A Review of Location-based Games: Do They All Support Exercise, Social Interaction and Cartographical Training?

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Abstract: Studies on location-based games ubiquitously report positive learning outcomes for the players. Particularly these games are shown to promote exercise, encourage to social interaction and increase geographical and cartographical knowledge. To find out whether these positive effects are game-specific or characteristic to all location-based games, we conduct a software search for available location-based games on iOS and Android platforms and evaluate if and how exercise, cartographical training and social interaction are supported. Based on our results we were able to identify six sub-genres of location-based games, and the positive effects associated with each genre. The most popular category in terms of number of games was scavenger hunts and the most popular category in terms of active installs on Android and iOS was location-based MMORPG's. Presence of factors associated with immersion and mixed reality were paired with the popularity and positive outcomes of the games. Cartographical practise, social interaction and exercise were supported the most in the location-based MMORPG sub-genre, to which, for example, Pokémon GO belongs to.

1 INTRODUCTION

Location-based games saw an explosion in popularity when Niantic launched *Pokémon GO* in July 2016. Since then numerous companies have attempted to recreate the phenomenon with games of their own, with various degrees of success. Location-based games (LBGs) by definition include gameplay which revolves around the users, or in some rare cases another object's physical location (Rashid et al., 2006). Most LBGs are also pervasive games i.e. games where the game experience is located within or mixed with the real world (Arango-Lopez et al. 2017).

LBGs in general have been identified as potential platforms for future learning (Söbke et al. 2017), because of a track record of positive learning outcomes (eg. Chen and Tsai, 2009; LeBlanc et al., 2017). The very nature of LBGs seems ideal for serious games (SGs) (Abt. 1970) that promote exercise or teach local geography. For example, the currently most popular LBG *Pokémon GO* (See Figure 1) has been identified to motivate exercise (Alha et al. 2019; Althoff et al., 2016), improve topographical knowledge and increase place attachment (Oleksy and Wunk, 2017) and increase social interaction (Sobel et al., 2017; Fettrow and Ross, 2017, Finco et al., 2018). However, *Pokémon GO* is mainly a game for entertainment, not an SG.

Figure 1: The main interface of Pokémon GO.

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Studies have reported similar positive outcomes for other LBGs as well (eg. Stanley et al. 2010; Chittaro and Sioni, 2012; Neustaedter and Judge, 2012) which lead us to form the hypothesis that these outcomes are characteristic to any LBG instead of being specific to the games analysed in above mentioned studies.

In this paper, we first introduce the background of the study by introducing the technical structure of LBG's and going through how they can be utilized in education, with an emphasis on promoting exercise and physical activity, practising geographical, cartographical and topographical skills and increasing social interaction. The background section ends with a look at immersion and its impact on players' engagement and motivation and a brief look at the risks of LBGs. We formulate our primary research question as follows: "Are the three main positive outcomes of playing LBGs characteristic to LBGs in general, or should they be attributed to the few games that have been studied?" and in addition examine how immersive each game is, based on indicators identified in previous studies. In the next section we describe our research design for searching the set of LBGs and for conducting an analysis based on the data. We sort the games into sub-genres and identify positive outcomes associated with each genre. We follow our results section with a discussion on interesting findings and finally conclude the paper with ideas for future work.

2 BACKGROUND

As LBGs are a relatively new genre in games, the terminology used in this field of research is not yet consistent. Among the earliest work on LBGs and their classification is a study by Nicklas et al. (2001) who divide location-based games into three categories: 1) Mobile games that do not rely on accurate location data; 2) Location aware-games, which can be played anywhere and require an accurate GPS signal; and 3) Spatially-aware games, which are usually played on small areas and rely on identifying real world location for triggering game events. This kind of thinking is outdated in the sense that mobile games are no longer discussed as LBGs and spatially-aware games are quite rare in comparison to location-aware games. Sometimes the term geolocation game or game with geolocation is used in describing LBGs (Silva et al., 2017). Since the vast amount of academic papers and even dissertations (e.g. Wake, 2013) has applied the term location-based game as a synonym for what Nicklas et al. (2001) call location aware games, we adopt LBG in our study as a term describing all games, which, in one way or another, utilize the players' location as part of the main gameplay.

Even though the term LBG is being adopted in this study, a body of research on LBGs is done under the term pervasive games (Arango-Lopez et al. 2017) with 25,400 results on Google Scholar with the keyword "Pervasive Games" in publications since 2015, in comparison to 33,000 results with "location-based games". LBGs are indeed in most cases pervasive games meaning that the gameplay takes place in the real world (Montola et al., 2009). In addition to LBGs and pervasive games, other terms used in research to describe some kind of a LBG include *AR-game*, and *mixed-reality games*. (Viinikkala et al., 2016). AR- and mixed-reality games are often *spatially-aware game*s as seen in Figure 2. LBGs can include elements of AR and mixed reality as they have been identified as means of increasing immersion (Shea at al., 2017). The integration of location-based gaming and AR technology could emerge as ubiquitous, collaborative and situated learning, and bridge the gap between formal and informal learning (Wu et al., 2013).

Figure 2: An academically developed mixed-reality game Wordsmith, which is also a spatially-aware game. The game augments 3D characters to historical locations inside the Turku Cathedral.

2.1 Technical Structure of LBGs

The most popular LBGs Pokemon GO, Ingress, Draconius GO, Jurassic World: Alive, The Walking Dead: Our World and Landlord Tycoon-Real Estate Investing Idle are all based on a client-server architecture. This allows, for example, multiplayer capabilities, social features and a place to save player

data in the games (Capece et al., 2016). In addition, running the game state on the server has the benefit of decreasing the likelihood of players succeeding in tampering of game files and other forms of technical cheating (Smed and Hakonen, 2017).

The most common types of LBG gameplay revolve around points of interests (PoIs) placed on the game map, which the player needs to travel to and interact with (Tregel et al., 2017). These points can be created in several ways, some of which are better than others. A random or even scatter of the points around the globe have the following disadvantages:

1) Database capacity will be reserved for points that are in the middle of the ocean, in places where nobody will ever go to.
2) PoIs are not linked with the real world in any way, thus decreasing the immersiveness of the game.
3) PoIs might be located on private property, or in dangerous inaccessible areas.

Using an algorithm that utilizes publicly available data to, for example, filter out points on military districts and oceans can already make an improvement. In order to connect in game PoIs to the real world, human resources can be utilized (Majorek and Duvall, 2016) or the data can to a degree also be created automatically (Tregel et al., 2017).

2.2 LBGs for Education

Parallel with the rapid invasion of technological tools into education, learning is transformed increasingly into fun-seeking activities utilizing educational games (SGs) that foster the learning experience through excitement and stimulation. From early on LBGs have been seen as potential tools for education as they extend the learning experience out into the physical world and provide new advantages such as accessing learning materials in the particular context, collecting field data in-situ, personifying the learning experience and deriving learning value from a personal mobile phone (Benford 2005). Location-based technology has been applied for educational purposes for example by narratives such as a location-based history game in medieval Amsterdam (Akkerman et al., 2009), an interactive LBG for teaching the English language (Chen and Tsai, 2009), a game for learning about cultural heritage (Mortara et al., 2014), and for games designed for museums (Laine et al., 2009; Melero, Hernández-Leo and Manatunga, 2015). Early findings from studies with location-based SGs and AR simulations show positive outcomes in player engagement, participation and physical activity, but also challenges (Dunleavy et al., 2009; Melero et al., 2015). Overall there are a wide range of examples of location-based and AR-technologies being used as part of formal education such as students creating their own AR games (Klopfer and Sheldon, 2010). LBGs will also blur the border between formal (context-free) and natural (informal; contextual) education.

More recent studies on LBGs for education have continued to focus on individual games. Instead of academically developed SGs, the focus has shifted towards commercially developed games and their impact (Hamari et al., 2018; Alha et al., 2019). Söbke et al. (2017) analyse the LBG *Ingress* and demonstrate that the three most thriving reasons players engage in that game and by extension to LBGs in general are 1) being outdoors, 2) detecting new spots in the local environment and 3) having a common activity with friends. All of these reasons are viewed as positive outcomes in addition to being motivating factors for playing. Another study provided additional evidence on how playing Ingress increases on average the wellbeing of its players. (Kosa and Uysal, 2018) Based on their findings Söbke et al. (2017) propose a framework for designing pervasive games, called Pervasive Game Design Framework (PDGF). The framework combines pedagogical objectives with assessment and difficulty. Difficulty or challenge is also identified as an important factor in increasing learning outcomes for serious games (Hamari et al., 2016) According to the model by Söbke et al. (2017), possible pedagogical objectives need to be included in the game flow without disrupting the core of the game that motivates players. Integrating learning objectives into the gameplay has also been studied extensively in the field of SGs and has been found to be paramount in building a successful lasting motivation for the players. (Arnab et al., 2015; Bedwell et al., 2012; Lameras et al., 2017)

2.3 Exercise and Physical Activity

In games that are based on moving around, exercise is a natural and integral component. LBGs which motivate players to travel to geographical points of interests have been identified to result in rapid increases of physical activity in the short-term, however lasting effects depend on the games' capability of retaining the interest of its audience (Licoppe, 2017; Althoff et al., 2016; LeBlanc et al., 2017). When comparing LBGs to health apps, the user demographics are different. Thus, LBGs are capable of reaching those demographics totally

uninterested in health applications and able to motivate them into increased physical activity (Althoff et al., 2016). Some LBGs are designed for the sole reason of exercise (Southerton, 2013), while especially the spatially-aware games fixed to certain small locations do not put any emphasis on exercise (Viinikkala et al., 2016).

2.4 Geographical, Cartographical and Topographical Practise

Location-based games are shown to automatically support cartographical and navigational practise if they contain a navigational interface based on real world maps (Lammes and Wilmott, 2018). Examples of these kinds of games are *The Walking Dead: Our world* displayed on Figure 3 and *Draconius GO* where the main gameplay revolves around navigating to nearby PoIs using the navigational interface provided by the game. The magnitude of the cartographical training depends on how long the game is being played, but also on the PoIs. If PoIs in the game world are not linked to locations of the real world, people are less likely to travel into locations with a significance. However, the existing databases of PoIs cover only certain areas, primarily cities, so algorithmically created PoIs supplement playing in rural areas better (Tregel et al., 2017). Randomly created PoI's also have the advantage of maintaining some novelty in the game and, at best, encourage players to travel to new and interesting places.

Games where PoIs are important real world locations are tentatively more effective in increasing players' cartographical knowledge than alternatives (Andone et al. 2017; Lammes and Wilmott, 2018). Good examples of such games are *Ingress* and *Pokémon GO*, which primarily utilize the same database of PoIs (Tregel et al., 2017). The games encourage players to travel to new places in different ways, for example, in *Ingress* players are rewarded medals for visiting unique PoIs and interacting with them and encouraged to travel long distances in order to create large triangles. The latter mechanic has also been identified as important to the development of geographical knowledge, as planning large triangles requires looking at maps and seeking out key locations via the map instead of the game (Söbke et al., 2017) *Pokémon GO* on the other hand keeps a map of all the gyms the player has visited, and is found to increase place attachment via the jym system (Oleksy and Wunk, 2017).

Figure 3: The Walking Dead: Our World.

2.5 Social Interaction

Multiplayer games by definition include social interaction (Cole and Griffiths, 2007). In all other kinds of games this interaction takes place online, however LBGs change the playing ground by forcing people to go outside and in the best cases, interact with other players. Online multiplayer games have been shown to include social interaction, however the type of interaction is limited and can still make players feel lonely (Ducheneaut et al., 2006). LBGs on the other hand allow for face-to-face interaction with other players and also interaction with people who do not play the game at all. These properties have been highly praised by studies on certain LBGs, primarily Pokémon Go (Sobel et al., 2017; Fettrow and Ross, 2017; Hamari et al., 2017). Some games provide benefits for working together with other players, while others focus more on the competitive side. At launch in 2016 *Pokémon GO* was a competitive game with minor team play elements, but has recently moved towards positive social interaction with recent patches including the addition of raids, trading and friendship levels, which are all game mechanics where the player benefits from working together with other players (Finco et al., 2018). Removing competitive elements might suit LBGs seeking to establish positive social interaction, but can also turn some players away due to the lack of challenge. Furthermore, as studies on SGs have

revealed challenges in social interaction with certain problem types (Dunleavy et al., 2009) or with the group size (Melero et al., 2015), more studies are called for to define the type of interaction LBGs should focus on so that the identified positive social outcomes could emerge (Wang et al., 2018).

2.6 Immersion and Motivation

One big topic among LBG research and development is immersion (Hamari et al., 2016). It is connected to many of the aspects analysed in this study, including the positive outcomes, players' motivation and audience retention. Immersiveness is difficult to objectively measure as it is wholly dependent on players' perception of the game, and depends on a multitude of factors (Kosa and Uysal, 2018; Wang et al., 2017). In pervasive and mixed reality games immersion is largely affected by how well the game is able to blend with reality (Montola et al., 2009; Viinikkala et al., 2016). Factors affecting immersion in LBGs include accurate GPS tracking, use of real world maps, AR features, a realistic story (Baker et al., 2017), real world -based points of interests, social features and taking into account the real world events, for example weather.

Games must be motivating in order for players to sustain interest long enough for the positive outcomes to occur (Deterding, 2012). Digital games in general are known to include addictive elements like instant feedback (Rigby and Ryan, 2011). Still, motivation and engagement are essential not only for encouraging players to play the game, but also to enhance the positive outcomes while playing. (Muntean, 2011). How motivating a game is depends mostly on the game design and implementation, which includes everything from gameplay to content, music and graphics, but also outside factors like social relations revolving around the game. All these elements have an impact on how motivating players perceive the game. A possible way to estimate the level of perceived motivation is to observe the popularity of the game over time. Games that sustain players' interest over a long period of time are agreed to be fun and engaging.

2.7 Risks of LBGs

Studies have highlighted several security and privacy concerns associated with games that have access to the players' location, or revolve around the player moving around in the real world. (Serino et al., 2016) As LBGs blend the game with reality, in the case of the most immersive games the boundaries of the game and everyday life can become blurred (Karpashevich et al., 2016). Players may alternate their moving patterns based on in-game situation and, for example, take longer to get home from work than they normally would (Karpashevich et al., 2016). Parents of the younger players of LBGs enjoy the increased exercise and time their children spent outside playing LBGs, but are worried about how the game might encourage their children to wander in unsafe territory or forget to pay attention to their surroundings while playing (Sobel et al., 2017).

In addition to direct security concerns, LBGs rise privacy issues. With the most popular LBGs featuring a server connection where player location data is stored, companies automatically have access to, for example, the players' location data (Hulsey and Reeves, 2014). In addition some LBGs publicly display players' movement and interaction patterns, which can be scraped and used to determine things like where the player lives, works and spends their freetime. The worst case scenario is that malicious parties use the available location data for criminal purposes, for example, to rob a player while they are away from home playing a LBG or to corner and mug a player in a convenient place. (Hulsey and Reeves, 2014; Karpashevich et al., 2016).

3 RESEARCH DESIGN

For finding a representative sample of LBGs, a general search was opted for in place of a systematic search (Kitchenham et al. 2009), due to the lack of objectively searchable databases of games. Instead we utilized previous research papers which list LBGs (Alavesa et al., 2016) and games found on research papers via the following research databases: IEEE Xplore Digital Library, ACM Digital Library and Scitepress digital library. From 15 academically cited location-based games for education in 2012 six spatially continuous games that fell to our criteria, which we in this paper refer to as location-based games, were *Feeding Yoshi*, *CitiTag*, *CityExplorer*, *Jindeo*, *hitchers* and *MobileHunters.* When searching for these games on Google Play Store in February 2019, we could not find any. As the games are old, mobile platforms have since developed by huge leaps and therefore we assume the old games are no longer maintained and cannot therefore be added into our current analysis. (Avouris and Yiannoutsou, 2012).

LBGs were also searched for directly from the online stores App Store and Google Play Store using the terms *location-based games*, *list of location-based games*, *pervasive games*, *list of pervasive*

games and *the best location-based games*. We used the search engines *duckduckgo* and *Google* using the following search terms and their variants: location-based games, AR games, mixed-reality games, pervasive games and GPS games. From these results we obtained a few final additional LBGs by tracking down games mentioned in *Online Encyclopaedia of Location-based games* (2019) and other privately or collaboratively created lists of LBGs.

3.1 Exclusion Criteria

We focused on games for the iOS and Android platforms, as these two dominate the mobile market at the moment, and provide the most widely spread and popular platform for developing LBGs. In addition to narrowing the platform down to iOS and Android, we decided not to include games which are discontinued or no longer supported. This decision was done in order to be able to obtain all the relevant information from the application, and also to provide direct access to the games. The third exclusion criteria was that the games were published within our linguistic abilities. Therefore the available languages covered were: English, Finnish, Japanese, Hungarian and Swedish. Finally we decided to exclude games which during our analysis proved not to be actual games but rather platforms for creating games. However, if the same app was used as a platform and as a game, it was included. Before categorization, duplicate games were removed and available games requiring unavailable server side support were excluded. Finally applications that supported an activity but were not games as we understand them, for example, Geocaching applications and their variants, (Schlatter and Hurd, 2005) were excluded.

3.2 Data Collection

We looked at previous studies on taxonomies and frameworks for LBGs (Söbke et al., 2017; Avouris and Yiannoutsou 2012; Anastasiadou and Lameras, 2016; Alavesa et al., 2016) and combined elements in order to determine what data to collect from the games. In addition, based on the previous studies on specific LBGs, we obtained factors in the game design which were shown to support positive outcomes and collected data to see if these factors were present. Our data collection scheme was therefore formed to be as follows:

1. Basic information:
   -Name of the app
   -Publisher
   -Platform
   -Year it was published
2. Immersive elements
   -Includes AR features?
   -Is based on a real map?
   -How PoIs are determined?
3. Positive outcomes related
   -Has a speed limit for moving?
   -Includes multiplayer?

Due to the large scope of this study, we used simple indicators for determining the results: a speed limit for moving was seen as an indicator the game wants to encourage the player to walk instead of driving, and the incorporation of a real world map or real world-based PoIs to the game was seen as an indicator of increasing the players geographical and topographical knowledge. If the game contained multiplayer features, we recorded that it encourages players to social interaction.

3.3 Creating Sub-genres of LBGs

Previous attempts on creating LBG characterizations have failed to create LBG-specific taxonomies, but instead, have produced general taxonomies that can be applied to any type of a game (Alavesa et al., 2016). Even though these taxonomies were found to provide tangible results, they failed at grasping the aspects which make LBGs unique among games. In our method for constructing the genres we utilized a grounded theory approach (Charmaz and Belgrave, 2007). We grouped games which shared similar gameplay features together. Our aim was to use collected data as an indicator to which category a game belonged, but we used prevalent gameplay features as the main (overriding) indicator for determining the genre. Existing genres were utilized where feasible (Nicklas et al., 2001). Games, which were left alone in our grouping phase, we moved into a category called *miscellaneous*, as a single game was not large enough a sample to define a genre.

4 RESULTS

The final list consisted 184 LBGs. We excluded 128 games due to their unavailability (discontinued or servers have been shut down), bugginess or the fact that the game was not location-based. This left us with 56 games. Currently the most popular LBG among these 56 LBGs is *Pokémon GO* with over 100,000,000 installs on Android devices only through Google Play Store. The second most popular LBG *Ingress Prime* sits at 5,000,000+ installs through Play

Store followed by *Jurassic World: Alive* (Figure 4), *Landlord Tycoon-Real Estate Investor* and *The Walking Dead: Our World*. Figure 5 shows the most popular LBGs compared to each other in popularity based on the amount of reviews on Google Play Store.

Figure 4: Jurassic World: Alive is currently the third popular LBG. This is the main interface of the game.

The descriptive statistics of the data are presented in Table 1. The most surprising finding was that only two games, both developed by Niantic, based PoIs on real world locations. Other games either randomly placed PoIs on the map, utilized data to automatically create the PoIs or did not utilize PoIs in their game design. 80.4% utilized real world maps, thus linking the game into the real world through cartography. Only 16.1% of the games had a speed limit for moving, which in our study was seen as an indicator that the game designers want players to move by exercising instead of driving a car. Multiplayer features were present in 64.3% of the games in a form or another, although there was large variance in what ways multiplayer was emphasized. Even if a game only included some basic leader boards or even minor interaction with other players, it was classified as a multiplayer game. Finally, AR-features utilizing the mobile phone camera were detected in exactly ¼ of the analysed games.

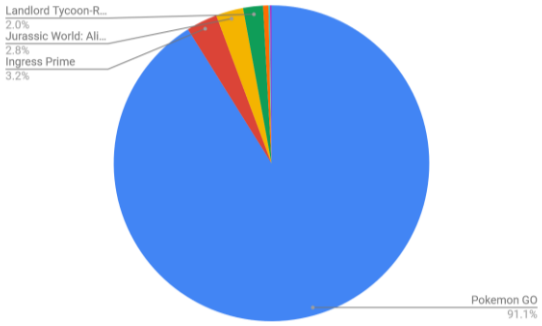

Figure 5: The amount of reviews on LBGs in Google Play Store (February 2019).

Table 1: The results of collected data.

Is the game based on a real map?	80.4%
Speed limit for moving?	16.1%
PoI's match real world locations?	4.0%
Multiplayer?	64.3%
Contains AR features?	25%

4.1 Sub-genres of LBGs

We discovered the following sub-genres of LBGs:

1) *Scavenger hunt/treasure hunt*
   -Players do various tasks in the real world and report them to others
2) *Location-based MMORPG's.*
   -Based on a real map
   -Main gameplay consists of travelling to PoIs and interacting with them.
3) *Spatially-aware games*
   -Designed for a specific environment. Can be inside buildings.
   -Utilize solutions and technologies that take into account that specific surrounding.
4) *Geolocation games*
   -Named after Landlord Tycoon.
   -Utilizes the users' location in gameplay, but does not accurately track user movement or display a local map.
5) *Movement -dependent games*
   -Game events trigger based on user movement, not location.
6) *Miscellaneous games*
   -Games which do not fall into any category

All 56 games were sorted into one of these sub-genres. The first genre and the one with most games was scavenger hunt -games, which is historically the first category of LBGs to emerge (Pirker et al., 2014). *Scavenger hunt games*, or treasure hunt games as they

	Exercise	Geography	Cartography	Topography	Navigation	Social interaction
Scavenger hunt/treasure hunt	medium	low	medium	low	high	high
Location-based MMORPG	medium	medium	high	high	high	medium
Spatially-aware games	low	low	medium	medium	medium	low
Geolocation games	low	low	low	low	low	low
Movement-dependent games	high	medium	medium	low	medium	low

Figure 6: Learning outcomes associated with each genre.

are sometimes called, rely on users creating temporary games, tasks and missions for each other (Pirker et al., 2014 Kohen-Vacs et al., 2012). One such task could be, for example, to travel to a certain location and take a picture of oneself holding a stick there. The scavenger hunt game platform provides functionalities like GPS tracking, storing and showing uploaded media, keeping a track of missions and their completion and giving players in-game rewards. The missions are often location-based, but do not have to be. Examples of these kinds of games are *Scavify* and *Social Scavenger*.

The second genre, location-based MMORPG, was based on games like *Pokémon GO*, The Walking *Dead: Our world* and *Jurassic World: Alive*. These games dominated the popularity charts lead by *Pokémon GO* and shared the following six characteristics:

1) Collecting things while playing.
2) Immersion. At least the following methods were utilized in order to increase immersion: basing the game on real maps, choosing PoI locations in a meaningful way, adding AR features and creating storylines that mix the game with reality.
3) A Map interface. Travelling to PoIs by navigating on a 2D map of the real world was identified as the central game mechanic.
4) Face to face social interaction based on sharing the game world with other players.
5) Limiting the travel speed. Going too fast is punished by limiting or completely removing PoIs. This encourages walking and also serves as a countermeasure for high velocity GPS spoofing.
6) Freemium business model. (Wilson, 2006) Even though not part of the game per se, all games in this category utilized this business model.

The third genre, spatially-aware games was based on the definition of Nicklas et al., (2001) and all games tied into certain places or areas were sorted into this category. Examples include *Oddfellow's Secret* based on Manhattan and *E-BIKEFEST Mountain Quest* created for the E-BIKEFEST event on the Tirolean Mountains. The fourth category, movement-based games based their gameplay on the user movement. Rather than having PoIs on the map to travel to, movement-based games either utilized player movement as a gameplay element or based occurring events on user movement. Examples of these kinds of games include *The Walk*, *Strut* and *Zombies, Run*! The fifth category, geolocation games only showcased a single game: *Landlord Real Estate Tycoon* which we will return to later.

4.2 Learning Outcomes Associated With Each Genre

Based on our review we assigned a 3-point Likert scale variable (low, medium, high) for each of the identified genres on how well a certain positive outcome was present in the games of that sub-genre in general. We looked at representative games for each sub-genre and based on identified factors, evaluated the positive outcome. This data is presented in Figure 6. Because games are extremely complex, the accuracy of the results only depicts what is typical for the particular sub-genre, not the actual magnitude of its impact. Our data does not account for the popularity of the games, meaning the more popular games will generally be more impactful than alternatives, as the effects will inevitably be multiplied by the time spent playing.

5 DISCUSSION

We managed to identify sub-genres for LBGs based on existing games, which are linked not only to the gameplay but also to the positive outcomes the games have. This result is more promising than what previous studies have come up with (Alavesa et al., 2016; Söbke et al., 2017) in the sense that the categorisation reflects actual games like Alavesa et al., (2016) but can also be used to determine positive outcomes and affordances for learning (Söbke et al., 2017).

Interestingly, the sub-genre with most identified positive outcomes, *Location-based MMORPGs*, was found to also be the most popular among players. *Scavenger hunt games*, albeit numerous, have radically smaller player bases and offer short-term amusement and health benefits. *Spatially-aware games* were found to contain on average more immersive elements than the other games, but were limited to a small area and hence their player bases remain small, as does the amount of time spent playing. The *movement-based games* which trigger events based on user movement, like *Zombies Run!* are designed for promoting healthy exercise. The gameplay is designed to motivate the player to run in an effective way, and these games usually do their best not to let gameplay interfere with the positive impact the game has, for example, by forcing the player to look at their phone instead of running. The *geolocation game* category is the odd one out, with gameplay revolving around real world objects, but without necessarily any map interface.

Landlord Real Estate Tycoon (Figure 7) was found to be the fourth most popular LBG with over 5,000,000 installs on Google Play Store and 256,752 and 9600 ratings on Play Store and App Store, respectively. The game was by far the most aggressive in its in-game advertisement among all analysed LBGs, featuring bonuses for sharing the game to friends as well as reviewing the game online. This kind of activity undoubtedly has an impact on the games' popularity. In comparison the fifth most popular game *The Walking Dead: Our world* had only 68,625 ratings on Play Store, however 13,509 ratings on App Store making it more popular on App Store than *Landlord Real Estate Tycoon*. These kinds of differences in popularity between platforms were not common in our sample of games. As we noticed no difference in the quality of the Android and iOS versions of the two games, we came up with two explanations for the popularity difference per platform:

1) Google Play search algorithms give an advantage to *Landlord Real Estate Tycoon*, due to its aggressive in-game advertisement or other factors, or
2) The average owners of iOS and Android devices vary so much in their interest towards games that the impacts on amount of reviews become observable.

Immersive elements like AR and real-world linked PoIs seemed to correlate with popularity directly, with the exception of Monopoly influenced *Landlord Real Estate Tycoon*, which in return included gameplay which we perceived to teach

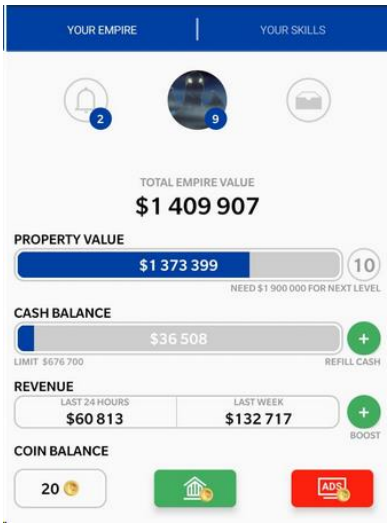

Figure 7: The main user interface of *Landlord Tycoon* lacks location-based aspects.

mathematics and finance (Shanklin and Ehlen 2007). With regards to popularity, our data relies on the information from Google Play Store and App Store, and we were therefore unable to find data on the actual number of players or the hours spent playing weekly. This fact might have resulted in minor inaccuracies in our study.

6 CONCLUSIONS AND FUTURE WORK

In this study, we found 184 LBGs of which 56 matched our selection criteria. Six subgenres were identified for LBGs based on our analysis. We estimated the intensity with which the positive outcomes were present in those categories based on observed indicators. To answer our initial research question we conclude that exercise, cartographical training and social interaction are characteristic to the Location-based MMORPG subcategory. Some of the three positive outcomes were present in other categories as well, but not all of them. Exercise was most strongly promoted in movement-based games and social interaction was present the most in scavenger hunt/treasure hunt games.

Our findings on the educational potential of LBGs are very much in line with previous studies (Söbke et al., 2017; Anastasiadou and Lameras., 2016). As the technology required for creating effective mixed reality LBGs is relatively new and still constantly developing, we expect the popularity and diversity of solutions to grow at an expanding rate. The currently

(2019) two most popular games *Pokémon GO* and *Ingress* are the only ones that create immersive experiences for the players by linking PoIs to real world structures. We wish to see new games on the market utilizing real world -based PoIs to see how big of an impact they really have on the success and popularity of a LBG. A system for automatically creating a database of real world location -based PoIs has been proposed, for example, by Tregel et al., (2017).

The majority of previous studies on LBGs focus on individual games and their impact on an individual sector, for example, exercise (Althoff et al., 2016; LeBlanc et al., 2017). However, understanding general trends and genres do not guarantee that an actual game fosters the predicted positive outcomes on players, so in the future studies on individual games and their impact will still be needed. Currently due to the small quantity of LBGs on the market, meta-studies on learning outcomes of individual games might not produce reliable results, but in the future such a meta study could supplement our understanding of different types of LBGs and associated positive outcomes.

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