Tag in the Park: Paving the way for Proximity-Based AI Pervasive Games

Eiman Kanjo, Kieran Woodward

***Abstract*—In this paper we introduce ”Tag in the Park”, a mobile platform merging short-range wireless communication and Artificial Intelligence (AI) to create an interactive gamified experience through virtual treasure hunts. Central to this is a mobile app that revolves around the interaction with a network of Bluetooth Low Energy (BLE) beacons and Near Field Communication (NFC) tags. These miniature smart devices provide contextual information, AI challenges, quizzes and nudges for a gamified, and active visitor experience which can help increase engagement and promote physical activity. ”Tag in The Park” is currently available for download on both Google Play and Apple Store and the platform is fully set up and open to visitors at Rufford Abbey Park, Nottinghamshire. Results indicate the mobile platform helps engage visitors, encourages exploration and increases visitor economy.**

***Index Terms*—SmartCity, Proximity, BLE, AI, Bluetooth, NFC, Gamification, App, pervasive, Location-Based**

I. Introduction

Location-based games offer fictive, large area, role-playing games that use the real world as the battleground between two game fractions. Players interact with the virtual and physical game space and overcome virtual challenges while moving around in the real environment. However many short-range communication technologies such as Bluetooth and Near Field Communication (NFC) are underutilised for entertainment purposes even though they can be used for proximity detection both indoors and outdoors. This provides an ideal opportunity to utilise this technology to gamify exploration and physical activity to improve health and wellbeing in cities and particularly rural areas such as villages where cellular and Global Positioning System (GPS) connectivity is often limited.

Pokémon Go [1] has received a lot of attention with the success of the game linked to the fact that it promotes physical activity and the exploration of nature. However, until recently, pervasive games have relied on GPS to locate players, which does not work well in indoor or urban environments due to urban canyons, where there are fewer visible satellites obstructed by tall buildings, causing the GPS signal to be degraded or lost. In addition, by relying on GPS, current location-based games do not connect players to their local environment, as the game can be played anywhere. There is a need for new types of pervasive games that are not solely reliant on GPS with venue-specific features that can link players to local Points of Interest (POI).

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The convergence of Internet of Things (IoT) and Artificial Intelligence (AI) has initiated a significant change in the way we perceive and connect with the environment around us. Tools such as Bluetooth beacons can help in providing an approximate location that can work indoors and outdoors and can help in identifying real-world physical elements. On the other hand, object recognition has significantly progressed in recent years with advances in deep learning and transfer learning, demonstrating great potential for a novel method of interaction. However, there has been little exploration of short-range communication and AI for entertainment purposes, particularly for location-based gaming.

This paper introduces a Bluetooth and AI-based gaming platform called ”Tag in the Park” that encourages people to identify a pre-defined set of Points of Interest (POI) by following the clues that are given to them as part of a virtual treasure hunt. At the heart of this platform is a mobile app that rewards players for visiting key locations by converging advances in AI and IoT for entertainment and removing the requirement for internet connectivity or GPS. These locations (POI) trigger quizzes and challenges and promote players to move strategically. These triggers are prompted when the players are in the vicinity of a Bluetooth Low Energy (BLE) device (SmartSpot) that can detect proximity and communicate contextual information. This enables a gamified, entertaining, and active visitor experience in large spaces including parks.

The contributions of this research is the novel combination of short-range communication and AI for entertainment purposes to promote physical activity and revolutionise location-based games by offering trails and activities that are customised to the host venue. This has much significance in GPS-deprived locations such as villages as it presents a way to offer location-based activities to the local community to educate and entertain through advances in smartphones, communication and AI. We have implemented our platform Tag in the Park at a local park using a real-world user testing methodology to gather feedback and report on the current status of the development. The remainder of this paper is organised as follows: Section II explores previous work, Section III discussed the method of developing the pervasive game, Section IV, examines the user testing and evaluation, Section V offers a discussion and Section VI concludes.

II. Existing Location Based Games

Combining exercise games (exergames) [2], and location-based features, Pokemon Go exploded onto smartphones in the summer of 2016 [1]. Many users have reported that their daily activity had increased since starting to play games such as Pokemon Go [3], which shows that location-based games can have a great benefit to the user's health. In the short term, the benefits that exergames bring to users' health are undeniable. However, for a user to maintain these health benefits for the long term, consideration of how to keep the user engaged also has to be considered.

Recently, there has been a rise in the number of location-based exercise games to promote physical activity including "World of Workout" [4] which is a mobile exergame that detects users' steps to play a conventional role–playing the game, completing quests by walking a specific number of steps. Similarly, in PiNiZoRo [5] players had to find enemies by walking and then complete puzzle games to defeat them. Zombies, Run! [6] encourages players to run in different directions in order to avoid virtual zombies. All of these games promote physical activity such as walking or running using only a smartphone app, however they all rely on GPS, not taking advantage of advances in IoT and AI to enable new game options.

Location-based games that rely solely on GPS could also include more technical issues due to the limitations and inherent flaws in GPS such as limited signal in densely populated areas. When users were asked about their experience using "Pokémon Go", GPS and networking issues were among the list of technical problems reported [7]. Since most location-based games rely heavily on GPS for location tracking, they don't link players to their local environment or key POI, which means the same game can be played in any place without giving the current area or venue any consideration. This demonstrates the need for utilising new alternative technologies for proximity and context awareness that is specific to the venue where the game is being played.

BLE has previously been explored for location-based games, [8] used beacons for outdoor positioning where the results showed BLE beacons' ability to provide better positioning results than GPS, not only in terms of accuracy but also in terms of stability of positioning results over time. BLE have also been used for geocaching however the experience had limited gamification and GPS was still used to measure distances [9]. Furthermore, mobile experiences using beacons have been developed for shopping malls [10] and attractions [11], [12] although these applications have very little gamification aspects and do not integrate other technologies such as NFC or AI. Furthermore many implementations are for basic navigation in city environments [12] where GPS would be better suited.

III. System Architecture

Motivated by the needs for new types of interaction that follow a challenge-based approach to keep people active while linking them with their local environment, we propose a proximity detection platform that combines short range wireless communication and AI using a gamification approach. A mobile app named "Tag in the Park" that integrates and communicates with short-range communication technologies has been developed to increase engagement with park visitors and promote physical activity. The app is currently available on both Google Play and Apple Store.

The "Tag in The Park" app has been implemented in a rural setting at Rufford Abbey Country Park, Nottinghamshire to engage visitors by offering specialised gamified trails and prompts users to remain physically active. Similarly to many rural areas, the park suffers from a lack of cellular and GPS connectivity making Bluetooth proximity detection an ideal solution. The platform was implemented as part of the Connected Forest project funded by the Department for Culture, Media and Sport. See [13] for an interview with the Mobile Magazine covering "Tag In The Park". The park currently hosts 16 SmartSpots that correspond to 16 POI, see Figure 1 for the game architecture linked to a map of the park.

The mission of this new type of proximity-based gaming experience is to encourage people to visit nearby PoI by providing engaging activities and educational content. A key design objective was to cover a large space and encourage users to explore the surrounding area through an interactive treasure hunt guided by prompts and nudges where as they get in close proximity to key POI the system can provide different modes of interactions. The app interacts with a network of devices equipped with short-range wireless communications (Bluetooth, and Near Field Communication (NFC)) that can unlock rich media content. Some of these devices (SmartSpots) are active utilising BLE and are distributed around the game space to represent POI, when the user gets closer their presence triggers a game action, for example in the form of a quiz or a camera-based AI challenge. Others are passive utilising NFC (SmartDots) which can be tapped, to provide venue-specific contextual information. The mobile platform offers the following features:

- **Gamify Everything**, the platform is customised to the features and attractions of the local environment and the seamless design is fully integrated in the challenges of the game. Players earn points when visiting locations and completing activities to provide an entertaining and motivating experience.
- **Reward based**, the platform prompts visitors to be physically active and to visit as many POI around the site as possible. The total points (p^{TOTAL}) is proportional to the number of POIs covered ($p^{\text{Locations}}$), the steps (p^{Steps}), the total distance covered ($p^{\text{Locations}}$) and the time taken (p^{Time}) as shown in the following equation:

$$\begin{aligned} p^t &= (p^{\text{Steps}}/1000) + p^{\text{Locations}} \\ p^{\text{D}} &= p^{\text{Distance}} / p^{\text{Time}} \\ p^{\text{TOTAL}} &= p^{\text{D}} + p^t \end{aligned} \tag{1}$$

- **Promote Physical Activity**, the game offers a real-time step count to encourage increased physical activity.

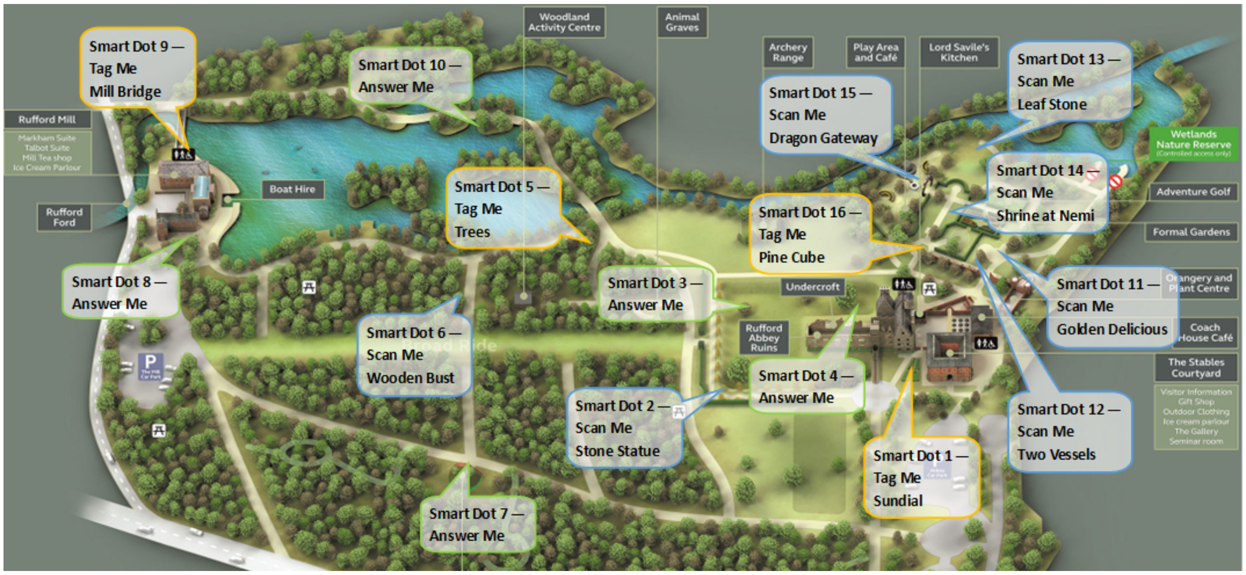

Fig. 1. Tag In The Park map showing each of the 16 PoI for the AI (Scan Me), Quiz (Answer Me) and NFC (Tag Me) activities.

- **A freestyle game**, players can start at anytime and at any point or location around the park, and there is no time limit for how long they can play. Furthermore, the game can be played in groups or individually.
- **Minimal Screen Interaction**, the game is designed to keep people in sync with nature. Players can walk freely and check their app when they get a notification (indicated by vibration) to take the next challenge.

A. *Proximity Detection*

"Tag in the Park" has been developed for open-space environments, indoors or outdoors where there is limited internet and GPS connectivity. Instead, BLE-based proximity detection poses a viable alternative to GPS-based location tracing as it relies on a short-range communication transceiver to detect the presence of users in nearby vicinity.

Short-range wireless communication transceivers such as Bluetooth (BT) are widely incorporated into smartphones. BT devices can interact with other nearby devices within their signal range ($10m$ to $100m$, depending on the radio transceiver) by emitting radio waves within a band of 79 different frequencies centred at 2.45 GHz. Using such radio waves, along with the identification capabilities provided by the unique MAC address assigned, a BT device can continuously sense the presence of other devices nearby.

Bluetooth beacons are low-power devices that emit a signal that can be detected by mobile devices within a certain range, typically between a few meters to tens of meters. Beacon communication is based on the modulation of the BLE signal, which includes the amplitude, frequency, and phase of the signal. iBeacon and Eddystone are two proximity beacon technologies that enable mobile devices to detect and interact with nearby beacons. iBeacon is a proprietary beacon technology developed by Apple that uses a fixed data format to transmit a unique identifier, called a UUID, along with a major and minor value, that can be used by mobile applications to determine the proximity of the beacon. iBeacon also allows for custom data payloads to be included in the transmitted signal. iBeacon uses a transmission power level between -30dBm to +4dBm, with a default value of -12dBm. In comparison, Eddystone is an open-source beacon technology developed by Google that uses a flexible data format to transmit several types of data, including a unique ID, telemetry data, and URL links, that can be decoded by mobile applications that support the Eddystone protocol. Eddystone also supports a configurable transmission power level between -40dBm to +4dBm.

The Received Signal Strength Indicator (RSSI) provides an estimated measure of the power present in a received radio signal. As shown by previous RF-based research [14], [15]. The RSSI can be used to calculate rough distances using equation 2 where N is a constant that depends on the environmental factor constant between 2 and 4, enabling the app to understand relative proximity to the beacon and therefore different POI at the park. RSSI measurement is a crucial component of BLE communication, as it is used for power control, adaptive frequency hopping, and distance estimation. The RSSI value is affected by several factors, including the transmission power, the receiver sensitivity, the noise level, the interference, and the fading. The channel condition can be characterized by the channel impulse response, which describes the propagation delay, the attenuation, and the phase shift of the Bluetooth signal.

$$\text{Distance } = 10\left(\frac{\text{Measured Power - RSSI}}{10^{\star N}}\right) \tag{2}$$

To explore the capabilities of Bluetooth-based distancing 3 phones were used to measure the distance from a BLE beacon from 0.5m to 30m. Table III-A shows the distances calculated using the received RSSI values. The results show that as the distance increases between the phone and the BLE transmitter the average error also increases from an error of 0.17m at a distance of 0.5m to an average error of 12.07m at 30m. This demonstrates that measuring nearby distances using Bluetooth signals can be relatively accurate but distances over 5m show larger variations. ”Tag in the Park” can therefore be used to detect when players are near, close and far from the location, making it ideal for a treasure hunt where the aim is for players to explore the surrounding area to find the location as more precise navigation instructions would defeat the purpose of the game.

TABLE I
COMPARISON OF ACTUAL DISTANCE FROM A BLUETOOTH BEACON WITH CALCULATED DISTANCE MEASURED USING THREE PHONES.

Actual distance	Pixel 3	Samsung S20	iPhone 11 Pro	Avg error
0.5m	0.8m	0.5m	0.3m	**0.17m**
1m	0.8m	1.5m	1.1m	**0.27m**
2m	2.8m	2.2m	2.2m	**0.4m**
5m	2.5m	1.4m	2.5m	**2.87m**
10m	5m	3.5m	8.9m	**4.2m**
20m	14.1m	8.9m	19.9m	**5.7m**
30m	50m	31.6m	44.6m	**12.07m**

”Tag in the Park” employs devices called SmartSpots that are based on Nordic Semiconductors nrf51822 chipset and simultaneously broadcast iBeacon for iOS users and Eddystone for Android users. The smartphone receives the BLE signals and provides direction to the users making the system workable in both indoor and outdoor environments. The main game screen of the app scans for these SmartSpots in the background while offering haptic feedback that increases in speed as the user walks closer to the POI. The screen displays text in the centre of the screen providing context to the player helping them to navigate to each of the locations by showing their approximate distance to the nearest POI along with its image, total points earned and image representations of each remaining treasure hunt locations.

When playing the game, as players gets in close proximity to a SmartSpot the app will give the following onscreen messages: (i) *keep walking* when no SmartSpots can be detected, (ii)*getting close* when a SmartSpot can be found but is a significant distance (20m+), (iii) *nearby* when the SmartSpot is 10m-20m away and (iv)*very close* when the SmartSpot is around 5m-10m away. While these contextual clues do not provide exact navigation, this is part of the gaming experience where players are encouraged to explore the surrounding area in order to find the treasure hunt POI. Once the player is very close (5m) to a location, the player will earn a point and an interactive activity (challenge) will be presented, these are (i) scanning an object: users are prompted to search for and tap a nearby NFC tag; (ii) Camera-based AI challenge: users are prompted to scan a nearby point of interest using the smartphone’s camera where an AI model infers whether the user is scanning the correct object; (iii) a quiz where users need to answer a location-based question.

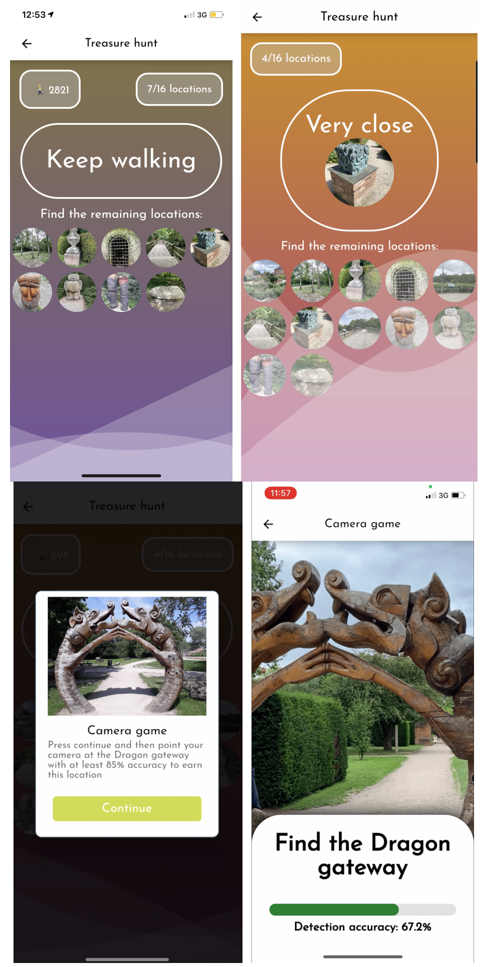

Fig. 2. ”Screenshots showing the main game screen when far away from a POI (top left), when very close to a POI (top right), the AI camera game instructions (bottom left) and when playing the AI camera game (bottom right).

B. Tagging

The use of radio frequency identification (RFID) has exploded contributing to the realisation of smart environments. Near field communication (NFC) is one of most widely used RFID standards when the communication range is short. NFC communication allows two devices to exchange data by bringing them close to each other, typically within a few centimetres. Passive NFC tags are low-power devices that can be attached to physical objects. NFC-enabled smartphones can read the data of passive NFC tags by bringing them close to each other, typically within a few centimetres.

Passive NFC cards (SmartDots) shown in Figure 4 have been placed in the park. As users approach the area, the app prompts them to find and tap a nearby SmartDot to earn a point and continue with the treasure hunt. The app then uses the smartphone’s NFC reader to read the data encoded within the NFC tag in order to complete the activity.

The NFC communication between the smartphone and the passive NFC tag supports several data rates. The data rate is affected by the signal strength, the distance between the smartphone and the passive NFC tag, and the interference from other wireless technologies. Attenuation can also affect the NFC communication between the smartphone and the passive NFC tag. Attenuation occurs when the NFC signal is weakened as it propagates through the environment, which reduces the signal strength and affects the performance of the NFC system. Attenuation can be caused by obstacles, metal surfaces, or other materials that absorb or scatter the magnetic field. Therefore, careful consideration is required when deploying NFC tags in real-world environments.

C. Object Detection

Advances in AI, in particular deep learning have resulted in the capability to classify images with increasing accuracy. However, the use of AI and object recognition for entertainment purposes within a game has not had much consideration. "Tag in the Park" utilises advances in object recognition as part of the treasure hunt where players are tasked with finding specific objects identified through the AI.

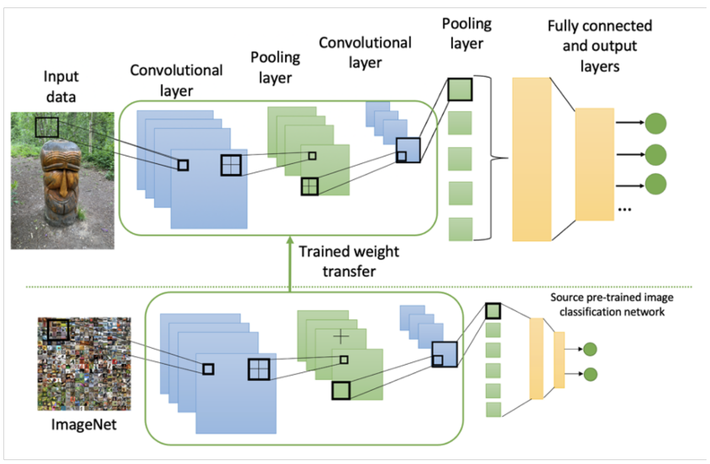

Fig. 3. Transfer Learning architecture, adapting a pre-trained model to classify park sculptures.

Transfer Learning (TL) is a common approach in deep learning to improve the learning of a target task to improving initial performance. TL capitalises on a large dataset stemming from a related problem to pre-train a model, and then adapting the model for the smaller target dataset. A pre-trained network alleviates the need for a large dataset while simultaneously decreasing the time required to train the model. TL has facilitated training new models in the visual domain using pre-trained CNNs and has been utilised within "Tag in the Park" to learn new objects for the AI object recognition activity.

Taking advantage of the unique PoI at Rufford Abbey Country park around 200 photos each of the 10 sculptures were captured with different angles and lighting conditions for model training. Using a pre-trained model initially trained using a large ImageNet dataset, a CNN was trained with the images of sculptures using a TL approach as shown in Figure 3. The accuracy of the model (using hold-out validation) is 99%, demonstrating the ability of the model to infer each of the key features with extremely high precision.

As users approach different sculptures, the camera turns on for the players to find the nearby POI which then gets identified by the pre-trained AI model embedded in the app, enabling frames from the camera to be classified in real-time. The real-time inference accuracy from the camera feed is displayed on-screen and if the accuracy is above 85%, the location has then been 'found' and the user earns a point. Figure 2 shows screenshots of the camera-based AI activity and the progress of the AI model detecting the sculpture.

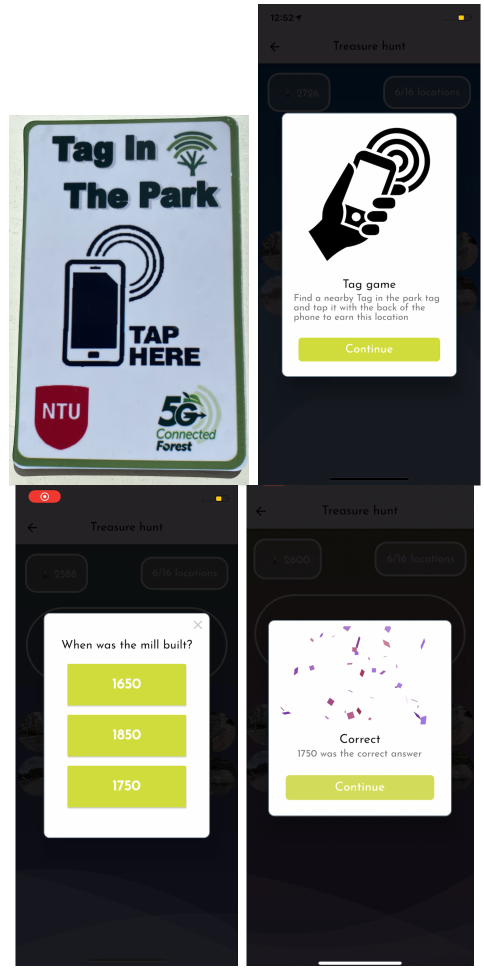

Fig. 4. "Screenshots informing the player to tap a nearby hidden smartDot (top right) and a smartDot tag (top left), an example quiz question (bottom left) and the congratulations screen after answering the question (bottom right).

D. Quiz

Informative questions with multi-option answers are triggered in areas where there is educational content, such as historical landmarks, asking the user a question that helps the players gain knowledge of the place's heritage. Once the player answers the question they are informed of the correct answer and can continue with the game.

IV. Users Testing and Evaluation

In total, "Tag In The Park" achieved 612 app downloads from the Google Play Store and the Apple Store in 6 months. Out of these users 120 participants aged 18+ (73 male, 44 female, and 3 other) were recruited to test the app and complete pre-app and post-app technology acceptance questionnaires with a focus on their opinions of location-based games and the performance of the app. When testing the app participants were encouraged to walk around the park and visit the treasure hunt locations within the park to unlock location-specific activities.

The results from the pre-app survey show that the majority of participants were extremely interested (55%) or very interested (32.5%) in location-based games and similarly were extremely (57%) or very interested (35%) in the concept of ”Tag in the park”. In particular, participants thought that a mobile app would help in encouraging visitors to attractions and parks and to spend more time in green outdoor spaces. In addition, most of the participants agreed that a treasure hunt-style app would greatly encourage families and children to visit the location, potentially helping promote physical activity.

Out of the 120 participants who completed the initial survey, 105 played the ”Tag in the Park” game at Rufford Country Park and then completed the feedback survey. Figure 5 shows majority of the respondents enjoyed the app, found the app easy to use, would use the app again to increase their physical activity and were likely to recommend it to a friend.

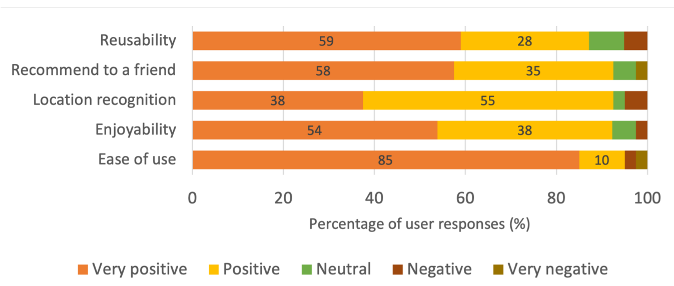

Fig. 5. Chart showing percentage of user responses for 5 questions.

One of the first remarks of our users was that the game was ”thrilling” in particular because it strengthened their relationship with the green spaces around them. Users also reported that they were attracted to the app and frequently engaged with it in particular due to its dynamic nature where the game can be started from any point and played in any order unlike traditional treasure hunts. Participants were also asked how long the game took them to complete, with the most common response being 2-3 hours compared to the 1-2 hours visitors normally spend at the park. This demonstrates the ability for ”Tag in the Park” to encourage visitors to spend longer at attractions, thus increasing the visitor economy. Furthermore, participants found the beacon distancing reliable and all but 1 participant visited more than half of the locations and 34% visited all 16 locations, demonstrating the ability for the mobile platform to promote exploration. For those who didn’t manage to find all of the locations many stated they aim to re-visit the park to find the remaining locations, demonstrating the positive impact of the app. Finally, participants stated that the only way to improve the game would be to add more POIs as the app helped them stay engaged with the park, benefiting their health.

V. Discussion

This work demonstrates the unique opportunities provided by recent advances in AI and short-range communication to create an engaging experience through the use of gamification without the requirement of internet connectivity or GPS. ”Tag in the Park” demonstrates the capability to develop venue-specific games that link people to their local environment, which large open games such as Pokemon go fail to achieve. This work has significant contributions for GPS-deprived locations to promote physical activity and increase engagement with the local environment. This work could have many implications for the development of smart villages to help gamify exploration while also promoting physical activity.

A unique aspect of ”Tag in the Park” is its ability to work both indoors and outdoors, with the current implementation at Rufford Abbey Country Park demonstrating the feasibility of the platform with a lack of cellular and GPS connectivity. While the BLE proximity-based approach used by ”Tag in the Park” requires physical devices to be placed around the host venue, this enables the platform to function both indoors and outdoors. Furthermore, the app is venue-specific, meaning it takes advantage of the local POI, which helps connect people to the local environment; it is not designed for immediate global roll out but rather a more tailored experience to digitise individual routes, attractions and villages.

While BLE distance estimation is not as accurate as location-based systems such as GPS, precise navigation is not required as part of the experience of the treasure hunt is exploring the surrounding area to find the location prompted by clues resembling the children’s ”Hot or cold” game. The distance estimation was reported to be accurate during the trial and offers a seamless experience compared to other technologies previously explored for digitised treasure hunts, such as QR codes, as it offers real-time clues to help users find locations. In comparison to previous works that mostly focus on using BLE for navigation [10]–[12], Tag in the Park gamifies the entire experience to encourage exploration and promote physical activity. We capitalise on BLEs strengths to guide the user to each of the POI rather than specific navigation.

Positioning the SmartSpots around the POIs requires much careful consideration. For example, a large hedge on the side of a statue has affected the proximity distance between the user and the key park feature, which triggered the AI object recognition activity even though the player could not see the statue. Furthermore, phone manufacturers use different BLE radio chips, resulting in slight inconsistencies when measuring RSSI values. This prevents the accurate measurement of distance between the phone and the SmartSpot, making the more generic on-screen messages that are used to guide users to the next POI ideal.

When evaluating battery performance, we found that the display was responsible for draining most power. One way to reduce power consumption is to let users turn off screen displays at their own discretion and rely on haptic feedback to alert the user when they are in proximity of a POI, which will offer higher fidelity. However, battery drain was significantly less than that of comparative GPS-based games.

VI. Conclusion and Future Work

Overall, "Tag in the Park" presents a significant opportunity by enabling a new form of physical location-based gaming. It opens the door to a new wave of opportunities for ubiquitous experiences by leveraging AI and short-range communication technologies such as BLE and NFC negating the requirement of GPS or internet connectivity for location-based exploration gaming. In general, the flexibility and venue personalisation aspects of the platform make it possible to engage communities and "Tag In The Park" is only one application of many that could be developed for smart cities such as those for retail, school, and museum settings.

Future versions of the platform will include: (i) Authoring tools toward a content-independent platform (ii) Improved interaction style to include voice, and (iii) a wearable version of the game.

VII. ACKNOWLEDGMENT

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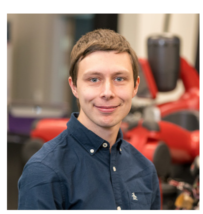

Dr. Kieran Woodward, is Research Fellow in Pervasive Computing at the Smart Sensing Lab, Nottingham Trent University. Kieran conducts research in Data Science, Affective Computing and Pervasive Technologies. He completed his PhD at Nottingham Trent University exploring the development of technological solutions for mental wellbeing monitoring. During this time Kieran developed novel deep learning approaches to improve the personalisation of affective modelling and improve classification performance resulting in numerous publications.