2084 – Safe New World: Designing Ubiquitous Interactions

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ABSTRACT
This paper investigates a concept for highly ubiquitous game interactions in pervasive games. Pervasive gaming is increasingly popular, but steadily improving mobile and ubiquitous technologies (e.g. smartwatches) have yet to be utilised to their full potential in this area. For this purpose, we implemented *2084 – Safe New World*; a pervasive game that allows particularly ubiquitous gameplay through micro interactions of varying duration. In a lab study, different interaction techniques based on gestures and touch input were compared on two mobile devices regarding usability and game input observability. A second study evaluated the player experience under more realistic circumstances; in particular, it examined how well the game can be integrated into everyday life, and tested boundaries of social acceptance of ubiquitous interactions in a pervasive spy game.

ACM Classification Keywords
K.8.0. General: Games; H.5.2. User Interfaces: Interaction styles (e.g., commands, menus, forms, direct manipulation)

Author Keywords
pervasive games; game interaction; ubiquitous interaction; social acceptance; player experience; usability; observability; smartwatch

INTRODUCTION
In recent years, pervasive games have seen a rise in popularity; e.g. *Ingress* [26] is very popular and has been attracting large numbers of players for years. *Pokemon Go* [27] is another pervasive game that enjoyed a very successful start upon its recent release [32]. While there are a variety of different definitions for the genre of pervasive games [4, 14, 24, 29], they usually have in common that the game's virtual world is in some way interwoven with the real world. However, the degree of this integration varies quite a lot from game to game. Pervasive games often cannot be very well integrated into the daily life of the players. In a lot of pervasive games, players must actively decide to play a game session, e.g. through deliberate exploration of a portal in *Ingress*. In this paper, we present the concept of particularly ubiquitous pervasive games, i.e. pervasive games that are interwoven more unobtrusively into everyday life.

* These authors contributed equally to this contribution.

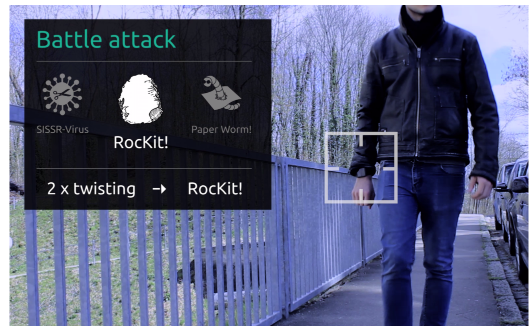


Figure 1. A player of the pervasive game *2084 – Safe New World* interacting with the game without interrupting his everyday life.

In order to achieve a high degree of integration into everyday life, it is important that a particularly ubiquitous pervasive game does not enforce game sessions that are entirely separate from the everyday activities of the players. For that purpose, players should be able to interact with the game via interactions with brief durations, before returning to their current activities, ideally with only a bare minimum of interruption to these. Thus, interaction with the game ideally consists of short and spread-out interactions rather than long clearly-defined periods of game play. In order to provide a well-rounded gaming experience, however, it is necessary that the interactions are embedded into a larger game metaphor. Thus, we argue for a game that is *always-on*, which can be realized by an extension of the game's temporal and spatial dimensions, e.g. through the mixed-reality hybrid game space that is inherent to the pervasive game genre. Consequently, interaction with the game takes place within this larger game metaphor and is often triggered by external factors such as for example temporal, spatial or even social circumstances. This design allows for the desired integration of the pervasive game into players' everyday lives, as the temporal, spatial and social features are not fixed factors but remain flexibly triggered.

We implemented the concept in *2084 – Safe New World*, a multiplayer pervasive spy game. Players are always part of the game's alternate reality, i.e. they become spies in a futuristic world in which data is used as currency. The players can interact with the game, i.e. with the other players, through two game modes: the *battle* and the *shadowing* mode. The *battle* mode employs a player-vs.-player paradigm using symmetrical micro interactions, i.e. both players can perform the same game input. This mode requires that players are potentially able to see each other and is thus triggered by physical proximity to another player. In the *shadowing* mode, a player has to stay in close proximity to another player (following them if necessary) for as long as possible, while attempting to not be noticed. This mode is also indirectly triggered by physical proximity of other players, but due to its slightly longer interaction time requires the player to actively indicate readiness to participate. The player that is followed, however, participates passively in this interaction and interacts with the system only when they suspect they are being followed. Thus, both game modes contribute to the game's integration into the players' everyday life in slightly different ways, in that game interactions can take place anywhere and anytime. Further, the game mechanics encourage brief interactions for which players often do not have to interrupt their non-gaming tasks during daily life at all, or can return to them very quickly.

The contribution of this paper consists of the following:

- the design of interactions for technology-based pervasive games including such that involve wearables which are particularly challenging because of their limited interaction space
- an empirical contribution in form of a user study exploring the effects of interaction methods in technology-based pervasive games on observability, usability, and social acceptance
- a second empirical contribution with a user study evaluating the social acceptability of playing a smartwatch-based pervasive game in a natural setting

RELATED WORK

The genre of pervasive games is an ambiguous domain, encompassing several overlapping or contradictory categories depending on the researcher's favoured definition [14, 7]. Most of them, however, involve the merging of a virtual and physical space into a hybrid game world, through spatial, temporal, or social expansion [24] of the so-called magic circle [39]. In 2007, Nieuwdorp published a detailed analysis of the terms used in this genre, in particular, the confusion over two different perspectives on "pervasiveness": technological (i.e. the focus lies on the technologies used, showing close ties with the genre's origins in pervasive computing) vs. cultural (with a focus on game world properties) [29]. Following her recommendation, we do not attempt to find the best suited label for the type of pervasive games we are investigating, but rather will describe the ways in which our concept is pervasive.

The focus of this paper lies on games that are *always-on*, i.e. the player can at any point in their daily lives be engaged in active gameplay (i.e. temporal and spatial pervasiveness). Active gameplay is triggered by player proximity, with a focus on player-vs.-player interaction, although players' identities are not generally known (social pervasiveness). While there are many pervasive games that affect social acceptability, e.g. *Killer – Game of Assassination* [16], in the following we focus on technology-enabled pervasive games.

Temporal and Spatial Dimensions

For the purpose of integrating our concept into a broader classification, we discuss dimensions of temporal and physical pervasiveness with the help of several examples. Some games are pervasive only in the physical sense, but not the temporal; the player can partake in the game at any location, but only at certain times. Any casual mobile game that enforces or restricts the times of gameplay can be considered part of this category. For example, *Clash of Clans* [40] features many periods during which the players can do nothing but wait, e.g. until the construction of a game object is complete. Other games are similarly temporally restricted, but additionally enforce a physical setting. For instance, the mobile multi-player game *Pirates!* [6] focuses on player-to-player proximity to trigger battles in a seafaring narrative. The game is temporally restricted (i.e. event-based [23]), but also physically restricted to a delimited area. Games such as *Mogi* [17] feature temporal pervasiveness, but physical restriction to a city, i.e. Tokyo. In this location-aware mobile game, players collect virtual objects located in the physical city space.

The addition of physical pervasiveness to this kind of game is exemplified by *Botfighters* [2] and *Alien Revolt* [37]. The latter was investigated in an early case study by De Souza E Silva. In this game, players are notified of each other's presence at a 3km range, while player-vs.-player fights are triggered when within 200m. The success of these fights is based on distance, luck, and equipment; the objective is to gain as many points as possible through winning fights. As such, their game principle is quite similar to part of our own, in that they feature player-vs.-player battles triggered by proximity. Similarly, *Ingress* (see [20] for an overview) gained popularity quite rapidly several years ago, and consists of geographic battles between opposing teams. Another game in this temporally and physically pervasive category is called *Feeding Yoshi*: this game is set up to be long-term and wide-area. Players collect points by growing and collecting fruit in the environment in order to feed Yoshi creatures. Player proximity triggers the opportunity to swap fruits.

Social Acceptance

The issue of social acceptance is especially problematic for pervasive games, as by definition they expand on traditional boundaries of play. The spatial expansion in particular means that players will likely encounter non-players during the game. Further, the social expansion mentioned previously blurs the line between the identity of players and non-players: players cannot be certain who is part of the game; sometimes, non-players are even actively involved through the game mechanics. The issue is further complicated by the fact that socially acceptable gameplay differs significantly between individuals [30]. Much like the definition of pervasive games, the issue of social acceptance can also viewed from two perspectives: technological and cultural, i.e. the acceptance of specific interactions in public, and the acceptance of playful behaviour in general. Playful behaviour is generally seen as positive, but nevertheless is subject to many social conventions. Certain interaction methods and devices may similarly be frowned upon or draw attention in certain situations, although there is little research comparing social acceptance for specific interaction and device combinations. The case study on *Feeding Yoshi*, for instance, discussed players feeling odd walking around with a PDA device. One player described being asked by a stranger if they were lost, and many reported strange looks: "the distinctive [...] movements required by the game would draw attention" [3]. Similar feelings can be expected for interaction with smartwatches as they are a new technology as PDAs were then. The involvement of bystanders has significant implications on privacy, as discussed by Niemi et al. [28] with a focus on design factors, e.g. ways of ensuring informed consent to participation, to whichever degree. They also found opinions on such privacy issues are highly subjective, and differ particularly between adults and adolescents, potentially hinting at a generational attitude shift. On a similar note, a study by Friedman et al. [13] indicates that people generally expect a modicum of privacy even in public. In-game social conventions also occur; players of *Mogi* developed the expectation of acknowledgement of other players' proximity (apologizing for delays in such). Face-to-face meetings were often suggested, but generally declined.

Our game concept includes a *shadowing* mode in which players are required to follow each other. This is a particularly difficult subject for social acceptance. For instance, *Mogi* game designers discussed safeguards against stalking (a case study of a suspicious proximity event in *Mogi* is discussed by Licoppe and Inada in a different paper [18]). However, other researchers have encouraged the use of playful interactions proxemic to bystanders and/or in public spaces. Mueller et al. [25] report that the breaking of social or cultural norms may be permitted or even thrilling, and cite examples such as *Twister* [21], their own *Musical Embrace* [25], and *WarDriving* [5] as such examples. In summary, the issue of social acceptance for pervasive games is difficult, but important, and requires a case-by-case analysis.

Ubiquitous Gesture Interaction

The nature of our game concept requires the design and implementation of ubiquitous interactions for the game mechanisms. We consider interactions ubiquitous when they fall in line with Weiser's vision of ubiquitous computing: unobtrusive and simple, so as to become part of everyday life [41]. Yet the game also requires that the interactions potentially be distinguishable by players in viewing distance. This necessitates a fine balancing in the interaction design. Further, for user acceptance, feedback appears to be particularly important for hands-free and eyes-free interaction methods [34, 9, 19], requiring a two-part consideration of interaction design: both the interaction itself and the type of feedback used should be considered socially acceptable. Nowadays, almost everyone carries a smartphone or a watch (smart or otherwise), or even a combination thereof. The interaction with these systems should thus not be obtrusive in and of itself, as the general public is accustomed to it. However, the least obtrusive method for this interaction is not immediately clear. The list of potential methods for human-computer interaction is long and varied, and even the reduction to two devices – the smartphone, and the smartwatch – leaves a lot of possibilities. The options include speech, gestures, haptics, and additional pointing devices, as well as various combinations thereof.

Social acceptability is considered an important factor in human-computer interaction, and researchers of this topic have discovered a multitude of variables that influence it, among them user type and culture [22]. Rico and Brewster [33] investigated various interaction methods in regards to their social acceptability through an in-the-wild study, and discovered that subtle movements are generally more socially acceptable, as are gestures which pass for everyday movements. The importance of small motions for greater social acceptability in gestures is echoed by Linjama et al. [19] and Ronkainen et al. [34]. Nevertheless, depending on the use case, the degree of noticeability and social acceptance for a specific interaction method may vary significantly. For instance, wrist rotations were found to be generally quite acceptable by Rico and Brewster, whereas participants in a study by Wiliamson et al. [42] reported feeling uncomfortable using this in public. Wiliamson et al. distinguish between different types of public settings: those with transient spectators (passersby) and those with sustained onlookers (e.g. being stuck in the same public transport carriage). Further dimensions to device input could be achieved, for example through adding degrees of freedom to the smartwatch's face, allowing more focused interactions [44]. However, this addition would require both hands, and may cross the line to becoming *too* easily distinguishable.

Pervasive Wearable Games

There is an increasing amount of games for use on wearable devices, however, many are simply the adaptation of already existing games for use on a new device, such as the puzzle game *2048 Wear* [10]. Yet the use of a wearable device offers many possibilities for pervasive games. Some games are of course more suited to this kind of adaptation than others; for example, the previously mentioned *Ingress*, one of the most popular pervasive games, has been extended to allow gameplay with Android Wear smartwatches [38]. Another game that features a pervasive element is *Sonic Dash 2* - this game is for mobile devices, but can be extended with an Apple Watch app that bestows helpful skills in-game for reaching a daily step goal [12].

So far, it seems that few games are designed explicitly with the properties of a wearable medium in mind. Nevertheless, we will discuss two games that exhibit such properties. Real-time interactive fiction games have found newfound popularity on the smartwatch with games such as *Lifeline* and *Spy Watch*. In *Lifeline* [1] (100,000-500,000 installs as of April 2016), the player has to help a crashlanded astronaut survive on a distant planet, by answering messages delivered through notifications on the player's watch. The principle of *Spy Watch* [8] is similar: the player acts as the handler of a fictional spy agent by sending instructions, and replying to questions sent through the watch's notifications system. This kind of game works well as a ubiquitous game that is played via micro interactions throughout everyday life. However, smartwatches are still not particularly prevalent among the general population, as shown by a recent survey by Shirazi and Henze [36]. This survey also showed how users rate the importance of notifications on various devices when considered for certain categories, among them games; 67.7% of 440 participants did not choose any device for the games category. Together, this may indicate that users require more experience with smartwatch games before they associate gaming with such devices.

THE GAME: 2084 - SAFE NEW WORLD

The main objective of this game consists of a high degree of integration into daily life, i.e. a particularly ubiquitous pervasive game. The concept is thus based on micro interactions with mobile and wearable devices, in order to provide a game that is *always on* – through two game modes with a total of three kinds of interactions. The first game mode provides a player-vs.-player mechanism, triggered by the system based on player proximity. The game input is contributed via micro interactions and is symmetrical, i.e. game interaction is the same for both players in this mode. The second game mode is asymmetrical, in that it consists of two different variants – passive and active – each with its own game interaction. The passive version occurs when a player comes to suspect that the second game mode is active; they can then attempt to verify this via a micro interaction. The active version consists of attempting to practise the second game mode unnoticed by another nearby player for as long as possible. This variant thus necessitates a longer game interaction, and is player-initiated.

Game Narrative

As suggested by the title *2084 – Safe New World*, the game takes place in a dystopian future in the year 2084, in which all traditional currencies have collapsed, and work is performed by machines. People pay with data, which has become the de facto currency. Therefore, the game's main goal is to collect as much data from other players as possible. It can be either be gained by theft i.e. "hacking" other players (*battle* mode), or generated by spying on them (*shadowing* mode).

Game Modes

The *battle* mode is triggered by player proximity, and was designed with symmetrical micro interactions for easier integration in everyday life. A battle occurs when two players are approximately in viewing distance of each other, i.e. up to a distance of about 100 meters between players. Both players are notified of the battle simultaneously through a vibration pattern on their device. The underlying concept of the battle is based on the well known game *Rock-Paper-Scissors*. Players must choose between three different game inputs: *SISSR-Virus*, *RocKit!* and *Paper worm*. The game allows a specific time frame for the game input; thus, the players do not have to perform their gestures simultaneously and have the opportunity to potentially identify and observe their opponents. A later input increases the chance to observe the opponent player and react accordingly. However, exceeding the time frame results in forfeiture of the battle. Strategies like hiding or feigning a gesture can increase the chance to win.

Compared to the battles, the active *shadowing* mode requires more effort. The user has to follow another player and stay as close as possible without being noticed and unmasked. This interaction is therefore inherently less integrated into the player's everyday life. The passive variant of *shadowing*, however, consists of a player noticing their follower, and unmasking them via a micro interaction, thus potentially achieving a similar degree of integration as the *battle* mode interaction. While the *shadowing* mode is activated, the *battle* mode is disabled and a map appears on the player's interface, to show where nearby players are located. The spatial approximation of these positions is re-calculated periodically via Bluetooth, to ensure that the user has to be within a range of about 10 meters to the other player to collect data. A countdown of five seconds appears once data collection begins, and has to be restarted by the player to avoid unmasking. The shadowing player is unmasked if the countdown runs out or the player being shadowed pushes the discover button. Thus, the *shadowing* mode provides an engaging social game experience for both player roles of this game mode.

System Architecture

As the game was designed to be played on several devices simultaneously, a client-server approach was chosen to connect all players and their devices. Each player runs the game as a background process on an *Android* smartphone; notifications only appear when in-game actions occur. If the player uses a smartwatch as their primary device, it will connect to the smartphone and act as an additional display for notifications and an input device for interactions. Each smartphone instance connects to the central server running *NodeJS* and *MongoDB*, providing a *HTTP REST API*. Push notifications are sent via the Google Cloud Messaging services. A custom transport layer was created for the communication between smartphone and smartwatch to provide a Bluetooth serialisation mechanism. For example, the map display is implemented via the *OSMDroid*[1] package on both devices. The smartphone downloads the map tiles directly as image files, whereas the smartwatch, lacking the internet connection, uses a custom wrapper to use the smartphone as the map file source.

Location Awareness

One of the most important aspects of the implementation consisted of location tracking. Using just GPS and the central server to evaluate positions did not yield reliable results in terms of visibility and distance. The server was unaware of visibility issues due to buildings or vegetation, yet the game design required players to be notified when they were within viewing distance. Thus the GPS locations were combined with peer-to-peer based wireless communication to create a more reliable tracking system. From the game's perspective, players move inside 200 by 200 meters cells within a larger grid, and only communicate with the server when they move between cells, or the server requests faster updates for the *shadowing* mode. To accommodate edge cases, such as a player moving along the border of two cells, the server always includes neighbouring cells in its location checks.

To determine whether two players are approaching each other, the game relies on Wi-Fi Direct technology: as soon as there are players in adjacent cells, their devices start periodically broadcasting and discovering Wi-Fi Direct services. As soon as a discovery is successful, each device knows that another player is nearby, and a battle is triggered. Early tests showed that the signal can reach up to 100 meters under ideal circumstances, but with obstacles such as buildings, detection may

[1] OSMDroid project, version: 5.1 (Release: 24.01.2016), https://github.com/osmdroid/osmdroid

occur at much shorter distances. With these signal propagation properties, the game can more reliably detect physical visibility between players.

While a suitable choice for the *battle* mode, Wi-Fi Direct was not sufficient for the *shadowing* mode. For this mode, Bluetooth technology was deployed instead. As soon as a player enters the *shadowing* mode, all players' devices in the surrounding cells are instructed to activate a Bluetooth server. The shadowing player then acts as a client and tries to connect to the others periodically. With each connection, a cache of in-game data is generated and awarded to the player. Compared to Wi-Fi Direct, Bluetooth can work with a much faster refresh interval and requires much shorter distances for connections due to its different propagation properties, making it ideal for the interactions of the shadowing mode.

Using this three-component approach to location awareness, the game is able to provide a reliable system for tracking multiple players, and at the same time account for physical visibility due to player surroundings.

Interaction Methods

Related work indicates that providing ubiquitous interactions in the context of pervasive gaming requires interaction methods to be simple and unobtrusive in order to become part of everyday life. In total, four different interaction methods were implemented for the *battle* mode. Two of these methods were based on gestures; a wrist rotation interaction for the smartwatch, and a knock-based interaction method for the smartphone. Both devices were also equipped with a touch-based user interface for comparison of the two gesture interactions with touch interactions. The touch-based user interface design offers three simple buttons for the game input during the *battle* mode. An overview of these interaction methods is illustrated in Figure 2. Active gameplay in the *shadowing* mode is based mainly on a map view to locate nearby players. Since the player's attention in this game mode is already focused on the device's display to identify opposing players, this game mode provides only the touch-based interaction method.

The design of the gesture-based interaction for the *battle* mode takes social acceptability into consideration by choosing gestures of modest spatial scale, yet also tries to provide a degree of observability to enhance gameplay. Both gesture-based interaction methods are based on a fixed user-independent gesture language, to contribute to fair gameplay by preventing users from defining their own advantageous gestures.

Smartwatch Gestures

As wrist-worn devices, smartwatches offer a more direct and less interruption-prone access than smartphones, which are commonly carried in a pocket. The *battle* mode requires the distinction of three different game inputs. These game inputs are communicated as the same single gesture and can be distinguished by the number of its repetitions, to supply a set of three gestures. To perform these gestures, players have to rotate their wrist (wearing the smart watch) one to three times. Wrist rotation can be regarded as a subtle and mostly *secretive* [31] in-air gesture, fitting our need for an unobtrusive, non-disruptive and socially acceptable gesture

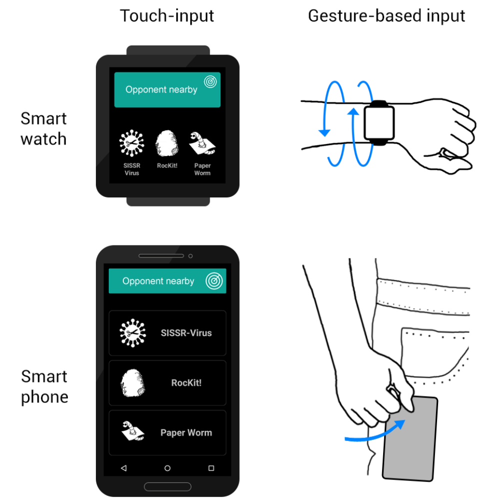


Figure 2. The four different interactions methods of the *battle mode*: touch-based input on a smartwatch *(smartwatch UI)* and on a smartphone *(smartphone UI)*, as well as gesture-based input on smartwatch *(smartwatch gestures)* and smartphone *(smartphone gestures)*.

set [33]. This gesture set is characterized by the rotational movement of the smartwatch around the x-axis of the device's coordinate system. This allows the utilisation of the internal gyroscope and a reduction of the relevant sensor data from three to one dimension. We applied and adapted a kinematic feature-based gesture recognition approach by Xian et al. [43], which includes the classification of gestures by the number of extreme values in the sensor signal (thus no training data is needed). With this approach, the characteristics of each gesture are analyzed beforehand and gesture recognition can be performed based on rules. Our implementation uses an activation threshold to ignore random hand movement and a cool-down period triggered by a deactivation threshold to stop the sample analysis. Extreme values in the sensor data are detected by using minimum distance thresholds and a rotation energy threshold. During pre-processing, the data is smoothed with a low-pass filter to ignore irrelevant small peaks or sensor noise. To further support the player with an unobtrusive type of interaction feedback, the smartwatch and the connected smartphone confirm the performed game input with a gesture-specific vibration pattern upon successful recognition.

Smartphone Gestures

For the gesture-based interaction with the smartphone, game balancing required an approach that equals the wrist rotation for smartwatch users in terms of required effort, social acceptance and observability. In particular, players should be able to interact with the game without having to take their smartphone out of their pocket or purse for every battle. We hypothesized that these requirements may be well met by knock gestures: instead of rotating their wrist, players knock on their smartphones up to three times. Knocks seemed to be well recognizable, they are relatively unobtrusive and non-disruptive in daily life. There is little research on this topic, yet, previous work indicates that the area of the interaction [15, 11] and the interaction method itself, i.e. slapping the phone in the pocket, can be considered socially acceptable [22].

The implementation is based on *KnockKnock*[2], which offers knock detection for *Android* smartphones by combining accelerometer and microphone sensor data to detect simultaneous peaks in volume and device movement. While the detection rate of *KnockKnock* was acceptable, too much force had to be applied in knocking on the phone. However, lower thresholds resulted in a drastic increase of false positives while walking. To address this issue, we implemented a simple form of activity recognition that blocks detection while the noise level caused by device movement exceeds a certain threshold. Nevertheless, preliminary evaluations showed that it was nearly impossible to detect single knock events when false positives are not acceptable, even given higher thresholds. Therefore, the smartphone gesture language was designed with double-knocks. A double-knock corresponds to one wrist rotation. Vibration feedback is given after each double-knock and at the end of the game input.

STUDY 1

A user study was conducted in a controlled lab setting in order to examine the interaction methods for the *battle* mode and the general player experience thereof. The study aimed to investigate how the interaction methods that were deemed suitable for the concept performed with regard to observability, usability, and social acceptance, as these variables were considered important for an overall positive playing experience. Further, the study examined the social acceptance and player experience of the *battle* mode in general.

Participants

The sample of this study consisted of 16 university students (12 male, 4 female) with an average age of 25.94 years (*SD* = 2.82). They were mostly from a background related to computer science. The participants were recruited in pairs in order to guarantee that they at least knew each other, which they confirmed in a demographic questionnaire. 13 participants reported that they had not heard of pervasive games. After reading a generic definition, 12 participants reported that they had never played pervasive games. Regarding mobile gaming habits, only three participants reported that they never play games on their mobile phones.

Procedure

The study took place in a lab setting in a conference room. Initially, the two participants were introduced to the background story of *2084 – Safe New World* and the general concept behind the *battle* mode. Players stated their consent and completed a short demographic questionnaire. They were then positioned face to face at marked positions at a distance of five meters which was deemed a compromise between a realistic playing scenario and optimal conditions to observe the other player.

The participants played the *battle* mode for each of the interaction methods consecutively. To avoid carry-over effects, the order of interaction methods was counterbalanced per pair of participants using a Latin square. For each of the interaction methods, the participants first watched a short introduction video demonstrating how to use the method. They then played three test runs against each other to ensure that they were well acquainted with the use of the interaction method. Subsequently they played five battles. For the first four battles of each interaction method, the participants were asked to stay face to face at the marked position without employing any gaming strategies such as turning away or hiding their input, to guarantee optimal conditions for observability. In the final battle for every interaction method, players were encouraged to employ gaming strategies as they wanted. After every battle the players recorded the game input they had wanted to perform and the input they suspected their opponent had executed on a questionnaire next to the playing area. They could select from a list with the three possible game inputs and *"not sure"*. Further, participants completed a short questionnaire after they finished all five battles for an interaction method in order to assess the suitability for everyday life and social acceptance. Two participants that wore trousers without pockets were provided aprons with pockets in order to simulate realistic conditions for the *smartphone gesture* condition. A third participant used the pockets of their jacket for this interaction. Finally, participants completed a concluding questionnaire in which they stated their subjective experience of the game and the *battle* mode in specific.

Results

Interaction Observability

After each battle, participants stated the input they had wanted to perform and the input they suspected their opponent had executed. The *mean observability* of each interaction method per participant was calculated by comparing these values and calculating the mean. The observability of the first four battles of each interaction method was calculated separately from the observability of the fifth battle, as gaming strategies influenced the overall observability greatly (see Table 1). A Friedman's ANOVA showed that the interaction method had a significant effect on the observability of the first four rounds, $\chi^2(3) = 23.894, p < .001$. Post hoc tests revealed that *smartphone gestures* were significantly more easily observable than *smartwatch UI*. Further, *smartwatch gestures* were significantly more observable than *smartphone UI* and *smartwatch UI*. There was no significant effect of the interaction method on observability in the fifth round where participants were encouraged to employ gaming strategies, $\chi^2(3) = 4.1351, p > .05$.

Interaction Usability

The interaction methods were examined with regard to their usability of selecting the desired input for the game. For this purpose, the input that players wanted to perform was compared to the input registered by the system, i.e. constituting the input recognition rate. A Friedman's ANOVA revealed a significant effect of the interaction method on the recognition rate, $\chi^2(3) = 26.2, p < .001$. Post hoc tests showed that the recognition rate of *smartphone gestures* was significantly lower than the rate of *smartphone UI* and *smartwatch UI*. While another Friedman's ANOVA showed significant effects of the interaction method on the recognition rate for the fifth battle including gaming strategies, $\chi^2(3) = 9.6923, p < .05$, the pair-wise comparisons showed no significant effects.

[2]KnockKnock by Turtum & Lien, 05.04.2016, https://github.com/KybDP/KnockKnock

	Smartphone UI	*Smartwatch UI*	*Smartphone Gesture*	*Smartwatch Gesture*
optimal conditions	20% (23%)	17% (18%)	44% (25%)	61% (27%)
with gaming behavior	25% (45%)	25% (45%)	12% (34%)	44% (51%)

Table 1. The mean observability (and standard deviations) (1) under optimal conditions and (2) with gaming behavior for every interaction method in the *battle* mode (values range from 0 to 100%).

Further, participants indicated the subjective usability of each method via agreement on a 7-point Likert scale (1 – *strongly disagree* to 7 – *strongly agree*) to the statement *I had no problems performing a game action*. A Friedman's ANOVA showed that the interaction method had a significant effect on players' ratings, $\chi^2(3) = 25.538, p < .001$. Post hoc tests revealed that only *smartphone gestures* were rated significantly worse than *smartphone UI* and *smartwatch UI*.

Social Acceptance of Interaction

Regarding the social acceptability of the interaction schemes, participants were asked to indicate their agreement to different statements on a 7-point Likert scale (1 – *strongly disagree* to 7 – *strongly agree*). In particular, the participants rated how comfortable they would feel using each interaction method in public (*Using this interaction in public would make me feel uncomfortable.*), how they would feel when noticing other players using it (*Players using this interaction would draw negative attention.*), and the suitability of the interaction in daily life (*This interaction is unsuitable for certain situations.*).

Friedman's ANOVAs were conducted on the participants' subjective ratings. The interaction method significantly influenced the perceived comfortableness, $\chi^2(3) = 24.713, p < .001$. Post hoc tests showed that participants would feel significantly less comfortable using *smartphone gestures* in public compared to *smartphone UI* and *smartwatch UI*. A significant effect was found for the players' rating regarding drawing negative attention, $\chi^2(3) = 23.167, p < .001$. Participants rated *smartphone gestures* significantly higher for drawing negative attention in comparison with *smartphone UI* and *smartwatch UI*. Regarding the suitability of the interaction in everyday situations, there was a significant effect of the interaction method as well, $\chi^2(3) = 14.186, p < .01$. Pair-wise comparisons revealed that only *smartwatch UI* was rated significantly more suitable than *smartphone gestures*.

General Evaluation of the Battle Mode

Participants were asked if they thought that generally they could integrate the *battle* mode well in their daily life on a 7-point Likert scale (1 – *strongly disagree* to 7 – *strongly agree*). The results show that participants thought they could integrate the *battle* mode well in their life (*M* = 5.06, *SD* = 1.18). Participants were undecided if they would have to disable the *battle* mode in many situations (*M* = 3.75, *SD* = 1.48), but they mostly agreed that there are several situations in which they would disable it (*M* = 5.62, *SD* = .96). Finally, participants had to indicate their agreement with several statements regarding their playing experience of the game in general. Specifically, they were asked how much fun they had (*Enjoyment*), how difficult they found the game (*Difficulty*), if they would like to continue playing (*Intention I*), if they would like to play the game again (*Intention II)*, if they would recommend the game to their friends (*Intention III)* and if they had felt immersed in the game (*Immersion*). The results (see Figure 3) show that the game generally did offer an enjoyable playing experience for the players.

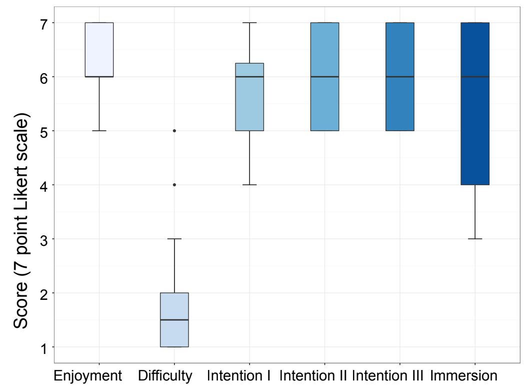


Figure 3. Results showing the gaming-experience of the *battle* mode measured by self-reported enjoyment, difficulty, intention to play and immersion.

Discussion

The results of this study showed that the interaction methods employing *gesture* paradigms were more observable under optimal conditions than the interaction methods that used *UIs*. When considering the setting of the study, i.e. a setting in which players stood face to face this is not too surprising. This might have differed in a setting that allowed for more observability of the *UI* interaction methods, e.g. scenarios that allow shoulder surfing. But for the presented game concept, a setting as the one in the study is more realistic and thus suitable for examination.

Concerning usability, the interaction with *smartphone gestures* performed worst objectively and subjectively. This may be due to several reasons, such as the very unfamiliar interaction scheme, the fact that three participants did not wear trousers with pockets, or just technical difficulties, as the recognition of input was often rather difficult. On the other hand, the *UI* interaction methods obviously provided the objectively best results for gameplay as there were no difficulties regarding the recognition of input. These interaction methods were also subjectively rated best as they performed with the least amount of errors and the interaction was familiar to all participants. The *smartwatch gestures* interaction, however, also performed quite well and not significantly different than the *UI* interaction methods, objectively and subjectively.

Regarding social acceptability of the interaction methods, *smartphone gestures* performed worst, while the *UI* interaction methods performed best. This might stem from the familiarity of the interaction as well, as touchscreen interaction is common in public while the *smartphone gestures* was new for the participants. Further, they might fear that the interaction would not work as reliably as other interactions. Again, *smartwatch gestures* performed a little worse than the *UI* interaction methods, but not significantly so. As this interaction actually might be less obvious than interacting with a touchscreen, the worse performance compared to the *UI* interactions might stem from the unfamiliarity and the fact that the interaction was pretty obvious in the setting of the study.

We therefore concluded that the interaction that provides the best trade-off between observability, usability and social acceptance is the most suitable for the presented game concept. *Smartwatch gesture* performed best with regard to observability together with *smartphone gesture* compared to the *UI* interaction methods, and also performed on par with the *UI* methods with regard to usability and social acceptance. We further suspected that the interaction would perform better with increasing familiarity and appear less obvious in a non-lab setting. Due to this and well balanced trade-off between the factors mentioned above, we decided that the *smartwatch gesture* interaction method was the most suitable to further evaluate the presented concept in a more realistic setting.

STUDY 2

In order to evaluate the game concept in a less controlled setting, we conducted a second study to investigate player reactions in scenarios simulating in-the-wild usage. The study had two objectives: investigating a) how well players are able to identify each other in both the *battle* and *shadowing* mode, and b) the social acceptability of playing the two modes in public. Based on the results of the first study, the second study was conducted only with the *smartwatch gestures* interaction method, as it provided the best trade-off between observability, usability and social acceptance. The *unmasking* option was deactivated for this study. As discussed in the section on related work, it is important that the gesture interaction remains as unobtrusive as possible for greater acceptability. The *shadowing* mode is particularly problematic, as the following of another person can look suspicious. A very high rate of successful player identification in the wild is also crucial, so as to not involve bystanders.

Methodology

The second study began with an introductory briefing wherein each participant was informed of the game concept. A video tutorial demonstrated the *smartwatch gesture* interaction method. The participants were then asked to participate in three mock battles with the instructor, as well as a trial run of shadowing the instructor. Before the study continued, they were asked to fill in a demographic survey. Subsequently, participants were asked to play the game while following a predefined route consisting of three stages:

- Stage 1: Walking from the exit of building A to the terrace of building B, where another (known) instructor was waiting.

Unknown to the participant, a previously unseen actor engaged in *shadowing* of the participant during this stage (starting with a distance of approx. 15m, consistently reducing this until overtaking the participant shortly before the first checkpoint). Additionally, the instructor waiting at the checkpoint (i.e. a known potential opponent) initiated a battle with the participant while the actor passed them.

- Stage 2: Walking through the cafeteria inside building B and performing a dummy task, i.e. looking up the price of an item.

During this stage, participants had to respond to an unknown opponent in *battle* mode once they reached a certain point in the cafeteria. The cafeteria was always filled with a minimum of five other bystanders when the study was conducted.

- Stage 3: Following an unknown player in *shadowing* mode; the task was to correctly identify the player, and follow them as long as possible.

The part of the final unknown player was performed by an actress who was instructed to walk at the same pace for each study iteration. She always stopped at the half-way point between the two buildings to search inside her purse, in order to evoke a scenario that was as realistic as possible to what can be expected in real-life gameplay. An actress was chosen for this part, as opposed to a male actor, as we expect the reactions to social acceptability to differ based on gender.

For each stage, the participants did not know in advance what was going to happen; however they were informed that the game would be running in its entirety, i.e. any game events could potentially occur. They were also instructed to attempt to identify their opponent (in case of either game mode) and their game input (in case of a battle). At each checkpoint, the participants were asked whether they had battled anyone or been shadowed, and then told whether the latter had been the case. After the final stage, the participants were escorted back to the starting point for a concluding questionnaire.

Participants

A total of eight participants (2 female, 6 male) were recruited for the second study, with an average age of 23.1 (*SD* = 2.26), none of whom had participated in the first study. The players were asked about their gaming habits; three participants reported having played a pervasive game before; three others denied playing any games on mobile devices. Regarding smartwatch experience, four participants reportedly had never used a smartwatch before, three participants had used one at least once, and one indicated frequent use.

Measures

At all checkpoints, the participants were asked to fill in a brief questionnaire with the questions *Do you think that somebody shadowed you while walking to this checkpoint?* and *Did a battle occur while walking to this checkpoint?* If the answer to either question was yes, they were asked to indicate the identity of their assumed opponents. After being informed whether they had actually been followed, they were asked to indicate how they had felt about the experience on a 7-point Likert scale (1 – *strongly disagree* to 7 – *strongly agree*), i.e. *I felt uncomfortable*, *I was embarrassed*, *I was scared*, *I felt as if I had no control*, *It was entertaining* and *It was funny*. After the final stage, the participants were asked to rate (on the same scale) how well they thought the game modes could be integrated into their daily life, as well as general questions regarding their enjoyment of the game, and two questions regarding passive and active shadowing (*I do not want to be shadowed by others* and *I would not want to shadow others*).

Results

Overall, the participants rated the game highly for overall enjoyment (M = 6.25, SD = 0.71), feeling immersed (M = 5.25, SD = 1.91), and wanting to play again (M = 6.25, SD = 1.03).

Player Identification

In the first stage, the battle was initiated by a known potential opponent. Seven of eight participants noticed that the battle occurred, and five correctly identified their opposing player. They attributed this to the instructor's wrist rotation, the look to the wrist, and eye contact. During the second stage, two battles did not occur in time due to roaming issues between access points. Two of the six remaining participants successfully identified the unknown opponent. Regarding player identification in the *shadowing* mode, three of eight participants noticed the shadowing player. In the second stage, however, two participants declared that they had been followed despite this not being the case; one of them indicated a bystander with a laptop had appeared suspicious. Similarly, three participants felt that they had been shadowed in the final stage (one reported the feeling of being followed, another suspected a bystander who by coincidence had also been at the second stage). For the active shadowing task, two participants followed the wrong person, once because one participant unfortunately recognised one of the observers as someone they associated with the project.

Reaction to Shadowing

After the first stage (when the participants actually had been followed), the majority of participants tended to disagree with the negative reactions to being followed (*uncomfortable*: M = 3.38, SD = 1.60; *embarrassing*: M = 2.38, SD = 1.06; *scared*: M = 2.00, SD = 1.19; *lack of control*: M = 2.50, SD = 1.19), while the positive emotional reactions received noticeably higher ratings (*entertaining*: M = 6.00, SD = 0.53; *funny*: M = 5.75, SD = 0.71). The active following of another player in the third and final stage received similar results (*uncomfortable*: M = 3.38, SD = 2.06; *embarrassing*: M = 2.62, SD = 1.50; *scared*: M = 2.00, SD = 1.07; as opposed to *entertaining*: M = 5.88, SD = 0.99, *funny*: M = 6.00, SD = 0.75). These affective results are summarised in Figure 4.

Integration into Daily Life

The battle mode received significantly higher scores (M = 5.88, SD = 0.83) for fitting well into the participants' daily life compared to shadowing (M = 4.50, SD = 1.69), $t(7) = 2.43$, $p < 0.05$, $r = 0.68$. Overall, both modes averaged a positive score for this item. The scores for feeling uncomfortable with either interaction were generally low, with a slightly higher mean for shadowing (M = 3.38, SD = 1.69) than the battle mode (M = 2.25, SD = 1.49). This difference was not significant. Regarding the participants' estimation of non-usage (*I would have to disable the battle/shadowing mode in many situations*), the battle mode received lower scores (M = 3.50, SD = 1.41) than the shadowing mode (M = 4.38, SD = 1.51), albeit not significantly so. Participants generally would not oppose participating in either active or passive shadowing. They were more inclined towards participating in active shadowing (M = 2.63, SD = 1.06) than passive shadowing (M = 3.13, SD = 1.73).

Discussion

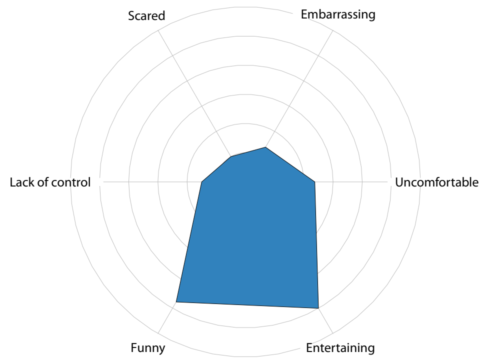
The *battle* mode appears to allow for reasonably high rates of player identification when the player knows who is potentially an opponent. This rate is reduced with entirely unknown opponents. Less than half of participants noticed the shadowing in the first stage, but the ones that did notice were all able to identify their follower. Interestingly, this mode may foster a degree of paranoia, as indicated by some participants' continued belief that they had been followed even during the stages when this did not in fact occur. Regarding active *shadowing*, the player identification rates were also high. However, as two participants followed the wrong person, and as this game mode can be considered socially more problematic, player identification may have to be supported more strongly for active *shadowing*. Future research will likely require qualitative evaluation of the social acceptability for this mode (including for non-players). The overall reaction to both the active and passive *shadowing* mode was nevertheless quite positive.

Both modes were well received regarding integration into the participants' daily life, and how they would feel using either mode in public. The *battle* mode's significantly higher scores for integration support the hypothesis that this mode exemplifies a socially acceptable micro interaction, whereas the asymmetric *shadowing* mode partly requires a longer interaction. This is also indicated by the estimation of non-usage; the *battle* mode would have to be disabled less often (although this was not a significant difference). Interestingly, for the distinction between active and passive shadowing, the participants disagreed more strongly with not wanting to actively shadow people than not wanting to be shadowed, i.e. they preferred the active to the passive *shadowing* mode, and tended to disagree with not wanting to use either.

LIMITATIONS & SUMMARY

The concept of the presented paper aims for a high integration of pervasive games into everyday life. However, players frequently use games as a means of diversion or to break away from their life [35]. Thus it may seem contradictory to aim for such an integration. However, such games are not meant to replace the recreational aspects of "regular" entertainment games, but can rather be used as gaming experiences that augment the enjoyment of players' daily lives.

Regarding the comparison of interaction methods in the first study, the choice for the interaction with the best trade-off may not actually be the best for real-life pervasive game deployment. There are also many other potential interaction paradigms, as well as devices, that could be investigated. In the conducted studies, participants reported that they could integrate the game modes of *2084 – Safe New World* (to varying degrees) well into their lives. However, this is a subjective estimation based on relatively short gameplay experiences. To



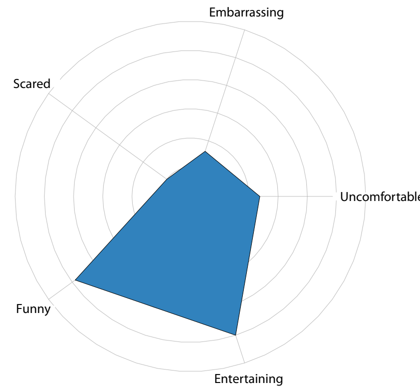


Figure 4. Spider plot of mean values for participants' emotional reactions to being followed by other players (left) and following other players (right) in the *shadowing* mode. The *Lack of control* item was only used for the passive *shadowing* mode.

evaluate if the concept holds up for real-life pervasive gaming, it is of course necessary to conduct a long-term field study.

Part of the concept is based on the assumption that integration of a pervasive game into players' everyday lives relies on social acceptability of game interaction. Thus, this aspect was examined via the participants' subjective rating regarding this construct. However, social acceptability is a concept that is hard to conceptualize and subsequently difficult to assess. Potentially, the subjective estimates of social acceptability do not really indicate if players will in fact be comfortable using such a game in public. The concept of games that are *always-on* can lead to several challenges only remotely addressed in this paper. These include technical issues such as the effect on battery life of mobile devices, issues regarding the privacy of players, as well as how the implementation of a not-available feature in an *always-on* concept would influence the multiplayer aspects of the game. Further, the player-vs.-player paradigm requires a user-base of a certain size, which is a limitation inherent to multiplayer games in which interaction is triggered by proximity and thus requires nearby players. This is in fact one major limitation of the concept and cannot be mitigated through AI-controlled "fake players" alone, as the game concept requires that players actually encounter opposing players in the real world.

The studies' results showed that a pervasive game that is integrated in the players' daily lives has to adhere to certain guidelines as providing the possibility to turn off the *always-on* aspect for specific social circumstances as well as supplying support for player identification. Finally, while the studies revealed that players had positive gaming experiences, this is not indicative of the game's ability to provide sustained long-term enjoyment, yet this is crucial for a temporally pervasive game. Thus, in future work we plan to extend the overall game to include systems that provide a more complete experience, for example through the addition of a more in-depth progression system or location-based items.

CONCLUSION

In this paper we presented a concept for pervasive games that can integrate thoroughly into players' everyday life. This is realised by the combination of a strong degree of ubiquity (the game is *always-on*) and of the interactions which are brief enough to not overly interrupt the players everyday activities. The concept was implemented in the prototypical pervasive multiplayer game *2084 – Safe New World*, which comprises two game modes: (1) a player-vs.-player *battle* mode that utilizes micro interactions and (2) a *shadowing* mode that aimed to test boundaries of social acceptability. A lab study confirmed that the *battle* mode was well received by participants. It further revealed that gesture interaction on a smartwatch provided the best trade-off between usability, subjective social acceptance and observability of the compared interaction methods for this game mode. A second user-study simulating in-the-wild usage suggests that both game modes of *2084 – Safe New World* can be integrated into players' everyday lives, and further showed that, within the game construct, shadowing other players can be socially acceptable. The effect on non-players requires further investigation. In conclusion, while more research on long-term in-the-wild usage is necessary, the studies suggest that the micro interactions can provide enjoyable gaming experiences for players of pervasive games. Further, this concept need not suffer unduly from issues of negative social acceptance, as long as the game mechanics adhere to criteria such as support of player identification and ubiquitous interactions.

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