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Shelter GO: multiplayer location-based game to promote knowing shelters for emergency evacuation

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Abstract

In the event of a disaster, we evacuate to a shelter. However, if we do not know where to go for refuge, we consume time or end ourselves at an unknown shelter. Furthermore, we cannot decide on a suitable shelter if we do not know its capacities and features. To promote knowing shelters in advance is essential for successful emergency evacuation. A promoting approach is the use of a location-based game. Thus, a prototype of a multiplayer location-based game known as "Shelter GO" was developed to promote players to become acquainted with shelters by adopting a game element similar to Pokémon GO. The game feature allows players to not only earn points by visiting and observing shelters and collecting digital creatures at disaster-related spots but also exchange their collected digital creatures with encountered players. The digital creature exchange entails knowledge exchange. A preliminary comparative experiment demonstrated that Shelter GO can promote knowing shelters and that knowledge exchange may not be frequently done but promote knowing shelters.

Keywords: Multiplayer location-based game, Digital creature collection and exchange, Knowledge exchange, Shelter, Evacuation, Disaster education

Introduction

Severe natural and artificial disasters have occurred globally, causing damage and deaths (CRED, 2023). Although simulation technology has advanced to predict the occurrence and strike of some disasters (e.g., typhoons), we may encounter unpredictable disasters (e.g., earthquakes and terrorist attacks). When disaster strikes or is predicted, we evacuate to a shelter depending on the circumstances. Evacuation is essential for saving lives in the event of a disaster, although it can be difficult at times, and the difficulty increases significantly with unpredictable disasters. For example, when a typhoon is approaching from afar, we can calmly decide which shelter to evacuate to and then begin evacuation. Contrarily, if an earthquake with a tsunami occurs, we must quickly decide which shelter to evacuate to. If we do not know where to go for shelter, we consume time until we decide or go toward an unknown shelter; in a worst-case scenario, lives may be lost.

Mobile applications have been developed to provide real-time evacuation support to avoid the worst scenario. For example, mobile applications for indoor evacuation can detect a user's current location using radio-frequency identification tags (Chittaro & Nadalutti, 2008) or fiducial markers (Kanangkaew et al., 2023) to navigate the user toward exits or safe zones by presenting location-aware instructions (e.g., arrow and line) based on building models. Other location-aware applications periodically present the shortest and safest evacuation routes from a building's environmental data (e.g., temperature and visibility) while considering user characteristics (e.g., age and health conditions) (Atila et al., 2018; Eksen et al., 2016). Focusing on outdoor evacuation, mobile applications employing a global positioning system (GPS) to detect a user's current location must consider a greater number of evacuation routes across a wider area than those applied in indoor evacuation. Furthermore, the sensors cannot be readily distributed over a wide area to collect the outdoor environmental data available for evacuation. To overcome this difficulty, certain mobile applications for outdoor evacuation adopted a GPS but smartphone-based cloud computing and recommended the best evacuation route while estimating the user's surroundings such as impassable or congested roads (Itoi et al., 2017; Xu et al., 2018). In the event of a disaster, these applications are expected to aid in successful evacuation. However, we may be unable to remain unruffled in the event of a disaster and appropriately utilize such mobile applications. Moreover, a mobile device may become physically unavailable due to breakage and loss. Therefore, for successful emergency evacuation, the shelter locations must be known in advance.

Hazard map and its drawback

Shelters are marked on a hazard map, which also shows simulated damage (e.g., inundation depth by flood or tsunami). Recently, hazard maps have been digitized using a geographical information system to provide multimedia content and interactivity for better disaster risk reduction (Dransch et al., 2010; McCallum et al., 2016). For example, web hazard maps showing simulated flood inundation areas and related explanations are used to promote risk communication (Oubennaceur et al., 2021) and to educate high school students on how to identify risk in their community (Song et al., 2022). The fusion of a web map and social media (Twitter) allows residents to upload and share local disaster information such as potential disaster-induced dangers (Uchida et al., 2021; Yamamoto & Fujita, 2015). Furthermore, three-dimensional (3D) hazard maps have emerged to aid in the intuitive understanding of simulated disaster risks, such as flood-caused water exposure (Macchione et al., 2019), using 3D visualization. Compared with paper-printed hazard maps, digital hazard maps can be easily distributed to modern people who have personal computers, including smartphones.

When an unpredictable disaster occurs, residents can begin evacuation by referring to the marked shelter locations on the map. Although when there is mental instability (e.g., panic), limited perception (e.g., low visibility due to a blackout), or unusable smartphones (e.g., disconnected Internet), residents may be unable to look at the map. In the event of such an unforeseen situation, it is still necessary to have known shelter locations. Even if residents are careful about disasters, to decide on a suitable shelter, they should be aware of not only shelter locations but also other types of shelter information such as capacity and features. For example, if a large number of residents rush into a small-capacity shelter, the overflowed is forced to abandon the crowded shelter and evacuate to another shelter. If sickly residents are unfamiliar with shelter features (e.g., main equipment), they can go to the nearest shelters that do not possess medical supplies. Some hazard maps show shelter capacities, but most hazard maps do not show enough information for residents to decide on a suitable shelter.

Location-based game as an alternative to hazard map

A method other than looking at a hazard map is required for residents to effectively locate shelters (i.e., location, capacity, and feature). Residents may visit and observe shelters as a means to know the shelters as perceptual experiences in the real world. These experiences can make knowing more impressive than the monotonous activity of looking at the map. However, residents may unwillingly accept this method because these experiences entail temporal or physical burdens. Thus, this method should adopt a motivational approach so that residents can visit and observe shelters beyond the burden.

To serve as a motivational approach, digital games have been actively introduced in the field of disaster risk reduction (Solinska-Nowak et al., 2018), with certain digital games focusing on disaster education. For instance, a strategic simulation game has been practically used by high-school students to learn flood protection based on social infrastructure (Tsai et al., 2015). A simple quiz-style game was explored for elementary school students to learn earthquake preparedness on their smartphones (Winarni et al. 2018). Location-based games are especially promising for visiting shelters. For example, Pokémon GO is a globally popular location-based game, and several studies have investigated not only its influences on physical activity (Lee et al., 2021), cognitive performance (Ruiz-Ariza, et al., 2018), and mental health (Watanabe et al., 2017) but also its availability for health education (Finco et al., 2018) and language learning (Wu, 2021). Besides Pokémon GO, location-based games have been actively applied to education, and location-based educational games are effective in making learning enjoyable and heightening learning efficacy in various learning domains. For example, a location-based educational game for local cultural learning demonstrates context-aware learning contents (e.g., quizzes) by detecting whether students are near historic monuments (Lin et al., 2018). A narrative-driven location-based augmented reality (AR) game has been developed for players to study English by interacting with nonplayer characters or for obtaining items displayed on a digital map (Lee, 2022). In addition, location-based games have been used in disaster education. For example, location-based mixed-reality games enabling human players and computer agents to interact have been used for first responder training (Ramchurn et al., 2016). A location-based game that provides multimedia content including AR at predefined locations or times depending on a disaster scenario has been used for earthquake and tsunami evacuation training (Mitsuhara et al., 2015; Mitsuhara et al., 2021). Although not a location-based game, a mobile application for tsunami evacuation training has been overlaid on a digital map with a simulated tsunami approach, allowing trainees to run away from tsunamis while seeing the map in a time-trial competition (Yamori & Sugiyama, 2020). From the reported advantages, location-based games are expected to be an alternative to hazard maps in knowing shelters.

Our previous research

Based on this background, we developed a prototype of a single-player location-based game that promotes a player (resident) to visit shelters by introducing a game element similar to that of Pokémon GO (Mitsuhara et al., 2022). In the game prototype, players visit a shelter to earn a point equal to the capacity of the shelter and then visit a disaster-related spot (e.g., disaster monument and alert sign) to collect (acquire) a digital creature by paying a required point from his/her earned points. The digital creature collection can promote players to visit different shelters while feeling enjoyable and not burdened, and consequently, players can know many shelters. Our preliminary experiment showed that the game prototype helped players to remember more shelter locations and accurate shelter capacities than just looking at a hazard map. However, the game prototype focused on a single-player mode and did not have a multiplayer game element. Pokémon GO introduced multiplayer game elements such as exchanging digital creatures (i.e., Pokémons) for more enjoyable, sustainable gameplay. If a multiplayer mode is implemented in the game prototype, players may be able to know shelters more effectively while interacting with other players.

Research purpose and questions

Our research promotes knowing shelters using a multiplayer game element (multiplayer mode). This is achieved by extending the game prototype to a multiplayer location-based game known as “Shelter GO.” Shelter GO promotes knowing shelters by enabling players to exchange their collected digital creatures. The concept behind the multiplayer mode is that digital creature exchange entails knowledge exchange.

Considering the flow from our previous research, we set the following research questions:

- RQ1. Which promotes knowing shelters more, the single-player mode or multiplayer mode (Shelter GO)?
- RQ2. How do players exchange knowledge in Shelter GO?

This study is organized as follows. First, a four-phase process for knowing shelters, the game element (digital creature collection), and the game prototype (the single-player mode) are described. Second, as the key game element in Shelter GO, digital creature exchange (knowledge exchange) is described together with the application user interfaces. Third, a preliminary experiment to answer the research questions is reported. Finally, this study is summarized, and future work is presented. This study contains reconstructed concepts and detailed experiment analysis (including partial data correction) as extended parts from Mitsuhara and Shishibori (2022).

Single-player location-based game for successful evacuation

When an unpredictable disaster strikes, we are often forced to evacuate. Therefore, we must prepare for a successful emergency evacuation.

Importance of knowing shelters

In the event of unpredictable disasters, the evacuation process (timeline) is as follows: 1) a disaster occurs; 2) individuals (or people present) recognize the disaster by receiving an alarm or perceiving it from their surroundings; 3) they decide whether to evacuate and which shelter to evacuate to; 4) they begin and continue moving to shelters; and 5) they reach the shelters. Step 3 occasionally takes time because of dither caused by various factors (e.g., perceived risk, cognitive bias, past disaster experience, and received information), and steps 3 and 4 may be hampered by unexpected situations (e.g., stupor, injury, and blocked road). Regarding the 2011 Tohoku earthquake in Japan, an investigation revealed that 10.1% of residents (surviving respondents) in a coastal area did not know shelter locations, whereas 42.2% were evacuated to undesignated higher places (Makinoshima et al., 2016). Residents in coastal areas should have evacuated to shelters before the arrival of the resulting tsunami (within 30 min in some areas), and many residents may have prioritized immediate survival by reaching undesignated higher places; however, the tsunami caused approximately 14,000 fatalities (approximately 90% of all fatalities). Following the earthquake, many shelters were built in tsunami-anticipated coastal areas, and residents were trained to evacuate to predesignated shelters as part of practical disaster preparation.

The more shelters that are built, the more residents can survive by reaching the shelters. On the one hand, residents should be aware of additional shelters to ensure their survival. This is because all residents cannot always evacuate to their predesignated shelters during unexpected situations (e.g., crowded or collapsed shelters), and some residents must quickly decide on another shelter, as stated in step 4. Therefore, residents must know multiple shelters for their survival. In other words, if this prerequisite is not satisfied, even residents who regularly participate in evacuation training may be unable to quickly decide on a suitable shelter other than predesignated shelters. Despite possessing a smartphone to obtain updated shelter information, residents may not always be able to utilize their smartphones while information and communication infrastructure is disrupted by a disaster.

The process for knowing shelters

Our proposed method aims at disaster preparedness, i.e., the set of actions to follow before the occurrence of an unpredictable disaster, and requires residents to visit and observe the shelters. To promote knowledge, we set the following four-phase process by introducing a game element.

Preview phase

As an introductory phase, a resident (or a resident group) previews a hazard map and gets a sense of shelter locations (e.g., distance and direction) at least, and then decide the shelters to visit. This phase can be skipped if the resident knows the shelter locations or dislikes knowing them in advance.

Walk phase

This phase involves not only walking (moving) but also grasping the shelter environment (e.g., ground condition), which is difficult to recognize by only looking at the hazard map. To avoid getting lost, the resident can walk while occasionally looking at the hazard map.

Walking may entail a temporal or physical burden and consequently cause residents to be unmotivated to follow the process. In this phase, it is important for the process of sustainability that residents can walk beyond the burden.

Visit and observe phase: VO

In this phase, residents visit (reach) and observe a shelter. The observation is often done visually from the outside because many shelters are released only in the event of a disaster; occasionally, residents may be allowed to enter the shelter or talk with the manager. By observing the real shelter, residents can:

- Know the shelter location deeply together with his/her impression. For example, "*this shelter is located on a hill, and a nearby tall tree is a landmark.*"

- Know the shelter capacity (shown on the hazard map) deeply by comparing it with his/her presumed capacity (impression). For example, "*this shelter looks spacious but actually cannot accommodate many residents inside.*"
- Know the shelter feature that can help determine whether the shelter is suitable for various disaster scenarios. For example, "*this shelter looks old and hygienically worrisome and may be unsuitable for long-day evacuation.*"

Each resident has a different impression of the observation. In other words, shelter information acquired by a resident during this phase includes the resident's subjectivity and is regarded as his/her shelter-related knowledge for successful evacuation. In addition, repeated observations can bring widely applicable knowledge (e.g., "*tall buildings are often designated as tsunami shelters. In an emergency, we can evacuate to a tall building*"). Such subjective shelter information, i.e., acquired knowledge, is not shown on the hazard map that attaches importance to objectivity and invariance.

Visit and collect phase: VC

Repetition of the Walk and VO phases results in knowing many shelters. However, unless the Walk phase is promoted, the repetition will not continue. To promote the Walk phase using a Pokémon GO-like location-based game, we set a new phase known as "visit and collect" (VC)—collect derives from our introduced game element.

In this phase, the residents visit a disaster-related spot and acquire lessons from the spot. For example, when visiting a monument conveying tsunami lessons together with the past tsunami's height, residents will acquire lessons impressively while comparing it with their height or circumstances.

Game element

Our introduced game element is a digital creature collection and works in the VO and VC phases to promote the Walk phase. The four-phase process including the game element is shown in Figure 1.

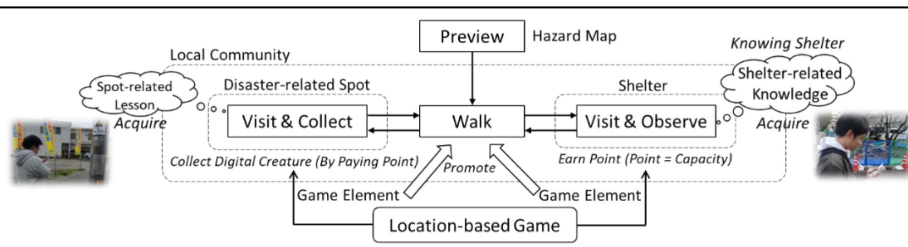

Fig. 1 Four-phase process and game element

Earning point in the VO phase

When visiting a shelter, players earn a point equal to the capacity of the shelter. The earned points can be used to collect digital creatures in the VC phase. Even if players return to a shelter at short intervals, they cannot re-earn the point at the shelter. However, re-earning a point is allowed after a certain time passes. This rule allows players to be promoted to visit many shelters and revisit the previously visited shelters to stabilize acquired knowledge.

Collecting digital creatures in the VC phase

When visiting a disaster-related spot, players can collect a digital creature by paying a required point from their earned points. A different digital creature is assigned to each spot, and the required point depends on the creature (i.e., the spot). This setting, similar to treasure hunting, can promote players to visit many disaster-related spots to collect their unknown creatures.

This digital creature collection promotes the Walk phase, i.e., visiting many shelters and disaster-related spots. Consequently, players can acquire more knowledge (shelter-related knowledge and spot-related lesson).

Game prototype

The game prototype was developed as a Unity3D-based geofencing mobile application (app) that works on a GPS-enabled Android smartphone (or tablet). The app with the single-player mode, which does not require an Internet connection, deals with the Walk, VO, and VC phases. The user interface of the game prototype is shown in Figure 2.

Walk phase

Figure 2-a shows the screenshots presented during the Walk phase. In this phase, the app always displays a digital map, a “gallery” button, and some information such as earned points. The map shows a player’s current location, shelters, and disaster-related spots as corresponding icons. When reaching a shelter (invisible rectangle area enclosing the shelter), players can move to the VO phase. When reaching a disaster-related spot, they can move to the VC phase. By tapping the button, players are taken to the gallery where they can see the list of the collected digital creatures. The app compulsorily takes players at random intervals to digital creature encounter events, which are not associated with the location. Although not originally required, this compulsory transfer is prepared to avoid a situation where players cannot efficiently visit disaster-related spots.

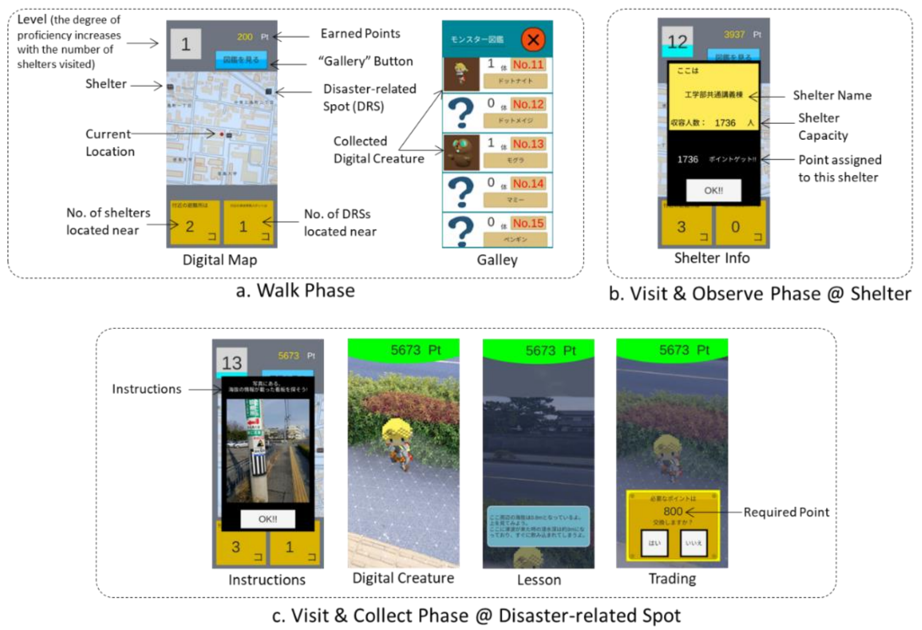

Fig. 2 User interfaces of the game prototype (single-player mode)

VO phase

Figure 2-b shows the screenshots presented in the VO phase. In this phase, the app displays the name and capacity of the visited shelter, and players receive a point equal to the capacity. Players can backtrack to the Walk phase by tapping the OK button. The app does not display a message encouraging players to observe the shelter. However, players can be triggered to observe the shelter, by comparing the displayed capacity and the shelter presented before them.

VC phase

Figure 2-c shows the screenshots presented in the VC phase. In this phase, at the reached spot, the app first displays instructions (e.g., "*please look at the disaster alert sign around you*"). Following that, the app activates the rear camera of the smartphone and displays a digital creature in an AR mode, which superimposes the digital creature CG onto real-time vision using a markerless AR framework. When players tap right on the moving-around creature on the screen, the app displays a lesson associated with the spot (e.g., "*anticipated tsunami height is 3.0 m in this area and 0.8 m above-sea level here. If you stay here after a big earthquake, you will be engulfed by the tsunami*"). When the compulsory transfer occurs, the app provides general lessons (e.g., "*school buildings are often registered as shelters*"). After reading the displayed lesson, players can acquire the creature by paying the required point.

Shelter GO

The game prototype promoted knowing shelters using the single-player digital creature collection while providing simple and player-dependent gameplay. Advantageously, players can start and stop play depending on their circumstances (e.g., free time). Contrarily, the game prototype provides lonely gameplay and is concerned with process sustainability, i.e., how long players keep playing without losing motivation. Our quick idea to remove this concern is to convert the single-player mode to a multiplayer mode.

The single and multiplayer modes have numerous learning-related merits and demerits, and game/instructional designers can suggest a better mode to maximize learning effects in future educational games (Harteveld & Bekebrede, 2011). Regarding Pokémon GO, Laato et al. (2021) reported that players' affection for fictional creatures and social connection with other real players can result in meaningful gameplay. Because encountering other real players may lead to maintaining motivation, the game prototype is extended to a multiplayer mode. The multiplayer location-based game is "Shelter GO."

Multiplayer mode toward visiting more shelters

It is rational from an efficiency perspective for players (residents) to only visit shelters and disaster-related spots in their local community (i.e., living area). The single-player mode was designed to work in four phases, assuming that individual players walk around their local community. However, players should visit more shelters within and outside their local community because where there are disaster strikes is unpredictable. This ideal process, which may entail long-distance walking, is anticipated to increase the walking-caused burden. Thus, a new game element special to the multiplayer mode is required to promote people to visit shelters outside their local community.

Involving other players

It is a waste that knowledge for successful evacuation only has been contained inside individual players. Therefore, knowledge should be shared among players. For example, a sickly player's knowledge of shelter features may be useful for not only homogeneous players but also for other diverse players, e.g., "*old shelters have no air conditioner and should be avoided in summer or winter.*"

The multiplayer mode involves other players in the four-phase process, assuming that players desire encounters with other players and will be motivated to walk around regardless of whether they are inside or outside their local community for more encounters. Furthermore, the encounter becomes the basis for a new game element. To make knowing shelters more enjoyable and effective, the multiplayer mode helps encounter other players during the Walk phase. A player can do the following in multiplayer mode:

- Maintain motivation by interacting face-to-face with encountered players.
- Acquire (receive) knowledge from encountered players—knowledge sharing.

Knowledge sharing imposes knowledge exchange (i.e., transfer and receive) between players. If focusing heavily on knowledge sharing (i.e., encounter with other players), players may be unmotivated to visit shelters. However, the encounter does not always happen because of factors such as player population, density, and personality. Consequently, players must acquire sharable knowledge in advance during the VO and VC phases to make the encounter attractive and meaningful, and they can be motivated to visit shelters.

Game element: exchanging collected digital creatures

Players can collect digital creatures in various local communities regardless of whether they are playing in single or multiplayer modes. To exceed the digital creature collection's enjoyment, we implemented a game element that makes knowledge sharing enjoyable. The game element we envision is digital creature exchange, which includes knowledge exchange. Encountered players can collect unique digital creatures and agree to exchange each player's digital creature. Players are expected to not only collect many digital creatures by visiting shelters and disaster-related spots but also collect unique digital creatures from other players via digital creature exchange. In other words, players are expected to acquire many pieces of knowledge by not only visiting shelters and disaster-related spots but also receiving from other players. The multiplayer mode and its game elements are shown in Figure 3.

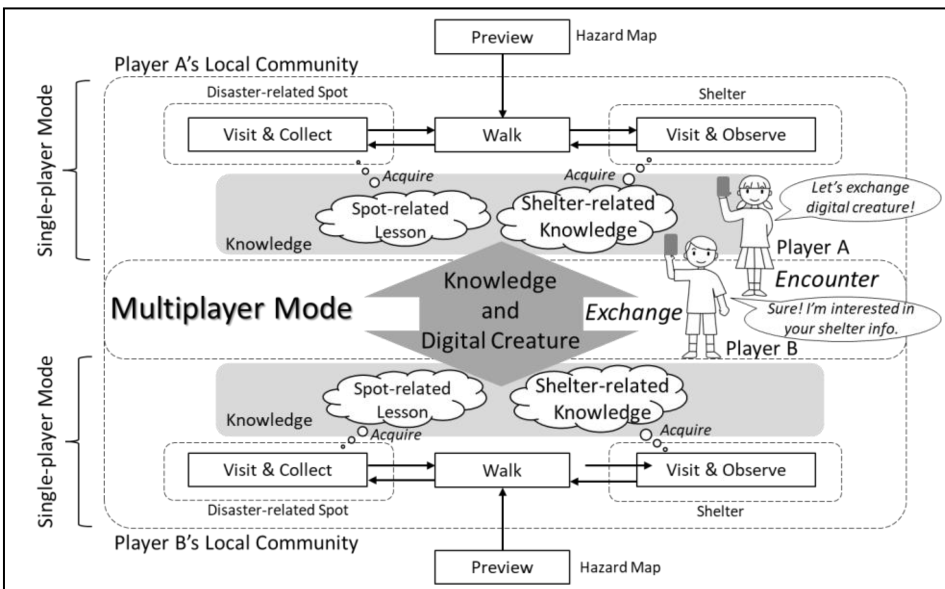

Fig. 3 Multiplayer mode and game element

The knowledge exchange is not done by direct interaction (e.g., conversation) between players but is done via the app. Therefore, the app imposes the following duties on the players.

Register knowledge

When acquiring a digital creature at a disaster-related spot, a player must register his/her knowledge of the creature. This registration is known as knowledge externalization, which helps stabilize knowledge. Registering shelter-related knowledge is most expected, but any type of knowledge useful for successful evacuation is accepted (e.g., "*do not forget to bring your indispensable medicines when evacuating*"). The registered knowledge will be a candidate to exchange via the app.

Transfer knowledge

When exchanging a digital creature with an encountered player, he/she must transfer the registered knowledge together with the creature. After exchanging the knowledge (digital creature), the player can no longer see the registered knowledge on the app. This rule may impose a burden on players, but it can motivate them to surely remember knowledge while assuming that their collected digital creatures will leave.

Implementation

Figure 4 shows the configuration of the Shelter GO app that works together with a server for the multiplayer mode. The Shelter GO app allows players to switch to single-player (i.e., without an Internet connection) or multiplayer modes (i.e., with an Internet connection). For the single-player mode, the app has basic modules (e.g., phase detection, phase transaction, and point management) and internal data storage (e.g., shelter, disaster-

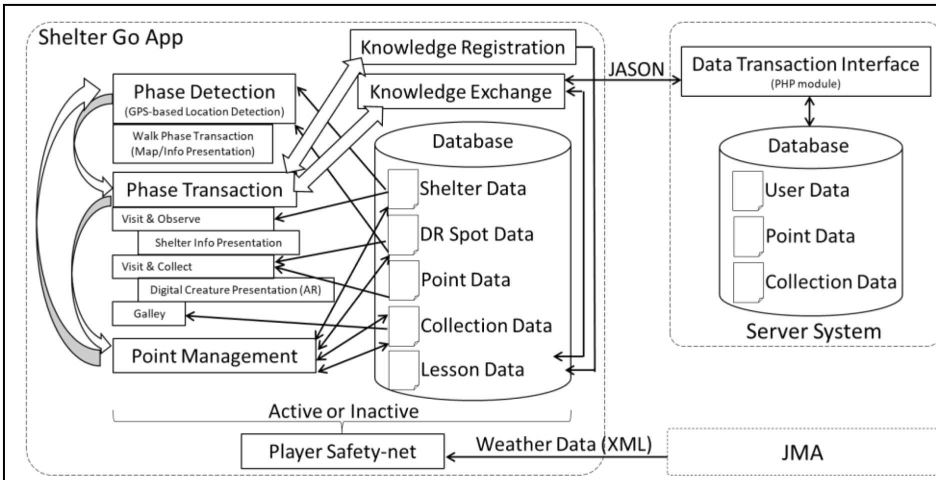

Fig. 4 Configuration of Shelter GO app

related spot, and point). Shelter data comprises name, latitude, longitude, and capacity (i.e., point). Disaster-related spot data comprise a latitude, longitude, digital creature, lesson, instructional message, and image. For the multiplayer mode, the app includes modules (e.g., knowledge registration and transfer) and external data storage required for knowledge exchange. The external data storage, where a data interface module (implemented by PHP) in a server system makes the transaction, has a comma-separated values (CSV) file for each exchange that records temporary data, such as player ID, player name, creature ID, and registered knowledge.

Location-based games potentially bring danger because of the outdoor gameplay with the fixation on the smartphone screen. For example, Faccio and McConnell (2018) reported that over 286 Pokémon GO-caused traffic accidents, including two deaths, occurred in a US county for 148 days after its release. We must avoid letting a player get injured or die in a disaster while using the Shelter GO app to protect lives from disasters. Therefore, we implemented a safety-net function that prohibits gameplay during bad weather. Although only applicable in Japan, this function collects open weather data from the Japan meteorological agency at short intervals and inactivates the app when a weather warning (e.g., heavy rain) is issued in the municipality where each player is currently located.

Register knowledge

Figure 5 shows the screenshots presented when registering knowledge. When a player acquires a digital creature in the VC phase, the app displays a text component to register knowledge of the creature (Figure 5-a). Players must input text after selecting one of the following three categories of knowledge: shelter-related, evacuation-related, and disaster-related. Furthermore, players can register some pieces of knowledge about the creature. After completing the registration, the app displays the creature together with a message "[the creature's name] just memorized new knowledge" (Figure 5-b). By tapping the "refer to knowledge" button in the Walk phase (Figure 5-c), players can refer to their registered knowledge as the list of the digital creatures collected (Figure 5-d).

Fig. 5 User interfaces for registering knowledge

Exchange knowledge

Currently, the app only allows two players to exchange knowledge (digital creatures), which occurs when two players meet face-to-face in the Walk phase and agree on the exchange.

Figure 6 shows the screenshots presented when exchanging knowledge. A player who recognizes a nearby player in the Walk phase can speak to the player and suggest a digital creature exchange. If the suggestion is accepted, both players tap the “creature exchange” button to display the menu (Figure 6-a). One player taps the “host mode” button and the app displays a quick response (QR) code (Figure 6-b). The other player taps the “guest mode” button and then scans the QR code using the rear camera of a smartphone. After a successful scan, the app displays another QR code for the host player to scan. When both scans are successful, the app displays a list of digital creatures (Figure 6-c). The list includes unexchangeable digital creatures (i.e., not-yet-collected digital creatures) on each player’s app. Each player selects one from the exchangeable creatures as a creature to transfer and then selects one or more knowledge registered to the selected creature (Figure 6-d). Then, the selected knowledge is transferred together to the selected creature. When both players have finished selecting, the app begins the creature exchange transaction and displays the creature CG and knowledge received from the server (Figures 6-e and f). Then, the data of the transferred creature and knowledge are deleted from the app. In the Walk phase, the player can refer to the list of knowledge received from other players together with the corresponding received creatures by tapping the “Knowledge Folder” button

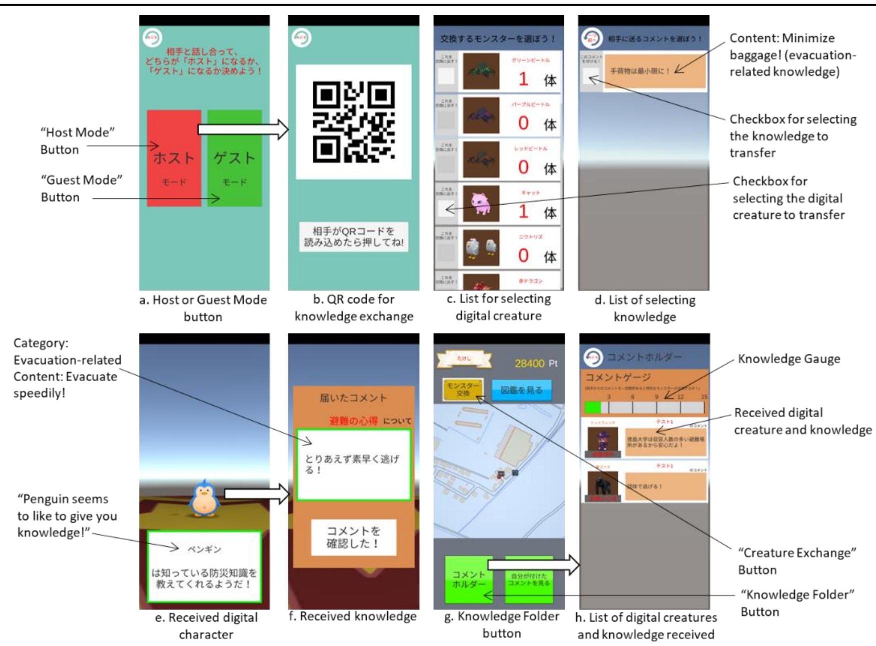

Fig. 6 User interfaces for exchanging knowledge

(Figure 6-g). A gauge called the “Knowledge Gauge” is displayed above the list (Figure 6-h). The value on the gauge indicates the amount of exchanged knowledge and expresses players’ activeness in knowledge exchange activity. Every time three pieces of knowledge are exchanged, a special digital creature not associated with a disaster-related spot appears. Players can acquire a special creature by paying the required point. These special creatures can promote the exchange.

Preliminary experiment

To answer the research questions, we conducted a preliminary comparative experiment between the single and multiplayer modes. We focused on the tsunami evacuation because participants resided in a coastal area where a tsunami can cause devastating damage. Thus, participants require to be aware of tsunami shelters.

Settings

Participant

We recruited participants by inviting acquainted undergraduate students of Tokushima University to participate without reward. The participants were ten undergraduate students who were in the same course (computer science course) and knew each other. A prequestionnaire revealed that they had little interest and knowledge about tsunami evacuation and shelters. They were divided into the following groups at random:

- Group A ($N = 5$): The participants simultaneously played an experimental Shelter GO that excluded the knowledge exchange function, i.e., the single-player mode with knowledge registration to digital creatures.
- Group B ($N = 5$): On a different day from Group A, the participants simultaneously played Shelter GO, allowing them to register and exchange knowledge. They freely decided whether to exchange knowledge.

Procedure

After the students were instructed on how to use their assigned Shelter GO app, we asked them to learn about the evacuation to tsunami shelters in an experimental area using the app installed on their smartphones. We did not impose a time limit, although they were informed that it would take approximately 1 h to visit the tsunami shelters.

Participants in each group started playing the game from a different location simultaneously. During the gameplay, the compulsory transfer to the VC phase, point re-earning by shelter revisit, and special digital creature acquisition based on a player’s activeness was deactivated. The Shelter GO app recorded participant behavior such as visiting shelters, registering knowledge, and exchanging knowledge.

Following the gameplay, each participant completed a surprise test and a postquestionnaire. The surprise test was a recall test asking about the shelter locations and capacities. To show whether they remembered the shelter locations, they marked them on a blank map of the experimental area with no designated tsunami shelters. Furthermore, they drew the shelter capacities on a map to show whether they remembered the capacities. The questionnaire required them to itemize all their acquired knowledge from the gameplay, and they were also asked about the effects of the gameplay.

Area

The experimental area, which was a familiar area for participants and covered a 700 m^2 of Tokushima University campus and its surrounding area, had sixteen tsunami shelters (buildings that met safety standards) and eight tsunami-related spots (e.g., alert signs against tsunami inundation). The capacities of the tsunami shelters ranged from 26 to 1,736.

Results

Because of the small number of participants, statistical tests were not applied to all the obtained data. The data of each participant are discussed below.

Behavior and recall test

The mean gameplay durations of Groups A and B were 43.4 min (37.9–49.5 min) and 52.6 min (43.2–67.3 min), respectively. The quantitative data obtained in the experiment are presented in Table 1. The mean values of Groups A and B for the number of visited shelters (Num_VS) were 9.6 (7–12) and 9.2 (6–13), respectively. The mean values of Groups A and B for the number of visited tsunami-related spots (Num_VTRS) were 5.4 (4–7) and 5.6 (3–8), respectively.

A recalled shelter location can be correctly recalled if a participant correctly marked the shelter–building correspondence on a blank map. All participants recalled locations only from their visited shelters; they did not answer the recall test by guess. The mean values of Groups A and B for the accuracy rate for all shelter locations (AccRate_ASL) were 43.7% (31.2%–68.7%) and 33.7% (18.7%–56.2%), respectively. The mean values of Groups A and B for the accuracy rate for visited shelter locations (AccRate_VSL) were 66.5% (41.6%–100%) and 59.3% (33.3%–100%), respectively. The mean values of Groups A and B for the number of capacity-recalled shelters (Num_CRS) were 3.6 (1–9) and 5.4 (3–9), respectively. All participants recalled capacities only from their visited shelters. For the accuracy of recalled shelter capacities (Acc_RSC), we calculated the mean absolute value of the difference between the correct and recalled capacities, and the mean values of Groups A and B were 86.9 (36.0–217.5) and 70.9 (47.0–141.6), respectively. Because these

Table 1 Quantitative data of each participant

Group A											
PID	Dur_GP	Num_VS	Num_VTRS	AccRate_ASL	AccRate_VSL	Num_CRS	Acc_RSC	DifRatio_RSC	Num_RK	Num_AK	
PA1	49.5	10	6	68.7%	100%	9	44.0	0.60	3	6	
PA2	37.9	9	5	31.2%	55.5%	3	101.0	0.35	10	2	
PA3	40.4	7	4	43.7%	85.7%	1	36.0	0.02	11	2	
PA4	46.1	12	7	31.2%	41.6%	1	36.0	0.02	4	4	
PA5	43.1	10	5	43.7%	50.0%	4	217.5	1.00	4	3	
M (SD)	43.4 (4.09)	9.6 (1.62)	5.4 (1.01)	43.7% (13.6%)	66.5% (22.3%)	3.6 (2.93)	86.9 (69.6)	0.40 (0.37)	6.4 (3.38)	3.4 (1.49)	
Group B											
PID	Dur_GP	Num_VS	Num_VTRS	AccRate_ASL	AccRate_VSL	Num_CRS	Acc_RSC	DifRatio_RSC	Num_RK	Num_AK	Num_EK
PB1	67.3	13	3	43.7%	53.8%	7	55.8	0.45	6	3	3
PB2	55.1	9	4	18.7%	33.3%	3	58.3	0.16	4	3	2
PB3	43.6	6	8	25.0%	66.6%	4	47.0	0.17	5	2	2
PB4	43.2	9	6	56.2%	100%	9	141.6	0.39	3	2	1
PB5	53.8	9	7	25.0%	44.4%	4	51.7	0.41	4	3	2
M (SD)	52.6 (8.85)	9.2 (2.22)	5.6 (1.85)	33.7% (14.0%)	59.6% (22.9%)	5.4 (2.24)	70.9 (35.5)	0.32 (0.12)	4.4 (1.01)	2.6 (0.48)	2.0 (0.63)

PID: participant ID, Dur_GP: the duration (min) of gameplay, Num_VS: the number of visited shelters, Num_VTRS: the number of visited tsunami-related spots, AccRate_ASL: the accuracy rate for all shelter locations (i.e., sixteen shelter locations), AccRate_VSL: the accuracy rate for visited shelter locations, Num_CRS: the number of capacity-recalled shelters, Acc_RSC: the accuracy of recalled shelter capacities (the mean absolute value of the difference between the correct and recalled capacities), DifRatio_RSC: the difference ratio between the correct and recalled capacities against the correct capacities, Num_RK: the number of registered knowledge, Num_AK, the number of acquired knowledge, Num_EK: the number of the exchanged knowledge, M: mean, and SD: standard deviation values may have depended on the capacities of individual participants' visited shelters, we calculated the difference ratio between the correct and recalled shelter capacities against the correct capacities (DifRatio_RSC), and the mean values of Groups A and B were 0.40 (0.02–1.00) and 0.32 (0.16–0.45), respectively.

Knowledge

The mean values of Groups A and B for the number of registered knowledge (Num_RK) were 6.4 (3–11) and 4.4 (3–6), respectively. The mean values of Groups A and B for the number of acquired knowledge (Num_AK), i.e., the knowledge that each participant itemized on the questionnaire, were 3.4 (2–6) and 2.6 (2–3), respectively. The mean value for the number of exchanged knowledge (Num_EK) in Group B was 2.0 (1–3). The participants registered and acquired knowledge are shown in Tables 2 and 3, respectively. The number of knowledge registered by Group A participants were 10, 8, and 14 for shelter-related, evacuation-related, and disaster-related, respectively. PA2 and PA3 registered more than two pieces of knowledge to each collected digital creature. The number of knowledge registered by Group B participants were 8, 7, and 7 for shelter-related, evacuation-related, and disaster-related, respectively. PB1 registered two pieces of knowledge to each collected digital creature. All participants in both groups registered knowledge without fixating on a single category. Participants other than PB4 registered knowledge about the university shelters (buildings on the campus), and participants other than PA4 and PA5 registered knowledge about the tsunami. Figure 7 shows the knowledge exchange among Group B participants using the labels of the registered knowledge shown in Table 2.

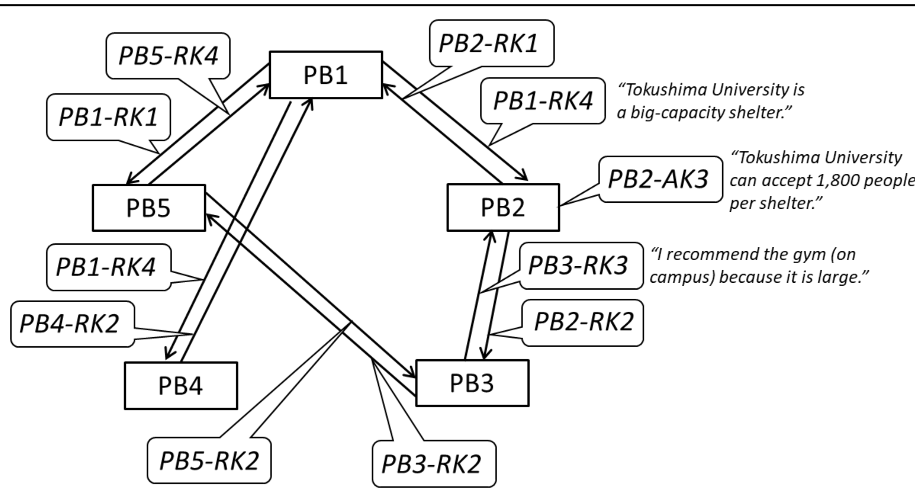

Fig. 7 Exchanged knowledge among Group B participants

Table 2 Registered knowledge

Group A					
	PA1	PA2	PA3	PA4	PA5
RK1	Shelters at Tokushima University have big capacities. [S]	Tsunamis come frequently. [D]	Tsunami will attack repeatedly. [D]	Be careful of afterquakes in the event of a big earthquake. [D]	Take action to evacuate speedily. [E]
RK2	We must be careful about even 1 m tall tsunami. [D]	The university’s shelters are wide. [S]	Tsunami becomes fast in the deep sea. [D]	Condominium buildings around the university seem tall and safe. [S]	We must mind afterquakes. [D]
RK3	We must be careful about fire in earthquakes. [D]	Even a tsunami of approximately 10 cm in height is dangerous. [D]	You should evacuate the K-building (lecture building) at Tokushima University [S]	Be careful of fire caused by an earthquake. [D]	The shelter at Tokushima University is the K-building. [S]
RK4		Roads around the Haitsu-Koho building are wide. [E]	I will evacuate on foot. [E]	Tokushima University has a big capacity. [S]	Do not return to pick up what you left. [E]
RK5		Do not shove someone even if you are evacuating in a hurry. [E]	It is good to evacuate the group. [E]		
RK6		Hide under a desk during earthquakes. [D]	Let us evacuate to a tall building. [E]		
RK7		The university’s shelters are tall. [S]	Tsunami becomes super tall. [D]		
RK8		The university’s shelters are robust. [S]	Protect my head when earthquakes. [D]		
RK9		Many people may rush into the university’s shelters. [S]	The AEON mall may be suitable for a shelter because it is tall. [S]		
RK10		Many things will fall when earthquakes. [D]	Be careful of tsunamis and earthquakes. [D]		
RK11			We should determine our shelters in advance. [E]		

Continued on next page.

Group B					
	PB1	PB2	PB3	PB4	PB5
RK1	Evacuate to the opposite side of the ocean. [E]	The Abestate building is a shelter. [S]	I recommend the K-building wide and tall. [S]	Just a 20 cm high tsunami makes us injured. [D]	Tsunami speed increases at the deeper sea. [D]
RK2	Tsunami waves that come later will be higher. [D]	Shelters on the Tokushima University campus are quite wide. [S]	The K-building wide and tall is my recommendation. [S]	Collect accurate information. [E]	Evacuate by not individuals but a group. [E]
RK3	You should go to a school building if you do not know where to evacuate. [E]	Tsunami comes faster than you suppose. [D]	I recommend the gym (on campus) because it is large. [S]	The second tsunami wave is higher than the first one. [D]	The university gym has a big capacity. [S]
RK4	Tokushima University is a big capacity shelter. [S]	Evacuate quickly by your proper mean. [E]	Be careful of large tsunamis. [D]		Tsunami waves come again and again. [D]
RK5	Public facilities may be more suitable for shelters. [E]		The K-building is wide and tall. [S]		
RK6	You should evacuate to a shelter built at as a higher place as possible. [E]				

RK: registered knowledge, PA: participants in Group A, PB: participants in Group B

[S]: shelter-related knowledge, [E]: evacuation-related knowledge, [D]: disaster-related knowledge

Table 3 Acquired knowledge

Group A					
	PA1	PA2	PA3	PA4	PA5
AK1	Surprisingly, many shelters have small capacities.	Tokushima University can cover more than 1,000 evacuees.	Tokushima University has shelters where approximately 1,700 people can evacuate.	There are more buildings designated as shelters than I guessed.	There are not many shelters outside the university, and the capacities are less than 100.
AK2	There are many shelters other than public facilities such as the university.	An apartment my friend lives is assigned as a shelter.	More shelters exist in this area than I imagined.	I was surprised that the university has big capacity shelters.	The K-building's capacity exceeds 1,000.
AK3	The above-sea level around the university is low.			I realized that I do not know about disaster risk reduction.	The above-sea level is 3 m around the university.
AK4	The Tsunami inundation depth is 3 m around the university.			A few shelters are gathered in narrow areas.	
AK5	A map does not show which entrance we can enter shelters from.				
AK6	Shelter locations are easy to find on a map but difficult to recognize the first time I visited.				
Group B					
	PB1	PB2	PB3	PB4	PB5
AK1	Tokushima University has multiple shelters.	A three-meter-high tsunami may come to the Suketobashi area, and the Abestate building is a shelter.	The university has many facilities probably available for shelters.	There are small-capacity shelters around the university.	The university gym has a big capacity.
AK2	There are many shelters that I do not know.	The Suketobashi area had fewer shelters.	A signboard on an electricity pole often shows above-sea level.	Even distant from the coastline, many places will be damaged by tsunamis.	The capacities of the condominium or apartments are smaller than I expected.
AK3	Signboards show the above-sea levels.	Tokushima University can accept 1,800 people per shelter.			I should not forget the above-sea level and tsunami inundations.

AK: acquired knowledge, PA: participants in Group A, PB: participants in Group B

Table 4 Mean values (and standard deviations) of the five-point Likert scale questions

Questions	Group A	Group B
Q1. Do you agree that this game is enjoyable?	4.6 (0.74)	4.6 (0.80)
Q2. Do you agree that this game increased your interest in tsunami risk reduction?	4.0 (0.48)	4.4 (0.63)
Q3. Do you agree that this game is more effective for knowing tsunami shelters than looking at a hazard map?	4.4 (0.80)	4.6 (0.63)
Q4. Do you agree that registering the knowledge to digital creatures contributes to learning tsunami evacuation?	3.2 (1.01)	4.4 (0.40)
Q5. Do you agree that exchanging digital creatures with other players contributes to acquiring new knowledge?	N/A	4.2 (0.74)
Q6. Do you agree that exchanging digital creatures is effective for learning tsunami evacuation?	N/A	4.2 (0.74)
Q7. Do you agree that you want to actively exchange digital creatures?	N/A	4.4 (0.80)

Questionnaire

Table 4 presents the mean values and standard deviations of the questionnaire with five-point Likert scale questions. The mean values of Q1–Q3 were 4.0 or higher in both groups. However, for Q4, the mean value in Group B was 1.2 points higher than that in Group A. The mean values of Q5–Q7, which were only given to Group B, were higher than 4.0.

Discussion

Knowing shelters is considered acquiring shelter-related knowledge. To answer the two research questions, we focus mainly on participants' recalled shelter location and capacity, as well as registered and acquired knowledge.

RQ1. *Which promotes knowing shelters more, the single-player mode or multiplayer mode (Shelter GO)?*

First, we focus on shelter location and capacity that can be evaluated as quantitative data. Although Group B played the game approximately 10 min longer than Group A, participants in both groups visited a similar number of shelters (Num_VS) and tsunami-related spots (Num_VTRS), indicating that Group A participants visited shelters and tsunami-related spots more efficiently than Group B participants. The longer gameplay time of Group B participants resulted from the time spent on knowledge exchange because knowledge exchange entailed face-to-face interaction and additional app operations. In the four-phase process, visiting shelters is the prerequisite for knowing shelters. If deciding only from Num_VS and Num_TRS (i.e., frequencies of VO and VC phases) whether to promote knowing shelters, we assumed that both single-player (Group A) and multiplayer modes (Group B) were effective and had no remarkable difference.

In the recall test, Group A participants remembered more shelter locations than Group B participants (10.0 points higher in AccRate_ASL and 6.9 points higher in AccRate_VSL). However, the values of AccRate_VSL indicate that not all participants in both groups could perfectly recall even the locations of their visited shelters in their familiar area. On the other hand, Group B participants recalled more shelter capacities (1.8 points higher in Num_CRS) and remembered more accurate shelter capacities than Group A participants (16.0 points lower in Acc_RSC and 0.8 points lower in DifRatio_RSC). In Group A, two participants (PA3 and PA4) almost accurately recalled just the highest-capacity shelter (1,736 people) as 1,700 people, whereas one participant (PA5) recalled double the wrong capacities on average. On the other hand, Group B had difference ratios that were less than half as large and not remarkably dispersed. Due to limitations such as the small number of participants and short gameplay duration, it is difficult to determine the superiority in remembering shelter location and capacity by simply comparing the mean values. However, we assumed that the two modes were effective in that all participants in both groups remembered the locations and capacities of their visited shelters not perfectly but moderately within 1 h.

Furthermore, we focused on shelter features possibly included in participants' knowledge. Group A participants registered knowledge of collected digital creatures more eagerly than Group B participants (2.0 points higher in Num_RK). However, Group A participants acquired (itemized) knowledge only slightly more than Group B participants (0.8 points higher in Num_AK). Group A's mean value reflected the number of PA1's acquired knowledge, which was twice its registered knowledge. In addition, PA2 and PA3 may have unsuccessfully acquired knowledge because their values of Num_AK were significantly lower than those of Num_RK. PA2 registered four small pieces of shelter-related knowledge, including the university shelters' features (width, height, robustness, possible congestion), and PA3 registered shelter-related knowledge including an off-campus shelter's feature (height). However, PA2 and PA3 roughly remembered the university shelters' capacities as a part of their acquired knowledge (PA2-AK1 and PA3-AK1) but did not remember features. PA4 registered knowledge including shelter features (height and safety) but did not remember the features. PA1 and PA4 acquired comprehensive knowledge not limited to any particular shelter by observing multiple shelters (PA1-AK1, PA1-AK2, and PA4-AK4). PA5 roughly remembered the capacity of its visited university shelter even though its registered knowledge did not include the capacity (PA5-AK2). In Group B, Num_AK was lower than Num_RK in all participants. PB2 and PB3 registered knowledge including the university shelters' features (width and height), while PB1 and PB5 registered knowledge including abstract descriptions of the university shelter's capacity. Following that, only PB2 roughly remembered the university shelter's capacity (PB2-AK3), while the other participants did not remember concrete numbers of shelter capacities. However, none of the Group B participants remembered the features. In both groups, some participants roughly remembered shelter capacities as their acquired knowledge, but none of the participants remembered shelter features. One possible reason for the lack of remembered shelter features is that participants may have attached importance to shelter capacities rather than features because all shelters in the experimental area were concrete orthodox buildings that did not differ significantly in appearance except for the width. As PA1-AK1 and PB5-AK2 demonstrate, these participants may have had a significant effect on small-capacity shelters by knowing the capacities through the gameplay and consequently acquired knowledge, including shelter capacities rather than features. In other words, they may have thought that the priority for surviving an approaching tsunami was to disregard shelter features and instead enter a shelter. In addition, some participants may have integrated or abstracted a few pieces of registered knowledge and acquired them as one piece of knowledge. For example, PA2 registered four pieces of knowledge about the university shelters' features and then acquired them as integrated knowledge, not features but a rough number of capacities (PA2-AK1). PB3 registered two pieces of knowledge about the features of the university shelters and then acquired abstracted knowledge mentioning possible shelters on the university campus (PB3-AK1). Shelter features may have been reasonably converted to shelter capacities in their acquired knowledge. Although the number of acquired knowledge was small in both groups, all participants in Group A and three participants in Group B acquired knowledge including shelter capacities. We assumed that both the single-player and multiplayer modes promoted knowing shelter capacities and that the multiplayer mode was slightly superior when focusing on Num_RSC, Acc_RSC, and DifRatio_RSC.

For the questionnaire results, the mean values of Q1–Q3 were favorable and similar between Groups A and B. These results indicate that a location-based game such as Pokémon GO was accepted as a measure for knowing shelters regardless of the single-player and multiplayer modes. However, the mean values of Q4 showed an unignorable difference, indicating that Group B participants accepted knowledge registration more positively. Group A participants registered their knowledge to collect digital creatures more actively, but they disagreed on the contribution of knowledge registration. This result indicates that knowledge registration can be a burden in gameplay, preventing players from knowing shelters, and the single-player mode without knowledge registration (i.e., the previous game prototype) can be more acceptable. However, the positive acceptance of Group B may have resulted from knowledge exchange with encountered players that could not be realized without registered knowledge. We assumed that knowledge exchange in the multiplayer mode can reduce the burden caused by knowledge registration. Only the Group B questionnaire results of Q5–Q7 indicate that the participants agreed on digital creature exchange, including knowledge exchange, in addition to knowledge registration. Based on these affirmative questionnaire results, we assumed that the multiplayer mode can promote knowing shelters through the combination of knowledge registration and exchange.

Answer to RQ1: Both the single-player and multiplayer modes can promote shelter knowledge, but the multiplayer mode (Shelter GO) is expected to be more effective in terms of remembering shelter capacity and not preventing shelter knowledge.

RQ2. *How do players exchange knowledge in Shelter GO?*

All participants in Group B exchanged knowledge at least once. PB1 registered six pieces of knowledge and exchanged three pieces of knowledge; the number of its registered and exchanged knowledge was maximum in Group B. PB1 may have eagerly registered knowledge for more frequent knowledge exchange (i.e., acquiring more candidate knowledge for exchange). However, the number of PB1's acquired knowledge did not exceed that of other participants in Group B.

Under the experimental conditions (i.e., five participants in a 700 m^2 area within an average of 52.6 min), encountering another player and exchanging knowledge was rare. We found one case where knowledge exchange may have successfully affected knowing shelters (knowledge acquisition). On the prequestionnaire, PB2 itemized two pieces of knowledge that had already been acquired before the experiment:

- *My apartment was assigned as a tsunami shelter. During the earthquake, I evacuated to a higher floor of my apartment.*
- *The tsunami may reach fast. Thus, I evacuate quickly.*

On the postquestionnaire, PB2 itemized three pieces of knowledge acquired using the gameplay:

- *A three-meter-high tsunami may come to the Suketobashi area, and the Abestate building is a shelter.* (PB2-AK1)
- *The Suketobashi area had fewer shelters.* (PB2-AK2)
- *Tokushima University can accept 1,800 people per shelter.* (PB2-AK3)

Before the gameplay, PB2 did not know that Tokushima University had tsunami shelters (i.e., K-building and gym). For a while after beginning the gameplay, PB2 moved toward the Suketobashi area (outside the university campus) and visited a few shelters, including the Abestate building; PB2 may not have been interested in the university shelters. Following that, PB2 received the following knowledge from two encountered players outside the university campus through knowledge exchange:

- *Tokushima University is a big capacity shelter.* (PB1-RK4)
- *I recommend the gym (on campus) because it is large.* (PB3-RK3)

After receiving PB1-RK4 and PB3-RK3, PB2 visited and observed the K-building, the university's highest-capacity shelter (1,736 persons); PB2 did not visit the gym, the second-highest-capacity shelter (1,658 persons). Following the gameplay, PB2 recalled the shelter location and capacity almost accurately (PB2's DifRatio_RSC for the K-building was 0.05) and itemized knowledge including the concrete number of the shelter capacity (PB2-AK3). If the knowledge exchange had not occurred, PB2 may not have visited and consequently known the highest-capacity shelter in the university. Although it is insufficient to clarify the effects of knowledge exchange, we confirmed a successful case that knowledge exchange promoted knowing shelters. In addition, the questionnaire results showed that Group B participants agreed to knowledge exchange.

Answer to RQ2: Knowledge exchange may not be done regularly, but it does promote knowing shelters. Exchanged knowledge not only allows a player to receive knowledge from other players but also motivates the player to visit shelters that were not initially intended to visit.

Possible improvement

Shelter GO originally aims to promote knowing shelters, i.e., acquiring shelter-related knowledge. However, in the preliminary experiment, participants in both groups acquired not only shelter-related knowledge but also evacuation and disaster knowledge. Tsunami-related knowledge occupied approximately 30% and 26% of their registered and acquired knowledge, respectively. This is because knowledge registration was performed during the VC phase, i.e., tsunami-related spots in the experiment. Focusing on the original goal, we should change the opportunity for knowledge registration from the VC phase to the VO phase. A player must register shelter-related knowledge to knowledge stored in the app when observing a shelter rather than when collecting a digital creature; from the knowledge storage, the player selects knowledge to be registered to a digital creature. If we are focusing on acquiring wider knowledge, we should allow players to register knowledge during the VO and VC phases. In addition, knowledge registration should allow the uploading of multimedia data (e.g., picture, voice, and video) because text-based knowledge registration can be difficult to represent shelter location and features.

In the experiment, participants in Group B exchanged knowledge at least once, but we cannot ignore the fact that they were acquaintances who tried exchanging knowledge whenever they encountered it. When Shelter GO is released to the public in the future, players may have difficulty speaking to strangers, even if they recognized them as other players. To promote knowledge exchange, the Shelter GO app should encourage speaking to stranger players. For example, the app is expected to display knowledge-exchangeable players on a digital map while being careful about privacy issues.

Limitations

The most significant limitation was that the small number of participants was demographically restricted (i.e., ten acquaintance undergraduate students). The obtained data could not be analyzed using statistical methods. Furthermore, participants were not examined and homogenized in terms of their characteristics (e.g., physical condition, perceptual trait, and motivation) between the groups. The small number of Num_RK may indicate that participants have not been accustomed to itemizing their acquired knowledge. Thus, the findings may not be versatile or reliable. Five participants in Group B may have been difficult to be encountered within approximately 1 h, despite the small experimental area (700 m^2). If the five participants were not acquaintances, they may not be encountered.

If long-time gameplay was allowed in a wider experimental area, participants may have visited and known more shelters. In other words, the gameplay time was insufficient to collect many digital creatures, and participants may have abandoned the game before they found enjoyment in the digital creature collection. Participants in Group B may not have felt motivated to acquire a unique digital creature through digital creature exchange due to the small number of their collected digital creatures.

Considering these limitations, we must carefully apply the findings to the improvement and practical use of Shelter GO.

Conclusion

This study described Shelter GO, a multiplayer location-based game, which promotes players to know shelters (i.e., shelter location, capacity, and feature) according to the four-phase process, including the Preview, Walk, VO, and VC phases. The Shelter GO enables players to not only earn points in the VO phase and collect digital creatures in the VC phase but also exchange their collected digital creatures with encountered players. Digital creature exchange involves knowledge exchange, which entails knowledge registration of their collected digital creatures. The preliminary experiment implied that Shelter GO can promote knowing shelters, and knowledge exchange may not be frequently done but promote knowing shelters. The small-scale experiment had some limitations and was insufficient to clarify the effect of Shelter GO. Therefore, we must conduct large-scale experiments involving a diverse range of participants. In addition, we will improve the Shelter GO app while refining the visual design (e.g., more attractive digital creatures) to make it more appealing to the public.

Abbreviations

GPS: Global Positioning System; VO: Visit and Observe; VC: Visit and Collect; PHP: PHP Hypertext Preprocessor; CSV: Comma-Separated Values; PID: Participant ID; GP: Gameplay; VS: Visited Shelters; VTRS: Visited Tsunami-Related Spots; ASL: All Shelter Locations; VSL: Visited Shelter Locations, CRS: Capacity-Recalled Shelters, RSC: Recalled Shelter

Capacities; RK: Registered Knowledge; AK: Acquired Knowledge; EK: Exchanged Knowledge; M: Mean; SD: Standard Deviation; PA: Participants in group A; PB: Participants in group B.

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Authors' contributions
Hiroyuki Mitsuhara: Conceptualization, Investigation, System Development, Evaluation, and Writing and Editing; Masami Shishibori: Review, Supervision, and Project Administration.
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Declarations

Competing interests
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References

Atila, U., Ortakci, Y., Ozacar, K., Demiral, E., & Karas, I. R. (2018). SmartEscape: A mobile smart individual fire evacuation system based on 3D spatial model. *ISPRS International Journal of Geo-Information*, *7*(6), 223. https://doi.org/10.3390/ijgi7060223

Centre for Research on the Epidemiology of Disasters (CRED). (2023). *Emergency Events Database (EM-DAT)*. https://www.emdat.be/

Chittaro, L., & Nadalutti, D. (2008). Presenting evacuation instructions on mobile devices by means of location-aware 3D virtual environments. *In Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI'08)* (pp. 395–398). Association for Computing Machinery. https://doi.org/10.1145/1409240.1409297

Dransch, D., Rotzoll, H., & Poser, K. (2010). The contribution of maps to the challenges of risk communication to the public. *International Journal of Digital Earth*, *3*, 292–311. https://doi.org/10.1080/17538941003774668

Eksen, K., Serif, T., Ghinea, G., & Grønli, T. M. (2016). inLoc: Location-aware emergency evacuation assistant. *In Proceedings of 2016 IEEE International Conference on Computer and Information Technology (CIT)* (pp. 50–56). The Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/CIT.2016.72

Faccio, M., & McConnell, J. J. (2018). *Death by Pokémon GO: The economic and human cost of using apps while driving*. http://dx.doi.org/10.2139/ssrn.3073723

Finco, M. D., Rocha, R. S., Fão, R. W., & Santos, F. (2018). Let's move!: The social and health contributions from Pokémon GO. *International Journal of Game-Based Learning*, *8*, 44–54. https://doi.org/10.4018/IJGBL.2018040104

Harteveld, C., & Bekebrede, G. (2011). Learning in single-versus multiplayer games: The more the merrier? *Simulation & Gaming*, *42*(1), 43–63. https://doi.org/10.1177/1046878110378706

Itoi, J., Sasabe, M., Kawahara, J., & Kasahara, S. (2017). An offline mobile application for automatic evacuation guiding in outdoor environments. *Scientific Phone Apps and Mobile Devices*, *3*, 1. https://doi.org/10.1186/s41070-017-0013-1

Kanangkaew, S., Jokkaw, N., & Tongthong, T. (2023). A real-time fire evacuation system based on the integration of building information modeling and augmented reality. *Journal of Building Engineering*, *67*(15), 105883. https://doi.org/10.1016/j.jobe.2023.105883

Laato, S., Rauti, S., Najmul Islam, A. K. M., & Sutinen, E. (2021). Why playing augmented reality games feels meaningful to players? The roles of imagination and social experience. *Computers in Human Behavior*, *121*, 106816. https://doi.org/10.1016/j.chb.2021.106816

Lee, J. (2022). Problem-based gaming via an augmented reality mobile game and a printed game in foreign language education. *Education & Information Technologies*, *27*, 743–771. https://doi.org/10.1007/s10639-020-10391-1

Lee, J. E., Zeng, N., Oh, Y., Lee, D., & Gao, Z. (2021). Effects of Pokémon GO on physical activity and psychological and social outcomes: A systematic review. *Journal of Clinical Medicine*, *10*, 1860. https://doi.org/10.3390/jcm10091860

Lin, Y. T., Tseng, Y. M., Lee, Y. S., Wang, T. C., Tsai, S. I., & Yi, Y. J. (2018). Development of a SoLoMo game-based application for supporting local cultural learning in Taiwan. *Educational Technology & Society*, *21*(4), 115–128.

Macchione, F., Costabile, P., Costanzo, C., & Santis, R. S. (2019). Moving to 3-D flood hazard maps for enhancing risk communication. *Environmental Modelling & Software*, *111*, 510–522. https://doi.org/10.1016/j.envsoft.2018.11.005

Makinoshima, F., Imamura, F., & Abe, Y. (2016). Behavior from tsunami recorded in the multimedia sources at Kesennuma city in the 2011 Tohoku tsunami and its simulation by using the evacuation model with pedestrian–car interaction. *Coastal Engineering Journal*, *58*(4), 1640023-1–1640023-28, https://doi.org/10.1142/S0578563416400234

McCallum, I., Liu, W., See, L., Mechler, R., Keating, A., Hochrainer-Stigler, S., Mochizuki, J., Fritz, S., Dugar, S., Arestegui, M., Szoenyi, M., Bayas, J. L., Burek, P., French, A., & Moorthy, I. (2016). Technologies to support community flood disaster risk reduction. *International Journal of Disaster Risk Science*, *7*, 198–204. https://doi.org/10.1007/s13753-016-0086-5

Mitsuhara, H., & Shishibori, M. (2022). Shelter GO: Multiplayer location-based game for learning evacuation. In S. Iyer et al. (Eds.), *Proceedings of the 30th International Conference on Computers in Education, Vol. 1* (pp.514–523). Asia-Pacific Society for Computers in Education.

Mitsuhara, H., Inoue, T., Yamaguchi, K., Takechi, Y., Morimoto, M., Iwaka, K., Kozuki, Y., & Shishibori, M. (2015). Web-based system for designing game-based evacuation drills. *Procedia Computer Science*, *72*, 277–284. https://doi.org/10.1016/j.procs.2015.12.141

Mitsuhara, H., Miyoshi, N., & Shishibori. M. (2022). Location-based game for memorizing shelter locations, capacities and features. In *Proceedings of 2022 11th International Conference of Information and Communication Technology (ICTech)* (pp. 277–281). The Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/ICTech55460.2022.00062

Mitsuhara, H., Tanimura, C., Nemoto, J., & Shishibori, M. (2021). Expressing disaster situations for evacuation training using markerless augmented reality. *Procedia Computer Science*, *192*, 2105–2114. https://doi.org/10.1016/j.procs.2021.08.218

Oubennaceur, K., Chokmani, K., El Alem, A., & Gauthier, Y. (2021). Flood risk communication using ArcGIS StoryMaps. *Hydrology*, *8*(4), 152. https://doi.org/10.3390/hydrology8040152

Ramchurn, S. D., Wu, F., Jiang, W., Fischer, J. E., Reece, S., Roberts, S., Rodden, T., Greenhalgh, C., & Jennings, N. R. (2016). Human–agent collaboration for disaster response. *Autonomous Agents and Multi-Agent Systems*, *30*, 82–111. https://doi.org/10.1007/s10458-015-9286-4

Ruiz-Ariza, A., Casuso, R. A., Suarez-Manzano, S., & Martnez-Lpez, E. J. (2018). Effect of augmented reality game Pokémon GO on cognitive performance and emotional intelligence in adolescent young. *Computers & Education*, *116*, 49–63. https://doi.org/10.1016/j.compedu.2017.09.002

Solinska-Nowak, A., Magnuszewskiab, P., Curl, M., French, A., Keating, A., Mochizuki, J., Liu, W., Mechler, R., Kulakowska, M., & Jarzabek, L. (2018). An overview of serious games for disaster risk management – Prospects and limitations for informing actions to arrest increasing risk. *International Journal of Disaster Risk Reduction*, *31*, 1013–1029. https://doi.org/10.1016/j.ijdrr.2018.09.001

Song, J., Yamauchi, H., Oguchi, T., & Ogura, T. (2022). Application of web hazard maps to high school education for disaster risk reduction. *International Journal of Disaster Risk Reduction*, *72*, 102866. https://doi.org/10.1016/j.ijdrr.2022.102866

Tsai, M. H., Chang, Y. L., Kao, C., & Kang S. C. (2015). The effectiveness of a flood protection computer game for disaster education. *Visualization in Engineering*, *3*, 9. https://doi.org/10.1186/s40327-015-0021-7

Uchida, O., Tajima, S., Kajita, Y., Utsu, K., Murakami, Y., & Yamada, S. (2021). Development and implementation of an ICT-based disaster prevention and mitigation education program for the young generation. *Information Systems Frontiers*, *23*, 1115–1125. https://doi.org/10.1007/s10796-020-10082-9

Watanabe, K., Kawakami, N., Imamura, K., Inoue, A., Shimazu, A., Yoshikawa, T., Hiro, H., Asai, Y., Odagiri, Y., Yoshikawa, E., & Tsutsumi, A. (2017). Pokémon GO and psychological distress, physical complaints, and work performance among adult workers: A retrospective cohort study. *Scientific Reports*, *7*, 10758. https://doi.org/10.1038/s41598-017-11176-2

Winarni, E. W., Purwandari, E. P., & Hervianti, Y. (2018). Mobile educational game for earthquake disaster preparedness in elementary school. *ARPN Journal of Engineering and Applied Sciences*, *13*(7), 2612–2618.

Wu, M. H. (2021). The applications and effects of learning English through augmented reality: A case study of Pokémon GO. *Computer Assisted Language Learning*, *34*, 778–812. https://doi.org/10.1080/09588221.2019.1642211

Xu, X., Zhang, L., Sotiriadis, S., Asimakopoulou, E., Li, M., & Bessis, N. (2018) CLOTHO: A large-scale Internet of Things-based crowd evacuation planning system for disaster management. *IEEE Internet of Things Journal*, *5*(5), 3559–3568. https://doi.org/10.1109/JIOT.2018.2818885

Yamamoto, K., & Fujita, S. (2015). Development of social media GIS to support information utilization from normal times to disaster outbreak times. *International Journal of Advanced Computer Science & Applications*, *6*(9), 1–14. https://dx.doi.org/10.14569/IJACSA.2015.060901

Yamori, K., & Sugiyama, T. (2020). Development and social implementation of smartphone app Nige-Tore for improving tsunami evacuation drills: Synergistic effects between commitment and contingency. *International Journal of Disaster Risk Science*, *11*, 751–761. https://doi.org/10.1007/s13753-020-00319-1

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