MapUncover: Fostering Spatial Exploration through Gamification in Mobile Map Apps

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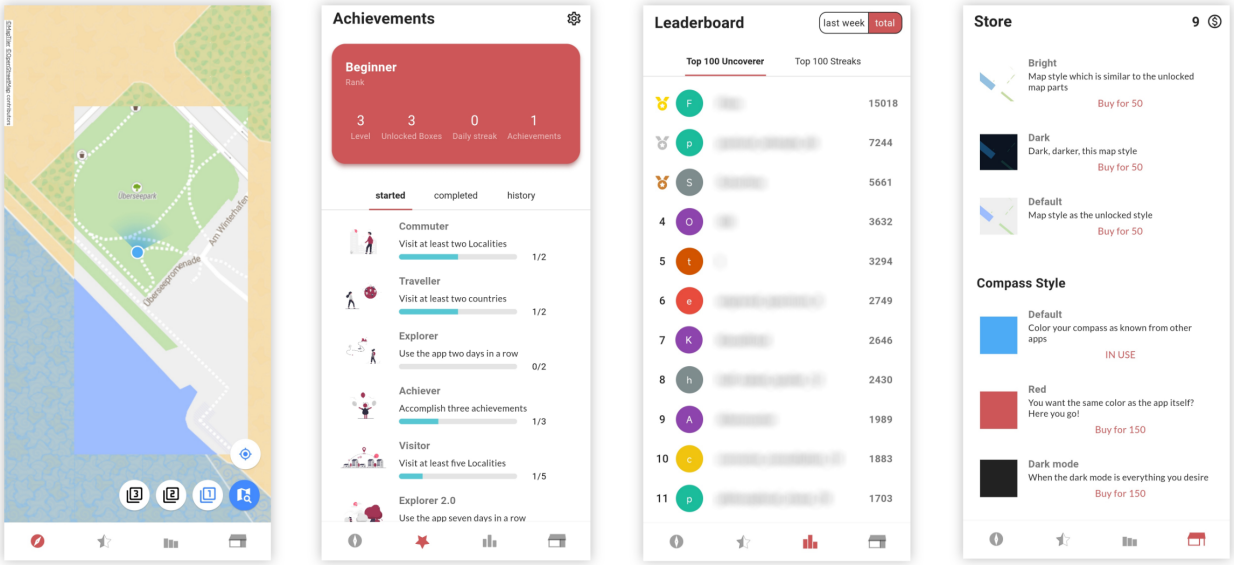

Figure 1: The MapUncover app: encouraging spatial exploration. Home Screen (a), Achievements (b), Leaderboard (c) and Store (d).

ABSTRACT

Getting from A to B has never been easier. Mobile navigation systems allow universal access to spatial information. However, following detailed route instructions leads to a decrease in spatial exploration behaviour and therefore a reduction of spatial knowledge acquisition. Facilitating spatial exploration has the potential to counteract this negative effect. This paper investigates how we can support people in re-discovering their surroundings. We designed and evaluated a mobile application to promote spatial exploration through gamification. The app requires active exploration behaviour to uncover a map. Gamification elements such as quests, statistics, and social competition are used to encourage exploration. We conducted an exploratory field study (n = 22). Our results show a significant increase in familiarity with the environment and a variety of exploration patterns. Based on our findings, we propose modifications to current mapping applications by limiting the visible cartographic elements and alternating routes to improve spatial knowledge acquisition.

CHI '23, April 23–28, 2023, Hamburg, Germany

ACM ISBN 978-1-4503-9421-5/23/04.
https://doi.org/10.1145/3544548.3581428

CCS CONCEPTS

• **Human-centered computing** → *User studies*; *Field studies*; *Empirical studies in ubiquitous and mobile computing*.

KEYWORDS

wayfinding; exploration; mobile spatial gamification; navigation; mobile; field-study

ACM Reference Format:

Eve Schade, Gian-Luca Savino, Jasmin Niess, and Johannes Schöning. 2023. MapUncover: Fostering Spatial Exploration through Gamification in Mobile Map Apps. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23), April 23–28, 2023, Hamburg, Germany*. ACM, New York, NY, USA, 13 pages. https://doi.org/10.1145/3544548.3581428

1 INTRODUCTION & MOTIVATION

In the last decade, navigating unfamiliar environments has become easier with the help of mobile navigation apps and location-based services, such as Google Maps. Users are instantly provided with detailed route instructions for different travel modalities making it efficient for them going from A to B. At the same time exploration, in the form of the aimless activity of wandering, becomes a "premium activity" without an immediate reward but rather with long-term positive effects (e.g. getting to know one's neighbourhood better) [1]. Even if mobile map apps are not used for routing, the design of navigation apps is usually focused on efficient navigation [20]. For instance, *faster roads* are emphasised, influencing the choice of routes in unknown environments [17]. Nevertheless, research suggests, that following detailed route instructions leads to a decrease in spatial exploration behaviours and therefore a reduction of spatial knowledge acquisition [32, 33]. Active spatial exploration, in turn, can increase navigation performance and spatial knowledge via active learning [15].

Consequently, a challenge for Human-Computer Interaction (HCI) is designing mobile navigation systems that support users in active spatial exploration activities. Therefore, in this paper, we explore how to foster spatial exploration in mobile map apps to increase spatial learning as well as the feeling of finding meaningful places, creating a sense of belonging, and generally creating a fulfilling experience. To motivate exploration behaviour, we turn to gamification by using elements of game design in a non-game context [7]. We take our main inspiration from video games, that use techniques to foster spatial exploration within the game world. Strategy games (e.g. Age of Empires IV) or MMORPGs (e.g. World of Warcraft) utilise a concept called *fog of war* by limiting the stream of information on maps in a variety of ways. Examples are e.g. hidden enemy units or whole parts of a map that the player has not visited yet [3]. Besides the fog of war concept, there are further gamification elements which are regularly employed in mobile games like the location-based game Pokémon GO [4], such as high-scores, leader-boards, among others.

To test whether gamification is a viable concept to encourage spatial exploration behaviour beyond a gaming context, we pose the following research question: *How do gamification elements in a mobile map app affect spatial exploration behaviour?* To answer this question, we developed a mobile application named MapUncover that makes use of gamification elements to foster spatial exploration. Users can unlock parts of the mobile map by physically exploring the area. MapUncover uses gamification elements, such as challenges, a store for map customisations, and a leaderboard for social competition. With an emphasis on exploration (e.g., *Visit at least two localities*, or *Unlock 100 boxes*), challenges provide goals which motivate participants to explore their surroundings. Successful spatial exploration behaviour also increases the player's level, experience points (XP), coins and general score. The latter allows players to compare themselves against others on the leaderboard. These aforementioned features differentiate MapUncover from common mobile map apps (e.g. Google Maps). In this paper, we investigate if these differences motivate users to engage in spatial exploration compared to the efficient navigation behaviour that current map apps provide. The development of the application was done in an iterative process, involving a pre-survey with 12 participants and a pre-study with three participants. During the user study, 22 participants used MapUncover over a period of 83 days.

Our results show that the app was well perceived as a general encouragement for exploration. MapUncover allowed people already familiar with their surroundings to significantly improve their familiarity even further. In addition to encouraging participants to explore their environment (e.g. varying their route to uncover the map), the competition aspect of the app also encouraged some to *cheat* by using other modes of transportation to increase their score. Based on our results we provide design recommendations for mobile map apps: (1) actively suggest alternate routes to foster spatial learning, (2) adapt the visible data on the map to the actual knowledge of users (e.g. personalised POIs), (3) motivating users to familiarise themselves with their environment through fog of war style information. In summary, this paper contributes the following: (1) a mobile map app using a fog of war mechanic and gamification elements to foster exploration behaviour, (2) a longitudinal field study (n=22), and (3) insights for designing future mobile map apps that support exploration behaviour.

2 RELATED WORK

Exploration is a topic that has been studied in the past with a particular focus on its positive effects for spatial learning [11, 15] and as a goal for finding meaningful places [39]. Despite these benefits, exploration is disappearing from today's mobile map [1]. In this section, we describe the state of the art in research about exploration, and how exploration differs from traditional routing for pedestrians using mobile map apps. We continue by highlighting how current location-based mobile games successfully utilise exploration as a game mechanic and which gamification components are most relevant in the mobile context. Finally, we summarise the design guidelines we extracted from the related work for the development of MapUncover.

2.1 Exploration Behaviour in Unknown Environments

Understanding exploration or wandering behaviour to discover interesting or meaningful places is a research topic of interest to the HCI community. Meaningful is to be understood as a place that creates a long-term meaning for the user [39]. Barkhuus et al. [1] conducted a study evaluating the exploration experiences and practices of 13 individuals who newly moved to New York. The authors emphasise that the process of exploring one's neighbourhood is

closely linked to discovering meaningful places to deepen one's connection to one's local neighbourhood. Their results also showed that mobile map apps such as Google Maps, Yelp or Foursquare did help users to navigate from A to B, but did not help them in discovering meaningful places. In contrast, users tended to find these places by rather wandering around and through personal recommendations. Furthermore, Barkhuus et al. [1] classified exploration behaviour into *Wandering* (looking for new places), *Walking* (looking to find goods) and *Heading for* (heading to particular places). They emphasise a difference between the exploration intentions of residents, who focus on longer periods of time and especially include their everyday needs, and tourists, who only want to experience the surroundings [1].

Similar approaches are used by tourists during their exploration process. Vaittinen et al. [36] conducted a study with 16 participants to understand the behaviour of tourists in urban environments. They found that participants fluently changed between different navigation phases. Navigation plans were decided *before* embarking on the trip with the help of web searches and *during* the trip e.g. by the colouring of the map layers, since scenic routing always played a part. The *en-route navigation* dynamically switched to *exploration* when interesting sites were identified. Finally, tourists tended to reflect upon reaching landmarks, by further discussing them [36].

The examples above highlight the need for supporting exploration behaviour and wandering, or more precisely walking around without meaning, or without any particular structured route. Nowadays, it is easy to just make use of mobile map apps to reach destinations the fastest way, and/or to find places which are recommended by algorithms. However, the most widely used mobile map apps today do not support exploration behaviour adapted to individual preferences and needs. As previous work has shown that people value exploration and wandering and consider these activities to be meaningful, further work is needed to explore how to support exploration behaviour with mobile map apps. In this study, our aim is to encourage users to discover meaningful places on their own and support them in expanding their environmental knowledge.

2.2 Mobile Maps and Pedestrian Routing

Mobile map apps are used by pedestrians to find the fastest routes between origins and destinations, and thus to efficiently navigate familiar and unfamiliar spaces. This focus on efficient routing means that exploration is a decreasingly important part of today's mobile map apps [1]. In 1995, Golledge [12] already showed that while time and distance are the most important criteria for people's route selection, other criteria like *most scenic / aesthetic* and the route being *different from previous* routes are relevant, too. However, current mobile map apps like Google Maps do not offer the possibility to choose many alternatives to the fastest route, for example choosing the most scenic route [31]. Elaborating on the relevance of emotionally pleasant routing, Quercia et al. [31] determined "beautiful, quiet, and happy" routes through crowd-sourcing. They highlight that more emotionally valuable paths do not inevitably have to have longer distances, with beautiful routes showing only a 12% increase in route length compared to shortest routes [31].

Additionally, the general perception of mobile maps is influenced by the visual map design. Current mobile map apps often put an emphasise on main roads with a large density of points of interest (POIs) contributing to an overload of spatial information [5]. In a recent study, Bartling et al. [2] argue for more adaptive maps to support different user groups with the appropriate information. These adaptations can have positive impacts on people's focus on their surroundings, and reduce the reliance on the map by removing unnecessary information from it [5]. Tourism paper maps are a good example of such adaptations. They often highlight only specific POIs and attractions, while they do not emphasise correct spatial representations [5]. Huck et al. [17] continue this concept even further, by suggesting individually changing the map in real-time based on the user behaviour, to motivate further exploration [5, 17]. Additionally, Vaittinen [37] found that highlighting only near vicinity POIs helps spatial awareness and allowed tourists to have an unrestrained process of finding establishments of interest. Overall, the route decision process is correspondingly accompanied by the frequency the path was taken or familiarity with it [12, 13]. Staying on the usual route creates habits, allowing pedestrians to perfectly plan their trips, enabling mindless walking while simultaneously doing other tasks [26].

Current mobile map and routing approaches focus largely on efficiency [1], shortest routes [12], and more generally criteria which are based on the average user instead of making use of more personalised solutions [12, 13]. This one size fits all approach creates habits based on frequent paths and perfect planning [26] and thus disincentives exploration. The results of the studies presented in this section show that emotionally pleasant routes are less in conflict with efficient routing than previously thought. Longer routes, discovered through exploration might thus not negatively impact the wayfinding experience. By employing the fog of war mechanic in a mobile map app, we investigate whether such an adaptation, which is dependent on user behaviour (by actively unlocking map tiles), can foster exploration behaviour and pose an alternative to the current baseline of common mobile map apps.

2.3 Exploration in Mobile Games

Examples of mobile apps that enable players to actively explore their surroundings are the augmented reality (AR) game *Ingres Prime*[1], the treasure hunting themed game *Geocaching*[2], or Pokémon GO [28]. The latter encourages players to move around in the real world by distributing virtual, collectable items. A simplified 3D map only shows buildings as objects based on their outlines, and street names, and features a limit on how far users can zoom out of the map [28]. Playing Pokémon GO influenced users' exploration behaviour [4]. Colley et al. [4] conducted a study with 375 Pokémon GO players. Their results showed that *60%* discovered a new place and *9%* a new locality. Furthermore, in *70%* of the cases, the game was played with others, and *11%* experienced situations that jeopardised their personal safety [4]. To date, studies primarily focused on exploring the fog of war techniques in gaming contexts. In contrast, we aim to evaluate the impact the fog of war techniques have on users in the mobile map context. In combination with concepts known to work in mobile games, like the ones presented above,

[1] https://www.ingress.com
[2] https://www.geocaching.com/

we focus on utilising a similar approach to encourage exploration behaviour for mobile maps.

2.4 Gamification Elements Supporting Exploration Behaviour

Mobile games can promote exploration, but the question remains which game elements enable such behaviour and how we can apply them to mobile map apps. Gamification is the "use of game-design elements in non-game contexts" [8]. Gamification has been applied in various contexts such as reproducible science [10], education [18], sustainable urban travel [21], and doing monotonous work such as cleaning [22], among others. Gamification can support users in achieving short-term and long-term goals [25]. However, there is an ongoing discussion if and how gamification influences intrinsic motivation [25]. Results by Mekler et al. suggest that gamification rather increases extrinsic motivation through gamification elements like leaderboards, which promote performance quality. However, they also found that the intrinsic motivation was not impaired by gamification elements [25]. Generally, different gamification elements approach different kind of rewards or motivations. Point systems and rewards are often used to support short-term oriented goals [29]. In contrast, long-term goals can be supported by gamification elements that have real-world implications beyond the immediate use of a gamified app [29].

To choose relevant and appropriate gamification elements, we take inspiration from the eleven identified gamification elements by Lessel et al. [22]. To create an initial interest in using the app (i.e. short-term goal), we opt for integrating a reward system in the prototype. Therefore, adding the gamification elements *Goals*, *Unlockables*, *Achievements* and *Points* [22]. Additionally, our prototype should encourage more long-term engagement with the app and consequently with the environment. Thus, we facilitate social interactions through *Social Competition* to motivate players that might not be as motivated by static gamification elements as others. Besides providing *Real Challenge*'s, *Knowledge/Skill Improvement* and *Exploration* elements [22]. Based on the findings of Lessel et al. [22], we implemented eight out of the eleven identified gamification elements. Three elements (i.e. *Teams*, *Collaboration* and *Socialization* [22]) are excluded from our design, since our study focuses on single-player behaviour. Furthermore, in line with the recommendation by Nicholson [29], the process of uncovering a map with the user's location creates a meaningful link between the virtual and the real world. Visiting a place in the real world unlocks the corresponding map tile within the MapUncover app. Moreover, the unlocked parts of the map should provide a base number of points of interest, helping with the spatial awareness and exploration process [37].

3 MAPUNCOVER: MOBILE APP DESIGN AND INTERACTIONS

To better understand how gamification can motivate users to explore their surroundings, we developed a mobile application. In this section, we describe the application design and its goals, while emphasising each feature in detail. It utilizes a fog of war as its main component, similarly to our extracted guidelines regarding

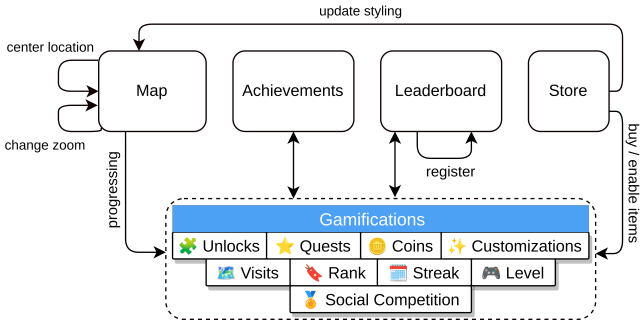

Figure 2: Primary components of MapUncover (Map, Achievements, Leaderboard, Store) and their relation and interaction with defined gamification.

the gamification elements found in previously discussed applications and frameworks, to promote active behaviour. The design and development process was coupled in an iterative user-centred process [34], whereby we collected feedback from end-users through a pre-survey and a pre-study. The results were then integrated into the application. In Figure 2 its main features are highlighted, whereby its components consist of:

- **User Interface** consisting of an introduction screen with a survey followed by the Map, Achievements, Leaderboard (optional) and Store.
- **Gamification** encourages active behaviour by rewarding exploration with an uncovered map, statistics customisations, achievements and social competition.

3.1 Map

The introduction looked into the mechanism of unlocking maps by revealing them, as it is common in games with an emphasis on exploration [35]. In order to utilise this technology, it was necessary to determine the information that the user needs to explore their environment. The highest possible level of abstraction at which the map remains discoverable is to reduce the elements to different types of surfaces. Therefore, removing points of interest (POI), the layout of buildings and streets, while only keeping it for bridges and borders. By using this *feature abstraction,* the dependence on the screen is reduced [5]. Resulting in a map only distinguishing between green, water and other surfaces, necessary for exploration on land. It contributes to users finding scenic surroundings themselves [36]. While the unlocked area can provide information about its surroundings, it is susceptible to a similar approach to the as-is state. Consequently, the design is inspired by visualisations like Google Maps. To allow additional information regarding the unexplored parts of the map, the base layer needed to be modified. Therefore, the app utilises the *Slippy Map* tiling system provided by OpenStreetMap [30]. The core feature of *XYZ tiles* based raster maps allows using the rough location history of the users to calculate a perimeter of unlocked location history represented as tiles. When a user position is tracked, the longitude and latitude can be converted into unique x, y and z parameters, while (x, y) represents the position and (z) the depth/zoom within. In order to work with an undiscovered and an explored part of the map, each tile needed

to have a different structure depending on its state. This allowed us to implement the fog of war mechanism, where users reveal parts of the map by actively moving around in the real world, triggering tile unlocks based on their location.

There are a variety of ways to modify the styling of the map to represent such content. But the purpose must still be to convey users to explore these places. With the help of user feedback from 12 participants (6 = female, 6 = male) in an online pre-survey and a pre-study (2 = male, 1 = female, location = Bremen, Germany), four mapping styles were designed with *Maputnik* [24] (see Figure 3). Whereby, the primary one makes use of characteristics (e.g., drawing of the water) to make it appear hand drawn. The poll resulted in a very close decision between the two styles. This lack of distinct preference between the users allowed us to include them within the store element (see Figure 1). Nevertheless, the *paper* theme was selected as a default for new users (see Figure 1 (a)).

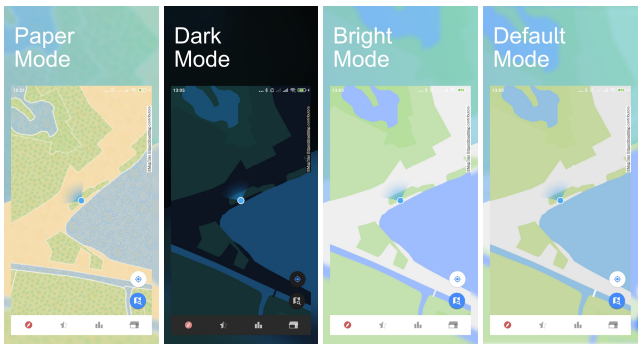

Figure 3: All covered map styles developed in Maputnik [24] during an iterative process in a pre-survey (n = 12) and pre-study (n = 3). The paper theme is the default styling, with the dark and light modes being adaptations of each other, and the default mode taking into account the same colour scheme as the uncovered styling. The user in this example has only uncovered one tile, making the map covered on higher zoom levels. © map data by MapTiler AG, OpenStreetMap contributors [23, 30].

The described method allows game content to be unlocked [21, 22, 27] and knowledge/skill improvement [21, 22], while enabling users to unlock content helping them to improve the knowledge about their surroundings. To allow an overall progression, the map uncovering is paired with receiving *points*, *coins*, *level* and *xp* for each unlock [21, 22, 27].

3.1.1 Exploration Challenge Expansion through Zoom-Layers. The (x, y, z) based raster maps persist of various zoom layers, with varying information. A tile that a user visits is associated with the zoom level, this way zooming out implies that the unlocked tile is not visually represented in the upper levels. This allowed us to define it as another challenge: Until a defined percentage of base layer tiles are visited, users will not be able to see the upper unlocked layers. This means that in order to view their progress zoomed out, users will need to actively explore more. To simplify the interaction, while persisting common map interaction design practices, the pinch-to-zoom gesture is complemented with manual buttons representing the first three zoom layers. Through the iterative process, the explanation for users to understand the mechanism was adapted to a looping GIF presenting all possible zooming stages with an attached description. The tutorial is shown the first two times by pressing the zoom-layer button, but it is also accessible through the settings screen (see Figure 4).

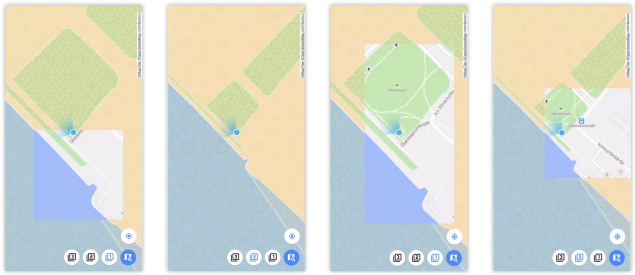

Figure 4: Image sequence of the GIF showing the zoom mechanism tutorial within the app. On image (a), the map is visible on the base zoom layer 1 with one unlocked tile; Image (b), shows that one unlock on zoom layer 1 does not unlock the bigger tile on zoom layer 2; On image (c), the user unlocked another tile on layer 1, making the bigger tile on layer 2 in image (d) visible. To unlock a tile on layer 3, the layer underneath must have at least 3 tiles unlocked. On layer 4, there is the need for 4 unlocked tiles underneath. © map data by MapTiler AG, OpenStreetMap contributors [23, 30].

3.2 Achievements

The achievements, visible in Figure 1 (b), introduce quests implementing challenges and the realisation of progression by providing badges and level improvement [21, 22, 27]. The app also attempts to convey the user to open the app every day, with the usage of a daily streak. Thus, when they open it every day, their streak positively reinforces reminding them to open the app by making use of time sensitive and reminder related elements [21, 22]. The screen is structured into the statistics, and the started and completed tasks in a list. In addition, based on the iterative process, the view was extended to a historic view to show continued motivation by providing a view of progress over time (amount of visited and newly unlock tiles). The visually highlighted statistics display the current rank, as well as the level, unlocked boxes, how many days in the row the app was opened and the number of completed achievements. The user is presented with a related image to the task, a title which also represents a possible rank in various cases, a description of what they need to do, as well as a bar and numbers indicating the progress. Every user starts with the rank "Beginner". On accomplishing achievements, the app presents users with success texts, for example: "You figured it out!" or "You really know what you are doing!". These are phrased in a personal manner to make them more welcoming to the user. The app attempts to convey the user to open the app every day, with the usage of a daily streak. Thus, when they open it every day, their streak positively reinforces reminding them to open the app.

3.3 Leaderboard

The leaderboard visible in Figure 1 (c) adds social competition to the user engagement, by enabling users to compare their scores [21, 22, 27]. The profile creation is limited to avoid sacrificing anonymity while allowing the comparison of only certain values between users. Registration for the leaderboard is voluntary and starts with the choice of a username, whereby anonymity can optionally be increased by applying a random name provided via the user interface. The leaderboard disregards user locations and limits the visible amount to up to 100 users, divided into the best *uncoverer* and *longest prevailed daily streaks*. General top lists have a common scheme that allows the top three users to receive a trophy visible next to their name, similar to sports competitions like the Olympics or in other game-based applications. On the contrary, the familiar use of profile pictures is discarded to keep the data obscured by design. The *uncoverer* list has the purpose of representing active exploration, while the streaks are to urge users to actively look into the app every day. These two factors are intended to create a strong bond, to encourage users to launch the app every day to stand out from the competition. During the pre-study, one participant suggested that the ranking should be extended to also distinguish between time-frames of the current week and a total, allowing users to reach the top of the ranking list if they join at a later stage as also suggested by Kazhamiakin et al. [21]. Likewise, by adding this challenge, it also becomes a time sensitive element [21, 22].

3.4 Store

The store visible in Figure 1 (d) rewards users for their exploration and thus a collection of coins to buy customisations for the map and its position icon [21, 22, 27]. The shop is divided into map and compass-style tab. Since the cartographic survey determined no distinct preferred map style preference, all updated designs are integrated for a small charge, allowing users to change the design more quickly. The shop interaction is simple. The user taps on an item, which will either trigger a purchase dialogue or an activation. A sufficient number of coins collected through active exploration is required.

4 METHOD

The goal of the user study was to understand how gamification elements in our mobile map app MapUncover affect spatial exploration behaviour. Instead of providing participants with efficient navigation instructions, like in common mobile map apps (e.g. Google Maps), MapUncover incentives participants to actively engage in spatial exploration behaviour. For the evaluation of the application, we utilised an exploratory research design. It was conducted in the field by releasing the Android application to the Google Play Store restricted to the EU. Other than the minimum age of digital consent for the use of personal data (18) [9], there was no limitation on who could participate. This applies both to users who are new to an environment, who are moving or are on vacation, and to users who are familiar with their area. Participants were free to use the application without any restrictions. Besides observing their movement behaviour, we examined the following hypotheses:

H1: The designed interface combined with gamified components increases participants' motivation to explore their environment compared to knowledge on common mobile map apps based on state-of-the-art literature.
H2: Active usage results in an improved self-perceived spatial knowledge.
H3: Participants, who are new to the neighbourhood, are generally more motivated by the proposed app design, than those who are familiar with it.

4.1 Measurements

To test these hypotheses, the app collected behavioural data in the background and simultaneously requested survey data at the beginning and end of the study.

- Demographic and personal data to characterise the user
- Standardised questionnaires: Santa Barbara Sense of Direction test (SBSOD) [16] and an unweighted NASA Task Load Index (NASA TLX) [14]
- General usage behaviour and statistical history (e.g. days of usage, unlocked achievements etc.)
- Uncovered parts of the map (rough location history)
- Personal evaluation of the application (feedback in the survey and the interview)
- Average Google Analytics usage statistics

4.1.1 Survey Structure. Our surveys comprise 26 non-standard questions around the themes of demographics, familiarity, exploration, and experience as well as 2 standardised questionnaires (i.e. SBSOD test and NASA TLX). The demographics covered the participant's gender, age, place of residence, knowledge of similar location-based apps and frequency of playing games. Whereby, the familiarity looked into the self-perceived knowledge about the environment, as well as the openness for exploration and being active. The familiarity theme was extended through the SBSOD test identifying participants' spatial knowledge deviation. The exploration topic questioned typical travel routines, discovery of new or meaningful places they tend/want to visit again, ways of orientation, and indicated communication with other people for help or app usage with others. Lastly, the experience theme looked into the utilisation of the app, the level of fun and experience, including the occurrence of dangerous situations as well as identifying their workload through the unweighted NASA TLX. The questionnaires were split up in two parts. An introductory survey covered 8 of the unique questions (i.e. demographics and familiarity) and the SBSOD test. A final survey covered 21 questions following the topic of familiarity, exploration, and experience (including the NASA TLX), with the SBSOD test and 3 familiarity-themed Likert scales questions being repeated. Overall, questions were a mix of 7-point Likert scales, multiple choice, and open text fields. The SBSOD test was optional in both surveys to motivate more participants to join the study, including the ones who were not willing to answer the 15 SBSOD questions.

4.1.2 Pre-Survey and Pre-Study. The design process of the MapUncover application included a pre-survey and a pre-study. The pre-survey focused on deciding on the primary cartographic design,

while the pre-study tested the app itself and the study design in the field. Both focused on gathering feedback for the final state. With two example screenshots for every design (uncovered and covered map), the pre-survey was conducted with 12 participants (6 = female, 6 = male), where they were required to rank them according to their personal preference. With an average age of 27.66 ranging from 21 to 55 ($median = 24$, $sd = 27.67$), eleven participants were aware of the game mechanism of uncovering a map, which made their feedback valuable for the final designs. Similarly, before publication, the app was tested within a pre-study in order to gain feedback from end-users and to determine if the background data collection was feasible. Following the same study design as the final study, three individuals participated in the study (2 = male and 1 = female, location = Bremen, Germany). This process led to changes in the proposed app design (e.g. Leaderboard weekly view or the unlock history list).

4.1.3 Qualification Requirements. Participants were not required to complete any tasks, but as usage varied, we only considered data which suggests active behaviour defined in a threshold. We made sure that participants had enough exposure to the app by setting the threshold based on three important values. We looked at the frequency of opening the app (min. 10 times), the number of tiles unlocked (min. 80), and the active days (min. two days). The number of app openings indicated whether users actively interacted with the gamification elements. The tile unlocks ensured active movement of the users, and active days ensured that the app was not used just on one day. We wanted to exclude one-time use cases and ensure that the behaviour was influenced by the app usage, so our results only include participants who actively used the app. Out of 31 total participants, 22 fulfilled all criteria (16 = male, 5 = female, 1 = not disclosed).

4.2 Participants

Participants were between 18 and 63 years old ($mean = 27.2$, $median = 25$, $sd = 9.4$). In total, 91% (20/22) lived in cities, one in a village and one in an outskirt. On a 7-point Likert scale from very frequently (1) to never (7), two people very frequently (1) played games, three frequently (3), six did so occasionally or sometimes (4-5), and eleven rarely or never (6-7) used similar apps ($mean = 5$, $median = 5.5$, $sd = 1.85$), with Pokémon GO being the remarked example.

4.3 Task & Procedure

After the MapUncover app from the app store, the interface introduced the app's functionality and the study, before prompting the first survey. The user was informed of the app's ability to track their rough location and its possible implications on four of the eleven pages within the introductory interface. In addition to a thorough in-app privacy policy describing every data point in easy understandable detail (e.g.: "*The exact time, when the user first started the app*"), the user was informed of the data collection and its usage for scientific reasons. Additionally, participants were given the option to withdraw from the study and force the deletion of their data through the provided interface. Relevant data were individually collected over a period of at least seven days, with the actual duration depending on the completion of the last questionnaire, allowing users to undertake the study for longer than the suggested length (see Figure 5). Participants were able to take part in a final interview in which they described their experience by indicating their email at the end of the final survey.

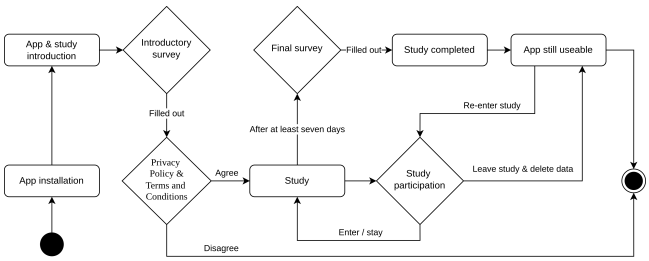

Figure 5: Procedure of the study in a BPMN [38]: (1) Introduction to app and study, (2) introductory survey, (3) study execution, (4) final survey after at least 7 days.

5 RESULTS

The results consist of recorded data the app collected (e.g. rough location history), a survey at the beginning and one at the end of the study, including qualitative responses, in addition to the collected data from Google Analytics. We also gathered additional qualitative data by conducting 13 interviews. The qualitative data was analysed using open coding and thematic analysis [34].

As the study duration was not fixed, participants completed the study between 168 *hours* (7 *days*) and 1008 *hours* (41 *days*), with a mean duration of 257 *hours* ($median = 191$, $sd = 185.9$). Overall, on a 7-point Likert scale ranging from strongly agree (1) to strongly disagree (7), the exploration process with the app was somewhat perceived as fun by 68% (1-3), while 18% neither agreed nor disagreed (4) or somewhat disagreed (14%) (5). A key component of encouraging exploration maybe openness to do so, but since 77% (17) of qualified participants were not recruited directly and were willing to participate, it was expected that the overall openness to explore from the introductory survey would be positive, while no significant improvement could be measured. During the design phase, we introduced multiple gamification elements focused on the same goal to encourage participants of being active. In this way, we were able to determine that participants were influenced by them in different ways, which made it an important step to evaluate each influence.

5.1 The Thrill of Unlocking the Map

The evaluation of the acquired qualitative feedback from the surveys and interviews suggests an overall successful adoption of the map's fog of war game mechanism. First of all, regarding the recording location history, the range of uncovered tiles varies from a minimum of 88 to a maximum of 3475 with a mean of 802.3 ($median = 506.5$, $sd = 908.9$). It was particularly emphasised in all interviews regarding the question of general experience and identified as the main incentive for exploration in the textual feedback by six participants. Foremost "*[...] that one sees, one has made certain progress, so you have direct feedback like that.*" (P1, Male, 21 years),

while also allowing them to see the paths they took, and which they missed: "*Oh, where was I now? Where haven't I been yet? And then I always look up the way to work after. Oh, where have I missed an area now? Or where I might have missed a path, that is take a few more steps to the left or right and then still get the area extra.*" (P5, Male, 24 years). Likewise, the process motivated walking through districts where there was no previous occasion to do so: "*And I know that the villa districts that we have here along the Alster are quite beautiful when you walk through them. So you're motivated to just look at that and then you can look at the pretty buildings and get to know the whole thing a bit*" (P4, Male, 33 years). These not visited areas can create the motivation to "*[...] walk[...] an extra detour to see exactly where it was, because only half the place was on the name.*" (P11, Female, 18 years). The names of streets and buildings were also emphasised in the pre-study, whereas they said it would be helpful to know where certain things are, in order to, later on, help others find those places. Finally, the unlocking process was also described as "*[...] kind of a thrill or something. Where you think worry, there is somehow still such a free area and it would be already good if I would somehow then also go on there.*" (P12, gender not disclosed, 40 years). In particular, one participant emphasised that if the map is used for active exploration, it can positively reinforce more knowledge about the environment (P11, Female, 18 years). Thus, the positive effect of unlocking the parts of the map to learn what's in the immediate area, as well as getting a historic overview of places one may not have yet visited. Finally, three interviewees mentioned that the higher zoom stages encouraged them to unlock and visit all adjoining tiles: "*[...] I think you need two or three [...] so that you unlock the big one somehow. Anyway, it always creates a sense of accomplishment.*" (P2, Male, 22 years). While two participants mentioned difficulties in understanding the zoom levels in the written feedback.

5.2 The Effects of Social Competition in an (Un)known Group

The leaderboard was one of the most effective motivators, with 91% of participants signing up to use it after a median of 120 *seconds* (min = 32 sec), making it an interesting factor which increased exploration behaviour. During the interviews, one participant particularly mentioned having been driven by the challenge the leaderboard created to compete against other volunteers they personally know. This suggests that it created users signing up, while the competition was their main driver. And it motivated participants who did not know about their social competition: "*I am very proud. I am in 5th place, on the leaderboard.*" (P28, Male, 24 years) and for those who knew them: "*Through the scoreboard, I could compare myself with my friends. I tried to be better than them and unlock more fields.*" (P29, Female, 28 years).

The interviews suggested, that after the app was shared within a student chat group in a larger city in Germany, it became a social challenge for them. During the interviews, two participants mentioned having been obtained by the chat group, where they also discussed the app with each other. Moreover, the number of participants located in Hamburg (9) suggests the same, as only one person from Hamburg was personally invited. In addition, they all met the threshold and thus accounted for 41% of the records considered. The previously introduced sign-up time suggests the leaderboard's influence on these users as well, since the introduction with its starting survey was done in the same time frame. In Hamburg, in particular, the median time for registration is 97 *seconds*. When only considering fast sign-ups, there are seven users taking a median of 77 seconds to sign up. This suggests, that within the Hamburg cluster, 78% instantly desired to look at the competition. This hints at the leaderboard being a key motivator. While the gamified element was an optional feature, adding competition to the exploration process, it was, for the most part, well adapted. Of the 22 participants, 20 joined, and it took them a minimum of 0.01 to 309.4 *hours* or 12 *days* to join ($mean$ = 26.5 $hours$, $median$ = 0.03 $hours$, sd = 71.5 $hours$).

5.3 Customisations, Achievements etc.

The cartographic survey concluded, that there was no distinct preference regarding the map styling; thus, they were made purchasable and unlockable, with coins that participants collected through exploration. An important motivation emerging through it was revealed by the interviews, since e.g., three participants were immediately driven to collect enough coins fast enough, to be able to unlock the dark map styling: "*It has totally spurred me on to finally have the points to get the dark mode.*" (P22, Male, 25 years). This also was visible through statistics, as the most bought customisation is determined to be the dark map theme. The introduced signposts (achievements and badges) were emphasised in qualitative feedback to be a nice motivator while generating great intermediate progress, whereby the included historic view was never mentioned. It was noted to be demotivating, that the achievements end at some point, spotlighting the need for a *challenge generator* as also emphasised in the work of Kazhamiakin et al. [21]. There are 13 predefined achievements, one of them is completed by entering the study. The total number of completed accomplishments varies from 4 to 11, with a mean of 7.1 ($median$ = 6.5, sd = 1.8). Some completed achievements unlock ranks/badges for the user, which are then visible in the achievements (see Figure 1 (b)). The rank values range from *Beginner* (0) to *Local* (7). The minimum rank *Achiever* (3) and the maximum rank *City hopper* (6) were reached. On average, the mean rank is determined to be 3.8 (*Achiever/Explorer 2.0*, $median$ = 3, sd = 1.1). The app rewards users starting it every day in a row, by incrementing their "streak" score. The individual streaks range from one to nine days, while the mean is 4.9 ($median$ = 4, sd = 2.7). The calculated level depends on unlocked tiles and achievements, whereby within the study it ranges from 11 to 60, with a mean of 25.77 ($median$ = 23.5, sd = 13.5). Lastly, on average, participants were able to unlock the customisations they wanted, since their coin sum was 648.8.

5.4 Most Engaging Elements

Besides the map being the main approach-driven feature, the qualitative feedback, interviews and Google Analytics statistics reveal a prioritisation of the components (see Table 1). The data sets cannot be directly compared, and merely show a tendency regarding each component. The leaderboard was viewed most of the time, and emphasised by the most, while its average engagement time manages only to attain 40% of the map's time. In addition, the feedback and interviews give the map a stable preference for 6 participants,

making up 50% of interview ratings. Depending on the focus, either the map or the leaderboard are preferred, while the achievements are distinctly preferred over the store.

Component	*Feedback*	*Interviews*	*Engagement (sec))*	*Views*
Map	6	6	896	15.73
Achievements	5	1	272	16.37
Leaderboard	7	4	353	21.11
Store	2	1	269	10.06

Table 1: The subjective preference of features, according to the feedback (n = 17), interviews (n = 12), and Google Analytics statistics. The feedback allowed more than one response, the interview one, and The Google Analytics values are based on an average of all users. Consequently, the outcomes show a general tendency.

5.5 Behavioural Influence

The use of those elements revealed both desired and undesirable side effects. For example, the application did not provide a way for collaborative exploration, still 55% of the 22 participants have used the app with someone else. An impact of physical activity, on the other hand, was only mentioned in two cases, whereby the walking frequency was positively impacted during the study. However, for example P17 (Female, 25 years) emphasised "*that [they] now do sports more often*" (P17). Furthermore, based on the face-to-face interviews, it was possible to divide the usage behaviours under certain circumstances into active and passive exploration. Specific statements were assigned to each behaviour. Whereas, there was some overlap in the behaviours of the individual participants. In general, the interviewees pointed with their replies out, that their passive use focused on utilising it in the background to collect points while unlocking the map and competing on the leaderboard. On the other hand, active explorers highlighted their active involvement in discovering new places or routes. The latter, e.g., described places they (re)visited during their exploration. Out of 13 interviewees, five described using it passively (38%) and eight actively (62%). In addition, the workload assessed with the unweighted NASA TLX was measured on a scale of 1-10 with an overall mean of 23% ($median$ = 23%, sd = 7%). The implemented design showed minimal effect on the workload. Participants were asked to assess the risk they took when using the app in their everyday life. On a 7-point Likert scale ranging from strongly agree (1) to strongly disagree (7), the appearance of dangerous situations and places both got the mean of 6.6 ($median$ = 7), falling in between *disagree* and *strongly disagree*. Additionally, no participant wrote about any dangerous situation or place they believe the app has caused, further suggesting no safety risks.

5.6 Active Exploration or Passive Collection?

Foremost, the study design allowed participants to use the app as they wanted to, implying, that their mere registration and filling out of the surveys would count as participation. Consequently, the study did not force any exploration practices, it just provided its tools. The impact of the exploration can be seen through familiarity, which shows a minimal, but measurable, statistically significant improvement, from a mean of 2.47 to 1.88 (1 very good to 7 very bad). The Santa Barbara Sense of Direction Score appeared to mean different things to participants, whereby it unexpectedly shifted one participant's understanding of direction. While most mentioned no particularised change, three participants highlighted specifics about their experiences, whereas P29 (Female, 28 years) noted that her conception of orientation changed as she described her left-right weakness as a poor sense of direction, she gathered through her improved SBSOD score, that knowing "*how to get to some other point or [knowing] where this point will be*", says more about her "*orientation ability*" (P29).

Possible discoveries of new places is to be constrained to the users' location; thus even if 91% (20/22) are living in cities, only 23% stated to have discovered new places, but thereby meaningful places have been found in nine cases (41%) and three have found spots in more than one category (*specific spots* = 7, *parks* = 4, *Landmarks* = 1, *Shops* = 1). Green spaces, such as parks, were perceived as an optional choice for a destination. While three interviewees emphasised that it was more interesting to visit the nature than "*the average city*" [P28]. P5 further emphasised that those do not need to be a target destination, but can persuade for a small detour [P5]. As a whole 68% of participants regularly follow a route. The unguided exploration process allowed one participant to find a new regular route to follow (6%), while six are still exploring (27%) and eight distinctively stated that they did not (36%), and seven do not have regular routes they want to follow (32%). The current design of the app was not intended to suggest routes, but as the qualitative results suggest, it can be an adaption to evaluate. Nevertheless, one participant's curiosity helped them find a new route.

Participants, who tended to use the application in a passive sense, also stick to their pre-determined sequences of locations through paths they knew, since in the example case of P13, there are people that can only use a fixed amount of routes: "*[...] I can only use those two [routes]. Everything else just leads far out [...]*". While on the other hand, participants who experienced an experiential feeling by finding new routes in between known surroundings, were also able to broaden or use their spatial knowledge to find and use shortcuts: "*So [...] we somehow found the other way to a subway station where we have been before. [...] And on my own I also once went a path where I came out again at a certain point, where I had expected that I would get out. So it was really quite exciting to see how the streets are actually connected to each other if you only knew them from other perspectives.*" (P29, Female, 28 years).

6 DISCUSSION

Inspired by a widely used game mechanic called fog of war, in this study, we investigated how gamification elements can foster spatial exploration in mobile map apps. Based on state of the art gamification literature, paired with a user-centred design approach, we developed a mapping application utilising (1) abstract cartography that can be uncovered by the location of the user, while additionally motivating them with (2) static challenges to complete, (3) statistical progression, (4) social competition and (5) unlockable customisations.

In this section, we discuss the results of our user study and the implications these can have for the future design of mobile map apps. Compared to classical pedestrian routing, as most mobile map apps use it today, exploration can induce a positive feeling of familiarity and meaningfulness when it comes to knowing your surroundings. We found that generally, the fog of war concept itself was the main incentive to unlock the map as participants saw it as direct feedback on their progress. Furthermore, the leaderboard was the most successful gamification element, as it got the most views inside the application. The social competition it motivated resulted in participants wanting to compete against their friends and feeling proud while succeeding against strangers on the leaderboard. We also found that participants found to be more familiar with their environments after using MapUncover.

6.1 Impacts of MapUncover on People's Exploration Behaviour

In this section, we look at the main results of the study. We discuss how the use of the MapUncover app over the study period impacted participants, and evaluate our three hypotheses.

6.1.1 Motivation of Gamification on Exploration Behaviour. Compared to the baseline behaviour we know from common mobile map apps focusing on efficiency and familiar routes (see Section 2.2), we can say that our design approach motivated users to explore their surroundings, thus confirming **H1**. Each gamified component played its own role in motivating users, with the uncoverable map (fog of war mechanic) impacting the behaviour of the majority of participants, as can be seen by their feedback and engagement times (see Table 1). Users were encouraged to vary their routes, take small and larger detours for the unlocking as a whole and also to unlock specific layers displayed on the covered map, like parks or points of interest. Nevertheless, the method of exploration per participant differed, making it hard to identify if they tried to explore their surroundings actively or just passively used the app. We used a threshold to ensure that a certain active behaviour was achieved. We allowed users to unlock parts of the map in the background, while simultaneously enabling them to actively explore. We made use of qualitative findings that demonstrate that the participants were aware of the app and its features, indicating an active interaction with it. Some participants were actively engaged in the process of uncovering parts of the map, e.g, P11 who experienced a scenario, where she did not unlock the complete name of a point of interest, and needed to take a detour to uncover it. This is a similar behaviour as shown by tourists who want to make sense of an unknown site [36]. The leaderboard on the other hand even encouraged players, who already had a strong sense of spatial knowledge of their environment and thus were not in every case interested in the exploration itself. For them, the leaderboard temporarily positively impacted their motivation of actively using the app. Whereby, others were encouraged by the competition the leaderboard provided. One negative side-effect of the leaderboard was that users found themselves using other modes of transportation to increase their exploration score (e.g. by using the app during a car ride). This negatively impacted the motivation of other users by setting unrealistic expectations. These effects of social competition are common and always represent a trade-off between those at the top and those at the bottom [29]. The static gamification elements, like quests, were found to be helpful, but only as a supportive measure. The predefined quests aimed to be sufficient for the study period. While constantly changing tasks can create a short-term gamification effect, the absence of quests after a certain point, combined with numerous users maintaining a high number of unlocks on the leaderboard, showed a decline in motivation in some cases. Through this insight, we come to the same result as Kazhamiakin et al., in that, making use of a dynamic quest generation would be a good way to counteract this problem and keep people engaged [21]. The addition of technologies, especially apps, that require users to focus on them while actively participating in reality can present challenges and security risks. As highlighted by Colley et al. [4], Pokémon Go brought up safety risks due to situations and unsafe areas. The participants in our study did not mention any such scenario, however results in this regard could have been under-reported since our study design did not focus on this aspect. The interviews suggested that not everyone was actively exploring, but some participants were just passively collecting points. It is possible that a large amount of exploration was done passively, just to boost the gamification statistics. The passive collection might have been due to the range of participants reaching the threshold, who already having a good familiarity with their environment, to begin with. In conclusion, the system encouraged both, active involvement and passive collection.

6.1.2 Effects on Spatial Knowledge. To test whether using MapUncover improved participants' spatial knowledge, we used the Santa Barbara Sense of Direction (SBSOD) test. Two participants did not take the optional test in the introductory survey, which reduced the available sample size for its deviation calculation to 20. From its results, we could not confirm that the approach increases spatial knowledge (**H2**). We saw a non-significant mean improvement of 0.1. Our hypothesis was based on the SBSOD authors that depicted its result strongly correlates with environmental knowledge and corresponding spatial abilities [16]. Although, anecdotal experience from general observations suggests an improvement of spatial knowledge, as several positive effects on spatial knowledge have been elaborated through interviews, they could not be formally proven. In particular, the app was able to significantly improve the users' self-perceived familiarity with their surroundings, and in exceptional cases even made it possible for participants to find new meaningful places. The impact on the participants measured familiarity and the statements from participants imply that the study helped them to find their way around better and thus become better acquainted with their environment. While one even found an alternative route, emphasizing Zhan Guo et al.'s mentioned likelihood of finding them through increased familiarity and longer paths [13]. Finally, 68% of people felt the process of exploration was fun, which correlates with the consolidation of spatial knowledge through finding new places ($cor = 0.76$, $p < 0.0001$) and the overall openness to exploration ($cor = 0.56$, $p = 0.007$).

6.1.3 Impact of Familiarity on Exploration Behaviour. **H3** has put forward the theory that participants who are new to the environment, tend to be more motivated by the proposed app design, than those already familiar with it. Having examined the effects of the app on spatial cognition and motivation to explore, the results do

not allow drawing conclusions that confirm this hypothesis. Since the examined data set only included two new residents, whereby one filled out the introductory survey before moving to his new place, their experiences cannot be generalised. Furthermore, the gamification, especially the leaderboard, led to a large amount of exploration behaviour, even among participants, who already were familiar with their environment.

In summary, our results suggest that gamification can be used to alter the user's exploration behaviour and also their feeling of being familiar with their environment. In the following section, we discuss the implications of our main insights on the design of future mapping applications.

6.2 Implications for the Future Design of Mapping Applications

Modern mobile map apps make use of a large amount of information displayed to the user in the form of cartographic hierarchies and points of interest. At the same time, turn-by-turn instructions are guiding users along predefined fastest routes with little to no variation. While this approach to mobile navigation has shown to be very efficient, it does not help to build up spatial knowledge for its users [32, 33] and limits the feeling of finding meaningful places. In the following sections, we discuss potential changes to these systems to address and counteract the associated impacts using exploration.

6.2.1 Re-enforcing Spatial Knowledge by Dynamically Alternating Routes. Current navigation systems do not sufficiently help in building up a lack of spatial knowledge through repetitive assistance in spatial tasks. With MapUncover we aimed to address this problem. Our results demonstrate that positive reinforcement of exploration can help strengthen the user's self-perceived familiarity with their environment and thus help in building spatial knowledge, creating the ability to let users find their own routes. Similarly, users were encouraged to alter their routes by the map indicating that they had already been there. Based on these insights, we recommend that current mobile map apps occasionally provide slightly altered routes to users for the same origin and destination, based on which paths the user already knows. By keeping the length of possible "detours" to a minimum, users will benefit from building spatial knowledge of their surroundings, while not spending too much additional time on their journey. Such alternate routes could be calculated based on personal preference for exploration environments of individual users. Through the environmental attributes of map tiles and prioritisation through their visit-frequency, such information could even be extracted from our data in a future study, identifying environments to explore for each user.

6.2.2 Facilitating Meaningful Discovery through Active Engagement with the Map Data. Mobile map apps feature a variety of data points that are displayed on the map. However, these so-called points of interest (POIs) might not be of interest to each and every user in different scenarios. Thus, a fitness tracking app does not necessarily need to provide information about nearby stores, for example [5]. Such seemingly random POIs might not be relevant for successful wayfinding, as they do not serve as landmarks because they don't actually carry any meaning for people. Thus currently, POIs cannot efficiently be utilised as landmarks for better navigation. Instead of using a large amount of POIs by default, our results suggest that through exploration, some landmarks have a deeper meaning for users as they actively explore them. Through its design, MapUncover created scenarios where users were willing to learn about their surrounding area. They explored different landmarks, whether it's public buildings or just the name of a park. Participants were engaged in making a detour to further extend their knowledge about the surroundings, by uncovering the names of POIs on the map. Evidently, participants mentioned their wish to learn more about their environment, so that in the future they would be able to tell where a place is located and also guide other people to those places. These lived experiences strongly suggest that reducing the number of directly visible data points on a map can impact the user's knowledge of landmarks while simultaneously decluttering it. We suggest that periodically reducing the amount of information on a map to a minimum, similar to the approach of Vaittinen [37], could positively influence the user's spatial knowledge.

In summary, general customisation of cartographic information, can have a positive impact on user behaviour and create sustainable exploration behaviour that improves familiarity with one's surroundings and spatial knowledge, which should be considered in future systems.

6.2.3 Fostering Familiarity with One's Environment. Exploration has a positive influence on the knowledge of one's environment. People can find new paths and places to generally feel more familiar with their environment. This can have a positive impact on psychological well-being, sense of belonging and generally create a fulfilling experience [40]. In addition to the significant improvement measured in self-perceived familiarity, qualitative feedback in our study showed the same effects. Whether it was a participant travelling through places in their city they would never have visited otherwise, or people taking the extra step and generally feeling happy about having their mental map validated. We highlighted in the introduction that exploration is becoming a "premium activity" [1]. That means people may not take the time to visit and find all areas or places meaningful to them. We have shown that this feeling of "knowing your way around" was positively described in our study, and therefore we strongly recommend incentivising users to visit surrounding areas that they may not yet have discovered. Our first approach relies on the same theme as our map unlocking mechanism, namely (1) prompting the user with invisible or highlighted areas on the map, to go through specific environments when they are in the vicinity. Another approach is (2) to remind the user of not knowing their surrounding area and hinting at to the user interesting points of interests, or (3) simply by suggesting a detour through unknown paths while navigating (see recommendation 1).

7 LIMITATIONS

Since there is limited research in the field of gamified mediated map exploration, we approached our evaluation with an exploratory research design. Our study design did not introduce a specific selection process for participants. We tried incorporating a variety of participants to see the effects of the exploration process on people new to their environment, already familiar with their environment, or even new to mobile games, or games that encourage exploration.

On the effect of this convenience sampling was that 91% of our participants lived in urban environments, which they were also most familiar with. Additionally, participants were mostly located in Germany, due to the origin of the study. As was pointed out in the interviews, the ongoing pandemic was the reason that some participants were less active since they worked from home and therefore had fewer opportunities to explore. Similarly, participants mentioned in most interviews that they would have explored more if it had been summer. Furthermore, we do not know how often participants have knowingly turned off the app for privacy concerns, since this is a major concern in other location-based studies [6, 19, 20]. However, none of the interviewees mentioned doing so actively for privacy reasons, but rather because of its battery consumption.

8 CONCLUSION

Our evaluation has shown that the proposed gamified system promotes exploration and allows people who are already familiar with their environment to become better acquainted with it. This behaviour acts as a countermeasure to the current baseline of common map apps, which provide efficient routing, creating routines and habits that inhibit spatial exploration. Users who knew their neighbourhood were more likely to explore passively in order to earn rewards and compete on the leaderboard. Others used the map to explore actively. Likewise, the uncovering helped find alternative routes and meaningful places new to participants. The competition led to the formation of clusters that used the exploration process to compete against people they knew. In future work, a longitudinal study with a larger sample size should confirm our findings and compare them against common map usage behaviour known from apps like Google Maps. Finally, we critically reflected on the design decisions and discussed implications for the future use of elements fostering exploration in map apps. We propose three design implications for encouraging exploration in mobile map user interfaces: (1) adapting the routing algorithm to include unknown paths to counteract on repetitive routing, (2) reduce the amount of visible points of interest to a minimum, to enable users to visit and then learn about them, and (3) to enable exploration of unknown areas, by the use of vicinity prompts, reminders to become better acquainted with one's environment or suggesting detours while navigating. Overall, these changes should enable the acquisition of spatial knowledge and reduce the overwhelming impact and spatial overload that the current state of mobile map application can have on its users.

ACKNOWLEDGMENTS

We would like to thank all participants of the studies who put great effort into their participation. Without their ambition, the completion of this work would never have been possible.

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