Tim Dutz, Sandro Hardy, Martin Knöll, Stefan Göbel, Ralf Steinmetz: **User Interfaces of Mobile Exergames.** In: Masaaki Kurosu: 16th International Conference, HCI International 2014, Heraklion, Crete, Greece, June 22-27, 2014, Proceedings, Part III, vol. 8512, p. 244-255, Springer, June 2014. ISBN 978-3-319-07226-5 (Print) & 978-3-319-07227-2 (Online).

User Interfaces of Mobile Exergames

Tim Dutz[1], Sandro Hardy[1], Martin Knöll[2], Stefan Göbel[1], and Ralf Steinmetz[1]

[1] Multimedia Communications Lab, Technische Universitaet Darmstadt, Germany
[2] Department of Architecture, Technische Universitaet Darmstadt, Germany
{tim.dutz,sandro.hardy,stefan.goebel,
ralf.steinmetz}@kom.tu-darmstadt.de,
knoell@stadt.tu-darmstadt.de

Abstract. Exergames are video games that require the player to be physically active. They can be roughly grouped into two categories, namely indoor exergames that are usually being played in the confines of one's living room, and mobile exergames, which run on a user's smartphone and can be played outside. While indoor exergames have been able to establish themselves as a popular type of video game, mobile exergames are still far and few between. An explanation for this phenomenon may lie in the difficulty of designing user interfaces for mobile exergames. This contribution analyzes the user interfaces of various existing mobile exergames and fitness applications, and proposes a methodology for the creation of such games.

Keywords: Serious Games, Exergames, Mobile Games, User Interfaces.

1 On Indoor Exergames

The purpose of a serious (video) game is to have a positive effect on the player besides mere entertainment [1]. This is usually achieved by motivating the player through the game mechanics to perform a task that she would otherwise consider dull or tedious, such as solving mathematical formulas, or going for a run. Games that motivate their players to be physically active are called "fitness games" or "exergames" (the latter being a commingling of the words "exercise" and "game"), and there are many examples for both indoor exergames played in front of one's PC monitor or TV screen, and mobile exergames, which are played using a smartphone or another type of mobile device while the player is out and about.

In 2006, Nintendo released the game *Wii Sports* for its game console *Wii*. *Wii Sports* requires the player to perform certain movements with her arms and upper body in order to succeed in various mini-games such as tennis or golf. The player's movements are tracked by the accelerometer sensors within the wireless *Wii Remote* device, which the user has to hold in her hand(s) while playing. Because the movements required for playing the mini-games are not exactly extensive and can even be reduced further to but a flick of the hand while sitting on a couch [2], it is questionable whether *Wii Sports* actually qualifies as a full-fledged exergame, although studies have shown that frequent playing can indeed contribute to weight management [3].

M. Kurosu (Ed.): Human-Computer Interaction, Part III, HCII 2014, LNCS 8512, pp. 244–255, 2014.

Nevertheless, *Wii Sports* clearly demonstrated the demand for games that integrate physical activity into their gameplay and that promise to turn the chore of working out into a more interesting and entertaining experience: in early 2014 – more than seven years after its release – *Wii Sports* was still the commercially most successful video game up to date with almost 82 million copies sold in total [4, 5]. But while *Wii Sports* may be the most successful representative of indoor fitness games, it was neither the first, nor the last of its kind.

A very early example of this type of game is Konami's *Dance Dance Revolution* (abbr. DDR). The US release of the first DDR game dates back to 1999, and the series has spawned many new releases since. It also comes to no surprise that Nintendo tried to repeat the success of *Wii Sports* and released more exergames for its console, of which the two most successful ones are *Wii Fit*, released in the US in 2008, and its successor *Wii Fit Plus,* released in 2010. As of early 2014, the combined sales of the two games exceeded 45 million units [6, 7]. *Wii Fit* is sometimes attributed as being the first real indoor exergame [8], which probably comes from its no-nonsense attitude when compared to earlier fitness games such as *Dance Dance Revolution* or *Wii Sports*. Instead, there is a clear focus on fitness and self-improvement, reflected in aspects like virtual trainers, training plans, and performance statistics.

A core challenge of all exergames is to determine the player's activities (and to adapt the game accordingly), and to that end, both *Dance Dance Revolution* and *Wii Fit* rely primarily on sensor mats placed on the (living room) floor. Of course, the utilization of such mats implies that the player has to be fairly stationary while playing the corresponding games. In late 2010, Microsoft introduced the Kinect sensor technology for the *Xbox 360* video game console and released a more powerful second-generation Kinect sensor three years later. The Kinect sensor is capable of tracking the movements of multiple persons within a distance of a few meters without requiring them to carry any type of sensor or marker in their hands or on their body. This practically allows complete freedom of movement while playing, at least within the confines of one's living room. Microsoft's game *Xbox Fitness,* released in late 2013 for the *Xbox One,* tries to tap into that potential. Very similar to the way that Nintendo gradually changed the character of its indoor exergames over time, Microsoft picked a much more serious tone for *Xbox Fitness* when compared to earlier fitness game releases such as *Kinect Adventures!* or *Kinect Sports. Xbox Fitness* now clearly targets adult users with a primary interest in improving their physical fitness. Apparently, indoor exergaming is coming of age.

This correlates with the fact that indoor exergames and supporting technologies such as sensors mats and Kinect sensors are not only relevant to the entertainment industry. Various research groups focus on the development of indoor exergames and/or on the analysis of the effects that such games have on their players. Often, the focus of such work lies either on children [9], or on senior users [10]. An interdisciplinary team of psychologists, sport scientists, and engineers developed a theoretical model for the customization of indoor exergames to the needs of such specific groups [11]. Summing up this introductory chapter, we find that in early 2014, indoor exergames have been both an established type of video game as well as a subject of scientific interest for more than a decade.

2 On Mobile Exergames

Interestingly, the situation changes when we look at the mobile counterparts of such games. Contrary to indoor exergames such as *Wii Fit* or *Xbox Fitness*, mobile exergames are played on mobile devices – oftentimes smartphones – and usually do not rely on external appliances such as sensor mats or TV screens. In other words: all the user needs to play such games is a smartphone (and possibly a pair of running shoes). Since the introduction of Apple's iPhone in 2007, smartphones have continued to grow in popularity and more than one billion units have been sold in 2013 alone [12]. Due to this, chances are that a given person already has one of these devices available – different to, for example, the aforementioned *Nintendo Wii* gaming console.

Indeed, this is just one of the reasons why in theory, the advantages that mobile exergames have over stationary ones are manifold. The second advantage is the pervasiveness of these games, as many of them can be played wherever and whenever the player pleases, for instance during travel. In this regard, mobile exergames profit from the smartphone characteristics that differentiate such devices from classic gaming devices such as PCs or video game consoles [13]: smartphones are *mobile* (light and small enough to be carried around in a pocket or hand), *available* (rarely more than an arms-length away), and *sensitive* (capable of determining many aspects of the user's contextual situation thanks to a multitude of integrated sensors). Finally, a good amount of people seems to generally prefer the outdoors when it comes to sports, and mobile exergames go well with such activities.

However, despite these alleged benefits, we find that only a small number of mobile exergames actually exists. An early mobile exergame and a game still being played is *Geocaching*. At its core, the game is a global treasure hunt, with people hiding so-called caches, small waterproof boxes containing some type of "treasure". The coordinates of such a cache are then made publically available on the Internet by its owner and other players will use this information to navigate to the cache's position and then try to find its exact hiding place. The first caches were hidden in the year 2000 [14], and early geocachers used handheld GPS trackers to find them. Today, smartphones with integrated GPS modules and cellular phone network enabled Internet access make playing *Geocaching* easy and consequently, the game enjoys a wide popularity. In early 2014, the official *Geocaching* website knew of more than two million registered caches and more than six million registered players [14].

Figure 1 shows a few screenshots of the official *Geocaching* application by Groundspeak Inc. As one can see from the screenshots, the user starts with viewing a list of nearby caches (depending on the user's position as determined by her smartphone's GPS module). If the user selects a cache from the list, she is shown a map that helps her navigate to the cache's hiding place. Alternatively, she can also rely on a compass to orientate herself. As many caches are located in forests and away from towns, geocaching almost always involves a good amount of walking and occasionally even climbing. Additionally, many caches are hidden extremely well in hollow trees or beneath bushes and as such, the player also needs to search her environment thoroughly once she has reached the approximate hiding place. This makes *Geocaching* a mobile exergame, even if the energy expenditure (EE) of playing it will oftentimes not be higher than walking the dog.

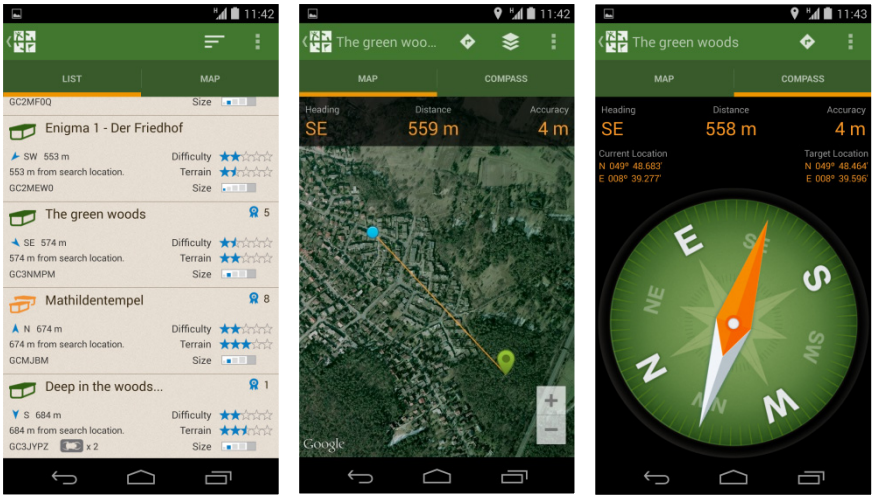

Fig. 1. Geocaching application [14]

Geocaching is also a so-called location-based game, a game in which the physical location of the player, determined by GPS, has influence on the way that the game plays. In other words: changing one's location, usually by foot, is an integral part of these games. Various location-based services and games exist, such as *Yelp* [15] and *Foursquare* [16], but of all the location-based games and services currently available, the game *Ingress* [17] is both the most interesting and the most successful one. In *Ingress*, players initially get to choose one of two factions and are then expected go out and conquer virtual portals for their team. These portals can be found in the vicinity of distinctive real-world structures, such as statues. If a player is close enough to a portal (that is, the corresponding real-world location), she can attempt to "conquer" it for her team by pressing the according GUI buttons. Such interactions with portals will gain the player virtual items and experience which are both required to progress through the game.

Similar to *Geocaching*, *Ingress* requires players to physically move to specific locations, and it is very clear about this aspect of the game, as can be seen from the left screenshot in figure 2. The central screenshot shows the map view that allows players to locate portals in their vicinity (note the two different colors representing control areas of the factions). The right image shows the portal interaction panel that becomes available once the player gets close enough to a portal. Although *Ingress* can be interpreted as being a mobile exergame, the aspect of movement is not as relevant to *Ingress* as it is to *Geocaching*. This is because in *Ingress*, a player can theoretically acquire virtual items and experience by conquering the same portals over and over again, for instance portals that are close to her home or working place. Furthermore, the player can acquire so-called "portal keys" of specific portals which will subsequently allow her to interact with these portals even if not being in their vicinity.

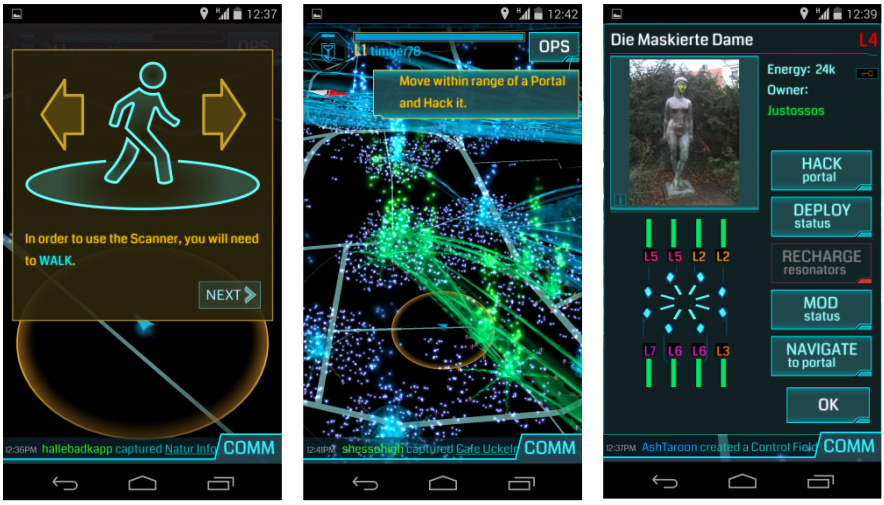

Fig. 2. Ingress [17]

Although location-based games such as *Geocaching* and *Ingress* require their players to change their location while playing, this can usually be done by walking or even by using a car. Consequently, the EE of such games is oftentimes low. This cannot be said for distance-based exergames, as they require players to cover distances by running or cycling. Different to location-based games, distance-based games are not bound to specific locations for which the "real-world anchors" that connect the virtual to the real-world (such as the caches of *Geocaching* and the portals of *Ingress*) have been set up a priori. Instead, the single parameter relevant to these games is the user's speed, which can be determined by either the smartphone's GPS module or its accelerometer. We find that many of the fitness applications used by runners and cyclers to track their training performances contain elements of gamification to make workout sessions more interesting, but that only a few actual distance-based games exist.

Starting with gamification in fitness applications, a good example is the *NikeFuel* concept of the *Nike+* running application [18]. For each training session, users are awarded *NikeFuel*, with the amount depending on the intensity of their training. *NikeFuel* is supposed to be a measurement unit for one's training performance and can be used for the comparison with other users. Another approach for gamification in fitness applications is the "Story Running" mode of the *Runtastic* application [19]. These *Story Runs* are audio books that mix spoken text passages and music, to which the user listens to while running. In the story "The Carrier of Truth", for example, the player listens to an actor that comments his ongoing escape from the Alcatraz prison. The identification with this actor is supposed to motivate the user to run faster and longer than usually. However, *Runtastic's* Story Running mode is not interactive and the user simply listens to the audio book while running, during which the application's user interface displays the usual information such as a map and the player's pace.

One of the few actual distance-based games is *Zombies, Run!* [20]. The game is based on the same core mechanic as *Runtastic's* Story Running, namely a series of audio books to which the player listens to while running. In the case of *Zombies, Run!,* these stories tell of a group of people trying to survive in a post-apocalyptic world of zombies. The survivors have managed to establish a small base, but members of the community have to leave the safe walls every now and then to gather supplies such as food and medicine from the outside world. These are the "runners", and the user is one of them, being addressed to as "Runner 5" by the voice actors.

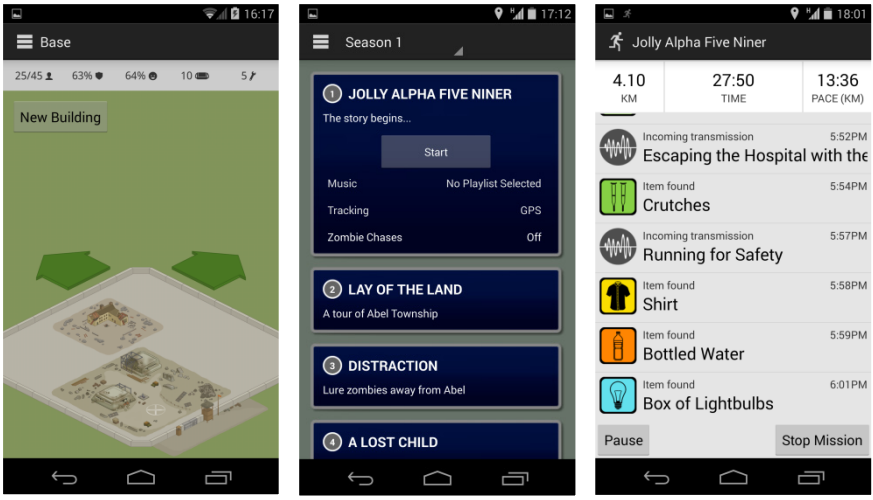

Fig. 3. Zombies, Run! [20]

While the story itself is supposed to be motivating, *Zombies, Run!* goes beyond *Runtastic's* Story Running by also providing an additional off-training game mode in which the player gets to manage her virtual community of survivors, for instance by adding new buildings to the base or improving existing ones. For all these actions, the player needs resources and she acquires those by physically running while listening to the stories. Figure 3 shows screenshots of *Zombies, Run!,* whereby the left screenshot shows the player's base (the game's off-training mode), the central screenshot the mission selection screen, and the right screenshot the application's main screen during a training session. We can see that besides a few performance statistics, such as the running distance and time, the training screen primarily shows the virtual supplies that the player has "picked up".

It is important to realize that *Zombies, Run!* is not a location-based game. The application uses the smartphone's GPS module or its accelerometer sensor to measure the distance that the player has covered, but the supplies that she gathers are not actually distributed in her surroundings – they are randomly rewarded during a training session. This means that instead of following a route through the city or the woods, the player could also run in circles on a dirt track and still gather the same amount of virtual supplies. To make the game more challenging, *Zombies, Run!* features an optional mode called "Zombie Chases". If activated by the player, virtual zombies may

randomly appear during a session. The player then needs to "outrun" these zombies by increasing her speed for a certain time, or lose all virtual supplies she has gathered up to this point. During zombie chases, the approaching zombies are represented by grunts and heavy breathing which is getting louder and more intense when the player is in danger of being caught by the zombies (because she is too slow).

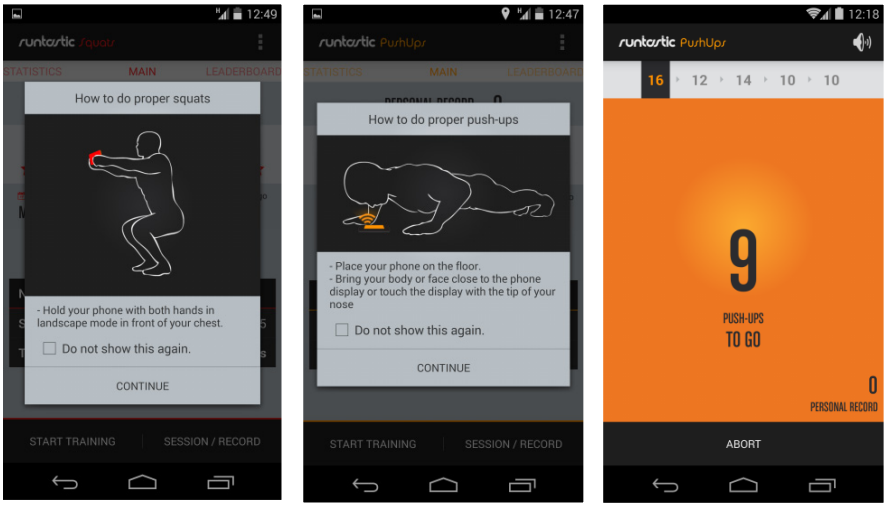

Fig. 4. Runtastic Pumpit apps [21]

All applications and games introduced up to here focus on motivating walking, running, and/or cycling activities – that is, training of the lower limbs and the cardiovascular system. Almost no applications try to use the smartphone's integrated sensors to support upper body training. Notable exceptions are the *Runtastic Pumpit* apps that use the smartphone's sensors to determine the number of push-ups, sit-ups, pull-ups, or squats that the user has performed. To this end, the user has to hold the smartphone in a proper way, as can be seen from the instructions on the left and central screenshots in figure 4. The right screenshot shows the GUI while the user is performing push-ups.

3 A Methodology for Interfaces of Mobile Exergames

As part of our work at the Technische Universitaet Darmstadt, we have created the location-based exergame *PacStudent* [22], which is based on the famous arcade game *Pac-Man*. The game is played on a smartphone and requires players to run along predefined lanes and collect virtual gold coins while trying to evade virtual ghosts. *PacStudent* uses the smartphone's GPS module to determine the real-world location of the player and then positions the virtual player icon on the virtual map accordingly. Being a classic location-based game, the game area where the game should be played at (the virtual game's real-world anchor) must be defined upfront by the developers. Ideally,

the corresponding real-world location already provides for paths or roads that can function as lanes for the game. The current version of *PacStudent* can be played at various locations at Darmstadt, Germany, among them the public park "Prinz-Georgs-Garten" which offers a nice layout of paths.

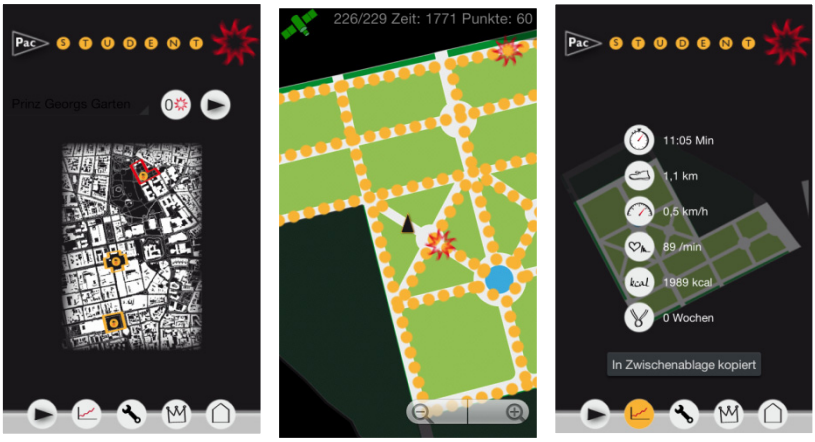

Fig. 5. PacStudent [22]

Figure 5 shows screenshots of the *PacStudent* game. To the left is the game area selection screen. The main interface of the game itself is shown on the central screenshot. The right screenshot shows the game's statistic screen. The user interface of *PacStudent* is fairly simple: the player sees a virtual map of her surroundings on the screen, along a virtual representation of herself (the black triangle that can be seen on the central screenshot), the virtual coins that she is supposed to collect (the golden ovals) and the virtual ghosts that she is supposed to evade (the red suns). Such a 2D-interface is typical for location-based games – but for this specific case, it is far from being optimal. Due to the inevitable shaking of the screen while running, the player is forced to stop every now and then in order to reorientate herself in the virtual world. Only through this, she can figure out where the ghosts and the remaining coins are at. However, while the player is standing still, the enemies keep moving and thus, the player runs the risk of being caught by one of them, simply because she is forced to pause and look at the smartphone's screen.

The aim of designing a better interface for *PacStudent* first led to an analysis of user interfaces of existing, popular mobile exergames (as detailed in chapter 2) and then to the realization that the complexity of the user interface must strongly correlate with the intensity of movement that is required for playing the game. As pointed out by Sinclair et al. [23], players must be able to focus on a narrow field of attention in order to feel entertained. If their attention lies elsewhere such as the road ahead, the game should not require too much of their concentration. Vice versa, if the player is not preoccupied with a lot of physical activity, the game interface should be able to capture the player's attention for an extended period of time. Thus, interfaces of exergames must balance the two factors complexity of interaction and intensity of movement. While this already holds true for all exergames, an additional challenge of mobile exergames is

that the smartphone's that they are being played on are both input devices and output devices at the same time. This differentiates mobile exergames from most indoor exergames such as *Wii Fit*, where there is a clear separation between the input device (in this specific case the *Wii Balance Board* sensor mat) and the output device (usually a TV screen). The main effect of this is that due to the steadiness of gaze and hand that is required for interacting with small elements on the smartphone's screen, the usage of most graphical user interfaces is impracticable when the user is performing even just mildly intense physical activities. And obviously, this holds even truer for all types of activities that require both hands (such as pull-ups).

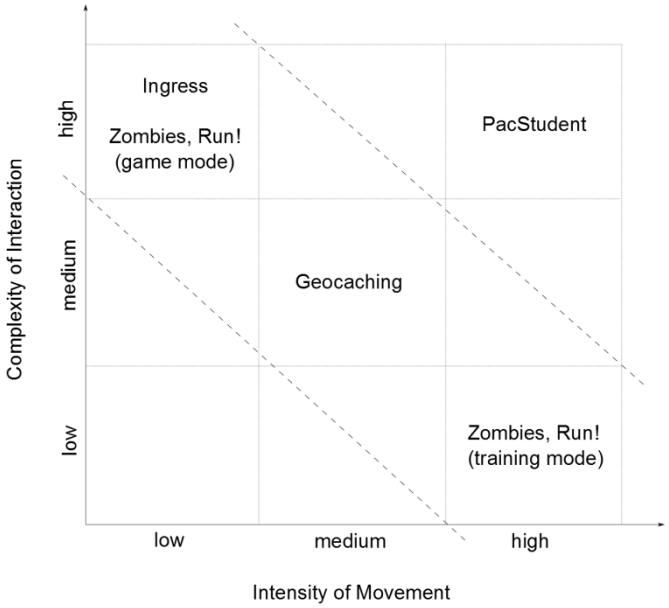

Fig. 6. The Focus Corridor

Figure 6 visualizes what we call the "focus corridor": the range of optimal combinations of user interface complexity and movement intensity for mobile exergames. Combinations "below" the corridor are likely to bore the player, as the amount of focus that is required to maintain her current level of physical activity (such as walking) is low enough to allow for complex interactions with the smartphone, but the game cannot provide for such. Accordingly, combinations "above" the focus corridor are likely to stress the player, because the intensity of her physical activity does technically hinder complex interactions with the device, but the game demands them nevertheless.

Two questions arise naturally from these considerations. The first question is how to classify the intensity of movement; the second question is how to rate the level of interaction complexity. Starting with the first question, we have already found that a difference between indoor exergames and mobile exergames lies in the fact that for

the latter, the smartphone is both the input device and the output device. This influences the extent to which the player can interact with the game and consequently, we can classify the level of physical activity in the context of mobile exergames as such:

- **Low-intensity activities** in the context of mobile exergames are all types of physical activity that enable the user to have both a steady view on her smartphone's screen and a steady hand for interacting with on-screen elements. Examples for this type of activity are sitting, standing, and walking.
- **Medium-intensity activities** are all those activities that prevent either a steady gaze on the smartphone's screen or a steady hand to interact with on-screen elements. Examples are various types of activities that involve the upper-limb such as push-ups, and normal cycling (when the smartphone is mounted to the handlebar).
- **High-intensity activities** are activities that prevent both a steady gaze and a steady hand, such as running and pull-ups.

For the interaction complexity, we propose the following classification:

- **Low-complexity interfaces** in the context of mobile exergames are primarily non-graphical interfaces, such as voice output and input, as well as haptic feedback (i.e., vibration). Depending on the nature of physical activity required for playing the game, very simple graphical user interfaces such as a single large button or a large text label that encompass the entire screen may or may not be counted among low complexity interfaces.
- **Medium-complexity interfaces** for mobile exergames are comparably simple 2D graphical user interfaces with large elements. For some activities such as running, augmented reality interfaces that enhance the camera feed of the smartphone with virtual elements can also be considered medium-complexity, as they allow runners to both focus on the road ahead and to receive visual feedback from the game at the same time.
- **High-complexity interfaces** for mobile exergames are complex 2D interfaces with small elements (such as the game mode in *Zombies, Run!*) and all kinds of 3D interfaces that require the player to use multi-touch gestures (such as in *Ingress*).

A solution to cope with the challenge that the focus corridor poses may lie in the creation of mobile exergames that adapt their interface complexity to the player's intensity of movement. The two game modes of *Zombies, Run!* are a step towards this direction, but more sophisticated games that dynamically adapt their interfaces to the player's physical activity seem reasonable. For instance, Macvean and Robertson [24] have created a prototypical mobile exergame named *Collect the Coins*, which is not unlike *PacStudent* and which uses audio and vibration feedback to notify the player when it is time to stop moving and to look at the smartphone's screen again. We are looking forward to experiment with such approaches in the future and intend to create interfaces that dynamically adapt themselves to the player's activity level, thus providing for a more fulfilling gaming and training experience.

4 Conclusions and Future Work

Motivated by the aim of improving the user interface of our own location-based exergame *PacStudent*, we have analyzed the interfaces of several existing mobile exergames and then developed a methodology for the selection of user interfaces for mobile exergames in general. As a next step, we plan to implement and evaluate various types of interfaces for *PacStudent* in order to determine the respective quality of experience that they provide.

Acknowledgments. This work is partially financed by the European Commission under the FP7-ICT-Project ALFRED (grant agreement no. 611218). The authors would like to thank Chris Michel, Gerhard Saeckel, Christina Stadler, Katharina Moebus, Jan Peter Glock, Juergen Kugler, Yannick Rabow and Ewald Klippenstein for the design and implementation of the original PacStudent game as part of their studies at the Technische Universitaet Darmstadt.

References

1. Goebel, S., Hardy, S., Wendel, V., Mehm, F., Steinmetz, R.: Serious Games for Health – Personalized Exergames. In: Proceedings of the International Conference on Multimedia. ACM, New York (2010)
2. Levac, D., Pierrynowski, M.R., Canestraro, M., Gurr, L., Leonard, L., Neeley, C.: Exploring Childern's Movement Characteristics During Virtual Reality Video Game Play. In: Human Movement Science, vol. 29(6). Elsevier, Amsterdam (2010)
3. Graves, L.E., Ridgers, N.D., Stratton, G.: The Contribution of Upper Limb and Total Body Movement to Adolescents' Energy Expenditure Whilst Playing Nintendo Wii. European Journal of Applied Physiology 104(4) (2008)
4. VGChartz.com: Sales of Wii Sports, `http://www.vgchartz.com/game/2667/wii-sports/` (accessed January 24, 2014)
5. VGChartz.com: Overall Video Game Sales, `http://www.vgchartz.com/gamedb/` (accessed January 24, 2014)
6. VGChartz.com: Sales of Wii Fit, `http://www.vgchartz.com/game/7480/wii-fit/` (accessed January 24, 2014)
7. VGChartz.com: Sales of Wii Fit Plus, `http://www.vgchartz.com/game/35077/wii-fit-plus/` (accessed January 24, 2014)
8. Stross, R.: Exergames Don't Cure Young Couch Potatoes, New York. The New York Times (June 24, 2013)
9. Graf, D.L., Pratt, L.V., Hester, C.N., Short, K.R.: Playing Active Video Games Increases Energy Expenditure in Children. Pediatrics 124(2) (2009)
10. Gerling, K.M., Schild, J., Masuch, M.: Exergame Design for Elderly Users: The Case Study of SilverBalance. In: Proceedings of the 7th International Conference on Advances in Computer Entertainment Technology. ACM, New York (2010)
11. Hardy, S., Goebel, S., Gutjahr, M., Wiemeyer, J., Steinmetz, R.: Adaptation Model for Indoor Exergames. In: Wiemeyer, J., Goebel, S. (eds.) Serious Games - Theory, Technology & Practice. Proceedings of Gamedays 2011. Springer, Heidelberg (2011)

12. IDC Press Release: Worldwide Smartphone Shipments Top One Billion Units for the First Time (2013), http://www.idc.com/getdoc.jsp?containerId=prUS24645514 (accessed February 3, 2014)
13. Dutz, T., Knoell, M., Hardy, S., Goebel, S.: Calm Gaming – How Mobile Devices Could Change the Face of Serious Gaming. In: Ziegler, J. (ed.) i-Com, vol. 12(2). Oldenbourg Verlag, Munich (2013)
14. Official Geocaching Website, http://www.geocaching.com (accessed February 3, 2014)
15. Website of Yelp, http://www.yelp.com (accessed February 3, 2014)
16. Website of Foursquare, http://www.foursquare.com (accessed February 3, 2014)
17. Website of Ingress, http://www.ingress.com (accessed February 3, 2014)
18. Website of Runtastic, http://www.runtastic.com (accessed February 3, 2014)
19. Website of Nike+, http://nikeplus.nike.com (accessed February 3, 2014)
20. Website of Zombies, Run!, https://www.zombiesrungame.com (accessed February 3, 2014)
21. Website of the Runtastic Pumpit apps, https://www.runtastic.com/en/pumpit (accessed February 3, 2014)
22. Website of PacStudent, http://pacstudent.de.im (accessed February 3, 2014)
23. Sinclair, J., Hingston, P., Masek, M.: Considerations for the Design of Exergames. In: Proceedings of the 5th International Conference on Computer Graphics and Interactive Techniques in Australia and Southeast Asia. ACM, New York (2007)
24. Macvean, A., Robertson, J.: iFitQuest: A School Based Study of a Mobile Location-Aware Exergame for Adolescents. In: Proceedings of MobileHCI 2012. ACM, New York (2012)