (P11, FB).* As participants were required to move to the different markings, their perspective on the airbase slightly changed, putting other buildings or areas, such as the tower or the landing zone, in focus (see Figure 1).

4.2 Understanding The Places' Historical Significance

During the follow-up survey, the participants reported how they understood the historical information provided during the experiment and how they set it to the historical context. In the open comments, we identified three overarching themes among the given statements. These were concerned with: (1) the accessibility and *comprehensibility* of information (n=22); (2) the *appreciation* of the historical protagonists and their actions (n=7); and (3) the *awareness* for and attachment to the location (n=3). We found that independent from the study location and app-condition, participants equally reported on the topic of comprehensibility (GEP informative: N=6, GEP dilemma: N= 5, FB informative: N= 5, FB dilemma: N= 6). Within that theme, they reported that the historical information was easier to understand based on the visualization, the apps' ability to create an exciting and involving situation, and the advantage of adding additional visual representation for no longer existing but relevant objects such as buildings.

In the case of GEP, we found that six participants reported being proud to have such an important historical location in their city, or they expressed acknowledgment for the bold initiative. *"I feel that having this place in [xxx] is a great enrichment, especially because of its name's history." (P40).* Only one (dilemma) participant acknowledged the extreme situation in which the police officers acted in the FB scenario. For both scenarios, there were more statements from dilemma app participants than from the informative ones (GEP informative: N=2, GEP dilemma: N= 5, FB informative:

$N = 0$, FB dilemma: $N = 1$). Lastly, three GEP participants reported that they felt more connected to the memorial site and that they were also more interested and aware of the location itself after the interaction; *"I was more aware when looking around and staying there." (P27).* No comparable statements were given in the case of FB.



(a) Place Identity

(b) Knowledge Factor

Fig. 4. Mean scores with standard error as a function of App, Location, and Measurement point for: a) Place identity per place: The interaction effect was greater for GEP participants than for FB participants. b) Knowledge per place: The interaction effect was greater for GEP participants than for FB participants. Asterisks represent significant bonferroni-corrected t-tests with $p < \alpha$ of .05.

4.3 Understanding Beyond-the-Study Connections

We also asked participants to indicate how they set the AR experience to their personal life and the contemporary political situation and issues. Overall, six informative apps (two at GEP and four at FB) and 19 dilemma apps participants (10 at GEP and nine at FB) reported reflections beyond the study context. In their statements, we found the following topics reflected: (1) concrete examples for related modern *conflicts* (N=13); reflection on the *justifiability* of the decision (N=9); importance of *remembrance* culture (N=5). In comparison, for the remaining informative app, users explained that they were missing information in the app to draw connections to nowadays events and happenings: *"The relation to nowaday's happening was missing." (P12, GEP). "Actually, I didn't really draw any connections." (P8, GEP). "There is little room for interpretation when it comes to historical facts." (P75, FB).*

4.3.1 Relation to Contemporary Conflicts. Regarding the participants' perception of how the historical events can be contextualized with today's political situations, we found that for GEP, three dilemma participants mentioned the historical scenario compared to today's conflicts. Two made a general reference, and one gave a concrete example: *"The question of how to decide in such a situation that there is no right answer is, I think, up to date at all times. I see it as problematic that one should not weigh human lives against each other and it is still (unconsciously) done. I see a relation to*

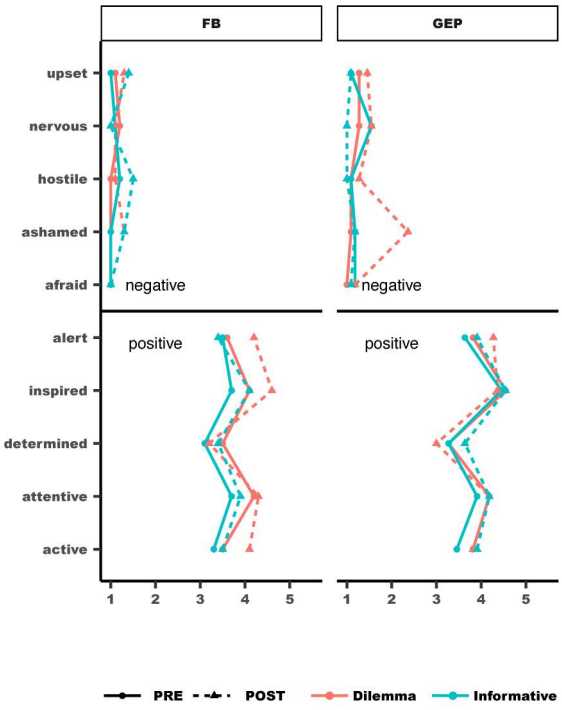


Fig. 5. Mean iPanas scores with standard error as a function of App, Location and Measurement point. The main difference among apps triggered the dilemma app at GEP. We have not conducted any statistical inference due to the overall value of the profiles.

today's events and problems, for example, to the refugee crisis and the death of people in the Mediterranean Sea." (P28, GEP). In the case of FB, in total, 10 participants stated to perceive a connection with modern situations (FB informative: N=3, FB dilemma: N=7) and nine saw a homogeneous comparability with topics such as racism, antisemitism, and terrorism. *"The information reminded me of current terrorist attacks and the growth of violence and agitation for anti-Semitic and racist reasons." (P13, FB).*

We saw that those who interacted with the informative app had thought less about connections beyond the presented scope. In contrast, almost all dilemma app users reported thoughts and reflections related to their interaction experience.

4.3.2 Justifiability. Nine dilemma app participants reflected and reasoned about the difficulty of deciding on the respective situation (GEP dilemma: N=7, FB dilemma: N=2). In both cases, the reasoning was rather general, pointing out the complexity of such situations and the challenge of not having a single right option to choose from, thus validating the construction of our dilemmas. Six users expressed their empathy with the presented characters emphasizing how complex the decision-making in the respective situation might have been on an individual level. It made participants reflect on the complexity of each case. *"It was most interesting to experience the story from the perspective of a Nazi supporter. As a result, one has dealt critically with the place and its history and not only perceived the positive." (P46, GEP). "Very emotional and stressful situation for the police officers." (P93, FB). "You noticed that there are always two sides to a story." (P46, GEP). "The information presented a situation in which one is faced with a decision for which there is*

no foreseeable better option. With situations that may have conditionally negative consequences, such a dilemma can be observed in many situations in modern politics and history. I, therefore, interpret the information as another example of such a dilemma, in which a decision must be made with unpredictable consequences." (P16, FB). This aligns with the results of the iPanas, which showed the GEP dilemma to have caused slightly negative emotions, which might have triggered participants to reflect more. They particularly felt more ashamed (see Figure 5) than before their interaction, whereas the informative app caused a positive effect. In turn, FB participants felt worse in both cases, dilemma and informative, by feeling slightly more upset and hostile than before the interaction. Overall, the dilemma apps caused participants to reflect more about the complexity of real-world situations, such as those presented in our AR scenarios.

4.3.3 Cultivating Rememberance. For both scenarios and apps, five participants stated that they see the importance of cultivating a remembrance culture to proactively counteract a repetition of such acts (GEP informative N=1, GEP dilemma N=2, FB informative N=2). They reported the need to educate society about such happenings and noted that such places are too little perceived for what they are. The need to remember the places' history is also reflected in the place identity ratings for GEP participants. The place identity increased for all participants significantly comparing before and immediately after the interaction. While slightly decreasing in the follow-up survey, the interaction effect on participants' place identity still shows about two weeks later, as shown in Figure 4. We have found only a significant main effect of measurement point, $F(1.61, 61.36) = 9.20$, $p < .001$, $\eta_p^2 = .19$ and an interaction of Location and Measurement point, $F(1.61, 61.36) = 9.55$, $p < .001$, $\eta_p^2 = .20$. The results do not resemble at FB because most participants already identified highly with the location as various participants grew up in the area and the location *"had always been there" (P11, FB)* and is *"basically located in front of our front door" (P57, FB).* Hence, there were no significant differences in the interaction but a slight decrease in the follow-up ratings.

4.3.4 Miscellaneous. Besides these three main topics, we found statements expressing other interesting perspectives and opinions. In the case of FB, three participants (FB informative N=3) explicitly stated that while living close to the location, they were not aware of its historical meaning and regretted that fact. In the case of GEP, one participant (GEP dilemma: N=1) explicitly stated that such an experience could help understand better how people felt and acted. Seven participants in the GEP scenario (GEP informative N=6, GEP dilemma N=1) stated that they could not relate the AR experience to a contemporary situation and only one for FB (FB informative: N=1).

Based on these results, we summarize that the apps' informative qualities were equally reflected in the participants' statements, but other aspects such as the appreciation of the historical actions differed.

4.4 Key Findings

Based on the results presented above, we summarize the main findings here:

- The physical prototypes were well embedded to the AR experience as indicated by, e.g., P15 GEP, P28 GEP, P11 FB, P72 FB, etc. but were little understandable on their own.
- The dilemma apps increased the likelood for participants to reflect on their experience beyond the study context as compared to the informative apps.
- Spatially contextualized AR interactions can increase users place identity, which, in turn, increased their need to cultivate remembrance for the respective location.
- The GEP dilemma had a stronger effect on participants' emotions compared to the other three implementations.

5 DISCUSSION

We explored two different physical and spatial setups and two types of AR applications for their effect on participants' *active indexing*. The overarching goal was to explore how we can use *active indexing* to increase the understanding for and sustainability of historical places of daily use. Our results show that *active indexing* can foster a meaningful user-place relationship to historical places of daily use by increasing the understanding for a) their historical significance, b) their relevance of contemporary events and problems, and c) strengthening users' place identity probably due to the emotion induction. Our field studies achieved a stronger reflection and active indexing effect by confronting participants with a moral dilemma based on verified historical conditions. However, we also saw a wildly divergent impact of our morally embedded AR stories between the places in our results. At GEP, participants testing the dilemma had to decide from a Nazi soldier's perspective of either torturing the assassin, who is now also celebrated for his civil courage, or to risk letting a bomb explosion kill various other soldiers and civilians. In comparison, the FB dilemma put participants in the role of a police officer who aimed at saving hostages from a racist-motivated kidnapping under the risk of shooting a colleague.

Below, we will discuss the different levels of embeddedness applied to foster *active indexing*. In particular, we embedded the content historically and morally, which can be considered an extension of the current active indexing concept. We will finish with our findings concerning sustaining the historical significance of places of daily use through embedded AR and the implications of providing users with morally challenging dilemmas.

5.1 Limitation

Our field studies differed in various aspects, such as spatial and physical integration and the surrounding conditions. Thus, a generalization of the results must be made with caution. Also, morally embedded storytelling cannot be applied to every historical situation and has to be carefully adapted to trigger an actual reflection effect in participants. Nonetheless, where moral dilemmas are not suitable to emotionally charge the situation and foster active-indexing other means of personally relevant emotion induction could be explored such as music [57], or interactive digital narratives [52]. Nonetheless, we believe that our findings reveal several insights about *active indexing* in the wild and the meaning of moral dilemmas in this context.

5.2 Spatial, Physical and Contextual Embeddedness

Active indexing is not a one-time event but a process. Setting our study in relation to prior work, we see different levels of enabling *active indexing* depending on the intended reflection scope. In Hornecker's and other work [4, 6, 16, 40–42, 72, 91], authors reported on their strategies on embedding their interfaces physically, spatially, and contextually but said little about the participants' reflection beyond the scope of the museum exhibitions. In line with their work, we composed all prototypes of the digital AR applications and physical components, either in a stationary telescope-like interface or the distributed floor markings. While our results confirmed the understandability and usefulness of the mixed composition for the interaction [64], the physical parts made relatively little sense on their own. Participants would neither have understood the physical components' meaning nor the possibility of receiving AR information. This relates to having little accessible information at historical landmarks [56] and emphasizes the need for physically and spatially embedded yet explicit interfaces. We see the need particularly at historical places of daily use as their contemporary usage is mainly independent of their historical significance [88]. The stationary telescope-like prototype appealed to participants' previous knowledge and familiarity, which partly set their expectations before the interaction.

The object choice finds repeated use in research [40, 73] but there are also other recognizable and embedded objects, such as QR codes [36]. As users approach such public places with different expectations than a museum context, the interface's physical embeddedness needs to communicate its interactivity and purpose. Thus, making interfaces explicit by reusing objects known as information interfaces can facilitate the process of spatially contextualized and physically embedded interfaces.

5.3 Historically and Morally Embedded AR

Adding to other cumulus of work on active indexing, [4, 6, 16, 40–42, 72, 91], we historically embedded the AR experience, informative, and dilemma, which all caused a similar learning effect. Going beyond learning facts toward understanding the meaning of the places' historical significance, the interaction effects greatly differed considering their moral embeddedness.

5.3.1 Informative and Moral Dilemma Effect. The moral dilemmas triggered almost all participants (19 of all 21 dilemma participants) to reflect the experience beyond the study context to contemporary issues and situations. In comparison, the informative apps triggered less reflection beyond the study scope. Participants that used the dilemma apps confirmed feeling empathy with the presented characters and their difficult situation, which aligns with findings by Schrier and others [34, 72, 74] that an emotional and personally-relevant narration supports the user's historical understanding. It aligns with their findings on enabling people to embed the historical information socially and thus, supporting the creation of meaningful relationships between the user, the history, and the place [16, 48].

However, while the qualitative feedback supports this statement, the iPANAS results were inconclusive. At GEP, we found a change in participants' emotional conditions after experiencing the dilemma app compared to the informative app. In contrast, at FB, both groups were slightly negatively affected. We assume that this could be due to the different characters that participants played. By comparing the characters' histories and the dilemma setups, the GEP dilemma might have been more provocative. Participants experienced it from the perspective of an anonymous character faithful to the Nazi regime. They had to decide about a character's destiny who was positively connoted from society for his civil courage. Participants entered the conflict at FB from the society-appreciated protagonist who acted against antagonists associated with antisemitism and terror. Thus, the dilemmas were potentially differently embedded considering the moral dilemma, which might have caused an either more substantial, in case of GEP, or weaker, in case of FB, change in the emotional state. As the killing due to racist motives is a very recent and strongly discussed topic, it might explain the increase in negative emotions in all FB participants due to its immediate personal relevance.

5.3.2 Pros and Cons of Morally Embedded Interfaces. Stories are effective tools to persuade people to change their behavior [65]. They are easier to understand, more engaging, and more memorable than purely informative content [18, 71]. However, they often represent one subjective perspective and narrative that is globally accepted as truth by ignoring a story's complexity and diversity [1, 54] and is thus, criticized to undermine facts [54]. Hence, we applied moral dilemmas which counterbalance the bias by leaving it more to the user to interpret and make a decision on how to act and what consequences to accept [14, 15, 39, 44].

However, our exploration showed the complexity of morally embedded AR storytelling. One challenge concerns the moral dilemma creation. The historical facts need to be truthfully mapped onto the dilemma criteria [14, 31], which requires available and extensive historical information and an according to the conflict situation. Another challenge relates to designing the AR scenario and contextually embedding the interface so that the interaction experience results in the required effect and affect. And lastly, as we saw in the iPANAS, the moral dilemma can arouse negative emotions

in a user and could thus promote disengagement in the long term. While video games already apply it to increase the player engagement [19, 37, 74], it is still out for discussion whether we can ethically accept to purposefully design for negative, potentially stressful emotions to communicate real-world historical significance. Therefore, both the increase of learning has to be weighed against the potential stress caused by using a moral dilemma. Still, we could not find any indication of disengagement caused by distress for participants in our study. In contrast, participants were more ashamed (according to the iPANAS, see Figure 5)after their interaction, showing that the dilemma triggered a certain degree of empathy and reflection. Thus, also negative sensations support active indexing and support building deeper connections with one's surroundings. However, this also places a responsibility on the designers of such experiences to balance moral involvement and expected benefits with emotional impact on users.

5.4 Implications for UIxD and Historical Places of Daily Use

Participants reported on the perceived lack of spatially and contextually embedded interfaces that would communicate local knowledge and history, which goes in line with prior findings by Krosche et al. [56]. Furthermore, some participants felt more connected to the place after the interaction. In the case of GEP, this also reflects in the increase in place identity independently from the AR narration style. It supports Wilson and Desha's findings [94] that learning about a place's history strengthens the user's place attachment [9, 30]. We explain the differences in FB scores with the already high place identity of participants and the slight decrease due to participants responding remotely instead of onsite, considering findings by Stals et al. [80]. From an UIxD perspective, it shows the importance of integrating and communicating a place's background and history to its users. Similarly, a place's social value can be increased and its significance sustained through active indexing and by providing the daily users with more information that is not only fact-driven but that enables users to emotionally connect and change perspective. Thus, our findings contribute to the growing research on place attachment in HCI by emphasizing the strong influence that historically and morally embedded interfaces can have on *active indexing* at historical places of daily use. However, they also show the complexity and ambiguity resulting from prior user knowledge and the different contextual conditions that influence the process.

Our technology choice proved a suitable medium [74] to convey the places' histories in both cases, stationary or mobile, which is also supported by the user acceptance model results. Yet, our results also show the need for shared, public places to be more pro-active in providing interaction possibilities, which also requires understandable indicators positioned in the environment to trigger users to enter into the interaction. Thus, a mobile AR application might not be sufficient but requiring further advances on mixed reality possibilities for historical places. Besides, we saw a much higher report beyond the study reflections from dilemma participants than informative apps participants. Hence, the morally embedded AR storytelling fostered *active indexing* more than informative, passive apps, which in turn increases the understanding of the places' social value [48]. Relating the finding to the need of sustaining historical places' significance [48], we argue that morally embedded interfaces should be further explored in the context of historical places of daily use to emphasize not only their architectural but also their intangible values [49, 76].

6 CONCLUSION AND FUTURE WORK

Overall, our findings show the importance of not only embedding the interfaces spatially, physically, and contextualized [41] but also historically and morally to achieve a higher *active indexing* effect. Furthermore, our results confirm that increased indexing activities supported a meaningful user-place relationship and strengthened the place's social value. We observed the effect particularly when participants were confronted with the moral dilemma, which may have

an emotional affect on users. However, the diverging results motivate future research on the making and embedding moral dilemmas to increase historical places' social value.

Thus, the next steps are to explore applying other moral dilemma characteristics or focusing on other domains of the moral foundation theory. This includes the investigation of influencing interaction factors on the interpretation. Lastly, alternative approaches increase the emotional experience and create a shared understanding, which are worth exploring. For example, one could connect people that visited the historical site by embedding usage marks and their reactions to the dilemma situation via digital representations in AR. One could also explore whether active indexing is supported across different time frames that may also differ concerning personal relevance, e.g., comparing the dilemma at GEP taking place in the 1930s to an adapted dilemma set in the present. Thus, there are interesting opportunities for future work on increasing the emotional experience of historical places by embedding meaningful digital media in the environment.

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