CONTINUATION AMIDST CONSTRAINT: FACTORS INFLUENCING RETENTION AND WELL-BEING FOR PLAYERS OF AUGMENTED REALITY GAMES

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DEDICATIONS

To my parents, Howard and May Lee, who believed in me and

supported me unreservedly in every way they could.

To the loving memory of my brother, Jeffrey Lee,

who was always more excited by *Pokémon* than I was,

and in whose footsteps I follow at Penn Nursing

And to my *fiancée*, Kathleen Yin,

whose inquisitive mind and sharp wit never fail to draw a smile,

and whose unwavering love and support has kept me whole through the darkest of times.

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Some days, it feels like an eternity since I first came to Penn. Other days, it seems like only yesterday, as if no time at all has gone by, with an eternity yet remaining. It reminds me a bit of climbing a great edifice – there is much labor involved, it is slow-going, often uncomfortable, and sometimes, in the middle of it all you wonder why you had the bright idea to start in the first place. Having reached the summit at long last, I find myself reflecting on the journey that has brought me here, after so many sleepless nights across so many years, and many words laden with blood, sweat and tears. So many times, I found myself hesitating, or lost, or wondering if I could take the next step, and then the next, and the one after. Alone, I could not have managed to reach the summit of what had seemed a lofty peak, once upon a time, with the kingdoms of the earth laid out below me, the sky above, and endless possibilities before me.

It is only with the help of my professors, my family, my friends, my classmates and even my worst critics (whose words filled me with motivation to succeed in spite of them) that I managed, so I want to take a moment to offer my thanks.

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ABSTRACT

CONTINUATION AMIDST CONSTRAINT: FACTORS INFLUENCING RETENTION AND WELL-BEING FOR PLAYERS OF AUGMENTED REALITY GAMES

Matthew Lee

George Demiris

Literature (Bonetti et al., 2010; Penko & Barkley., 2010; Maddison et al., 2007; Walburton et al., 2007) suggests that exergames can bring about measurable benefits to physical and mental health, though enforced or prescribed play results in play becoming viewed as a burden or chore (Madsen et al., 2007; Heeter et al., 2011), leading to either elimination of benefit from play or discontinuation. The benefits of exergaming are thus contingent on players actively choosing to engage with them, yet there is little research on what drives players to engage, or whether those factors differ across varying populations. With societal changes from COVID-19 possibly rendering many of the traditional avenues and approaches for promoting physical activity either inaccessible or unviable, understanding this becomes critical. This dissertation seeks to addresses this through an investigation of the player bases of *Pokémon GO* (Niantic, 2016) and *Harry Potter*: *Wizards Unite* to expose the factors underlying their continued engagement, as well as players' experiences of these factors affected any benefit they derived from play.

Prior to COVID-19, a demographic questionnaire, physical activity measure, and open-ended proforma were administered to players via four subreddit forums dedicated to the exergames. A total of 1052 participants responded to this survey, with 762 (72%) having played PGO and 691 (66%) having played HPWU. A combination of demographic segmentation and psychographic mapping revealed a number of factors that

either constrained or sustained engagement, with players' experiences with the game and the extent to which factors were important differing based on how they classified themselves as gamers (hardcore, in-between, casual, or no idea). A second survey deployed during COVID-19 (demographic questionnaire, video game use, mental well-being scale, open-ended motivation questions) received responses from 2165 participants across 66 countries. A significant positive relationship between hours of participation in gaming and total hours of exercise per week was noted, coupled with a significant increase in the use of video games, suggesting that AR games continued to promote physical activity during the pandemic. Qualitative results supported this, with achievement, entertainment, exercise and social connection being prominent motivations. Implications for practice and research are discussed.

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CHAPTER 1: INTRODUCTION TO THE BODY OF WORK

1.1 Introduction

Over the last few decades, the increasing proliferation and sophistication of digital technologies in our world has greatly affected every aspect of human life. How (and when) we work, how we shop, how socialize, and how otherwise spend our time – none of these are untouched. In general, these technologies have reduced the amount of physical labor performed by the average worker, increased the speed (and volume) of communication and commerce, and drastically altered the job market, resulting in much higher qualifications being required to obtain even entry-level jobs in the Western world (and much unskilled labor being outsourced, save for that required by service industries). These changes have produced several second and third-order effects in areas such as education, politics, economic impact, and of course, human health.

In terms of technology's effects on human health, there are two core narratives prevalent in the literature. The first is that digital technologies have made – and can be used to make – health information and healthcare more readily accessible to the general population. Indeed, the explosive growth of the internet-using population [1, 2], coupled with the rise of social media platforms and mobile apps, has led to more frequent – and in-depth – patient-provider communications, more complex public health campaigns, as well as the rise of telehealth and telemedicine, with great benefits for traditionally underserved populations [1, 3, 4]. Yet amidst this, the development of consumer-focused (patient-facing) resources such as health websites, forums, or apps has been largely

overlooked, for reasons including insufficient reach, difficulties ensuring adherence, or simply having little expertise in the area. Changing this has been designated a priority by many organizations, with the National Institute for Nursing Research identifying investment "in health information technologies to promote health, engage patients in their own care, and linking underserved populations with available resources to promote health equity," as being vital to the advancement of nursing science [5].

This focus on technology as a means of broadening access to healthcare is part of a broader cross-discipline move toward patient self-management, with individuals being expected to take on additional tasks to manage their own health [6, 7]. This shift has spawned fields of research such as burden of treatment' [6, 7] and 'patient work' [8], which examine the contextual barriers that prevent patients from obtaining maximum benefit from self-management. Specifically, they focus on the financial, temporal, and cognitive costs of the tasks that individuals undertake to manage their health, seeking to quantify and reduce the amount of disruption placed on individuals by the expectations of self-management.

Electronic health resources such as serious games, often perceived as being inherently more engaging and 'fun' than traditional interventions [9, 10] fit into this framework, often being touted as a way to help patients overcome the cognitive burden of behavioral modification. Fitness-oriented serious games (exergames), which mediate physical exercise [11], are a common implementation of this, given that exercise – whether electronically mediated or not – is associated with cognitive, physical, and psychological benefits [12-16]. However, in many cases, the engagement generated by

the intervention is short-lived, with study participants coming to perceive having to play the game as a burden or a chore in as little as a few weeks [17]. This is quite concerning, given findings that this perception of game play as burdensome either can eliminate any positive impact one might derive from the intervention, or in some cases, cause participants to discontinue the intervention entirely [18].

The second narrative touches on the negative effects of digital technologies on human health, and until recently, has largely focused on the complex relationship between physical work, energy expenditure and health. Specifically, most research touches on how decreases in physical activity in the general population due to labor-saving devices and technologies have impacted one's physical wellness, as well as how incorporating regular bouts of exercise into modern life can compensate for this decrease in required physical activity [19, 20]. Current public health recommendations, supported by a robust evidence base, suggest that engaging in at least 150 minutes per week of moderate-to-vigorous activity may help prevent and manage chronic conditions such as cardiovascular disease, type 2 diabetes, and obesity. The last of these is of particular interest, as obesity, in addition to being associated with poorer mental health outcomes and reduced quality of life, is also known be linked to the leading causes of death in the United States and worldwide, which include the aforementioned conditions.

It is thus of no surprise that public health has devoted a great deal of time, attention, and funding to efforts aimed at reducing the financial, cognitive, and temporal barriers that keep people from choosing to exercise. Such efforts have included financial incentives to encourage healthy lifestyle choices (i.e. providing discounts to health

insurance for individuals with gym membership), campaigns with organizations challenging their members or employees to be more active for a given period of time (taking 10,000 steps a day for a month, using the stairs instead of elevator/escalator for a week, etc), or designing environments such that engaging in exercise is either seen as convenient or is simply unavoidable. Conventional examples of this last strategy include corporate campuses being designed to require individuals to get up and walk to reach bathroom facilities, meetings rooms, and the like, companies and apartment complexes offering on-site gyms for the use of employees and tenants, or creating civic and commercial spaces such as malls where gyms, fitness centers, and other facilities for recreation can be found in close proximity to either residences or vendors for essentials (i.e. grocery stores, pharmacies, etc).

These approaches have received a great deal of funding and attention, both from private organizations as well as public bodies. Affecting choices through lowering barriers to accessing available solutions, utilizing group dynamics in existing organizations to encourage participation, and altering patterns of movement and behavior through environmental design are all well-understood and produce greate returns on investment. However, these approaches also have significant limitations, as they assume that individuals possess *at least* one of the following: 1) an interest in exercise that is hampered by other barriers, 2) an emotional investment with the group issuing a challenge and a way for the group to keep members accountable, or 3) the ability or need to use or access these designed spaces.

When these assumptions are violated, these strategies fail to be effective.

This takes on special significance in the context of the COVID-19 pandemic, as the restrictions implemented to curb the spread of the virus rendered these fundamental assumptions moot. The shift to working remotely by many industries during the pandemic meant that individuals no longer needed to use – or were unable to access – corporate or university campuses designed to encourage physical activity. The lack of a shared environment and the absence of face-to-face interactions led to a diminishment of any emotional investment in co-workers as a potential social group, as proximity is a sustainer of community. Its absence thus weakens both the motivational power of a community challenge, as well as removing the ability to hold members of the community accountable. Beyond that, with gyms, fitness centers, and other interior spaces designed for exercise either closed due to being hotspots for the spread of COVID-19 or working out indoors being less comfortable due to masking requirements, these venues may no longer be the default option for those interested in exercise.

Many of these problems will hold true *even in a post-pandemic world*. For one, many industries have indicated that they will continue to allow working remotely either entirely or in part, with some studies suggesting that a sizable percentage of work across all industries and occupations will continue to be conducted via telecommuting following the end of the pandemic. Indeed, nearly 85 percent of companies intend to offer some remote work options post-pandemic [21, 22], with the percentage of paid work done remotely projected to be 25 percent across all industries, up from 5 percent pre-pandemic. This figure is likely to vary heavily by industry and occupation, given that more than half of the workforce have roles which cannot be performed remotely, or where the quality of

work performed may suffer if done remotely (i.e. teaching, legal services). This reflects disparities seen during the pandemic, as those in professions which could not transition to remote work often suffered economic (job loss) or health consequences, while even among those who could, those employed in education experienced a drastic reduction in working remotely when many districts re-opened in late 2020, while a large percentage of those employed in management, finance, or business operations continued to working remotely, and those employed in the technology sector continue to work remotely at high and persistent rates [23].

Beyond where people work, however, there are other behavioral changes to consider. Several studies have indicated that, even after the rollout of COVID-19 vaccination has successfully curbed the pandemic, less than a third of all individuals would consider fully return to pre-COVID behavior patterns. A larger percentage indicated that their behavior would reflect a substantial return to pre-COVID conditions, but even these expressed a reluctance to take public transport, use crowded elevators, go to gyms/fitness centers, or engage in other activities that place them in close contact with large numbers of people. This reluctance presents an additional cognitive burden that traditional approaches must overcome, just as the shift to remote work presents financial and temporal burdens. For those working from home, it will no longer be convenient to use a company's exercise facilities before leaving for the day, or to visit a fitness center after some post-work shopping, even if one is not averse to using such shared facilities.

Any approach to encouraging increased physical activity in the post-pandemic world must thus account for the shifting of a substantial part of the labor force to remote

work, as well as the attitudes, habits, and routines that individuals have developed during the pandemic. All of these are likely to have a profound impact not just on urban economies, transportation, and consumer spending, but also human health. Given this, it is important to examine less conventional approaches to encouraging exercise, especially those which address individuals through contexts other than the work environment, which do not involve tapping into a pre-existing interest in exercise, and which do not rely on individuals being part of a pre-existing community.

One approach of particular interest that lies at the intersection of the two narratives involves leveraging digital technologies to create engaging, entertaining experiences where progression requires players to engage in moderate-to vigorous physical activity. Targeted at individuals, this approach seeks to bypass cognitive barriers towards exercise by reframing exercise as entertainment, with the physical activity players perform being an emergent outcome of play itself.

This notion of 'exergaming', as it is called, first came to popular attention following the 1998 release of the groundbreaking *Dance Dance Revolution (DDR)* series by Konami Corporation's Bemani music games division, though its roots go back to how video games were first experienced in the arcades of the 1970s. In those days, games were not seen as sedentary leisure pursuits. Playing an arcade game such as *Pac Man* [24] or *Galaxian* [25] was a whole-body experience, requiring players to stand in an upright position in front of an arcade cabinet for extended amounts of time while engaging in vigorous jostling of the controls with a great deal of body english involved [26]. Though play on home consoles was engaging in its own way, the more sensitive handheld

controllers and the fact that players were often seated on couches while playing tended to minimize the physical activity required, leading to gaming being considered a sedentary leisure activity.

The ‘exergaming’ experiments of the 1980s, with games being designed for use with alternative controllers such as the Atari 2600’s Foot Craz pad and the Nintendo Entertainment System’s (NES) Power Pad, early precursors to the DDR-style dance pad, were designed to recapture the essence of gaming as a physical activity [26, 27]. These mostly sports or exercise-themed titles met with limited success commercially and did not have much staying power on a cultural level. Part of this may have been due to the lack of market penetration of consoles at the time, due to consoles being more expensive than today in relative terms (a dollar in 1980 having the purchasing power of $3.40 in 2021). However, these games also had additional hardware (i.e. a specific console and the alternative controller for that console) and space requirements (space to store equipment when not in use, space to set up equipment for play, space for freedom of movement during play) compared to non-exergames, and the theming (sports or exercise) appealed mostly to those interested in exercise to begin with.

This lack of success continued until the late 1990s, when *Dance, Dance, Revolution* was released in Japan – first as an arcade game, and later for home console – to runaway commercial success. Indeed, in the six months after its initial launch in September 1998, sales of the title were strong enough that Konami, the developer and publisher of *DDR*, saw a 260 percent increase in its net income over that of the previous fiscal year [28]. Neither was its success and popularity limited to Japan, with its

availability quickly expanding from a few test locations in Illinois and California to quickly becoming one of the most popular arcade games across the USA, despite initially being dismissed by Western critics as an "obscure Japanese title with little to no chance of coming out in the US" [29].

Today, *DDR* is regarded as one of video gaming's longest running franchises, with dozens of arcade-based releases across several countries and hundreds of home video game console releases. It is also the title which first popularized the use of video games as a medium for exercise. What investigation has been done regarding the reasons for the success of this unconventional, genre-defining title suggest that three factors were at play. First, Konami of America marketed DDR as a rhythm game which could be enjoyed by non-gaming audiences, advertising and promoting it in music magazines, parenting magazines and other publications in addition to the usual gaming channels [30]. This was apparently effective enough that even "grandmothers and grandfathers" were playing it, as well as those who were interested in "learning to dance" [28]. Secondly, *DDR*, whose mechanics involved players using their feet to press arrows on a touch-sensitive dance pad in time with hip hop, dance pop, rave or '70s music, with colorful on-screen cues and backdrops prompting players as to steps were coming up next, launched at a time when there was strong interest in dance music and rave culture in the United States [28, 30]. This was particularly so on the West Coast, where many of the initial test locations for DDR were located. Finally, unlike any prior exergame – and most exergames since, with the exception of augmented reality games such as Niantic Inc's *Pokémon GO* [31] – the DDR experience involved more than simply playing the game

[30]. Because the game was installed at arcades, and was exceedingly popular, it was not uncommon for large numbers of individuals to be waiting to play. To pass the time, players often found themselves either watching those currently playing or talking with others in line, with shared interest in DDR being an easy icebreaker among players who were otherwise strangers. This was rather unusual at the time, given that arcades were generally viewed as places one visited with people one already knew, not seen as social spaces where one went to meet new people, so striking up conversations with strangers was seen as somewhat taboo [32]. Even more unusual was how attendees of these impromptu gatherings created websites and message boards such as DDRFreak.com to continue socializing with one another online [30]. These online spaces provided a place where DDR enthusiasts could interact outside of the arcades – and where newcomers could learn about the game, thus increasing the popularity of DDR [33]. Online, people would trade gameplay tips, discuss how to best add their own improvisations to their DDR performances, share where the newest machines were located, or make plans to gather offline. That is, they expanded the definition of participating in the DDR community from playing the game to discussing it with others. This sort of player-driven online community development for a game was nearly unheard of at the time, especially in support of an *offline* activity.

DDR's success sparked renewed interest in exergaming. To the game industry, it demonstrated that it was possible for games that made gaming a more physical activity to become a critical as well as a commercial success. To healthcare providers, it was a possible way to combat the growing obesity crisis by getting individuals who were not

already interested in fitness to exercise. Indeed, in controlled classroom settings, and more generally in school-age children, exergaming shows some promise at increasing levels of physical activity beyond what more conventional approaches are capable of [34, 35]. More recent studies show that exergaming can be an effective short-term behavior change strategy for adults not engaged by traditional exercise methods [36], though there continues to be little scholarship regarding exergaming's efficacy among older adults or as a long-term health promotion strategy [36, 37].

Until recently, however, the usefulness of exergaming as an intervention has been hampered by accessibility issues, given that beyond the specialized hardware (consoles) or high-end computers needed to play modern video games, which few could afford prior to the last decade, exergaming has generally required additional equipment such as virtual reality headsets [38], exercise equipment [26, 38, 39] or alternative controllers – the costs of which can be prohibitive. Prior to the last decade, *Wii Sports* [40], a sports simulation game originally bundled with the Nintendo Wii, was one of the few exceptions, requiring nothing more than the game and console it came with to function. Notably, Wii *Sports* was also very influential in attracting new demographics to gaming, expanding the potential audience for future games [41].

This expansion of the gaming demographic would pay dividends following the introduction of smartphones in the late 2000s. The widespread availability of these smart devices, coupled with improvements to national cellular infrastructure to support data transmission on top of voice, not only provided more people than ever before with access to the internet, but has led to the explosive growth of the gaming market [2, 3].

Improvements in (mobile) internet infrastructure and more affordable smartphones over the last decade only accelerated these developments. Today, almost two-thirds of the global population has access to the internet, a stark contrast compared to the < 1 percent of the 1990s [2]. Beyond that, smartphones have shifted from a popular and affordable way to play games to the largest segment of the global game market [42], with mobile gamers accounting for 2.5 billion people out of the 2.7 billion people playing games worldwide, and the revenue from the mobile games market ($77.2 billion) accounting for 48 percent of the expected revenue from the global games market. For the sake of comparison, it should be noted that out of the population of those playing games, 1.3 billion people play games on computers, and 0.8 billion on home consoles [43].

Given the developments of the last decade, it would not be untrue to describe smartphones as the most democratic of gaming platforms, with the proliferation of these devices and the affordances they allow having reduced or eliminated many of the traditional barriers to gaming. Today, games are more accessible than ever before, making the leisure pursuit available to many who could not previously afford it. This is especially so given that the mobile market is dominated by games utilizing the free to play revenue model [43, 44], a model where games can be accessed for free by users, with revenue acquired through microtransactions, purchases of optional in-game items or other conveniences for small sums [45, 46]. In addition, the plethora of sensors on a modern smartphone, which include, but are not limited to, cameras, microphones, GPS location, accelerometers, and gyroscopes [47] capable of tracking one's position in the physical world, motions, posture, and even where one is looking or what direction one is

facing means that gaming on these devices need not simply be limited to simply interacting with a screen.

The complexity and ubiquity of these devices has led to a new wave of interest in using such technologies for health promotion via exergaming, especially following the launch of *Pokémon GO (*PGO*)* [3, 48, 49]. A free-to-play mobile game developed by Niantic Inc, *Pokémon GO* leveraged many of the smartphone's technical features to create a play experience which involved players exploring the physical world to discover (and capture) virtual creatures called Pokémon. As such, it was an example of a mobile augmented reality (AR) game, with augmented reality being defined as an interactive experience that overlays or augments an individual's experience of real-world environments with computer-generated data or effects [50]. While not the first example of augmented reality in mobile games, or even mobile exergames – this distinction likely going to *Zombies, Run! [51]* – it was the first – and remains the only – to enjoy a similar level of commercial and popular.

In just a week after its July 2016 launch, *Pokémon GO* had already become the most popular game in US history, with its relatively simple play mechanics providing a very low barrier to entry [52]. Indeed, like *DDR* a decade and a half ago, *Pokémon GO* quicky became a social phenomenon. However, while *DDR* could originally only be experienced in arcades in several test locations on the West Coast and Illinois, *Pokémon GO* was freely available to anyone with a smartphone and an internet connection, with the game being downloaded over 100 million downloads in its first month [53] and nearly 45 million people playing every day worldwide (28.5 million in the US). Shortly

thereafter, articles were written that promoted the potential of *Pokémon GO* as a health intervention, with several early studies finding that it increased walking in all players regardless of socioeconomic confounding factors, such as ethnicity or income [54, 55], with one study suggesting that this effect was greatest in individuals who had previously led more sedentary lifestyles [56]. Some studies also suggested that *Pokémon GO* could affect different aspects of one's social sphere to encourage outdoor exercise [57, 58].

As the *Pokémon GO* community became less visible with the onset of winter, news outlets began to report that the game started to lose significant portions of its player base [59], with at least one prominent researcher dismissing it as a fad that was past its time [60]. It is true that player numbers did drop considerably from the initial peak, however, the rush to dismiss *Pokémon GO* as a fad was premature. Despite being an augmented reality game, with unique player constraints due to the physical world being the play environment, *Pokémon GO* still boasted a player base of 5 million people playing daily at the end of 2016 – a number comparable to other successful mobile games [61]. While *Pokémon GO* did lose a substantial portion of its original player base, this is expected for mobile titles, for which the barrier to entry – and thus the barrier to exit – is particularly low, especially among those who do not traditionally classify themselves as gamers. Indeed, even at launch *Pokémon GO*'s weekly retention rate of 75% was on par with that of other top-rated games such as Candy Crush Saga – without having developed the same mechanisms that these other games use to keep their retention rate high [61, 62].

Pokémon GO continued to thrive over the next few years, retaining a player base comparable in size and activity to other top-rated mobile games, and coming in as one of

the top 10 highest grossing mobile games in 2017, 2018, 2019, and 2020 [61]. This longevity presents an unusual opportunity to assess the long-term impacts of an exergame on its players – something which no study has done to date, despite many having identified the lack of research on long-term impacts as a clear gap in our understanding of whether exergames can be useful as behavior change interventions in any timeframe beyond the short-term.

Also of interest is how *Pokémon GO*'s user numbers and revenue both increased during the COVID-19 pandemic, despite restrictions that both made it difficult for players to go outside and which closed many of the public spaces where players traditionally gathered the game. Indeed, the number of monthly active users of the game rose by 45 percent between January and August 2020, and the game's revenue in 2020 was the highest in its history, exceeding even the figures from 2016 [63]. This is very unusual for a game whose basic design requires players to go outside and walk around, and so presents a curious case of continuation amidst significant constraints which warrants closer examination.

In the context of the ongoing pandemic, and especially for designing interventions for a post-pandemic world, it is critical that we understand the factors that influence retention and well-being for players of augmented reality exergames, with the example of *Pokémon GO* as a popular exergame possibly providing insights for the design and implementation of future exergames – or indeed, future digital public health interventions in general.

Most current studies involving exergames or serious games in general involve bespoke apps created by researchers for the purposes of a particular study, with said studies often being conducted with homogenous populations over a limited timeframe [49, 64-66]. While convenient from a data collection perspective, such design choices do not consider the complexity of the modern computing experience [67] nor the circumstances of the intended users. Among the largest shortcomings of these traditional approaches are that: 1) individuals recruited for the purpose of a study may not match the characteristics of the target population; 2) the study protocol may bypass many of the barriers that an app would face on the market, with users being provided with the game – *and the hardware needed to run the app*; and 3) forced use of an app or game has been known to decrease engagement, reduce levels of enjoyment, and reduce or eliminate benefit [18].

Notably, the factors which drive individuals to engage with a given intervention or not are rarely examined, and if they are, rarely over time. This limited context is problematic as the conditions in which digital interventions are intended to be used are rarely as well-regulated as those of a randomized control trial, meaning that the applicability of findings from such trials is limited. At best, one may be able to infer short-term impacts. Neither what drives players to engage with an intervention, now how willing a player may be to use an intervention outside of a trial or whether any impact shown can be sustained in the long term can be assessed.

What little has been done to assess how people engage with technology over time in a more naturalistic setting has come from looking at games which have not been

designed for health purposes, but from which many health apps borrow design principles or elements [68]. By and large, such research has focused on massively multiplayer online role-playing games (MMORPGs) such as *Everquest* [69] or *World of Warcraft (WoW)* [70], with the latter being one of the world's longest running examples of the genre. MMORPGs, however, are noted for the complexity of the social structures permitted in their virtual environments, with as participation in these resulting in tangible reductions in negative psychological symptoms and increased player retention [71]. Such structures also occasionally result in interesting emergent phenomena, with the Corrupted Blood Incident being one of the most notorious. In this incident, a programming oversight where virtual pets of players unwittingly became asymptomatic carriers of a virtual pathogen, coupled with the ubiquity of fast travel led to a virtual pandemic ravaging the world of *WoW*, turning densely populated cities into mass graves [72]. While is somewhat disconcerting to compare this incident with the COVID-19 pandemic, clear parallels can be seen in how despite repeated attempts to contain the outbreak, including social distancing recommendations, attempted lockdowns, and the like, wide-scale access to rapid transport, asymptomatic carriers, and unanticipated behavior resulting from misinformation, panic, or simply not taking the pandemic seriously rendered such efforts moot.[72] There the parallels end, given that WoW exists only as an online game. Blizzard Entertainment could simply turn back the clock to a time before the Corrupted Blood Incident, while there is no such way to so offline. Thus, while the study of MMORPGs may be useful in provide some insight into retention for such games or ways to study or influence health behavior, it is not directly applicable to games where play involves interacting with non-virtual locations [72, 73].

Further, following the release of smartphones and their rise to popularity in the last decade, the dominant gaming platforms and how engages with them has also shifted. It is no longer MMORPGs like *WoW,* where engagement with the game and its community is primarily through long periods of play, that attract the most sizable or diverse user populations, but mobile games, where play tends to occur in intense, but intermittent, bursts and complex social structures are almost entirely absent [2, 67, 68, 74]. The communities that eventually form around them are *user-driven*, much like those which sprung up around *DDR*, though today, such communities are easier to establish, due to the existence of social media platforms such as Reddit, as well as services such as Facebook or Discord.

That users put in the effort to create these communities, even without support from developers, suggest that they fulfill a useful function, and that the relationships they provide may be an important part of the play experience – though whether participation in these communities affects retention has not been studied [75, 76]. In other contexts, research has shown that a person's likelihood of choosing to engage – and persist – in a behavior is often related to the number of others they know who engage in said behavior, and the frequency with which they interact with those individuals [6, 77, 78]. Whether this holds true in these *user-driven* communities is currently unknown.

Anecdotal evidence from the DDR era that suggests that these sorts of user-driven communities serve a key purpose in deepening relationships and bringing more people to the games they support, with the discussions they allow and their facilitation of offline meetups being as important for sustaining interest in a game as actually playing it [30,

33] but there has been little research done in this area. The community around *Pokémon GO* has parallels to the one that sprang up around DDR, given that like the popular rhythm game, *Pokémon GO* is also played in public physical spaces. And just as with the communities that discussed DDR, *Pokémon GO's* user-created online spaces both facilitate discussion of the game and help players to find others to play with in their local area [79, 80].

What happens to such a community then, when it is unable to serve one of its primary functions due to the COVID-19 pandemic? From what we know to date, the pandemic prompted major shifts in how people socialize and share information, with many individuals being forced to reduce or eliminate face-to-face interactions with those outside their households due to prohibitions on in-person gatherings [81]. These individuals have had to rely on other channels to maintain relationships, such as social media, chat programs or phone conversations [82] – technologies which were largely designed to supplement face-to-face interactions, not replace them. While the exact percentage of information that is conveyed non-verbally may be disputed [83], as well as how important such information is to facilitating understanding and connection, it cannot be denied that these alternate channels do not convey as much information as a face-to-face conversation. These alternate channels seem less "human" [82], especially when visual cues cannot be shown. Some research suggests even largely text-based channels such as social media and messaging services can be used to maintain friendships, familial ties, and emotional connections at a distance [84, 85]. Yet, how well does that apply when individuals may not feel a sense of connection to individual members of a given

community, but to a community as a whole due to engaging in shared activities? [57] What happens to this sense of connection when individuals can no longer engage in these activities together, or can only do so remotely? [63] Research has shown that complex tasks and collaboration can suffer [22, 82], and that forcing individuals to engage with technology on terms other than their own may result in them losing most of the potential benefits [18], yet despite these constraints, *Pokémon GO*'s user community does not seem to have suffered, given how its player base and revenue numbers both grew during the pandemic. Why was this the case, and are there aspects to its resilience in the face of constraints that can be applied to the design of future interventions?

This is important to understand, given that after nearly five years, *Pokémon GO* continues to be the top performing exergame on the mobile market, as well as the top performing augmented reality mobile game, commanding 84% of the market share for location-based games in terms of players [61]. This is not for lack of would-be rivals – several major augmented reality titles have been released in the past few years, backed by popular intellectual properties – yet *Pokémon GO* has retained its dominant position, with no serious competitors globally, and no other game even coming close to replicating its global success. Even *Harry Potter*: *Wizards Unite [86]* (HPWU), Niantic's follow-up to *Pokémon GO*, failed to do so, despite being based on one of the largest entertainment IPs in the world and using a more complex implementation of augmented reality [87, 88]. This suggests that neither technical complexity, nor the strength of the underlying intellectual property, play a major role in determining whether a game will be successful, either in terms of earning revenue, or attracting a large, dedicated userbase. The first of

these may not be important for interventions designed as population level strategies for promoting exercise, but the second certainly is. To that end, research needs to be done to determine what factors are important to the success of an augmented reality game, with particular attention to noting which factors are tied to commercial success, which are tied to their efficacy as exergames, and whether this varies according to the preferences of different populations of players.

In anticipation of the changes in the post-pandemic world, it is critical that any interventions created to replace or supplement traditional approaches to combating obesity be designed to be accessible, engaging, and resilient against disruption from contextual restrictions. The state of the science, as it stands, is insufficient to ensure this, as there are several major gaps in the literature that need to be addressed.

1.2 Purpose of Study

Based on the above analysis of the outstanding issues in our understanding of what makes augmented reality games successful both as exergames and commercial properties in the face of constraints, the primary goals for the proposed research are to fill the gaps in the literature via a review of the gaming literature to identify how *Pokémon GO* either builds on or diverges from conventional design principles, as well as a mixed-methods investigation of the player community of *Pokémon GO* to gain a better understanding of the factors influencing their retention and wellbeing, both prior to and during COVID-19.

Specifically, the goals of this project are to explore:

(1) how exergames are currently evaluated;

(2) how *Pokémon GO* (and augmented reality) fits into what is known regarding exergame (and game) design;

(3) whether augmented reality exergames can have a long-term impact on health behavior;

(4) how factors underlying player preferences and health outcomes vary across player populations;

(5) the impact of COVID-19 social restrictions on the physical and mental well-being of AR game players;

(6) the impact of COVID-19 social restrictions on usage of video games and motivations for use;

(7) the potential role of AR games (and video games in general) in supporting well-being in the context of COVID-19.

1.3 Significance

In accordance with the goals specified above, the results of the study are intended to advance our understanding in the following areas:

(1) By examining how exergames are currently evaluated, the proposed study will be able to identify weaknesses in existing methodologies that hamper our ability to design effective, long-lasting digital interventions.

(2) Having a better awareness of how *Pokémon GO*'s design compares with predecessors and contemporaries may help us to identify commonalities - design features that are likely to be effective if used in other games – as well as areas for future study.

(3) While literature exists regarding the effectiveness of *Pokémon GO* and other exergames as short-term interventions, there have been no studies on long-term effects. This is a crucial gap to fill in, as whether long-term effects are present drastically affect how viable exergames – and serious games in general – are as an alternative to traditional health promotion techniques.

(4) Exergames, like serious games in general, are designed to both entertain as well as to promote physical activity. While general design factors for promoting both are well known in the literature, what is not known is how different types of players (assessed both demographically and psychographically) interact with these factors. A better understanding of this may lead to improved retention (via better meeting player preferences), and improved health outcomes (as a byproduct of play).

(5) Though *Pokémon GO* flourished commercially during the COVID-19 pandemic, exceeding even its 2016 numbers in terms of revenue, it is well-known that commercial success does not necessarily translate into improved health outcomes for players. By assessing the well-being of players during the

pandemic, we can see how they may have done compared to the general population, and what factors may have been behind this.

(6) At the height of the pandemic, stay-at-home 'lockdown' and quarantine measures led to severe disruptions to the usual functioning of society. While other studies have shown that the amount of time spent on games spiked during this time, evaluating whether this came about due to a universal rise in time spent on games or resulted from groups who did not game as much traditionally has interesting ramifications for the design of future interventions – especially in future crises.

(7) Similarly, understanding the qualitative reasons behind this increase, and what roles different groups of players see as serving may help us better understand the characteristics of this population. Understanding of the similarities or differences between groups may also help us determine whether some findings from other studies can be applied to certain groups. This, in turn, may set the stage for future research.

1.4 Organization of Dissertation

This work will be structured as a three-paper dissertation, with each paper addressing a subset of the overall project goals.

(1) **Paper 1, "**When the mind moves freely, the body follows – Exergame design, evaluation, and the curious case of *Pokémon GO*" [89], is a review of the literature regarding exergame design and evaluation, especially as it applies to

Augmented Reality. It serves as an overview of the exergaming genre, and addresses project goals (1) and (2). This paper was published in the *Journal of Games, Self, & Society*.

(2) **Paper 2,** "Developing a novel demographic-psychographic qualitative mapping method to profile players of *Harry Potter: Wizards Unite* and *Pokémon GO*", will be addressing project goals (3) and (4). It is a mixed-methods examination of data collected from the *Pokémon GO* and *Harry Potter: Wizards Unite* communities from February 1 to March 1, 2020, prior to the implementation of COVID restrictions. This paper explores how constraints, involvement, and the construct of involvement are experienced differentially across different player types and contexts, as well as how changes in physical activity due to AR games may be linked to such identities. Notably, this paper is the first to report long-term impact from exergame use, with clear differences seen in impact across user profiles, as well as research into how the construct of involvement (attraction, sign-value, centrality, & risk) may help to create strong attitudes toward resistance to change in the face of obstacles. This paper has not yet been published but will be submitted to the *International Journal of Serious Games*.

(3) **Paper 3**, "COVID-19 as 'Game Changer' for the Physical Activity and Mental Well-Being of Augmented Reality Game Players During the Pandemic: Mixed Methods Survey Study" [90] will address goals (5), (6), and (7). It is a mixed-methods examination of data collected from the *Pokémon GO* and *Harry Potter: Wizards Unite* communities from May 15 to May 29,

2020, in a period during which countries were under COVID-19 restrictions. As part of the greater body of work represented by this dissertation, this exploration of how COVID-19 and the constraints it imposed affected the *Pokémon GO* and *Wizards Unite* can be seen as a natural experiment testing the validity of the profiles from Paper 2, as well as testing whether AR exergames are useful in the context of COVID-19. Originally published in the Journal of Medical Internet Research (http://www.jmir.org), 22.12.2020.

Data for papers 2 and 3 was collected as part of an experimental protocol titled "Augmented Reality is not a panacea: A *Pokémon GO* and *Wizards Unite* player engagement comparison." Ethical approval for the original protocol was obtained from Macquarie University's Human Research Ethics Committee for Medical Sciences (Reference No: 52019601512435), with use of data from the protocol for the purpose of this dissertation granted exempt status by Penn IRB #8 (Protocol 844394).

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WHEN THE MIND MOVES FREELY, THE BODY FOLLOWS- EXERGAME DESIGN, EVALUATION, AND THE CURIOUS CASE OF POKEMON GO

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Abstract

Exergames, video games that mediate physical exercise, have been used with demonstrable success to improve physical fitness. However, the health impact that exergames can achieve is not restricted to increasing the amount of physical activity players engage in. These games have been used in other aspects of healthcare, such as cognitive training and mood-improvement, and may reduce the burden of treatment experienced by patients. To measure such parameters, researchers require different kinds of methodologies that can assess the subjective perceptions of patients *and* take into account the social relatedness, autonomy, and sense of competence offered by good exergames. This article provides an overview of the health benefits of exergames that have been measured to date, the methods by which the data on these benefits has been obtained, and the design principles that maximize the self-motivation that serious games can evoke from their players. We provide an analysis on the factors that propelled

Pokémon GO into becoming one of the most successful exergames in recent memory and the apparent decline of interest towards the game. By assessing the lessons learned from *Pokémon GO* as an example of successful exergame design, and by developing innovative and comprehensive methodologies for evaluating effects, this paper suggests how exergames more broadly may better serve the holistic health benefits of players at a large scale.

Introduction

Exergames, defined as video games that mediate physical exercise [1], are one of the earliest examples of video games used for purposes beyond entertainment. From the 1988 Nintendo Entertainment System title *World Class Track Meet* [2] to Wii and Xbox Kinect systems that drove wide public adoption of exergames, to phone-based exergames and virtual and augmented reality—the experience offered by exergames continues to encourage players to perform physical activities by giving these activities meaning. Exergames used for the purposes of physical therapy or to promote physical exercise have been shown to be beneficial in observational studies [3], mixed-methods studies [4], calorimetric studies [5, 6], and in randomized-controlled trials (RCTs) [7, 8]. Because of studies such as these, exergames are one of the stable examples that demonstrate the benefit of video games in healthcare. Even off-the-shelf exergames on the Wii and Xbox Kinect platforms have been utilized for therapeutic as well as preventative purposes [9-13].

While exergames found success as a suitable augment to exercise or physical therapy, these successes are not always consistent in the literature. The games' effects are commonly measured outside the environments in which they were designed to be played.

One of the core reasons for using video games in healthcare is to take advantage of the various mechanisms by which games elicit player motivation [14, 15], resulting in health consumers being more willing to engage with the game in their free time [16]. However, the controlled laboratory settings in which exergames are usually assessed do not reflect this play environment, and thus do not reflect the true behaviors and motivations of participants when they access the game in on their own. As such, despite quantitative RCTs being considered the 'gold standard' for producing evidence in health research, its inability to capture the full extent of the health effects of these games in the context of everyday use creates significant drawbacks.

Purely quantitative methodologies struggle with taking into account the individual characteristics of participants and the subjective, qualitative context surrounding health-related actions [17-21], both of which affect the burden of treatment experienced by health consumers. Medical therapies intrude into people's existing daily routine in an ergonomic sense, demanding both material and mental resources from the patient and their environment [22, 23]. The investigation of the physical, cognitive, and opportunity costs for engaging in health therapy is a growing field of research [24, 25]. Exergames—and serious games in general—are interventions poised in-between voluntary entertainment and regimented therapy, and their effects on reducing treatment burden deserve to be explored

It is important to remember that for all their therapeutic benefits, most exergames are still fundamentally designed first as games, employing mechanisms such as competition and narrative to motivate participation and increase retention. For example, *Wii Sports,* one of the most commonly used exergames for health today, was created to

be a social game. The presence of a community (and the social support derived from it) greatly impacts whether an individual who tries an activity or lifestyle will continue with it for any length of time. Other games, such as *Zombies, Run!*, instead increase immersion by integrating exercise into the game narrative. During this game, a player is placed in the role of a zombie apocalypse survivor tasked with retrieving supplies for a settlement of fellow survivors. As they run, gathering supplies and accomplishing objectives, they unlock more of the story and interact with other survivors, fostering a sense of competence and connection that goes beyond the satisfaction of the activity itself. There would be little point to creating an exergame without utilizing these mechanisms given that interactive media in and of itself has no inherent ability to motivate people. Rather utilizing the elements of interactive design transform blind repetitive activities such as exercises into engaging experiences.

Despite the positive results of purpose-built exergames, one of the most successful exergames in recent years is in fact *Pokémon GO* [26], with more than 147 million players at its zenith. Though not promoted as such, as a *de facto* exergame physical activity (walking) is required to progress in *Pokémon GO*, yet the lack of emphasis on exercise in any messaging reduced the sense of cognitive burden experienced by players reluctant to exercise. It also should not be discounted how much *Pokémon GO*'s success lay in its ability to create a sense of community among its players, especially by using something other than competition via the quantified health paradigm upon which most conventional exercise apps are built [27]. A reduction of burden [28] and a sense of community [29] are known to positively correlate with health

behavior change and are utilized frequently in community-based care in the form of patient support groups.

This paper provides an overview of the current methodologies that have been used to examine the effectiveness of exergames. Just as exercise is known to bring more to holistic health than just physical enhancement, the contribution of exergames to players could well lay beyond simple improvements in physiological parameters. Common strategies employed by games to increase intrinsic motivation will also be discussed as fostering patient motivation for achieving health goals is one of the fundamental reasons for using games in healthcare.

Holistic Benefits of Exergames

Exergames have been compared extensively to sedentary activities and standard exercise, assessed through a variety of parameters such as heart rate [30], oxygen consumption [31], electrocardiograms [32], and self-reported duration of exercise [33], all of which concluded that exergames bring about measurable physiological benefits. Specifically, RCT studies agree that exergames have the potential to improve physiological parameters to an extent comparable to light exercise [8]. There is ample evidence regarding the impact of exergames on physical health and fitness, as long as participants spend enough time playing such games on a regular basis.

The physiological benefit may vary depending on the type of exergame. Peng, Lin, and Crouse [34] found in their meta-analysis that exergames did not produce more physiological changes than standard moderate-intensity physical activity, and are potentially not suitable as replacement for vigorous exercise. Exergames that mainly

involve movement of the lower body have greater physiological effects than games that involve only upper body movement [6]. Also, children have higher energy expenditures than adult participants [5, 6]. These findings suggest that games involving larger, more full-body movement for children have the highest potential to increase player energy expenditure and elevate exercise intensity.

Exergames have also been used to improve higher cognitive function for patients recovering from stroke while also providing equal or better physiological improvements compared to standard rehabilitation [35-37], making exergames a possible alternative therapy for these patients. Similarly, exergames were also used for cognitive treatment in Parkinson's Disease, Alzheimer's Disease, and other health conditions with neurological disabilities [38]. The games were found to yield comparable results to conventional therapy and participants report a good sense of satisfaction following exergame use [36].

Exergames can be effective for mood improvement [39], similar to other forms of exercise. In fact, mental health is one aspect of healthcare where serious games are known to make a significant impact [7, 40] and the efficacy of exergames in the field is to be expected. Indeed, exergames were specifically found to have a beneficial effect on the mood of geriatric patients [41, 42]. Li et al., in their meta-analysis [39], note that exergames that are more 'playful' (eg. *Wii Sports*) have a significantly larger effect size regarding mood-improvement compared to exergames that are less 'playful' (eg. *Wii Fit*, which consists of explicit fitness activities such as yoga).

Exergames may also be of interest to the growing field of 'burden of treatment' and 'patient work', which examine the contextual barriers that prevent patients from obtaining maximum benefit during health treatment. 'Burden of treatment' [22, 23] and

'patient work' [43] are branches of self-management that focus on the tasks that health consumers have to undertake in their care and the costs of these tasks, acknowledging that medical treatment is a major disruption to the patient's life. As the very foundation of game-based therapy rests upon the idea that games can overcome barriers to behavioral modification by providing fun and incentives, exergames are uniquely positioned to address this emerging recognition of treatment burden. After all, when patients are self-motivated and no longer feeling an immense cognitive burden from the treatment, they are much more likely to adhere to therapy.

Self and Socially-derived Mechanisms of Motivation in Exergames

With games, much like activities such as sports or exercise, *sustained* participation is rooted in how well an activity satisfies three fundamental human needs: competence (sense of efficacy), autonomy (volition and personal agency), and relatedness (social connectedness) [44, 45]. In fact, the Cognitive Evaluation Theory (CET), a sub-theory of Self-Determination Theory [46], suggests that the extent to which an activity satisfies these psychological needs strongly influences the extent to which they affect player well-being.

Drawing on the CET, the Motivational Model for Video Game Engagement (MMVGE) [44, 47] posits that two additional factors play a role with games: mastery of controls and the experience of immersion. Mastery of controls is defined here as the learned ability to perform intended actions in a game's environment, a necessary but not sufficient condition for achieving psychologically need-satisfying play. Immersion, on the other hand, is a key moderating construct which reflects an illusion of non-mediation

between a player and the gaming context, so that a player feels directly embedded within a virtual environment [48]. In the MMVGE, immersion is trifurcated into the dimensions of physical presence (feeling one is actually in the world of the game), emotional presence (feeling that game events have real emotional weight), and narrative presence (the extent to which one has a personal investment and engagement with the story) [47]. Varying the level of immersion across these dimensions has been shown to affect memory of the experience [49], enjoyment of an experience [47], and the carryover effects of content into real-world outcomes [50].

The studies on which the MMVGE was based also uncover a curious finding: many popular games are designed to satisfy psychological needs, with substantial differences in enjoyment, immersion, and pre-to-postplay shifts in well-being [47]. The importance of this finding for the field of serious games—especially games for health—cannot be overstated, as player need-satisfaction in such games has often been deemed unimportant, set aside as frivolity that interferes with learning objectives. Such a stance is only possible as the developers of such games are rarely financially vested in the success of a given intervention, with funding provided up front by a client or a grant [51].

Granted, this was not the case twenty years ago, when a number of serious games like *Captain Novolin* (Raya Systems, 1992), a Super Nintendo game in which players controlled a diabetic superhero and were tasked with managing his blood glucose levels by collecting food powerups to help him fight off aliens, enjoyed a degree of commercial success, being sold in stores alongside entertainment-focused game titles like *Indiana Jones and the Fate of Atlantis* (LucasArts, 1992). These games were no less clinically successful than those being made today, with *Captain Novolin* and similar diabetes

games successfully reducing a diabetic child's likelihood of hospitalization from a hyperglycemic crisis by 77 percent [52], as well as decreasing social stigma around diabetes and helping children speak with their friends about their condition [53]. Unfortunately, due to market pressures and downward pricing by retailers in the following decade, the edutainment industry went into a steep decline [54]. Today, most serious games are no longer distributed commercially, with many developers preferring to fund their titles in a manner that does not leave them at the mercy of the retail marketplace [51]. What few remain in this space tend to either call themselves exergames, or refrain from calling themselves serious games at all.

Two examples of the first are *Wii Sports*, which carries the distinction of being the bestselling single-platform game of all time, and *Zombies, Run!*, an immersive running game which became the highest-grossing Health & Fitness app on the Apple App Store within two weeks of release despite its high price point [55]. To achieve their success, both were designed with player need-satisfaction in mind, with a number of elements implemented not only to lower the cognitive burden of the physical activities they promoted, but to lower the cognitive burden for playing the game.

In *Wii Sports*, players interact with the game by using the Wii Remote to mimic the actions of real-life sports. The game requires no hardware beyond what is provided by the Wii system and the motions are intuitive thanks to the Wii Remote's built-in motion sensors. This gives it a substantial advantage over games which require expensive extra hardware, especially those with a steep learning curve (and thus, a higher barrier to mastery of controls) like the Xbox Kinect. Similarly, with *Zombies, Run!*, the primary interaction a player has with the game is listening to the narrative while running, with the

built-in accelerometer of the smartphone tracking the player's movements. No additional hardware is required, nor does a player have to do much when running, save for following instructions to speed up, slow down, or turn to escape the undead hordes.

Considering the settings in which the games tend to be played and how this shapes the resulting play experience is also important. While *Wii Sports* does have a robust single-player practice mode, it is far better known for its multiplayer functionality. Indeed, outside of the therapeutic context, the title is most commonly played in local multiplayer mode at parties and other social gatherings. As such, the design of the game draws upon a sense of social connectedness and playfulness to encourage people to participate and allows players to create their own narratives around competition [39].

Zombies, Run!, by contrast, is a much more solitary experience: an interactive audio-book paired with a survival game, in which players are given the role of a survivor of a helicopter crash, Runner 5, through whose perspective the story of the game unfolds [56]. The design is highly immersive, with the protagonist's narrative synchronizing with the player's actions such as collecting resources while running. As well, it provides meaningful choices regarding what to do with those resources, influencing the course of the story. *Zombies, Run*! fosters a sense of personal investment into the events of the story, tapping into what Adrian Hon, the game's producer, calls a fantasy that many people have: that they can be the hero of their own action movie [56]. This is not dissimilar to the core conceit of many conventional role-playing games and the deep individual immersion they create, even if these games are interacted with via a keyboard or controller. However, such an immersive experience often requires a significant investment in time, effort, and mental energy. The burden of deeply-immersive narrative-

driven games like *Zombies, Run!* tends to be balanced by the knowledge that these investments are finite—at some point, the story will come to an end. This luxury is not shared by health consumers diagnosed with a chronic condition such as heart disease, which cannot be completely cured no matter the investment they may painstakingly put into self-management.

But what if the goal of the game—and the treatment—is to create a non-finite play experience? A continuous behavior modification? To keep players motivated and coming back time and time again? Immersion, via narrative or otherwise, only works for finite periods of time. A game can release large amounts of content, but digital content in and of itself does not necessarily generate interest. As popular games like *Wii Sports* suggest, fostering a sense of relatedness and creating a space which supports the growth of communities, whether formalized or not, is a strategy that motivates players to return.

Fostering this kind of community-building space usually involves incorporating multi-player elements into a game. In some of the largest multiplayer digital games, this takes the form of gameplay modes where players either find themselves pitted against one another or in group content where players cooperate to overcome a challenge insurmountable by any single one of them. Given hardware and practical limitations, these scenarios are less common in mobile applications. Many mobile games implement some sort of unit loan system—a sort of asynchronous play where one borrows a character from a friend to support them though difficult content. In either case, in-game mechanisms are supplemented by online communities that exist outside the game on platforms such as forums and social media. In these virtual spaces, players can share information, show off their achievements [47], and find general support—players can see

that they are not alone—and consequently feel they are part of something bigger than themselves, even if the interactions between them and the community may be limited. Occasionally, portions of these virtual communities will be brought together at offline meetings, during conventions, expos, or more informal gatherings [57]. At such meetups, representatives of the developers often solicit feedback, lead attendees through bonding activities, and otherwise work to promote solidarity and connection among community members, which research has shown to increase activity in a given community [58].

For players, participating in any of these multi-player mechanisms offers a way to address their relatedness needs, which are as much a key to long-term retention as autonomy or competence [44]. The social meetings also reinforce the players' sense of emotional presence, reinforcing the meaning of continued participation in the game and affecting their activity level and length of retention in a given community, as well as their own perceived well-being [59, 60]. Within the context of a game, relatedness and connection can cushion individual players against frustrations during play, technical challenges, or boredom from repetitive tasks, while giving them opportunities to contribute to the game (such as offering support themselves to other players) and making them feel more positive.

Notably, while multi-player options and player communities are common in successful commercial titles, they are not usually seen in titles explicitly marketed as exergames. Indeed, aside from the local multiplayer mode central to *Wii Sports*, the majority of exergames feature only social media integrations that allow players to compare their fitness achievements with others or share how far they ran on a given day. While these methods are a start, it is not sufficient to foster a sense of community

founded in something besides physical activity goals, meaning that the only people who seek out the exergame—if it is labelled as such—tend to be those already interested in exercise. Or, in the case of *Wii Sports*, people who already own a Wii and want something they can play with other people.

The focus of exergames was never to make exercise more rewarding for those already doing it however, it was to reach those not currently getting enough exercise. To truly take advantage of the various mechanisms of motivation and engagement—including relatedness—perhaps there is a need for a title which at the very least fulfils the core features of an exergame but does not advertise itself as such.

The Curious Case of *Pokémon GO*

Or perhaps one already exists in the form of *Pokémon GO*, the augmented reality game by Niantic Labs designed "to encourage healthy outdoor exploration and social interaction" (Niantic Labs, 2016). A game grounded in the basic principles of augmented reality, *Pokémon GO* tasks players with acquiring virtual creatures called "Pokémon," either by capturing them when they appear on the map, or by hatching them from eggs via walking between 2 to 10 kilometers with the egg in their possession, with exact distance depending on the type of egg. These eggs can be obtained only from interacting with "Pokéstops" (prominent landmarks), which require walking to them, as the game used the phone's accelerometer to prevent people from simply driving, locking players out if they were moving too fast.

At its launch in July 2016, *Pokémon GO* quickly became the most popular game in the United States in less than a week [61] with its relatively simple and largely single-

player experience. Despite server instability and a lack of social features, the title became a social phenomenon, with over 100 million downloads during the first month [62] and nearly 45 million people playing every day [63]. In its first month, a number of articles were written citing the potential of *Pokémon GO* as a health intervention, promoting physical activity, social interaction, and more [26, 27, 64]. Most of these were commentaries, though Althoff et al (2016) did find that users of the Microsoft Band who played *Pokémon GO* walked approximately 25% more steps on average.

In the months following, much of the scientific community lost interest and a number of news outlets began to report that the game started to lose significant portions of its player base [65]. Many began to dismiss the game as a fad despite the game's weekly retention rate of 75%, on par with that of other top-rated games such a *Candy Crush Saga* [66]. This was particularly outstanding for *Pokémon GO* given it lacked the mechanisms other games had developed over the years to raise retention rate, and the developer's lackluster response to many early technical issues [67].

In fact, *Pokémon GO* at launch was nearly devoid of design aspects that evoke social elements, either in the form of a friend system or the trading and battle systems of previous *Pokémon* titles. There was a primitive multi-player versus system, in which players could have their virtual creatures defend or assault landmarks to gain "Poké Coins" (the game's premium currency) as a member of a color-coordinated team. Aside from this basic interaction, there was very little to promote a sense of community. Unlike other games that drew in new users via advertisements, *Pokémon GO*'s virality was primarily driven by word of mouth and by people posting pictures on social media about the odd places they found Pokémon [68]. The app lacked social media integration upon

release, meaning that players could not simply share pictures from within the game but had to open social media applications manually. Even so, *Pokémon GO* pictures flooded Facebook and Twitter, drawing more and more people to the game, including those who may not consider themselves gaming enthusiasts or inclined to physical activity.

There are several dynamic factors that contribute to the need for physical activity and that support community development. First, the likelihood of encountering each species of *Pokémon* depends on location, time of day, terrain, and other environmental conditions, making it difficult to know what is likely to be found at any given location. Rare Pokémon can be lured to Pokéstops if players place a lure module, making the process of catching the creatures far less tedious. Lure modules are rare to find and expensive to buy, but there are certain locations—usually parks, shopping malls or other large public spaces—where Pokéstops may overlap each other. Due to high volume of traffic, there is a higher chance a player will have placed a lure module at these places. These areas become real-life locations where *Pokémon GO* players congregate—*de facto* community hubs where people come with their phones (and chargers) to talk about *Pokémon*, catch Pokémon, and to spend time in general. After all, since the virtual creatures do not permanently exist in the landscape and there is no indication of what Pokémon will spawn, players who wanted to "catch 'em all" had to spend time walking, waiting, and inquiring about where certain creatures may be from others.

The very lack of social features within the game necessitated players to communicate via social networks, consult online databases and unofficial online maps, and attend local player gatherings. In a major public relations gaffe, Niantic Labs shut down the unofficial maps, declaring that they violated the terms of service and were not

how the game was intended to be played. As time went by with no official replacement for the maps and no word on when something would be implemented to fill the niche, many previously avid users eventually left.

By the start of 2017, the number of daily active users shrank from 45 million to 5~8 million [63, 69], where it stabilized. While this is a steep reduction from the original number of *Pokémon GO* players, it is still comparable to the figures of other major mobile games such as *Clash of Clans* [66]. To put things in perspective, *Clash of Clans* is not only one of the most popular mobile games in the world; it was also the first to reach $2 billion USD in global revenue [70]. Saying that these games *merely* have 5 to 8 million daily active users is itself misleading. At the same time, the rate of monetization was higher for *Pokémon GO* compared to *Clash of Clans*. *Pokémon GO* set records for the mobile game industry by reaching $500 million in global revenues in 2 months and reaching the milestone of $2 billion USD in approximately the same timeframe as *Clash of Clans*, demonstrating that *Pokémon GO* has become more effective at monetizing from a smaller audience [70]. And, unlike *Clash of Clans* and its contemporaries, which make players pay to skip long wait timers, buy extra lives, and the like, *Pokémon GO'*s only monetization options are its item shop and its avatar costumes. None of these premium items are necessary for the full play experience—an experience which has only grown richer after the re-implementation of a tracker system, a re-design of the battle system, a friend and gifting system, a buddy system where one "walks" with a chosen Pokémon, and the addition of "raid" content, which can only be completed in cooperation with other players.

Today, there are no more mobs of people wandering the streets playing *Pokémon GO*, and many of the large forums and subreddits lay silent. Yet it would be wrong to say that *Pokémon GO*'s time has passed. In every major city, there are groups of players (each with their own Facebook groups) ready to gather for a raid target, even if they no longer walk for kilometers in search of Pokémon, having already "caught them all." With new exclusive creatures being released, the recent launch of several Nintendo Switch titles that benefit from player actions in the mobile game, and the highest user numbers the game had seen since 2016, perhaps a *Pokémon GO* resurgence is near at hand.

Lessons learnt from *Pokémon GO*

Whatever the outcome, *Pokémon GO* provides a number of lessons for exergame design. As a game that was never marketed as a health app, it still effectively improved physical activity outcomes and did so to a vast population in a more *consistent manner* than any traditional exergame. Notably, social connectedness and perceptions of physical or virtual community—vital for *Pokémon GO*'s dissemination—are also areas that previous health games have not given enough thought. Despite the game's commercial success, we still have difficulty measuring its impact on a large and holistic scale without proprietary data access, as the only data typically accessible is from those already invested in quantified health paradigms. Investigating game data or devoting more efforts into modifying existing methodologies may be the necessary next steps for the field of exergame research to further its credentials and reach. Still, as indicated in Table 1, *Pokémon GO* features a collection of good exergame design features, which combine to form its colossal success.

Exergame design feature	Implementation in *Pokémon GO*
Lower body exercise instead of upper body exercise	Focusing on using walking to find and hatch Pokémon
Target a younger audience	Pokémon models focus on ‘cute’ designs
Competence	Simple controls and shallow learning curve
Autonomy	No set exercise goals
Relatedness	Main character is a player insert
Mastery of controls	Simple controls and shallow learning curve
Experience of immersion	Exercise has a purpose and meaning (finding and hatching Pokémon
Allows for social interactivity	Encourages physical interactions between players due to Pokémon congregating in certain locations
Sense of community	Physical gatherings, existing Pokémon fanbase
Novel and fun features	Augmented reality gameplay

Table 1. Good exergame design features in *Pokémon GO*

According to Yang & Liu, the motives for which people play *Pokémon GO* were found to be associated with wellbeing [71]. Those who play *Pokémon GO* for fun benefited the most from the game experience, reporting higher perceived bonding, physical health, and reduced loneliness. Those who play to maintain existing relationships also reported higher satisfaction with life, indicating better mental health. Results in other areas are mixed. While Yang & Liu (2017) report that playing for nostalgia resulted in higher feelings of loneliness, they also report a high correlation between nostalgia and both friendship maintenance and relationship initiation. Another study found that *Pokémon GO* in fact resulted in a higher sense of belonging, with nostalgia fostering a deeper sense of connectedness [72]. Players playing for escapism, however, reported on lowered life satisfaction [73]—an indication that despite reaching similar physiological goals, the motivations behind playing exergames matter greatly for players' holistic health outcomes [27].

It is also important to remember that *Pokémon GO* benefited from a vast and long-running existing multi-media property. Nintendo's *Pokémon* was initially designed to have walking as a meaningful part of the gameplay and gathered a faithful community of players over more than twenty years, a feat that many other exergames cannot claim. The existence of an established player community and incorporation of walking in in-universe gameplay helped *Pokémon GO* greatly. Moreover, just like all health interventions, participants need to be aware of negative effects from exergames. Players who play *Pokémon GO* while driving, or walking without paying attention to their surroundings, pose potential dangers to themselves [74]. Approximately 43% of players surveyed by Wagner-Green et al. [74] reported they are likely to play *Pokémon GO* while

riding a bike, and 37% reported they are likely to sacrifice sleep to play more of the game. The full extent of effects from exergames thus requires more research, with trials that take these traditionally unexpected adverse effects into account.

Trial design for exergame studies

To emulate the natural environment that games are played in, trials for exergames should avoid enforced play at the very least. When exergames are examined in an enforced setting, the group subjected to the intervention is not playing out of their own volition, in a comfortable setting or a timeframe that fits naturally into their daily lives. It is therefore no surprise to see study participants starting to report exergames as boring after a few weeks of enforced play, especially if these participants have unconsciously started to perceive the game as a burden or a chore [75]. Disliking a game is one of the most significant factors contributing to participant discontinuation of serious games; even if players continue playing, it increases their cognitive burden and voids the positive impact a game may have had [76].

The assumption that games, like drugs, can exert their physiological effect regardless of a participant's inclinations or motivation, is fundamentally flawed. It is therefore heartening to see that exergame researchers have already taken steps to modify and create methodologies to better fit the nature of games. There are more studies that examine the mental benefits of exergames and some studies have also included intervention groups where the participants were merely *provided* with a given game, rather than being forced to play for a set amount of time per day [77, 78]. In such studies,

the only difference between the intervention and the control groups was whether the participants had access to the game software (or in some cases, the hardware the game required), not whether they were observed to play, mimicking the realities of community-based behavioral health interventions.

In one geriatric study in Sweden [77], participants were provided with a Wii console and the *Wii Sports* game, together with an instruction session at the beginning of the study. Participants also had access to an instructor via telephone if they needed technical assistance during the trial. It is interesting to note that while participants only received a vague suggestion regarding play requirements – that of "playing 20 minutes per day by themselves or with others" – the mean playtime in the trial was 28 minutes per day per person, exceeding that of the recommended daily play time. It is possible, therefore, that trials do not have to rely on enforced participation for participants to gain the benefit of the exergames, unlike in traditional RCTs where strict adherence to the intervention is vital.

Other modifications of the RCT methodology allow exergames to be examined with rigorous trial design while maintaining player agency. A trial with school children and a mobile-based exergame [78] employed a protocol that consisted of within-subject comparison (the participant's exercise baseline data was used as their own control), a washout period (participants were monitored for a week after losing access from the game), and alternating exposure to the game (the two groups of participants received access to the game during different time periods). In a trial such as this, the intervention group was not so much 'playing the game', but 'being exposed to the game', retaining the sense of autonomy that is particularly important for the development of intrinsic

motivation. The inclusion of a washout period is also important, as it allows observation for any residual effects of game exposure, or if other factors were confounding the amounts of exercise the participant conducted. As the study showed the amount of physical activity performed during the participants' baseline week and washout week were not significantly different, the trial design allowed the identification of a direct causal relationship between playing the game and participating in more exercise, independent of other potential confounding factors.

The impact of global hits such as *Pokémon GO*, on the other hand, enable participant numbers at a scale not seen before for exergames. The study by Althoff et al. (2016), an anonymous trial involving 32,000 Microsoft Band users, identified *Pokémon GO* players through the users' search engine history. Microsoft Band users who actively searched for *Pokémon GO* tips online were assumed to be playing the game. The study found there was a significant increase in step counts (~25% increase in step counts compared to prior activity levels, $P<0.001$) for these participants in the first 30 days after the launch of *Pokémon GO*. Most importantly, the authors note that *Pokémon GO* had a beneficial effect for all players irrespective of age, gender, or other factors, and that a higher number of internet searches for *Pokémon GO* tips was correlated with higher increases in step counts, indicating that interest (and potential engagement) in the game could be directly related to increased exercise. Whether these results are confounded by the concern that people who own Microsoft Bands may already have a greater interest in health and wellness, the study manages to draw data from a number of participants impossible to achieve in lab-developed exergames. These findings were only possible due to the authors' affiliation as Microsoft employees at the time, which also provides a

positive example of the exergame research community benefiting from working with commercial companies.

In seeking to study the effects of *Pokémon GO*—or other commercialized exergames whose success is tied in part to good mechanisms in design—it may prove necessary to pursue collaborations with the companies developing such titles, as the data they possess on player engagement, retention, and activity is by necessity more comprehensive—and analytically accessible—than the proxies used in current exergame studies. In particular, such collaborations can shed light on the details behind observed social effects and boosts in motivation, and in turn yield valuable insights on optimal design for such games for health.

Conclusion and Recommendations

Exergames, by their interactive nature, are more than simply another prescribed drug. Without patient input and participation, the long-term promise of behavioral modification through exergames cannot be reached in healthcare despite their demonstrable short-term benefits during periods of enforced play. Such controlled consumption of the medium in no way taps into the rich potential of self-motivation that good games are designed to elicit from their players. Exergames are also beneficial to players beyond merely improving their physical fitness in ways that standard interventions struggle with, due to the immersive and participatory nature of the games—e.g. improved cognitive functions, mood-improvement, and an increase in the internal perception of well-being.

To capture the true scope of these benefits, it is therefore necessary for researchers to modify the methods we currently use to assess and validate therapies in the healthcare sphere. Progress has already been made in designing trials that take into account the beneficial effects of voluntary play, while maintaining the rigor of controlled trials. To assess the full scope of advantages that exergames bring to community care, researchers need to have trials that address the 'invisible' benefits of such interventions such as reductions in perceived treatment burden, which is known to affect adherence rates and thus health outcomes. Alternative data sources, such as data from developers, may need to be accessed to analyze such changes on a population scale.

At the same time, exergame design would do well to keep the holistic benefits of gaming in mind. As perhaps the most prolific exergame in history, *Pokémon GO* has many lessons to offer those designing and researching exergames regarding the factors that led to its success and its ability to retain a large, loyal base of players. Research is necessary on the nature of the real-life connections and communities *Pokémon GO* supports, specifically the factors which give rise to them and sustain them, and whether the social factors which made the game a success can impact player wellbeing. Another research direction involves examining other game-based communities and seeing what lessons they may have for exergames and serious games as a whole. *Pokémon GO* also validated past work regarding player motivation, and highlighted the importance of social factors in play. This aspect of the game is something that exergame developers can certainly learn from.

Good games are more than a collection of tasks and goals. Good exergames should motivate the player to continue participating in the therapeutic intervention, as

well as reducing the cognitive burden involved. Ultimately, the goal for exergames isn't to have the player constantly be engaged with the game, it is to allow players to change their lifestyle by way of playing the game. The study of serious games, rooted in human psychology, has found that factors such as social relatedness, a sense of belonging, autonomy, and feelings of competence are essential qualities of a good game—more so than flashy graphics or the use of sophisticated technologies such as augmented reality. In the end, while games can achieve more than a list of tasks can ever manage, they can only do so if one is designing them with the player in mind, treating the game not as a simple prescription for a patient who needs treatment but as an option for a person with limited time and energy, who has the ability to make choices about their life and wellness.

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DEVELOPING A NOVEL DEMOGRAPHIC-PSYCHOGRAPHIC QUALITATIVE MAPPING METHOD TO PROFILE PLAYERS OF HARRY POTTER WIZARDS UNITE AND POKEMON GO

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Abstract

Augmented Reality (AR), a form of technology which creates immersive interactive experiences by overlaying digital information (visual elements, sound, or other stimuli) onto the physical world, has the potential to improve health outcomes by transforming gaming from a sedentary leisure pursuit to an active leisure pursuit, with physical, psychological and social implications. Originally developed for purposes of art, commerce, and remote collaboration, public interest in this technology surged after the 2016 release of *Pokémon GO*, an Augmented Reality mobile game that not became a social phenomenon, but demonstrated that AR could be used for health purposes, primarily by increasing users' levels of physical activity, at least in the short term. In this paper, we seek to address whether AR can change health behaviours in the long-term, as well as examining the factors that underlie player preferences and behaviours, and how can we harness this knowledge to improve Augmented Reality serious game design. To

do so, we qualitatively mapped demographic and psychographic data from the player base of the Augmented Reality games *Harry Potter: Wizards Unite* and *Pokémon GO*, in order to better understand how we can better design AR serious games to improve exercise and health.

Data was collected through an online mixed-methods survey hosted on Qualtrics, which included an open-ended, textbox proforma. Participants were reached via virtual snowballing. The survey was posted on four subreddit forums dedicated to *Harry Potter: Wizards Unite* and *Pokémon GO* for two weeks and completed answers were obtained from 1052 participants. Our novel qualitative mapping method aligns with a deductive category application, with all highlighted excerpts coded using a predetermined coding scheme.

Responses from players indicate that behaviour change driven by AR games can persist in the long-term. Further, a combined demographic-psychographic qualitative mapping method on player preference and behaviour sheds light on how constraints can negatively influence loyalty while activity involvement acts to sustain gaming across different gamer-types and should not be underestimated as a powerful influence in decision-making, choice behaviour, behaviour change and ultimately loyalty. This information can be used to inform the design of future Augmented Reality games, especially those meant to elicit health benefits.

Introduction

Augmented Reality (AR) applications designed for mobile devices have been shown to increase physical activity across multiple populations [1-3]. This increase, driven by AR's ability to transform gaming from a sedentary leisure pursuit to an active leisure pursuit, has positive physical and psychological implications, with the potential to improve overall health outcomes [1, 4, 5]. Niantic Inc's *Harry Potter: Wizards Unite* (HPWU) and *Pokémon GO* (PGO), two of the best-known AR games to date, incorporated such benefits into popular franchises by packaging them for easy experiential consumption [6]. In these games, AR was used to enhance immersion by bringing the wonders of a fantasy world to life, with the hope of facilitating more profound and longer-lasting user engagement. Yet AR design factors for serious games and commercial ends are not always aligned. Serious games aim to accomplish a non-entertainment focused goal (i.e. improving health, training workers, etc.), which do not necessarily enhance the experience of playing said games (player experience) [7]. This can create tension between aspects of AR games designed for improving health, and those intended to promote commercial success. The extent to which said factors align, or if they do at all, is an interesting and complex dynamic that is highly dependent on how both touch on player preferences. As such, there is a pressing need to better understand the factors that hinder or enable digital interactivity preferences for different sub-populations, as these can affect both choice behaviour (player preference) and behaviour change (improving health outcomes). Existing research on this topic was largely conducted before the advent of AR and tended to be focused around factors relating to

commercial success, with little research directly relevant to health-related serious game design [7] or games for health using qualitative research as applied to Segmentation Theory [8].

Segmentation Theory

Traditionally, researchers have used Segmentation Theory (dividing participants into segments to understand preferences and habits) to inform serious game design [8-11]. Demographic segmentation (descriptive features) using gender or age was found to be too simplistic as well as problematic in the gaming literature with some researchers suggesting that a focus on these aspects was insufficient to determine pertinent differences between game players [11-13]. Instead, there has been a deliberate movement towards considering player engagement typologies of *casual, in-between,* or *hardcore* players [8, 10, 11, 14] or psychographic variables *(involvement, constraints, loyalty)* [15-17]. Also, few studies, if any, in the game's literature have applied qualitative methods to Segmentation Theory [8], despite these qualitative methods' potential benefit to provide a deeper understanding of player preference, with attendant implications for AR serious game design for health.

Methodological contribution

Our study is novel in that it provides a qualitative mapping method to segmentation that utilizes both demographic (player typologies and status) and psychographic (constraints, involvement, loyalty) aspects of player populations to explore the different factors that interact to enable or hinder gaming preferences and behaviour. To achieve this, demographic segmentation, categorising players by descriptive features (player type & player status), is used in combination with psychographic mapping. Psychographic mapping can be used

as a qualitative tool when creating profiles of players [9], as we recognise that players are heterogeneous in their levels of involvement (attraction, sign-value, centrality, & risk) [16-20] constraints (structural, interpersonal & intrapersonal) [16-19], and loyalty (word-of-mouth, attitudinal/behavioural) [16-19] (See Table 1). A combined demographic-psychographic mapping method to sort different gamer profiles into meaningful homogenous subgroups is lacking in the literature, yet it is an important endeavour for developing tailored AR game design strategies for health [17, 21]. At present, in-depth internal psychographics, including player constraints, involvement and loyalty, remains hidden from game designers and health practitioners alike [15-17, 22-24]. Yet this information is highly useful in psychographic segmentation, with the constraints that people are exposed to during play influencing player preferences [19, 22, 25, 26]. Likewise, involvement, an unobservable state of motivation, arousal, or interest towards an activity (HPWU/PGO) (p.246) [27] has a well-established relationship to loyalty in the maintenance of strong attitudes toward resistance to change [15, 19, 28, 29] (See Table 1). Together, an understanding of constraints, involvement and loyalty may provide game designers and other stakeholders a better understanding of how to implement design changes to enhance player perceptions and experience of health-focused AR games for health. Our novel qualitative mapping method will help identify what current as well as former HPWU or PGO players experience in relation to constraints, involvement and loyalty, providing valuable insight into player preference and experience. Similarly, a more detailed examination of current players' involvement and loyalty despite constraints, can be compared to that of former players to provide rich insight into choice behaviour and player preference.

Table 1: Definitions from studies on the identification and categorisation of previous works based on establishing key demographic-psychographic features used in both serious games and the health-related benefits of physical activity literature

Authors	**Descriptive features**	**Demographics**			
	Player status	**Current Player:** currently playing	**Former Player:** A former player of either PGO or HPWU, but could still be playing one or the other game		
Manero et al. [8], Tuunanen & Hamari [9], Loporcaro et al. [10], Ip & Jacobs [11], Kirman & Lawson [14]	**Player self-identification group**	**Hardcore** Values competition, challenge, excitement – fast-paced/skill-based player)	**In-between** Those players that exist in-between Hardcore and casual players	**Casual** Enjoys games that are easy to pick up and play)	**No-identification** Those players who have not yet established a clear player identification
Authors	**Psychographic Domains**	**Psychographic factors**			
Alexandris et al. [16, 17], Jun et al. [22] Smith & Smith [19], Smith [26]	***Constraints*** 	**Structural:** Constraints external to an individual (distance, cost)	**Interpersonal:** Inability to find partners to participate	**Intrapersonal** Internal psychological constraints (confidence, lack of interest)	
Havitz et al. [15], Alexandris et al. [16, 17], Smith & Smith [19], Smith [26]	***Involvement*** 	***Sign-value*** Symbolic value – an individual can express their identity through the activity	***Centrality*** The degree to which the activity is central to one's life	***Attraction*** Perceived importance and hedonic value	***Risk*** The perceived or actual risk of switching games

Howat et al. [29], [23, 24] Tsiotsou et al. [23], Mahony et al. [24], Smith & Smith [19], Smith [26]	***Loyalty***	***Composite (Attitudinal & behavioural)*** The affection held toward the brand and the frequency/ intensity/duration spent in the activity	***Word-of-Mouth recommendation:*** Behavioural intention of word-of-mouth recommendation

Aim

To develop a novel demographic-psychographic mapping method to define how player preference (involvement and loyalty) is shaped by constraints in augmented reality games.

Methods

A qualitative approach was used by applying a combined demographic-psychographic qualitative methodology to explore player psychographics constructs (constraints, involvement and loyalty) [16, 17, 19, 26]. Ethical approval was obtained from the Macquarie University Human Research Ethics Committee for Medical Sciences (Reference No: 52019601512435).

Sample and recruitment

We conducted a qualitative proforma in 2020 (2 February – 1 March 2020 inclusive), a sub-study of a larger study examining PGO and HPWU use and player experience. Ethical approval was obtained from Macquarie University's Human Research Ethics Committee for Medical Sciences (Reference No: 52019601512435).

Participants were recruited online via four subreddit forums dedicated to PGO or HPWU (r/WizardsUnite, r/PokemonGO, r/harrypotterwu, and r/TheSilphRoad). A recruitment post was pinned to the top of each subreddit from 2 February to 1 March 2020, directing individuals to the participant information page via Qualtrics. Participants were informed that participation was voluntary, that they could withdraw at any time before submitting their final responses, and that to be eligible they needed to be 18 years or older and have played the English versions of PGO or HPWU for at least a week. Those who consented to participate were directed to an online questionnaire which, in addition to the open-ended, text-box survey (proforma), collected information about participant demographics and physical activity frequency both prior to and after becoming a user of AR games. No incentives were offered for taking part. Participants were informed not to provide any identifiable personal information. IP addresses of participants were recorded by Qualtrics to identify repeat visits. Duplicate entries were not permitted after the participant had submitted the survey. We received completed answers from 1052 participants, with 762 (72%) having played PGO and 691 (66%) having played HPWU.

Proforma (open-ended, text-box survey)

The proforma included a total of 25 open-ended questions. The proforma is a qualitative data collection tool taking the form of an open-ended, text-box survey, comprising several specific open-ended questions [30, 31]. Proformas are designed to encourage expansive answers from participants (see Table 4). To collect additional participant information, adaptations to traditional development and application of the

proforma allowed for the addition of demographic questions such as self-identification (see Table 3). Proformas differ from structured interviews or closed question surveys [32, 33] which are highly formalised and can be rigid. For full proforma open-ended questions, please see Supplementary materials Appendix 2.

Analysis

Players of PGO or HPWU were asked to categorize their gameplay style as being *hardcore, in-between,* or *casual,* with a fourth category for those who had no idea how to identify (*no identification*). Differences in constraints, involvement and loyalty between each group were evaluated based on self-report. The second level of demographic data was also used to categorise participant profiles based on whether they were still playing the games or had discontinued one or both.

We extracted psychographic characteristics (perceived constraints, involvement, and loyalty) [16, 17, 19, 26] from replies in the open-text proforma questions. The two demographic levels of 1) player status - whether one is a current player or former player of the game and; 2) player self-identification group - how one self-identifies as a gamer (*casual, in-between, hardcore, no-identification*) were combined with the psychographic aspects of constraints, involvement and loyalty in the analysis using NVivo 12 Plus (QSR International; qualitative data analysis software facilitating the collection, organising and analysis of data) [34]. Our framework was developed using Framework Analysis [35], as it is a qualitative framework that is aptly suited for mapping and coding framework domains. Our coding framework is based on previous work [18, 19], which also provides a clear coding structure to apply on data to specify and examine loyalty, involvement, and constraint domains that

formed our codebook (See Supplementary materials Appendix 2). The research coders (JS, KY, ML) identified and categorised the sub-factors to their domains derived from an analysis of answers from open-ended text-box questions. The mapping methodology was chosen to code factors (word-of-mouth, centrality, distance, etc) to their related domains (loyalty, involvement, constraints). By assigning framework component labels where appropriate, the initial coding scheme was reviewed contextualised and adapted. The researchers (JS, KY, ML) regularly met to discuss data, in an iterative process until consensus was met. Data were sifted, charted, and sorted to address key domains of the framework. This involves a five-step process (familiarisation, identifying a thematic framework, indexing, charting, mapping and interpretation) [35]. Finally, the method displays the collapsed data by juxtaposing demographic and psychographic factors. In this way, the researcher can look across the demographic-psychographic map (See Table 4) providing a high-level interpretation of interrelated, interlinked, or interdependent relationships that are visually mapped and displayed.

In addition to the above, self-reported physical activity data was extracted from Qualtrics and directly imported into SPSS (version 25). Some data variables were recomputed and cleaned for further analysis. Exploratory data analysis was performed using descriptive statistics and paired sample t-tests to assess whether those playing HPWU and/or PGO demonstrated increased physical activity levels, and if so, if there were differences according to self-identified categories.

Results

Demographics

General demographics data are presented in Table 2. The sample includes existing players and former players of both PGO and HPWU to provide a more comprehensive range of constraints, involvement and loyalty for these segments.

Table 2. Demographics Data

Gender	Female		Male		Other/No Answer
	n=470 (45%)		n=381 (36%)		n=201 (19%)
Age	18-25 years	26-35 years	36-45 years	46-55 years	>55 years
	n=240 (23%)	n=460 (44%)	n=183 (17%)	n=80 (8%)	n=43 (4%)

The largest group of players were those who self-identified as female casual players, taking up 64% of female participants and 35% of all participants. The second-largest group were male casual players (40% males, 18% all). The smallest group was male players who could not self-identify as a player type (3% males, 1% all), followed by female hardcore players (5% females, 3% all). All age groups were similarly represented across self-identified player groups.

Group self-identification is noted in Table 3.

Table 3: Self-identification characteristics of the sample

Self-identification characteristics	n	N
HPWU current players		512
Self-identification		
Group one: Something in between	137	
Group two: I have no idea	38	
Group three: Casual	295	
Group four: Hardcore	42	
HPWU former players		90
Self-identification		
Group one: Something in between	35	
Group two: I have no idea	8	
Group three: Casual	34	
Group four: Hardcore	13	
PGO Current players		550
Self-identification		
Group one: Something in between	189	
Group two: I have no idea	34	
Group three: Casual	245	

Group four: Hardcore	82	
PGO former players		152
Self-identification		
Group one: Something in between	36	
Group two: I have no idea	13	
Group three: Casual	91	
Group four: Hardcore	12	

Physical Activity

Participants across all player types had a significant increase in exercise frequency after starting to play PGO or HPWU, as suggested by paired sample t-tests. Participants were asked to indicate how many days they walked for at least 30 minutes in a typical week before and after they started playing. Hardcore players displayed the largest change in their exercise patterns ($t(108) = -9.99$, $p = 0.00$), walking for 30 minutes or more a day for 2.78 days a week on average (SD = 0.22) prior to playing and 4.99 days (SD = 0.21) after starting to play. Casual players walked for 3.05 days a week (SD = 0.10) before playing and 4.58 days (SD = 0.09) after ($t(498) = -18.36$, $p = 0.00$). The group that identified themselves as between hardcore and casual walked 3.21 days a week (SD = 0.14) before playing and 5.00 days (SD = 0.12) after ($t(292) = -14.28$, $p = 0.00$), and the group that could not identify themselves as a player type walked 3.08 days a week (SD = 0.26) before playing and 4.80 days (SD = 0.25) after ($t(70) = -6.61$, $p = 0.00$). This was not confounded by any discrepancies in duration of play, as the majority

of participants indicated they had played PGO for more than 2 years or played HPWU for more than 3 months. PGO and HPWU also appeared to affect exercise differently. Across our participants, 76% stated PGO was the game that caused them to exercise more, while only 55% chose PGO as the more fun game to play. This trend was observed across all player groups and held true regardless of which game players started with.

Presentation of the qualitative mapping method

The final task was to visually represent a simplified account of player preference within a qualitative demographic-psychographic summary of results (See Table 3) highlighting different levels of factors across the current and former player views and different self-identification types of player. Detailed summaries of the framework related to each category of player are provided in **Supplementary materials Appendix 3**. This summary of player preference and behaviour data was further reduced to create a final qualitative map to represent the 'presence' or 'absence' of vulnerabilities (showing constraints can be experienced in several ways) and sustainers (showing enablers). This map may be used to interpret the relationships across different factors and is presented in Table 4, with the themes and related sub-themes broken down into categories in Table 5.

Demographics	Psychographics	
	Vulnerabilities	**Sustainers**

Player Type	Player Status	Game Type	Distance	Lack of time	Lack of access/opportunity	External obligations	Cost	Lack of knowledge/ understanding	Lack of interest	Lack of confidence	Lack of significant others	Sign-value	Risk (switching)	Centrality	Attraction	Word-of-mouth	Attitudinal & behavioural
Hardcore	Current	HPWU	X	X	✓	✓	✓	X	✓	X	✓	✓	✓	✓	✓	✓	✓
	Current	PGO	X	X	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hardcore	Former	HPWU	X	✓	✓	✓	✓	X	✓	✓	✓	✓	X	✓	✓	X	✓
	Former	PGO	X	X	✓	✓	X	X	✓	✓	✓	✓	X	X	✓	✓	✓
In-between	Current	HPWU	✓	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Current	PGO	✓	X	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
In-between	Former	HPWU	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Former	PGO	X	X	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	✓
Casual	Current	HPWU	✓	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Current	PGO	X	X	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
Casual	Former	HPWU	✓	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Former	PGO	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	✓
No identification	Current	HPWU	X	✓	✓	✓	✓	X	✓	✓	✓	✓	X	✓	✓	✓	X
	Current	PGO	X	X	✓	✓	✓	X	✓	✓	✓	✓	X	✓	✓	✓	X
No identi	Former	HPWU	X	✓	✓	✓	X	✓	✓	✓	✓	✓	X	✓	✓	✓	X

ficati on	Former	PG O	X	X	✓	✓	X	✓	✓	X	✓	✓	X	✓	✓	✓	X

Table 4: A demographic-psychographic qualitative mapping method of current players and former players and the interaction across vulnerabilities (constraints) and sustainers (involvement and loyalty)
KEY: ✓: The extent to which factors were present**;** X: The extent to which factors were absent

Table 5: Key themes and related sub-themes

Themes
Theme 1: Loyalty
Attitudinal and behavioural loyalty
Word-of-mouth recommendations
Theme 2: Involvement
Sign-value
Risk of switching sustainers
Centrality
Attraction
Theme 3: Constraints
Distance
Lack of time
Lack of access/opportunities to play
External obligations/other priorities
Costs
Lack of knowledge and understanding
Lack of interest
Lack of confidence

Lack of Significant others

Theme 1: Loyalty

Attitudinal and behavioural loyalty

Only the current and former players in the *no identification* group reported no type of attitudinal or behavioural loyalty. In contrast, past behaviour and familiarity with the company brand Niantic Inc. revealed that both attitudinal and behavioural loyalty existed across all other gamer groups of current and former players of HPWU and PGO:

"[playing] to support Niantic (I'm a former ingress player)." (PGO game: current in-between player)

Word-of-mouth recommendations

HPWU and PGO results, across all gamer groups for current and former players, indicated that word-of-mouth (from friends, partner, family, discord, etc) resulted in strong adoption of the HPWU and PGO games:

"I was playing Pokémon GO *at the time and some friends from that community were talking about it [HPWU]." (HPWU game: current no identification player)*

Theme 2: Involvement

Sign-value

Sign-value was present across all types of current and former self-identified players. Across the different gamer profiles, sign-value was strongly influenced by the Harry Potter and *Pokémon* franchise, this key driver strongly ties and connects people to identify themselves as a fan. Participants, therefore, expressed their preference for the game type through a connection to either Harry Potter or *Pokémon*. As such, the role of AR for these players is to provide an experience that is a realization of a fantasy, embedding them in a mysterious world that strongly resonates with their chosen identity and their sense of nostalgia (experiential consumption). This converges across all player groups of HPWU and PGO, for current and former players alike:

> *"collecting Pokémon felt like being a part of the show." (PGO game: former casual player)*

Risk of switching sustainers

In the current player group, several excerpts mention players switching their preferences from playing both games to solely play either HPWU or PGO. Among hardcore, in-between, and casual members of this group, switching behaviour was offset by Fear Of Missing Out (FOMO) or sunk costs associated with their involvement with the game, or in some cases, with the larger community. *In-between* and *casual* former players of HPWU mentioned that it was simply impossible to play both games at the same time on one phone, and so chose PGO, despite considerable time invested into HPWU. Interestingly, former players of PGO did not report any type of risk or cost associated with switching behaviour, while for current players of PGO, as opposed to

HPWU, the perception of sunk cost was not necessarily with regards to their involvement with the game itself but the larger community of players:

> *"Sunk costs and a sense of obligation: if I leave my mod duties, it will be extremely difficult for anyone or even multiple people to take over what I do." (PGO game: current hardcore player)*

Centrality

Playing HPWU and/or PGO provides a sense of routine, accomplishment, and a reason to go outside. Besides the discovery of new places, the importance of motivation and challenges were apparent as well, with individuals directly altering plans to fit their vacation around PGO/HPWU playtime (*causal in-between* and *hardcore* self-identified player types). This signifies that playing these games is very much central to an individual's life.

> *"I'm going to St. Louis because of* Pokémon GO*. I've been there before, but this trip is specifically because of* Pokémon GO *and I would not have gone otherwise." (PGO game: current hardcore player)*

Attraction

Attraction was present across all types of current and former self-identified players. Both games were perceived as fun, with player preference geared towards enjoyment and pleasure, a finding that has consistently been shown across gamer groups of current and former players alike. Interestingly, for those self-identified as either *in-*

between or *no identification* players, playing HPWU was brought about by having played and enjoyed PGO initially. This, as much as their interest in the Harry Potter franchise, motivated them to try HPWU:

> *"I already loved playing* Pokémon GO*, and Harry Potter, so this seemed perfect." (HPWU game: former casual player)*

Theme 3: Constraints

Structural Constraint: Distance

In *current players*, our study found that a need to travel long distances (e.g. beyond comfortable walking distance) to game-associated locations often necessitated the use of personal transportation. Beyond acting as a constraint to gameplay, this also negatively impacted social interactions, as players who had access to transport often chose to stay in the comfort of their cars while carrying out what were usually collaborative in-game activities. In contrast, the majority of former HPWU and PGO players did not report distance to be an issue, with one exception of a current HPWU *casual* player who had switched from PGO reporting that there were not many nearby spots to grind for items around where they live:

> *"Not much is available within walking distance." (HPWU game: current casual player)*

Structural Constraint: Lack of time

Lack of time was more often cited as a constraint by current and former players of HPWU compared to PGO players. For current players of HPWU, lack of time was mostly

related to aspects of game design such as wait time between tasks and waiting for people to join for group play, which was a barrier across all groups except for *hardcore* players. In contrast, for former players of HPWU, this type of game design issue was tied to a more general lack of time and was a problem faced across the different player identities. For former players of PGO, it was commonly stated that getting more out of PGO would have required a significantly larger time investment than they were willing to give:

> *"Getting more out of the game would require exponentially more time investments" (PGO game: former casual player)*

Structural Constraint: Lack of access/opportunities to play

Lack of access was a strong and consistent constraint for player profiles across all player identities (current and former gamer) and games. Bugs, glitches, and faulty game mechanics combined with a lack of Foundables for HPWU or the impossibility of obtaining regional Pokémon were mentioned as barriers to engagement across gamer self-identified player types:

> *"Dislike regional Pokémon--the idea is fun, but realistically most people will never be able to legitimately obtain regionals from all over the world, and as a completionist, this does bother me" (PGO game: current hardcore player)*

Structural Constraint: External obligations/other priorities

For current players of either game, family or work obligations were important factors that affected how much they could engage, something which was not true for former players. Their most important constraints were prioritising one game over the

other and not wanting to invest more time in gaming were important constraints. Former players specifically reported having to choose between the two games, as it was simply too difficult to play both games at the same time, with their choice of which game to stay with coming down to which they enjoyed more:

> *"It was also hard to combine with* Pokémon GO *and I preferred that game so I deleted WU" (HPWU game: former in-between player)*

Structural Constraint: Costs

Cost to play was an important factor for current and former players of both games. Interestingly, neither the *hardcore* players of PGO nor the *no-identification* group of former HPWU and PGO groups reported cost to be an issue, though the reasons behind this varied by group.

> *"Super limited spell power resource means you don't do much until you start paying for upgrades to this." (HPWU game: former hardcore player)*

Intrapersonal Constraint: Lack of knowledge and understanding

Only some of the former players of both POGO and HPWU (the former in-between, former *no-identification* and former *casual* PGO players) reported a lack of understanding and comprehension of game mechanics.

> *"Constant changes with no easy way to know how to utilize the new system. i.e. appraisal changes". (PGO game: former casual player)*

Intrapersonal Constraint: Lack of interest

For current players of PGO and HPWU, all groups mentioned boredom and the repetitiveness of the HPWU or PGO games. For former players, boredom and game preference (selecting either POGO or HPWU) was a reason that some PGO players switched over to HPWU and some HPWU players switched over to PGO. This type of switching behaviour was again consistent across different types of gamer profiles.

"I realized I liked Pokémon Go a great deal more and WU was taking time away from it." (HPWU game: former casual player)

Intrapersonal Constraint: Lack of confidence

Current players across the majority of groups (excluding current *hardcore* HPWU players and *no identification* former PGO players) raised concerns over the difficulty of the game and a lack of confidence in meeting strangers, something subsequently highlighted as a safety issue by *in-between* players. Most HPWU players raised concerns about the finger dexterity required to cast spells on the phone, mentioning that it was more difficult than throwing a ball, and that because of this, the game was very difficult to play while moving. Players generally had a lack of confidence in their ability to deal with the difficulty of the game, stating that it was too complicated and presented too much information to process. *Hardcore* players also stated they disliked being forced to interact with others. Former players of both games echoed these sentiments, as they noted that the games were just too complex and felt it was impossible to progress or win.

"Needs some here's what you do, and why" (POGO game: former in-between player)

Interpersonal Constraint: Lack of Significant others

Current players of both games reported that a lack of significant others playing the game, an inability to play with friends living in other countries, and a requirement of having to play with strangers, spoofers (i.e. Players who alter their GPS data to 'travel' in the world without physically moving), or toxic local players who negatively influenced player perceptions negatively impacted their play experience. This constraint was present across all groups of current HPWU and PGO players. For former players of PGO in the *no identification* group, a lack of significant others playing was also a reason to switch to HPWU where they had existing playing companions. The need or desire for virtual teammates to replace strangers was also reported, echoing the issues related to group play (waiting time, etc). Also, for both current and former players, spoofers, lack of community and lack of linking with local players were seen as problematic.

> *"Lack of local players (compared with PGO)." (HPWU game: current no identification player)*

Discussion

Our study notes sustained behaviour shifts in players of PGO and HPWU, as demonstrated via changes in participants' levels of physical activity. Interestingly, the largest shifts were found among individuals who self-identified as hardcore players, who as a group reported the lowest levels of physical activity prior to taking up PGO or HPWU. In considering players' experience in PGO and HPWU using a combined demographic-psychographic qualitative mapping method, our approach allowed us to

gain an enhanced understanding of the variation between player preferences (based on demographic-psychographic mapping) for both current players and former players of HPWU and PGO. Through this, our study found that our three themes of 'constraints', 'involvement' and 'loyalty' were highly inter-related, with identified factors (sub-themes, e.g., sign-value, word-of-mouth etc) relating to choice behaviour. We also identify recommended areas for improvement to AR serious game design by considering specific information on the relationships between differing psychographics among the player identities present in our sample.

As suggested by prior studies [19, 36, 37], constraints to player preferences were experienced in several ways for both current and former players and across different player identities. In line with this principle, we also found that constraint factors interacted in several different ways. Smith and Smith [19] suggest that interactions between constraints are important to identify due to the potential for several (structural, interpersonal intrapersonal) different constraints to interact and operate at the same time, and this can inhibit player preference and behaviour. This was demonstrated in our study in the following ways: 1) having to drive instead of walk to places as locations were too far away to walk, or living in a cold climate, which prevented some individuals from venturing out of their cars, 2) major technical glitches in the game that negatively impact upon gameplay, 3) difficulty in playing both games (HPWU and PGO) together resulted in players having to choose one over the other, 4) a lack of desire for social connectedness with the broader *Pokémon* or Wizard Unite community, 5) feeling forced to engage in group play, especially with strangers, 6) a lack of other players in the local area, 7) recurring costs to play, 8) the monotony and repetitiveness of the game. Several

instances of switching behaviour in the data can be attributed to such constraints [38]. Understanding the factors that sustain HPWU/PGO player preference and behaviour [18, 38] (See Table 3) requires an understanding of attrition in terms of sustainers of player preferences and why some consumers choose to exit or switch, as well as what they do when they switch. In the case of this sample, many players who dropped one Niantic Inc AR game (HPWU or PGO) did so to focus on another of the company's AR titles (HPWU or PGO), suggesting the sustainer factor of risk for switching (FOMO and sunk costs) could keep players within a brand, if not with a given game. When switches did occur, they were often due to external obligations or lack of significant others playing. Understanding this can help us to build actionable design strategies by understanding the needs and wants of players [18].

Improving game design through involvement

Our use of psychographic criteria in combination with demographics to understand the preferences and behaviour of HPWU and PGO players has interesting implications for establishing clear target groups for AR games and leveraging appropriate game design strategies to promote loyalty and behaviour change. Our study shows that activity involvement is one potential game design strategy that can be used to enhance loyalty and sustain gaming preferences – something with clear implications for health-focused serious games [7]. Involvement was shown to play a central role across current and former player identities, with some individuals even going so far as to organise their holidays around their gameplay (centrality). For the majority of respondents (excluding former hardcore PGO players), gaming was central in their lives, serving as both a

component of their identity, as well as being a fun and enjoyable source of entertainment. Indeed, many stated that playing PGO or HPWU had enriched their lives, whether by providing them with motivation, introducing them to a new community, providing them with an opportunity to share an experience with friends or family, or letting them live out childhood fantasies. Interestingly, few, if any, mentioned having the desire to increase their level of physical activity when they began the game, despite self-reported changes to their physical activity levels. Nor, with the exception of those who lived far enough away from game-associated locations that personal transport was required, was there any mention of the amount of physical activity required to play these games being a constraint. This suggests that a crucial part of the success of these games was that the elements promoting physical activity were not seen as interfering with the fun of the game, but were incorporated in a way that was congruent with player immersion and nostalgia [7]. Indeed, for the majority of self-identified players, the maintenance of strong attitudes toward resistance to change preferences for the Niantic Inc. brand [19, 25] (word-of-mouth and attitudinal and behavioural loyalty) were inter-linked with involvement (sign-value, centrality, risk) with Harry Potter and *Pokémon* franchises. The idea we pose here is that a keen focus on increasing gamers' involvement (as measured via attraction, sign-value, centrality and risk) through good design may ultimately increase their loyalty to a game and its brand, thus indirectly influencing health outcomes by promoting increased physical activity and other pro-social behaviours [7].

To consider this further, for some individuals, player preference may be related to fun or symbolically extraordinary or memorable emotional experiences that drive player preference, in this case to Harry Potter or the *Pokémon* franchise. Indeed, fun and self-

expression were highlighted as a central aspect of player preference for the *no identification* group (those players who have not yet established a clear player identification). This group did not report any loyalty or attachment (e.g., attitudinal/behavioural) with regards to the actual brand represented by Niantic Inc, and rarely with regards to the franchises (*Pokémon* or Harry Potter) the games draw upon, with player preferences being related to a strong attachment to both the symbolic elements of play and pleasurable aspects reflecting the hedonic value of play (attraction and sign-value). This is in line with the expectations of a group which has yet to develop a player identity or strong attitudinal/behavioural attachment with the Niantic Inc. brand. Our findings suggest that this particular group plays for fun and self-expression, given that unlike other player identities, current and former *no-identification* players did not report any risk of switching sustainers (FOMO, or sunk costs associated with their involvement). As discussed previously, for all other player identities, self-expression through symbolic value and positive attitudes toward the franchise and brand ignited attitudinal and behavioural loyalty, which has been shown to influence choice-behaviour and preferences [19, 39].

Involvement factors such as sign-value and attraction were inter-related and are interesting aspects to further highlight. Some individuals refer to themselves as 'Potterheads' or have a fantasy of becoming a '*Pokémon* trainer in real-life', with AR allowing these games to serve as an extension of their reality and self-identity. This symbolic value may be perceived to improve or maintain one's player-identity and self-expression by helping a player relate to those in their gaming sphere [6, 40], as shown by the factors of attraction (involvement) and sign-value related to an AR experience. Thus,

AR does not simply provide players with memorable experiences, but links them to a fun and magical world that is deeply tied to their existing sense of identity [41]. Indeed, player responses indicate that through AR, fun experiences with the characters can in fact reinforce one's self-image. This suggests that gamer preferences in AR games, and thus their continued behaviour, are linked to their affective and emotional attachment to these games. For example, individuals who feel that they have gained something extraordinary as a result of being able to be "part of" the Harry Potter or the *Pokémon* worlds, thus tapping into childhood memories and nostalgia, are unlikely to change their preferences as a result of constraints encountered [19]. Understanding how these factors motivate users of AR games and being able to address them may be useful if one seeks to encourage activities leading to improved health outcomes through designing future games and other tools) (7).

Conclusion

This study provides real-world research on obstacles that players face and how the construct of involvement (attraction, sign-value, centrality, & risk) may help to create strong attitudes toward resistance to change despite encountering significant constraints. Involvement and its constituent components, therefore, help to explain why participants continue to engage with Niantic Inc and its products even when said brand or products fail to meet their expectations. Furthermore, a better recognition of the role of involvement and its components may enhance our level of understanding as to what keeps players of AR games playing even when they are constrained by factors such as a lack of other players in their

local area, a lack of time, or other difficulties. Beyond that, the qualitative mapping method demonstrated here may be applied on a wider basis, potentially providing a mechanism through which designers and other stakeholders can better understand potential audiences, allowing for improvements in the design of health-focused serious games to reduce/prevent discontinuation, and better improve health and society. Future research should look beyond retention to further examine the relationship between involvement and physical activity outcomes, as well as how this relationship is affected by differing implementations of AR.

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Abbreviations

AR: Augmented reality

HPWU: Harry Potter: Wizards Unite

PGO: Pokémon GO (PGO)

Supplementary material

Appendix 1: Proforma (open-ended, text-box survey)

Appendix 2: Codebook

Appendix 3: Still playing and former players

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Supplementary Material Appendix 1

Demographics questions

- Gender (Female / Male / Other / Prefers not to say)

- Age (18-25 years old / 26-35 years old / 36-45 years old / 46-55 years old / >55 years old / Prefers not to say)

- Geographical Territory (Free response)

- How did you **hear** about this survey? (free response)

    - From *Pokémon GO* subreddit
    - From one of the *Wizards Unite* subreddits
    - From family / friend
    - From online forums / Discord servers
    - Others (please specify) (Free response)
    - Prefers not to say

- I typically play videogames

    - At least once every day

- 3-6 days every week
- 1-2 days every week
- Less than once a week but more than once a month
- Less than once a month
- Prefers not to say

- I would consider myself a:

- Hard core gamer
- Casual gamer
- Something in between
- I have no idea
- Prefers not to say

- When I play other games, I usually play them on (multiple answers allowed):

- Computer
- Home console
- Handheld console
- Mobile phone
- Prefers not to say

- When I play other games, I most prefer the following way of playing games (multiple answers allowed):

- Single player
- Local Co-op
- Online Co-Op
- Competitive Multiplayer
- MMOs
- Prefers not to say

- Do you have an unlimited data plan on your mobile device? (Yes / No / Prefers not to say)

- What operating system does your mobile device use? (Android / iOS / Prefers not to say)

- How often do you spend money in mobile games?
- Never
- Occasionally
- Sometimes
- Often
- All the time
- Prefers not to say

- How often did you walk before you started playing *Pokémon GO* or Wizards Unite?
    - Walked for **at least** 30 minutes every day
    - Walked every day, but for **less** than 30 minutes per day
    - Walked for at least 90-150 minutes a week
    - Walked for at least 30-90 minutes a week
    - Walked for at least 30-150 minutes a month
    - Walked for 0-30 minutes a month
    - Prefers not to say

- How often do you walk **now**?
    - Walked for **at least** 30 minutes every day
    - Walked every day, but for **less** than 30 minutes per day
    - Walked for at least 90-150 minutes a week
    - Walked for at least 30-90 minutes a week
    - Walked for at least 30-150 minutes a month
    - Walked for 0-30 minutes a month
    - Prefers not to say

- Do you **currently** own a Fitbit or other devices that could track your physical activity (aside from a mobile phone)? (Yes / No / Prefers not to say)

- Prior to playing *Pokémon GO* or *Wizards Unite*, did you own a Fitbit or other devices that could track your physical activity (aside from a mobile phone)? (Yes / No / Prefers not to say)

Open-ended questions
What made you decide to download and play *Wizards Unite*?
If you have spent money in *Wizards Unite*, what do you did you usually purchase?
Have you been to any places you had not been before because of *Wizards Unite*?
Were there goals you set for yourself in the game E.g. "During my time playing, I wanted to…"?
What do you like the most about *Wizards Unite*?
What do you dislike the most about *Wizards Unite*?
What do you want to see in *Wizards Unite* that is missing?
What keeps you playing *Wizards Unite*?
What made you drop *Wizards Unite*?
If you are still playing *Wizards Unite*, do you intend to increase, decrease, or maintain the

amount of time you spend playing this game in the future?
If you had quit playing *Wizards Unite*, what has taken its spot, in terms of time?
What do you like the most about *Pokémon GO*?
What do you dislike the most about *Pokémon GO*?
What do you want to see in *Pokémon GO* that is missing?
What made you decide to download and play *Pokémon GO*)?
Has your average daily play time changed from when you started (How had it changed)?
If you have spent money in *Pokémon GO*, what do you usually purchase?
About how much have you spent in total in *Pokémon GO*?
Has the activity you spent the most time in *Pokémon GO* changed over time (How so)?
Have you been to any places you had not been before because of *Pokémon GO*?
Were there goals you set for yourself in the game E.g. "I want to catch this specific Pokémon?
What keeps you playing *Pokémon GO*?
If you are still playing *Pokémon GO*, do you intend to increase, decrease, or maintain the amount of time you spend playing this game in the future?
What made you drop *Pokémon GO*?
If you had quit playing *Pokémon GO*, what has taken its spot, in terms of time spent?

Supplementary Material Appendix 2: Codebook

I. Constraints	Factors perceived or experienced by an individual that limit the formation of leisure preferences or inhibit participation and enjoyment
Structural Constraints	Definition: Structural impediments are either financial, (i.e., an individual has the desire to play the game but the on-going cost is too expensive), or accessibility issues (i.e., the person cannot access the location due to it being too far away) etc.
Lack of access/opportunities	Relating to a lack of opportunities such as no pokestops are around me/my city is small/I live rurally

	External obligations/other priorities	Relates to not wanting to interrupt one's daily schedule, or obligations keeping an individual away from gaming.
	Distance	Refers to the availability within walking distance (or needing to use transportation) that may inhibit or prevent a person participating in the activities of PGO/HPWU
	Lack of time	A lack of time to spend playing the game or the time it takes to complete tasks
	Cost	Refers to cost to play, affordability etc.
	Interpersonal constraints	Definition: Constraints that are largely driven by interactions with other individuals, such as a friend or partner, other people you participate with, your family, your friends, and your work colleagues (in other words significant others for the individual).
	Lack of significant others	Relating to a lack of significant others for the individual to play PGO/WU with
	Intrapersonal constraints	Definition: Intrapersonal constraints focus upon the very personal constraints we place on ourselves that we internalize and for this reason become personal constraints.
	Lack of knowledge and understanding	Understanding and knowledge of the game in order to play
	Lack of interest	Includes statements about a lack of interest in PGO/HPWU or the game is repetitive / a grind / do not see the point in this game.
	Lack of confidence	Refers to a lack of safety in going to new places and meeting strangers
II.	Involvement	Definition: Involvement is defined as an unobservable state of motivation, or interest toward PGO/HPWU. It is evoked by a particular stimulus and has drive properties
	Attraction	Definition: Attraction is conceptualized as players' perceptions of activity importance and pleasure gained through playing PGO/HPWU.
	Risk of switching sustainers	Definition: Risk of the probability and consequence of making a bad choice of switching (PGO/HPWU) due to sunk costs, total costs, FOMO etc.
	Centrality	Definition: Centrality of the game within the context of players' overall life. PGO/HPWU is central when other aspects of life are organized around the activity and is reflective of commitment.

Sign-value	Definition: Refers to the unspoken statements that participation of PGO/HPWU conveys about a person.
III. Loyalty	Constructs: Loyalty is a deeply held commitment to or attachment to a brand, regardless of situational influences and marketing efforts having potential to cause switching behavior.
Attitudinal	Definition: Attitudes towards the brand (Niantic). A Psychological decision making or evaluative processes. Understanding of the attitudes and perceptions toward the brand.
Word-of-mouth recommendation	Definition: Is reflective of the adoption or repatronage intention of the product or service based on word-of-mouth recommendations.

Supplementary Materials Appendix 3: Current player of either (or both) HPWU or POGO

Self-identified player type		No identification	Casual	In-Between	Hardcore
Theme 1: Loyalty					
Word-of-mouth	HPWU	My Daughter is a huge Potterhead; friends; partner; kids; co-workers; Pogo community	Fiancé; friends; partner; local community; Facebook; Reddit; discord	A suggestion from an acquaintance; family; friends	A friend; ingress; PGO; daughter
	PGO	Kids; family; siblings; work colleagues; students were playing it	Friends; grandfather; siblings; partner	Partner; friends; sister; kids; discord	Friends; co-workers; partner
Attitudinal	HPWU		I liked ingress; Niantic games; played PGO; played Ingres; POGO;	Ingress: *Pokémon GO*; Minecraft Earth player; it's a Niantic product	Played *Pokémon GO* and ingress before; Niantic brand
	PGO		Ingress; Niantic	Ingress; Niantic; Ingress	Niantic game
Theme 2: Involvement					
Sign-value	HPWU	Fandom; magical experience [AR]; Connection to Wizarding world	Nostalgic connection to the place (Harry Potter world); connection to literary series; theme; familiarity with characters	Going into the HP universe; fan of books; fantasy; magical experience in real life; feeling part	Fandom; connection to the story; 'Pottervers e'; 'Potterhead'

				of the wizard world; fandom; being a loyal 'Potterhead'	
	PGO	*Pokémon* franchise; nostalgia from childhood; Pokémon characters; fan	Connection to activity (catching *Pokémon*); fan; memorable; felt like being part of the show	Fantasy and magical experience in real life; fan	Fantasy and magical experience
Risk (switching costs)	HPWU		FOMO; lose progress [if quit]	Only played PGO to compare with WU [FOMO]	*Pokémon* world is dull compared to Potter world; preference for potter world
	PGO		Sunk cost (time); addiction & FOMO	Sunken cost fallacy	Sunk costs; duty and obligation to other players; FOMO
Centrality	HPWU	Cooperative game play and the in person and online community of people I've met and gotten to know; motivates me to walk and get outside; mark off; complete daily tasks everyday	Challenge; special events; the sense of accomplishment of completing tasks (finish skill tree), being encouraged to walk to new places in the real world and pay attention to locations I did not before	It's part of my daily routine; Habit; collect everything; completing time restrained tasks; goals	Completion; travel to Indianapolis Fan Fest; I went to the Indianapolis Park where the first WU event was
	PGO	Motivates me to walk; takes me away from grad school grind; habit; incentive to walk`	Habit; seeing Pokémon in place I visit on vacation; motivation for exercise;	Habit; back pains are gone as walking more; part of my	Having a reason to go out and walk; walk the dog; explore

			change behaviour from taking the bus to the store now instead walking there	routine; gets me out walking; collecting different Pokémon; Visited Vienna and Dortmund events as well as other neighbourhoods to gold Gyms; While on vacation I even used *Pokémon GO* as an interactive map, showing me points of interest to go to	and POGO shows all local parks; I'm going to St. Louis because of *Pokémon GO*. I've been there before but this trip is specifically because of *Pokémon GO* and I would not have gone otherwise; on a family trip to Nashville I went to multiple locations out of the way to find a carnivine (regional that was unavailable where I live)
Attraction	HPWU	Play POGO and like Harry Potter; Makes walking more fun; fun; discovery; interest; fun	It's fun; sense of accomplishment; love Dumbledore; escapism; play *Pokémon Go* and I love Harry Potter, so it was a no brainer.	Fun; like PGO so tried HPWU; interesting; fun	I was really interested in the AR aspect of it at the time
	PGO	Pokémon are cool! fun; novel; virtual reality aspect of it	Enjoy the collecting aspect, AR aspect; curiosity; fun idea of the game	I just play for the fun game; fun catching Pokémon; novel and new; interesting Pokémon	It's so much fun. It's something to do in my free time, and I haven't gotten bored of it!

Theme 3: Constraints					
Structural Constraints					
Distance	HPWU		Not much is available within walking distance	Not enough Inns near me [drive to location]	
	PGO			Gameplay from car, driving from one suburban location to another	
Lack of time	HPWU	Wait time between tasks & wait required to get into fortress and lack of continuation of story	Waiting; stalling [Hard to get to an energy level where I can use many runestones at once]	Time it takes (Traces) to complete	
	PGO				
Lack of access/ opportunity	HPWU	Need better distribution of fortresses; bugs that don't count my distance; glitchy and GPS tracker is faulty; privacy invading adventure sync	Glitchy; Glitchy GPS tracker; region locks; lack of Foundables and lack of balance between greenhouses; inns; fortress; rare spawns are too infrequent; more opportunity to catch emergency Foundables; certain Foundables; algorithm makes some things hard to catch; bugs expensive gold packs and slow announcements	Better and more varied spawn rates; broken game mechanics; limited content; live in cold climate hard for me to go outside- need adaptions so can continue to play; need to be able to cross locations and hunt Foundables	Glitchy; errors; bugs; incomplete buggy rollouts; constant Niantic bugs

	PGO	Being able to trade from a distance –(can't do this); I never win battles; at college I can play at home I have to go out of my way to find pokestops; Pokémon only in some countries cant access; glitches	Not enough diversity in my area; more rural stops; bugs that need fixing; GPS faulty; low spawn rate in my area; need loot box odds – bugs and glitches;	Bugs; technical issues; design issues; regional aspect; ; bias towards city ; urban paly; hard to play in winter in Norway (adapt it to play)	Lack of informatio n about chance to win something – shiny rates and egg hatches; buggy; lacks a good layout for rural players who miss out and lack options; lack access to regional Pokémon
External obligations and priorities	HPWU	Kids and full time job; other commitments;; focus on studies	Worry that game interferes with my life; game requires dedicated play; need to focus on school	Family; work; other family events; busy schedule; competing games Ingress; HPWU; POGO and Dominant	Playing PGO; too busy
	PGO	Sleep	Work; split the time with HPWU; personal life events	Interfere with life; busy schedule; job; education; work commitme nts	Study; working; changed jobs
Cost	HPWU	Monetised - Money to complete or have a chance of finishing the rare Foundables	Too many events and features now that require payment; The lottery box machine - which is the	Pay to win; pushing in-app transaction; money spent on different challenges;	Too focused on microtrans action s

			same reason I quit POGO; POGO became an unfun loot box-machine; battery drain; high data use	data usage	
	PGO	Battery usage; in game shop; incubators cost too much; cash payment for event	Rapacious monetization; pay less now as I split with HPWU; COST OF INCUBATORS	Pay to win is increasing; monetisation; drains; certain Pokémon are behind egg paywall; battery; money grab by Niantic	Paywalls; cost of powering up Pokémon; micro transactions; very expensive
Intrapersonal Constraints					
Lack of knowledge and understanding	HPWU				
	PGO				
Lack of interest	HPWU	Repetitive; bored; pointless	More story needed; new lessons needed - It feels repetitive	The story line is getting thin; lacking excitement; grind	The tedious nature of the game; bored; tired
	PGO	Repetitive; bored; grind	Addition of new generations; switched; reduced play due to HPWU; repetitive	Repetitive; new content needed; grind	Dropped when HPWU came out; excitement faded; repetitive; Can't build relationship with Pokémon - They all feel the same

Lack of confidence	HPWU	Too complicated	Too complicated; Meeting strangers and danger playing alone; introverted person; can't complete wizards challenges	Not safe meeting strangers; hard to play while walking; lack of confidence in Niantic; Hard to play while walking (higher skill to complete Foundables)	
	PGO	Fighting in PGO is really hard; an explanation of game mechanics;	Too many features; too many variations of Pokémon and impossible to catch; complicated; impossible to catch all new Pokémon so many of them	Overcomplicated, need clear information and lack of transparency from developers; A way to control when eggs open and when to pick them up. A revamp of the friend's system that doesn't make gifting so tedious (basically a gifting system designed more like *Wizards Unite* in	Transparency form Niantic about raids; needs a support that actually supports players; need More quest lines, such as the ones in *Wizards Unite*. Badges and achievements that mean something.

				function and gift capacity	
Interpersonal constraints					
Significant others	HPWU	Lack of local players (compared with PGO); need for better ways to find; locate people who play within the game; requires other people; groups; coordination of people for timing of raids; unlike POGO, there are not enough players easily found to attack higher level fortresses	Play alone friends stopped playing; more solo options needed; smaller community than POGO	Need for artificial intelligence teammates for those who do not prefer to meet up with other players; Doesn't allow non-local interaction; problems with in-game system to arrange meetups; unable to play with a group across the country; unite better	Requires coordination of people; difficult to find players
	PGO	Coordination of people; strangers for raids; friends in different countries can't play with; rural players	Spoofer; toxic local player community; designated times; Forced group play; inability to play alone; features require coordinating; spoofers; spoofer apps	Hard social elements; The requirement to interact with other people; cheaters; negative social aspects; toxic	More coordination between developers and players; improved communication from Niantic; spoofers and

			allowing people to cheat; Niantic's push for co-op play; features poor at connecting with local people; friends have quit	people	cheaters and no action taken to deal with these people; need large group to complete tasks; need to socialise to complete tasks

COVID-19 AS 'GAME CHANGER' FOR THE PHYSICAL ACTIVITY AND MENTAL WELL-BEING OF AUGMENTED REALITY GAME PLAYERS DURING THE PANDEMIC: MIXED METHODS SURVEY STUDY

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Abstract

Background: Location-based augmented reality (AR) games, such as *Pokémon GO* (PGO) and *Harry Potter: Wizards Unite* (HPWU), are shown to have beneficial impacts on physical activity, social connectedness, and mental-health for their players. In March 2020, global social distancing measures related to COVID-19 prompted the AR games developer Niantic to implement several changes to ensure continued player engagement with PGO and HPWU. We sought to examine how physical and mental well-being of PGO and HPWU players were affected during the unprecedented COVID-19 restriction period, as well as how video game engagement was impacted.

Objective: (1) To examine the impact of COVID-19 social restrictions on the physical and mental well-being of AR game players; (2) to examine the impact of COVID-19 social restrictions on usage of video games and motivations for use; and (3) to explore the potential role of AR games (and video games in general) in supporting well-being during COVID-19 social restrictions.

Methods: A mixed-method, online, self-reported survey was conducted in May 2020, during which COVID-19 social restrictions were enforced in many countries. Participants were recruited online via four subreddit forums dedicated to PGO or HPWU. Data collected contained quantitative data on demographics, time spent playing video games, physical activity, and mental health, as well as qualitative data on motivations to play and video game impact on mental health during COVID-19 restrictions.

Results: We report results for 2,004 participants (58.8% male, average age=30.5 years). Self-reported physical activity during COVID-19 social restrictions

significantly decreased from 7.50 hours per week on average (SD=11.12) to 6.50 (SD=7.81) (p<.001). Over half of the participants reported poor mental health (n=925/1766, 52.4%; WHO-Five Well-Being Index (WHO-5<13)). Being female, younger age, and reduced exercise were significant predictors of poor mental health. Participants reported a significant increase in video game play from 16.38 hours per week on average (SD=19.12) to 20.82 (SD=17.49) (p<.001). Three in four participants (n=1102/1427, 77.2%) reported that playing video games had been beneficial to their mental health. The changes made to PGO and HPWU were very well received by players, and players continued to use these games while exercising and to maintain social connection. In addition to providing an escape during the pandemic and as a form of entertainment, participants reported that they also used video games for emotional coping, to lower stress, relax, and alleviate mental health conditions.

Conclusions: AR games have the potential to promote physical and mental-health during the COVID-19 pandemic. Used by populations under isolation and distress, such games can improve physical and mental health by providing virtual socialization, sustained exercise, temporal routine, and mental structure, all of which are factors that allow games to become digital behavioral interventions that maintain human well-being.

Keywords

Augmented reality games; COVID-19; *Pokémon GO*; Harry Potter: Wizards Unite;

Physical activity; mental health

Introduction

Coronavirus disease 2019 (COVID-19) was first reported in Wuhan, China, on 31 December 2019 [1, 2], escalating to a global pandemic. COVID-19 is transmitted between humans in close proximity, making physical (or social) distancing a key measure for reducing its spread [3]. By April 2020, most countries had introduced quarantine measures, travel bans, cancelled social events, and closed public services to contain COVID-19 [4]. With the introduction of stay-at-home 'lockdown' and quarantine measures, electronic video gaming was at an all-time high [5]. Reputedly, 82% of global consumers played video games and watched video game content during the height of the COVID-19 pandemic lockdowns [5]. Increased online gaming was viewed as complementary to public efforts to promote physical distancing [6]. Most notably, the World Health Organization partnered with the gaming industry in March 2020 to launch the campaign #PlayApartTogether to encourage people to stay at home, play video games, and practice physical distancing [7].

Although online gaming has played a supporting role during the COVID-19 pandemic in maintaining physical distancing, concerns have been raised about encouraging video gaming [6] as previous research linked excessive gaming with poor mental health, sleep problems and physical inactivity [8]. Protracted periods of isolation, technology-based activity, and limited social interaction can also solidify unhealthy lifestyle patterns, intensify technology-related disorders and potentially lead to difficulties to readaptation once the COVID-19 pandemic has passed [6].

For this reason, "healthier" gaming options that promote increased physical activity and social connection [6, 9, 10] are being encouraged. Location-based augmented reality (AR) games such as Niantic Inc's *Pokémon GO* (PGO) and *Harry*

Potter: Wizards Unite (HPWU) [11] are of particular interest as they were designed to increase physical activity [12, 13] and have been found to increase players' social connectedness [14] and mental well-being [12, 15]. Such games require players to explore outdoor public spaces and engage in social events as part of the normal play experience, using cellular, Wi-Fi, and Global Positioning System networks to determine a player's approximate location. This in turn affects their ability to interact with game features and other players.

With government-issued restrictions during the COVID-19 pandemic encouraging – or requiring – individuals to stay home, playing such games in the manner they were originally designed became challenging [10, 16]. Niantic implemented several in-game changes to PGO and HPWU to prevent these restrictions from having deleterious effects on the play experience, make them easier to play at home and in social isolation [17]. These changes ensured PGO and HPWU continued to flourish [16]. However, they do not necessarily translate to improved physical and mental well-being for players, as many game play features designed to promote physical activity and social activity were removed or altered [16]. This study sought to examine the physical and mental well-being of players of PGO and HPWU during COVID-19, as well as to how players viewed the role of AR games – and video games in general – on their mental health during the pandemic.

As such, our aims were:

1. To examine the impact of COVID-19 social restrictions on the physical and mental well-being of AR game players.
2. To examine the impact of COVID-19 social restrictions on usage of video games and motivations for use.

3. To explore the potential role of AR games (and video games in general) in supporting well-being during COVID-19 social restrictions.

Methods

Overview

We conducted a mixed-methods online survey during the period in which many countries were under COVID-19 social restrictions (15 May – 29 May 2020 inclusive) [4]. This survey is part of a larger study to examine PGO and HPWU use and player experience during COVID-19. Ethical approval was obtained from Macquarie University's Human Research Ethics Committee for Medical Sciences (Reference No: 52019601512435).

Sample and Recruitment

Participant recruitment was conducted online via four subreddit forums dedicated to PGO or HPWU (r/WizardsUnite, r/PokemonGO, r/harrypotterwu, and r/TheSilphRoad). A recruitment post was pinned to the top of each of subreddit from May 15 to May 29, 2020, directing individuals to the participant information page via *Qualtrics* [18]. Participants were informed that participation was voluntary, that they could withdraw at any time prior to submitting their final responses, and that to be eligible they needed to be 18 years or older and have played the English versions of PGO or HPWU for at least a week. Those who consented to participate were directed to the online survey which took 15 to 20 minutes to complete. No incentives were offered for taking part. Participants were informed not to provide any identifiable personal information. IP addresses of participants were recorded by Qualtrics to

identify repeat visits. Duplicate entries were not permitted after the participant had submitted the survey.

The survey

The survey included a total of 40 questions, both quantitative and qualitative. Demographic information was collected from participants, including age, gender and country of residence. Responses from quantitative questions relating to video game use, exercise and mental well-being are reported here, as well as responses from two qualitative questions regarding motivation to play and the effect of games on mental health (**Multimedia Appendix 1**).

Video game use

Participants were asked whether they identified as a 'hardcore gamer', a 'casual gamer' or 'midcore gamer' to identify their usual play patterns and level of engagement. [19]. Hardcore gamers are defined as those who invest a significant amount of their recreational time and resources to gaming, and who also have more knowledge and skills in games [19-21]. On the other hand, casual gamers are defined as those who play games casually, in short sessions or infrequently [22, 23]. Midcore gamers fall in between and refer to those who regularly play video games but are not "super serious" [23]. Participants were also asked for their typical video game playing frequency prior to COVID-19 (number of hours per day and days per week) and during the COVID-19 lockdown (number of hours per day and days per week). In addition, participants were asked whether they continued to play either PGO or HPWU during the lockdown (Yes/No).

Physical activity

Respondents were asked to report their typical exercise frequency prior to COVID-19 (number of hours per day and days per week) and during the COVID-19 lockdown (number of hours per day and days per week).

Mental well-being

The WHO-Five Well-Being Index (WHO-5) [24] is a five-item measure of current mental well-being. The WHO-5 consists of five items assessing positive mood, vitality, and general interest over the past two weeks, scored on a six-point Likert scale from zero (at no time) to five (all of the time). Scores are summed to create a total 'raw score' (range 0-25), with lower scores indicating impaired emotional well-being [24]. A total 'percentage score' is obtained by multiplying the total raw score by four. A raw score of <13 (or <50%, or a score of 0 or 1 on any of the items) is considered an indicator of impaired mental wellbeing, and likely depression [25, 26].

Qualitative questions

This paper focuses on responses to two qualitative questions: (1) "What motivates you to play PGO or WU during the COVID-19 shutdown?" and (2) "How has playing video games affected your mental health during the shutdown?".

Data analysis

Quantitative survey data was analyzed using IBM SPSS Statistics Version 25.0 (IBM Corporation, Armonk, NY, USA). Reported total hours of participation in gaming and exercise per week were calculated by multiplying the number of hours by the number of days they were performed. Game play and exercise change scores (pre-COVID minus during COVID) were also calculated. Differences between males and

females and between self-identified player types were examined using chi-square analysis or multinomial logistic regression for categorical variables or t-tests for continuous variables. Binary logistic regression was used to determine factors associated with impaired mental wellbeing. Due to the large sample size, the significance level was set at $P < .01$ for all analyses.

Qualitative responses were analyzed via thematic analysis using NVivo [27]. Thematic analysis using a six-step process [28] was undertaken independently by two researchers (LAE and MDL). Codes were developed using an iterative process in order to finalize and map important themes and ensure consistency with the data [29]. The broader research team were included throughout each stage of the analysis process to help resolve any differences, with frequent discussions concerning themes. The qualitative findings were used to triangulate and build upon the quantitative data.

Results

Demographic results

In total, 2165 participants responded to the survey. The sample was reduced to 2004 after excluding participants with more than 30% of survey data missing. In the sample, most participants were male (58.8%) and aged between 25 and 35 years (49.3%, M=30.5, range:18-99). Participants were drawn from 66 different countries, with almost half from the United States (49.7%). The characteristics of the survey respondents are presented in Table 1. Only countries with more than 50 respondents are shown.

Table 1. Demographic characteristics of survey respondents (n=2004)

		n	*%*
Gender	Female	807	41.2
	Male	1153	58.8
Age	18-24 years	523	26.2
	25-34 years	985	49.3
	35-44 years	329	16.5
	45 years+	161	8.1
Country	Australia	77	3.9
	Canada	146	7.5
	Germany	90	4.5
	The Netherlands	52	2.6
	United Kingdom	177	8.9
	United States of America	987	49.7
	Other	458	23.1
Self-identified player type	Casual gamer	905	46.6
	Hardcore gamer	392	20.2
	Midcore gamer	646	33.2

Note. Columns may not equal total N due to missing demographic responses.

Self-identified player type

When asked to self-identify as a 'hardcore', 'casual' or 'midcore' gamer, most respondents considered themselves 'casual' gamers (n=905/1943, 46.6%), followed by 'midcore' gamers (n=646/1943, 33.2%), and 'hardcore' gamers (n=392/1943, 20.2%). Hardcore gamers were significantly more likely to be male (n=324, 84.2%) than female (n=61, 15.8%) ($\chi 2$ (1, N = 1901) = 160.23, $p < .001$), and significantly younger than casual gamers ($\chi 2$ (1, N=1293) = 53.97, $p < .001$).

Quantitative Results

Impact of COVID-19 on physical activity

Prior to COVID-19, participants reported exercising for an average of 7.50 hours per week (SD=11.12). At this time, 'hardcore' players (M=9.07, SD=12.92) exercised significantly more than 'casual' gamers (M=7.19, SD=11.10; $t(1129)=2.48$, $p<0.5$), and males (M=8.31, SD=13.00) exercised significantly more than females (M=6.35, SD=7.88; $t(1929)= 3.59$, $p<0.01$). During the COVID-19 lockdown, participants decreased their exercise to an average of 6.50 hours per week (SD=7.81). This reduction in exercise between pre- and during-lockdown was significant (t(1636)=4.31, p<.001). During the COVID-19 lockdown, males (M=7.05, SD=8.31) exercised significantly more than females (M=5.82, SD=3.14; $t(3.14)= 3.59$, $p<0.01$); however, there were no longer significant differences in exercise by self-identified player type. We also identified a significant positive correlation between total hours of gaming and exercise per week both during COVID-19 (r=.198, p<.001) and prior (r=.257, p<.001).

Mental well-being during COVID-19

Over half of participants reported poor mental health (n=925, 52.4%; WHO<13) at the time the survey was conducted. A multivariate binary logistic regression analysis was conducted with age, gender, self-identified gaming type, difference in video game play, and difference in exercise entered as predictors. The model identified being female (p<.001), being younger (p<.001), and reduced exercise (p=.008) as significant predictors of poor mental health during the COVID-19 lockdown. At a significance level of p<.01, self-identified player type (p=.215) and

difference in video game play (p=.039) were not significant predictors of poor mental health (**Multimedia Appendix 2**).

Impact of COVID-19 on video game use

Three in four participants (n=1261/1675, 75.3%) reported that during the COVID-19 lockdown, they played video games 'a little more' to 'a lot more'. Twenty percent (n=335) reported 'no change' and only five percent (n=79) reported playing 'a little less' to 'a lot less'. Prior to the COVID-19 pandemic, participants played video games for an average of 16.38 hours per week (SD=19.12). At this time, 'hardcore' players (M=20.24, SD=22.47) played significantly more than 'casual' gamers (M=13.97, 17.32; $t(1276)=5.41$, $p<0.01$), and males (M=17.90, SD=20.77) played significantly more than females (M=14,26, SD=16.34; $t(1929)=4.13$, $p<0.01$). During the COVID-19 lockdown, participants increased their video game play to an average of 20.82 hours per week (SD=17.49). A paired samples t-test indicated that the difference in video game play between pre- and during-lockdown was significant ($t(1940)=11.17$, $p<.001$). Notably, during the lockdown, there were no longer significant differences in average play time by self-identified player type or by gender. Further, virtually all participants (n=1962/1975, 99.3%) reported that they were continuing to play either PGO or HPWU during the lockdown.

Qualitative Results

Motivation to play AR games during COVID-19

For the first qualitative question, "What motivates you to play PGO or HPWU during the COVID-19 shutdown?", several key themes emerged from participant

responses (**Multimedia Appendix 3**). The most prominent themes were entertainment, achievement/challenge, in-game modifications, and exercise.

Entertainment. Many participants (n=506/1527, 33.1%) indicated they played PGO or HPWU during the pandemic as these games were "fun" and "entertaining". Some participants noted that these games provided them with "something to do" during the lockdown, as there were few alternatives they could enjoy while "stuck at home" and in some cases, under financial constraints due to being un- or under-employed. Other participants mentioned that COVID-19 related restrictions gave them more time to play, with one stating that it gave "an opportunity to come back to the game after a few years", that he "missed playing it" and it gave him "something to do in [his] downtime" (male, 25).

Achievement/Challenge. Almost one third of participants (n=500/1527, 32.7%) stated that achievement and challenge were a key motivating factor for playing PGO or HPWU. Participants stated that the "daily challenges" and "daily tasks" gave them a "sense of accomplishment". Many PGO players said that they were driven to accomplish the primary objective of the game — "Catch Pokémon", as well as other objectives such as hunt for "shinies" and receive in-game "rewards". Several participants specifically identified having PGO and HPWU tasks and challenges to complete as providing them with beneficial temporal structure and achievable goals, given the disruptions to work/school posed by COVID-19 restrictions. For example, one participant noted that it provided: "a challenge/task to complete when most of the deadlines have been removed from my life" (female, 35). Another said: "I've been playing *Wizards Unite* during the lockdown as a way to fill time and have an activity that provides a sense of progress and achievement" (female, 24).

In-game modifications. Many respondents (n=343/1527, 22.5%) highlighted that they liked, or even "loved", the new changes made to PGO and HPWU. The games became "more accessible to play from home" and the "increased rewards and events have kept [people] engaged". One participant praised Niantic for their efforts: "Niantic has done well to implement features that make playing from home easier" (male, 30). Notably, changes such as the "Knight Bus" in HPWU (a function that enabled players to cooperatively face in-game challenges from home) and the opening of "the GO Battle League" in PGO (which allowed players to challenge others and compete for rankings), reduced or eliminated the need to walk outdoors. One HPWU player (female, 53) elaborated: "The Knight Bus completely changed game play for me…Online instructions and the ability to 'travel' to a Fortress has made the game 100% more interesting." PGO players also appreciated the addition of "spotlight hours, improvements to the incense and such" (male, 20), but it was "GO Battle League" that was cited as "game-changing", with one player mentioning that the removal of walking requirements to participate had "renewed [his] interest in the game" by providing "a measurable way to make [and measure] progress" (male, 30).

Exercise. One-fifth of respondents (n=316/1527, 20.7%) noted that they used PGO or HPWU while exercising. Many stated that it motivated them to exercise more, with one participant mentioning that "it is the only thing that motivates me to go on walks outside" (male, 24), and another saying that these games were "the only reason to step outside" and she was "actually exercising more during lockdown" (female, 33). For others, it gave them "something to do during exercise" (male, 29), or during other activities such as "walking the dog" or spending time with family members. Some elaborated on their exercise routines during the COVID-19 restrictions, with a typical example below:

"*Pokémon GO* is the one thing that keeps me going outdoors and moving each day. It gives me a purpose to keep walking to different parts of the city but also lets me do so while staying away from clusters of other people" (female, 28).

Impact of video games on mental wellbeing during COVID-19

Analysis of responses for the second qualitative question indicated that over three in four participants (n=1102/1427, 77.2%) believed playing video games during COVID-19 lockdown had been beneficial to their mental health. Twenty percent of participants gave a neutral response (n=295/1427, 20.7%) and only 2% (n=30/1427) reported a negative impact. For participants who reported a positive mental health impact, several key themes described the role of video during COVID-19 (**Multimedia Appendix 4**).

Escape/distraction. Half of participants reporting a positive mental health impact (n=541/1102, 49.1%) identified that video games had been helpful in "providing a much-needed escape" and "a great distraction" from the current situation. A number emphasized that games were particularly helpful in how they took their "mind[s] off the constant depressing news coverage of COVID-19". One participant elaborated: "I can focus on the game instead of obsessively checking the news and stressing out" (female, 34). Another said: "[They] kept me away from watching the news all day. It was quite nice to not be surrounded by COVID news all the time" (male, 27).

Activity/Entertainment. Almost half of participants (n=535/1102, 48.5%) stated that video games gave them "something to do", helped them to "stay busy" and kept them "entertained" during COVID-19 lockdown. Games gave them "something

fun to focus on" and "helped to relieve boredom" while "being at home 24/7". Many described how games gave them "something to look forward to", with one individual even stating that beyond keeping him "motivated and busy", games helped him to "get out of bed and do something" (male, 30).

Emotional coping. In addition to providing an escape and serving as a way to pass the time or be entertained, many participants (n=469/1102, 42.6%) identified how video games had helped them "cope" and maintain "a calm and positive outlook". Playing video games allowed them to "relieve some stress", "relax", and "lifted [their] mood". One participant wrote that video games were "possibly the only thing keeping me sane right now" (female, 30). Some respondents also wrote about using video games to alleviate specific mental health conditions:

> "It's kept me in a safe place mentally. While college was in session I had depression and anxiety and it's still lingering as of now. It takes my mind off of the outside world." (male, 19)

> "I suffered from anxiety and depression prior to the shutdown, too, and used games for the same escape then." (female, 42)

Social connection. One in five respondents (n=219/1102, 19.9%) emphasized the importance of video games in strengthening social connections. Many indicated that they played video games with others in their household (e.g., children and partner), thus, "providing bonding opportunities". Multiplayer games provided an opportunity to stay in touch with friends and "still share in something together". One participant described that: "It has helped because it's the only social interaction I get" (male, 30). Some highlighted the importance of the local "community" these games create, noting that playing let them feel "less isolated":

"In *Pokémon GO*, the local app group makes me feel part of a community, even if we cannot all meet face to face right now." (female, 31)

"My HWPU/ingress community connections have been vital in having someone to talk to, and learning about other people's experiences." (female, 54)

Discussion

Principal Results

The COVID-19 pandemic has significantly disrupted normal activities globally. In this study, we sought to examine the impact of COVID-19 on physical and mental well-being and on video game use. We also sought to explore the potential role of video games (and AR games in particular) in supporting the mental well-being of players during COVID-19 lockdown. We summarize our key findings in accordance with our three objectives.

1. Impact of COVID-19 social restrictions on the physical and mental wellbeing of AR game players

Due to the COVID-19 stay-at-home restrictions, exercise levels dropped significantly from an average of 7.5 hours to 6.5 hours per week during the pandemic. Despite this drop, this level of activity is still well above the level of 150 minutes (2.5 hours) of moderately-intense activity recommended per week to achieve minimum health benefits [30]. From the quantitative survey data, we also identified a significant positive relationship between total hours of participation in gaming and total hours of exercise per week, indicating that rather than hardening unhealthy lifestyle patterns [6], AR games continue to promote physical activity, even with the COVID-19 restrictions. This finding was also supported by our qualitative results, with players consistently mentioning that AR games were keeping them motivated to exercise

throughout the pandemic. This is particularly important as our results also show that reduced exercise is a significant predictor of poor mental health, even after taking participants' gender and age into account.

Further, consistent with emerging research [31], our study suggests that the impact of COVID-19 lockdown on mental wellbeing is high. Over half (52.4%) of participants in this study reported poor mental health. Compared to previous estimated prevalence of poor mental health of around 25% [32], our identified prevalence of over 50% suggest the numbers have doubled during COVID-19. The substantial impact of the current pandemic situation on mental health has also been identified in other recent studies [31, 33], raising considerable cause for concern.

2. Impact of COVID-19 social restrictions on motivation to play and video game use among AR games players

Consistent with reports from popular media, the study found a significant increase in the use of video games during COVID-19 lockdown, mostly driven by casual gamers – females in particular – increasing their video game play. Despite the inconveniences to normal game play caused by COVID-19 restrictions, nearly all respondents continued to play PGO and HPWU. In fact, the qualitative results indicated that the in-game changes Niantic made to PGO and HPWU were a key motivating factor for players' continued use of the game during the pandemic, with many reporting that they "loved" the changes or had returned to the game because of them. This is also consistent with recent research on social media reactions across three popular PGO subreddits, which showed overwhelming appreciation towards PGO in-game changes [34].

3. Potential role of AR games in supporting the mental well-being of players during COVID-19 social restrictions

Despite previous concerns about increased video gaming during COVID-19 lockdown [6], over three in four participants in this study suggested that video games helped to support

their mental health. Qualitative results suggest that during ongoing lockdown and social distancing, video games provided an escape from the fear accompanying the pandemic and provided players with something to do while their usual routines (work, school, hobbies) were disrupted. Beyond that, video games were also being used to aid emotional coping: to lower stress, relax and alleviate specific mental health conditions. Respondents also reported that games played a critical role in maintaining social connections and encouraging physical activity. Recent research has highlighted the importance of social connection [35, 36] and exercise [37] to mitigate the negative psychological consequences of the COVID-19 pandemic, making the games a beneficial coping mechanism for the players.

Limitations

Our study was limited in some ways that must be taken into consideration when interpreting the results. Although the study drew participants from 66 countries, the survey was conducted in the English language only due to resource constraints, thus excluding participation from non-English speakers. Examining cultural effects on AR game use and gamers' wellbeing could be an important area for future research. Females are also known to be less likely to self-identify as someone who plays video games than males [23, 38, 39], possibly contributing to an under-reporting of the number of participants who are hardcore, especially for females. Our survey was also cross sectional, and therefore we are unable to imply causality between game play and

physical activity based on the current study alone. Further, the study may be subject to sample bias, with recruitment occurring via four subreddit forums dedicated to PGO/ HPWU and thus, the results may not be generalizable to the entire population. This study also relied on self-reported data with the potential for recall bias. With our mental health assessment, we relied on the WHO-5, as a non-invasive assessment of subjective well-being. Although this measure cannot be used to clinically diagnose mental illness, previous research supports the use of the WHO-5 to effectively screen for depression. The international scope of our sample also meant different participants had different COVID-19 shutdown experiences, as some countries enforced a strict lockdown at the time of the survey while other countries imposed few social limitations.

Comparison with Prior Work

Prior to the COVID-19 pandemic, the potential of video games to improve physical and mental well-being [15] had already been well-demonstrated. Beyond providing entertainment, games have the capacity to foster positive emotions [40, 41], create engagement and commitment [42, 43], encourage new and long-lasting social relationships [44], provide purpose and meaning to daily life [45], and deliver a sense of accomplishment and competence [43, 46]. Exergames, defined as video games that mediate physical exercise [47], have been reported to be effective in clinical rehabilitation [48, 49] and general exercise promotion [50, 51]. They also provide holistic, cross-sectional improvements in mental health [52, 53]. Within the first six months of PGO's release, the game was already recognized as an extremely complex behavioral intervention [54, 55] that increased the duration of physical exercise for all its players, regardless of socioeconomic status [56]. Individuals and organizations globally had also started to use games during the COVID-19 shutdown as a means of

health education, mental coping, social bonding, and providing a sense of control and routine [57]. Our findings, which indicated that PGO and HPWU players are supporting players' physical and mental well-being, support much of this earlier work.

A recent report from Canada [58] reported that adults are spending more time on "screens" during the pandemic. The authors of this study argued an increase in sedentary screen time may be contributing to a decline in mental wellbeing during COVID-19 lockdown. However, the focus of the Canadian study was not on AR games such as PGO and HPWU. In our cohort, playing more PGO and HPWU maintained participants' weekly exercise well above recommended levels of 150 minutes of moderate exercise a week [59] and helped with preserving mental wellbeing. Specifically, our study suggested that PGO and HPWU motivated participants to maintain a walking and socialization schedule. These behaviors reduced loneliness, which is known to correlate with worse mental health during the COVID-19 shutdown [35, 60, 61]. Interestingly, casual players, who previously played less of PGO and HPWU than the hardcore group, are now playing as much – and exercising as much – as the hardcore group. Our qualitative findings suggest that the casual players, who are usually less engaged with games, are using games to both distract themselves from the pandemic and provide themselves with a sense of challenge/achievement that they usually sourced from activities currently disrupted by the pandemic.

Participants in this study indicated that they were using games in general to stabilize their mood and prevent further emotional stress. Overwhelmingly, participants indicated that video games were beneficial to their mental health. Holistically, AR games such as PGO and HPWU provide virtual socialization with

other people, motivate players to sustain exercise, offer a daily routine during the lockdown, therefore establishing mental coping strategies to benefit well-being during COVID-19 lockdown. As stated recently in a commentary on gaming in the time of COVID-19, Kriz (2020) suggested that: “games have the potential to entertain and relax, to lower stress (maybe even provide an escape for a while from the real problems and fear accompanying the pandemic) and to provide the opportunity to interact with friends through (virtual) forms of play” (p.406).

Conclusions

The benefit of location-based AR games such as PGO and HPWU on physical and mental health already held the potential to be deployed as digital interventions before the time of COVID-19. We provide insight into the effect of continued PGO or HPWU game play on a global population. Participants reported increased game play which coincided with their maintaining exercise levels well above international recommended levels and using the games as a means for mental coping. Increased game play was significantly associated with increased exercise, and not associated with worse mental health during COVID-19 lockdown.

Mentally, our participants reported they continued to play the games out of a desire for entertainment, for having some structure in their daily lives, for the feeling of accomplishment, and a means to continue exercise. On a larger scale, the participants played video games to cope with the negative psychological impact of the COVID-19 lockdown. They used games to distract themselves, escape briefly from reality, to have something to do during their days, to manage their emotions and mental health, and to stay socially connected with other people. User goals such as these indicate PGO and HPWU were already being used as veritable digital

behavioral interventions by the participants to self-regulate emotional distress, especially during periods of intensive social isolation associated with COVID-19.

By understanding the phenomenon of how game players globally are using the interactive and immersive medium of video games to manage their own mental health, we are glimpsing the massive potential video games have in becoming behavioral medicine for populations under stress. Location-based AR games have greater potential due to their propensity to encourage exercise and social connections. It would be beneficial for the healthcare system and digital health professionals to leverage these interactive softwares effectively during the mental health crisis emerging with COVID-19 lockdowns, providing virtual relief and maintaining holistic well-being.

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Abbreviations

AR: Augmented reality

COVID-19: Coronavirus disease 2019

HPWU: Harry Potter: Wizards Unite

PGO: *Pokémon GO* (PGO)

WHO-5: WHO-Five Well-Being Index

Multimedia Appendix 1: Questions asked in the web-based survey presented in this study.

Qu #	Area/sub area	Question text	Answer options/format
1	Demographics	What is your gender?	*Select one:* - Male - Female - Other - Prefer not to answer
2	Demographics	What is your age?	Numerical entry box
3	Demographics	What is your country of residence?	Country list dropdown box from Qualtrics
4	Self-identified player type	Regarding video games, I would consider myself a:	Select one: - Hard core gamer - Casual game - Something in between - I have no idea - Prefers not to say
10	Video game use	Prior to the COVID-19 shutdown, how many days a week were you playing either *Pokémon GO* or *Wizards Unite*?	Numerical entry box
11	Video game use	Prior to the COVID-19 shutdown, how many hours a day were you playing either *Pokémon GO* or *Wizards Unite* during the days that you did play?	Numerical entry box

12	Video game use	Are you still playing either *Pokémon GO* or *Wizards Unite* during the shutdown?	*Select one* - Yes - No
13	Video game use	How many days a week do you play now?	*[Noted only presented if 'yes' was selected for Q12]* Numerical entry box
14	Video game use	How many hours a day do you play now, during the days that you do play?	*[Noted only presented if 'yes' was selected for Q12]* Numerical entry box
15	Exercise	Prior to the COVID-19 shutdown, how many days a week were you exercising?	Numerical entry box
16	Exercise	Prior to the COVID-19 shutdown, how many hours a day were you exercising during the days that you did physical exercises?	Numerical entry box
17	Exercise	How many days a week do you exercise now?	Numerical entry box
18	Exercise	How many hours a day do you exercise now, during the days that you do physical exercises?	Numerical entry box
20	Mental well-being (WHO-5)	During the past 2 weeks... - I have felt cheerful and in good spirits - I have felt calm and relaxed - I have felt active and vigorous - I woke up feeling fresh and rested - My daily life has been filled with things that interest me	*Likert scale - select one per item* - All of the time - Most of the time - More than half the time - Less than half the time - Some of the time - At no time
21	Motivation to play	What motivates you to playing *Pokémon GO* or *Wizards Unite* during the COVID-19 shutdown?	Open-ended text box
29	Mental well-being	How has playing video games affected your mental health during the shutdown?	Open-ended text box

Multimedia Appendix 2: Multivariate binary logistic regression analysis.

Variable	B	SE	Wald's χ^2	df	P	OR	OR CI 95%
Constant	.397	.206	3.711	1	.054		
Gender	.672	.115	33.923	1	.000**	1.958	1.562 –2.455
Age	-.020	.006	11.148	1	.001*	0.980	0.969 – 0.992
Self-identified player type			3.074	2	.215		
HvCM	-.174	.155	1.270	1	.260	0.840	0.621 – 1.137
CvCM	.890	.123	.530	1	.467	1.093	0.860 – 1.390
Game Play	-.007	.003	4.245	1	.39	0.993	0.987 – 1.000
Exercise	-.016	.006	6.991	1	.008*	0.984	0.972 – 0.996

Notes: [a]R2 =0.040 (Cox and Snell); 0.054 (Nagelkerke); Model χ^2 (6, N=1469)= 60.538; *P<.01 (two-tailed), **P<.001 (two-tailed)

Gender (Male=0, Female=1); HvCM (Hardcode=1, Casual=0, Midcore=0); CvHM (Casual=1, Hardcore=0, Midcore=0); Game play= Game play change score (during-COVID minus pre-COVID); Exercise=Exercise change score (during-COVID minus pre-COVID).

Abbreviations: SE, standard error; df, degrees of freedom; OR, odds ratio; CI, confidence interval.

Multimedia Appendix 3: Summary themes identified for motivation to play *Pokémon GO* or *Harry Potter: Wizards Unite* (N=1527).

Theme	Representative quotes	n (%)
1. Entertainment	"*Pokémon go* is just fun" "Playing these games gives me something to do with the time I would not normally have" "I really enjoy the game and have plenty of free time on my hands" "Something to do instead of being stuck at home" "It's a fun way to pass the time. I love Harry Potter" "I missed playing it, and this gave me an opportunity to come back to the game after a few years. It gives	506 (33.1)

	me something to do in my downtime and gets me moving a bit more"	
2. Achievement/Challenge	"Completing quests" "Daily challenges, sense of accomplishment" "It provides some sort of daily goal to accomplish while my workplace is temporarily frozen" "Gotta Catch 'Em All" "To keep my daily streak going and to try and grind to level 40" "It gives me a daily goal during this pandemic"	500 (32.7)
3. In-game modifications	"Enhanced play from home functionality, especially the addition of the *Wizards Unite* Knight Bus. Fortresses have always been one of my favourite parts of the game, but as a player in a fairly rural community I had never been able to participate in any grouping bigger than a pair with my SO. I can now fortress with my WU friends from around the world, a feature I had always hoped for before the shutdown" "The Knight Bus completely changed game play for me. I have no local fortresses and didn't have time/inclination to go park by one to actually do the challenges. I also don't know anyone near me who plays so I had no team members to learn with. Online instructions and the ability to "travel" to a Fortress has made the game 100% more interesting" "I feel like Niantic has made changes (because of corona) that have benefit Pokemon Go and made it more fun to play if you are at home, like the spotlight hours, improvements to the incense and such. So overall it is still a lot of fun to play the game" "My interest in Go actually increased quite a bit during covid due to removing the battle league walking requirements. I mostly play Go for battle league these days, and I hope the walking requirement isn't reinstated" "I already have quite a bit of motivation to walk to earn candies so I can build up new *Pokémon* for battle league"	343 (22.5)
4. Exercise	"It motivates me to go out for walks" "PG and HPWU are the only reasons I go for a walk nowadays" "It is the only thing that motivates me to go on walks	316 (20.7)

	outside” “I am overweight and it keeps me on walks longer. It gives me something to do while exercising that I normally wouldn't have to do” “I picked the game up again during the shutdown because I’m going on many more walks for fun, and it seemed like a good way to keep encouraging me to go on walks”	
5. Routine	“They’ve become an important part of my daily routine since this shut-down” “Part of my daily routine” “It's been a daily habit for a long time”	257 (16.8)
6. Social connection	“I feel a bit less isolated playing” “To spend time with family (who play and live in the same household)” “Spend time with friends online” “I have discovered a group to play with online” “Talking with other players on Discord, FB Messenger, etc about current events within the games”	173 (11.3)

Multimedia Appendix 4: Summary themes identified for the impact of video games on mental health (N=1427).

Theme		Representative quotes	n (%)
Positive benefit			1102 (77.2)
1. Escape/distraction		“Something to distract from all the bad stuff happening around us during this time” “It's a way to escape the horrors of the real world and just have a fun time in a world where you can be whatever you want to be” “It's kept my mind off the news” “It has highly	541 (49.1)

		increased my mental health, making me forget about Covid-19” "Allows for a healthy escape to another world”	
2. Activity/entertainment		“I think it's given me something to do so that I don't go crazy staying at home all the time” “WU and *Pokémon Go* give me something to look forward to” “Gave me something to do. Avoiding boredom” “It’s a nice way to pass the time…” “They keep me entertained and my mind busy”	535 (48.5)
3. Emotional coping		“Possibly the only thing keeping me sane right now” “Helped keep me calm and level headed and not to over worry about what is going on in the state of the world.” “It helps with my anxiety” “Usually lifts my mood even if it’s just by a bit” “Helps with my stress and anger from the current living situation” “They also bring a great deal of joy to my life which is otherwise very bleak at the moment”	469 (42.6)

		"Helped keep me stable" "It helps to get me out on a walk even when I don't feel motivated, and the walk helps manage my stress and anxiety"	
4. Social connection		"It keeps me sane. I do a lot for my community and everyone is happy to see me. Everyone trusts me to help them" "It has helped because it's the only social interaction I get" "It's been helpful; been staying in touch with friends and having fun" "I am playing with my friends a lot during this shutdown. I find it relaxing and great to keep in contact during these times" "Having something my whole family can happily do together has been very helpful" "I'm glad they exist, and I'm glad for the sense of community some of them create" "My HWPU/ingress community connections have been vital in having someone to talk to, and learning about other people's experiences"	219 (19.9)
5. Achievement/Challenge		"It has helped me positively and has kept me focusing on small wins in the game. It has definitely become	173 (15.7)

		an outlet for my health” “Helps immensely to keep the mind active and achieve goals/progress on things” “It has given me little goals to work towards so I can still feel like I am achieving things even though they're only for a game”	
6. Routine		“It’s my rock of normality” “Normality through routines before lockdown” It helped relax and structure the day” “Provides a lot of motivation and structure to my day that helps everyday not feel the same” “Playing video games at certain times have offered structure through my day, helping it feel more 'normal'” “I enjoy Pokemon Go and I feel like I can continue to work towards goals and do something I was doing before still. So it is some continuity in life, which there isn't a lot of otherwise!”	137 (12.5)
Neutral impact		“Neutral impact” “No effect” “No change”	295 (20.7%)
Negative impact		“Addicted” “Playing too much” is “bad”	30 (2.0%)

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CHAPTER 5: CONCLUSIONS, IMPLICATIONS, AND FUTURE DIRECTIONS

5.1 Conclusions

Substantial research literature has established the importance of competence, autonomy, and relatedness for motivating engagement with games [1-3] as well as for human behavior in general [4]. In addition, some evidence suggests that the extent to which an activity addresses these influences the extent to which it affects well-being [1, 5]. With regards to serious games in particular, several studies have found that autonomy is particularly important to achieving good outcomes, as the primary reason for discontinuation of a serious game is coming to dislike it or becoming bored of it. Further, when individuals are – or feel – compelled to engage with a serious game despite disliking it or becoming bored of it, the positive impacts of that game may be largely negated [6, 7]. This is supported by burden of treatment' [8, 9] and 'patient work' [10] research, which finds that cognitive burdens make one much less likely to adhere to a treatment or derive benefit from that treatment.

This background ties into goal (1) of the overall dissertation: to explore how exergames are currently evaluated. Exergames – and serious games in general – are meant to be more engaging than traditional methods, but many studies do not evaluate whether they are engaging, instead simply mandating engagement to test their effects on physical activity. Findings from the literature suggest that enforced play – that is, players being required to play a game for a given amount of time per day over a prolonged period

– can lead to boredom [6]. This has interesting implications when taken together with literature on the short-term effects of exergames [11], especially with regards to the fall-off in physical activity outcomes some studies report seeing several weeks in [12, 13]. As such, some newer studies have begun to simply provide participants access to an exergame and any required hardware, without mandating a certain amount of play during that period in which they have access [14, 15]. This was done to emulate a more naturalistic setting where individuals could choose how much they engaged with a game of their own volition, allowing them to retain a sense of autonomy, yet still proved to have beneficial effects. Crucially, even when instructed to play at their convenience, without specific direction as to how much was required of them, participants still played more than a minimum suggested amount [14], resulting in higher levels of physical activity [15]. Thus, when designing ways to evaluate exergames, one should consider how a given design works to evaluate them as games that individuals will choose to play (or if individuals will choose to play them), instead of merely evaluating them for their efficacy as interventions aimed at increasing the physical activity of those who play them.

Previous literature was also considered in terms of goal (2): exploring how *Pokémon GO* fits into what is known regarding exergame (and game) design. To do this, we examined how *Pokémon GO* compared with past exergames, as well as how it fit into the established conventions of good game design, using the Motivational Model for Video Game Engagement [1, 3], a model commonly used in game studies, as a reference. What was found was that *Pokémon GO* is designed in accordance with known best practices in exergaming, in that it was it was playful [16], appealed to children [17, 18], and focused on lower body movements [17], though unusually for the genre, it

encouraged “healthy outdoor exploration and social interaction” [19], rather than fitness as an end in itself.

These discrepancies can be explained by reconciling these best practices with the Motivational Model for Video Game Engagement [1, 3], which identifies competence, autonomy, relatedness, mastery of controls and immersion as key design considerations for games. In that sense, *Pokémon GO* styled itself as a community exploration and social game to preserve player autonomy and immersion, while still functionally being an exergame due to its incorporation of goals and challenges that required exercise to accomplish. Crucially, players can choose what challenges or creatures they go after, much as they did in the adventure games on which *Pokémon GO* is based. Given that nostalgia was a motivating factor for many players [20], who expressed joy at the chance to live out a real-life *Pokémon* adventure, this was an important design consideration, especially as previous studies have shown that varying the level of immersion a game provides affects players’ memory of a play experience [21], enjoyment of an experience [3], and the carryover effects of content into real-world outcomes [22]. In terms of competence, the game displays the locations of creatures within a certain (easily walkable) radius of the player. Players, as they approached a given creature, would often find another appearing at the edge of their awareness, motivating them to move from one challenge or creature to the next, in a simple, sustainable gameplay loop. The game’s relatively simple controls helped with this, as interacting with the game could easily be done while walking, so there was no interruption of immersion. Finally, while *Pokémon GO* did not have in-game features to promote social connectivity at launch, it did provide players with opportunities to interact with others in the physical world, making people

feel more connected to those in the communities around them [20]. Indeed, it managed this even when players were not actively seeking companionship, with even those playing the game for fun reporting higher perceived bonding, better physical health, and reduced loneliness [23].

Taking all this into account, *Pokémon GO* was both a well-designed exergame and game in general, but that alone is not sufficient to explain its success. Two other possible factors – the intellectual property (IP) it was based on and it being an augmented reality game – may have played a part, however the extent to which they affected the reception the game received is unknown. While there was likely some effect from being linked to a vast and long-running existing multi-media property, given that the first *Pokémon* game had launched 20 years prior, that alone is not sufficient to explain its success. Else, then all things held equal, one would have expected many more downloads for *Harry Potter: Wizards Unite* (HPWU), which is also based on a massive global IP property. Its augmented reality features were also likely an element of interest, though it was not the first augmented reality game, and its implementation of augmented reality was rather simple compared to that found in the games that came before and after.

These other factors bore closer examination in the second part of this body of work, given that previous studies have found that different sub-populations of players experience different outcomes from playing *Pokémon GO*, with stronger and more lasting effects on physical activity for those who previously had lower levels of daily physical activity, and differing holistic outcomes in life satisfaction based on differing motivations for play *[12, 23]*. These outcomes did not appear to vary with age or gender, so were

these outcomes linked to some other factor else? For this, an examination of the gaming literature was warranted, given that it has more sophisticated ways to segment populations of players for analysis, with demographic segmentation using gender or age being insufficient to determine pertinent differences between game players [24-26]. Such approaches tend to consider players in terms of how they engage with games, classifying them as *casual*, *in-between,* or *hardcore* players [25, 27-29] or in terms of psychographic variables such as *involvement, constraints,* and *loyalty* [30-32].

In this paper, we sought to go further by utilizing both demographic (player types and status) and psychographic (constraints, involvement, loyalty) aspects of player populations to explore how these factors interact to create the different preferences and outcomes observed in previous studies. To achieve this, demographic segmentation, categorizing players by descriptive features (player type & player status), was used in combination with psychographic mapping, with physical activity data (how many days individuals walked for at least 30 minutes each week) used as an outcome measure.

To ensure applicability of any findings to augmented reality games beyond simply *Pokémon GO*, this study collected data from both the *Pokémon GO* community as well as that of *Harry Potter: Wizards Unite*, with both games being created by the same developer and being based on widely known intellectual properties.

As with previous studies, participants reported a significant increase in physical activity after starting to play either *Pokémon GO* or *Harry Potter: Wizards Unite,* with stronger effects shown for those who previously reported lower levels of physical activity. However, our study shows that these effects are also tied to player types, with self-defined *hardcore* players going from walking 30 minutes or more a day for 2.78 days

a week prior to playing any AR game to 4.99 days a week after, *casual* players going from 3.05 days a week to 4.58 days, those *in-between* going from 3.21 days a week to 5.00 days, and those who could not identify as any player type going from 3.08 days to 4.80 days. Given players who adopt the *hardcore* label tend to have associations of greater knowledge of games and the gaming industry, preferences for more complex games, and being more likely to invest time and money into their hobby [25], their lower level of physical activity prior to playing any AR game is not particularly surprising. What is surprising is the magnitude of their pre-post shift, especially when compared to that of the *in-between* and *casual* players, particularly fitness games such as *Wii Sports* has traditionally been targeted at *casual* players [33]. Interestingly, across our participants, a majority (76%) stated that *Pokémon GO* was the game that caused them to walk more, including players which stated that *Harry Potter: Wizards Unite* was the first AR game they played. These results suggest that long-term benefit via exergames may be possible, given that most participants indicated that they had been playing *Pokémon GO* for more than 2 years, or *Harry Potter: Wizards Unite* for more than 3 months.

Delving further into player experiences using a combined demographic-psychographic qualitative mapping method, we found that sustainer factors (loyalty, involvement) and constraints were experienced in several ways for both current and former players and across different player identities, though there were areas of commonality across all identities. One of these is that few players mentioned having the desire to increase their level of physical activity when they began the game, despite self-reported changes to their physical activity levels. Nor was the amount of physical activity required to play these games mentioned as being a constraint. This suggests that a crucial

part of the success of these games was that the elements promoting physical activity were not seen as interfering with the fun of the game. Rather, they were incorporated in a way that was congruent with player immersion and nostalgia [34].

This ties in with the second area of commonality, which is that for players across all identities, a major reason behind playing an AR game was how it connects to their identity as a fan of the IP. It appears that for players of these games, the role of AR for these players is to provide an experience that is a realization of a fantasy, allowing them to step into a world of wonder in a way that resonates with their chosen identity and their sense of nostalgia (experiential consumption). This provides some interesting context for one of the constraints: current non-hardcore players of *Harry Potter: Wizards Unite* expressed a lack of confidence over the game's mechanics being too difficult, stating that casting spells on the phone required more finger dexterity and precision than throwing a ball, and noting that the game was very difficult to play while moving. *Harry Potter: Wizards Unite* players also expressed concerns about not having enough time to play, citing the excessive waiting time between tasks, and issues waiting for others to join for group content.

These constraints, which cut across nearly all player types and involve issues with *Harry Potter: Wizards Unite*'s core gameplay, suggest that the game's basic design is at fault for its issues attracting and retaining players, as well as being less likely to encourage walking. By contrast, the unique constraints of *Pokémon GO* players tended to involve being unfamiliar with creatures they had not encountered before or challenging

new gameplay elements that had recently been introduced, but which are not critical to the basic experience of playing the game.

The strongest and most consistent constraints, experienced across all player-types and responsible for the majority of switching behavior, were external obligations such as work, school, family or other outside factors that took priority over gaming, as well as a lack of significant others playing the game. In this context, significant others refers to friends, family, or a local community of players that one is acquainted with and on good terms with.

External obligations and lack of significant others were followed closely by constraints that impacted the ability of individuals to play the game as intended, either due to technical issues, a cold climate (making it unpleasant to walk outside), or a general lack of access to game-associated locations or resources due to living too far away or other restrictions. Interestingly, distance was only seen as a constraint when game-associated locations were far enough away that they could not be reached on foot and necessitated personal transport (driving). Other constraints which emerged were a perception of high cost to play, or loss of interest in a game due to play having become repetitive.

All of these are bad enough in isolation, but may be worse taken together, as prior studies [35-37] suggest that switching behavior is often not predicted by any individual constraint, but by interactions *between* constraints. This behavior may also be prevented or modified by other factors that act to sustain player preferences or behaviors.

All players who identified with a player type also reported a sense of loyalty to Niantic, the developer of both *Harry Potter: Wizards Unite* and *Pokémon GO*. This may be part of the reason that when players dropped one title (as it was difficult to find time for both), they often did so to focus on the other. Another sustainer that functions to prevent switching behavior across all groups is risk, which largely involves the investment one has already put into a game (in the *Harry Potter: Wizards Unite*) or the community (in the case of *Pokémon GO*). It is important to note that time invested into gameplay alone may not be enough to sustain engagement, as former in-between or casual players of *Harry Potter: Wizards Unite* mentioned that despite considerable time invested into the game, they switched to *Pokémon GO*. This, together with the fact that other reasons to play a given game involved word-of-mouth recommendation, implies that involvement with a community surrounding a game may be as important – or more important – than the game itself.

Taken together, the insights from using a combination of psychographic criteria and demographics to evaluate player constraints, behaviors and attitudes across both *Pokémon GO* and *Harry Potter: Wizards Unite* provide us with better understanding of the needs and wants of different types of players, which may serve as the basis for actionable design strategies [38]. Aside from being the first study to examine the differential effects of exergames in relation to player types, and demonstrating that there may be long-term benefit from the use of exergames, the results of this second paper show that involvement with a game is not merely time spent playing the game, but the degree to which a game addresses the factors of attraction (whether a game is perceived

as fun), sign-value (whether a game is linked to an identity individuals have a strong attachment to), centrality (whether a game provides an individual with a sense of routine, accomplishment, and a reason to do things) and risk (whether a one has sunk a considerable amount of time into a game *or* its community). This has clear implications for the design of not just augmented reality exergames, but for serious games and other tools for health behavior change in general [34].

The third and final component of this dissertation, which examined the player communities of *Pokémon GO* and *Harry Potter: Wizards Unite* during the COVID-19 pandemic [39], provided a unique opportunity to assess changes in player behavior and preferences during a time in which players' usual routines were severely disrupted. While it is tempting to simply treat government-issued restrictions encouraging – or requiring – individuals to stay home [40, 41] during the pandemic as a constraint which, like unpleasant weather, affected the willingness and ability of individuals to play as intended, it was not the only factor to consider. Layoffs, school closures, and the shift to remote work affected the nature of players' external obligations, while the closure of parks, commercial areas, and such meant players had no ability to access game-associated locations or resources, especially for those living in rural areas. What must also be considered is the impact of the developer's response to these disruptions, with Niantic making removing many of the features designed to promote physical activity to make *Pokémon GO* and *Harry Potter: Wizards Unite* easier to play at home, while at the same time restricting communities from arranging meetups [42].

These changes were well-received by participants in our study, with many noting that they were one of the most prominent motivations for continuing to play during the pandemic. To these players, the changes, which included added functionality to allow players to cooperatively face in-game content from home, as well as universal access to modes of gameplay usually gated behind physical activity, made the game more accessible and interesting. These changes appear to have both lessened the impact of restrictions on lack of access to game-associated locations, as well as weakening the loss of interest constraint.

Players also reported that *Pokémon GO* and *Harry Potter: Wizards Unite* provided them with something fun to do during the pandemic, that the tasks in these games provided them with a sense of accomplishment (and beneficial temporal structure), and that the games motivated them to exercise more, often being the only thing that motivated them to go on walks. This last motivation is rather curious, given that the in-game changes specifically reduced or eliminated the need to walk, but is supported by the quantitative survey data, as we identified a significant positive relationship between total hours of participation in gaming and total hours of exercise per week.

In addition, while exercise did decrease from pre-pandemic levels, going from an average of 7.5 hours per week to 6.5 hours a week during the pandemic, these levels are still well above the 150 minutes (2.5 hours) of moderately-intense activity recommended per week to achieve minimum health benefits [43]. Interestingly, during the pandemic, there were no significant differences in exercise levels by self-identified player type, which may be linked to our finding that casual gamers – females in particular – increased

their use of these games, such that there were no longer significant differences in average play time by player type or gender. This is an important consideration, as reduced exercise was a significant predictor of poor mental health during the pandemic.

Overwhelmingly, participants indicated that these games were beneficial to – and supported – their mental health, with qualitative findings suggesting that these games helped to distract themselves from the pandemic, provide themselves with a sense of challenge/achievement that they usually sourced from activities currently disrupted by the pandemic, and stabilize their mood and prevent further emotional stress. Of further note, despite the restrictions on in-person meetings imposed by both governments and the developer, participants suggested that these games played a critical role in maintaining social connections, highlighting the importance of the local communities of *Pokémon GO* and *Wizards Unite*, as having people to talk to and share experiences with made them feel like part of a community even though they could not meet face to face.

Given that research has shown that social connection [44, 45] and exercise [46] help mitigate the negative psychological consequences of the COVID-19 pandemic by reducing loneliness [47], it is likely that these games played a role in supporting well-being during the pandemic. How much of a role may bear further investigation, given that prior studies have found that motivations of players affect their holistic health outcomes, with escapism in particular [48] being noted to result in lowered life satisfaction. Further, it should be noted that some of the players who reported that they were playing for fun also mentioned that they had no other alternatives while stuck at

home and either un- or under-employed, which evokes concerns regarding whether participants felt forced to play, and if so, what impact that might have had [7, 48].

Player behavior during the pandemic also served as a demonstration of how construct of involvement (attraction, centrality & risk) was crucial in not only keeping respondents playing *Pokémon GO* and *Wizards Unite*, despite the presence of significant constraints – but having these games continue to motivate them to exercise, despite the removal of in-game elements that required it. These games were ready sources of fun and entertainment, which in the absence of other routines, provided them with a sense of purpose, challenges and a reason to go outside. Further, despite being barred from arranging gatherings to complete group content, the communities around these games also retained their importance, with players considering them a vital part of their pandemic social circle.

As a body of work, the dissertation provides several key contributions:

(1) Situating AR exergames within the context of past exergames and the gaming literature as a whole;

(2) Providing the first evidence that exergames may be useful as long-term behavioral interventions;

(3) Demonstrating that physical activity outcomes for AR exergames may be tied to player types, with clear differences seen in the absence of an external crisis;

(4) Demonstrating how constraints and sustainers affect players in different ways according to types, suggesting the need for different design strategies to appeal to each subgroup, or for more general appeal;

(5) Identifying involvement as a construct that predicts continuation amidst constraint, with involvement being defined as the degree to which a game is perceived as fun, whether a game is linked to an identity than an individual has a strong attachment to, whether a game provides an individual with a sense of routine, accomplishment, and a reason to do things, and whether a one has invested time into a game and its community;

(6) Placing augmented reality within the context of involvement – the technology is not necessarily attractive in and of itself, but only in terms of how it connects with existing identities and impacts the play experience;

(7) Identifying the importance of social connection – in the form of belonging – and user-driven communities in attracting new players and keeping them involved with AR exergames;

(8) Evaluating the impact of COVID-19 restrictions on players of AR games, exploring data in the face of constraint;

(9) Exploring the role AR exergames played in supporting physical and mental well-being during COVID-19.

5.2 Limitations

The work within this dissertation was limited in some ways that must be taken into consideration when interpreting the results. While the sampling approach (drawing from subreddits dedicated to the *Pokémon GO* and *Harry Potter: Wizards Unite*) allowed us to reach a large group of players in a short amount of time, this approach was not without its drawbacks. First, this approach only captures players who frequent the subreddits – given the location-based nature of augmented-reality games, many players use smaller, region-based groups to collaborate and communicate with players in their local community. Second, studies of other games have shown that the population of players who participate in surveys does not necessarily reflect the general player population. The *Pokémon GO* subreddits r/PokemonGO and r/TheSilphRoad feature a total member count of 3.1 million and 650,000 members respectively, with active member counts hovering around 3000-4000 for r/Pokemongo and 7500 for r/TheSilphRoad, while the *Harry Potter: Wizards Unite* subreddits of r/WizardsUnite and r/HarryPotterwu have total member counts of 41,000 and 42,000 members, with active online counts of less than 100 each. Thus, one has to consider the issue of self-selection bias – while the themes of the player types hold true, it is quite possible that there is a much larger proportion of hardcore players reported in this sample than within the general player population.

Second, aside from possible issues caused by the sampling approach, this work also relied on self-reported data with the potential for recall bias. This is of particular concern with regards to the physical activity data in the second paper, given that the

majority of those playing *Pokémon GO* in that study had been playing for over 2 years. Recall bias, in the literature, has been known to exaggerate the association between various factors and outcomes, and it is possible that hardcore players simply believe that they walked more due to *Pokémon GO* or have conflated playtime and walking. Our survey was also cross sectional, and therefore, despite the positive association we found between play time and exercise, we are unable to imply causality between game play and physical activity based on the current work alone.

We did not collect information on socio-economic status, race/ethnicity, or whether individuals lived in urban environments, suburbs, or rural areas, as early studies showed that *Pokémon GO*'s effects on walking were not affected by income or race. However, not doing so may impact the wider applicability of our findings, given that we are examining retention and well-being. It is possible that for communities of color, safety issues when playing such games may be of concern, although this has not been studied in the literature. For communities of low-socioeconomic status, certain constraints such as cost or distance may be felt more acutely – follow-up should be done to further segment the player population and assess how constraints and sustainers vary across other demographic factors.

Finally, our survey was conducted in the English language only due to resource constraints, thus excluding participation from non-English speakers. Examining cultural effects on AR game use and gamers' wellbeing could be an important area for future research.

5.3 Implications for Practice

In this extended study, we sought to better understand the factors that made augmented reality games successful both as exergames and as commercial properties out of a desire to apply our findings to the design of future tools for health behavior change. Originally, the drive for this was the possibility of developing interventions that could function as population level strategies, given that *Pokémon GO*, a mobile augmented reality exergame demonstrated the ability to get millions of people to increase their levels of physical activity [12, 48, 49]. Prior to this study, the reasons for its unprecedented success were largely unexamined, with many having dismissed the events of 2016 as a fluke [50] as no other augmented reality exergame since has accomplished what it did.

The analyses and findings of this study suggest that this is not the case, with the success of *Pokémon GO* being largely explained by a combination of the construct of involvement, best practices in exergaming [16], and good game design in general. With regards to involvement, at launch, the two most significant components were likely *attraction* and *sign-value*, with *centrality* and *risk* coming later – except for those who were already fans of the IP.

Attraction – that the game was perceived as being fun – came from its playful theming, use of a new technology, and designing for engagement according to the model used by the industry today [1, 3]. *Sign-value* – whether a game is linked to an identity that individuals have a strong attachment to – comes from gameplay matching the themes of a given IP. Players in this study strongly identified as fans of the *Pokémon* IP, a

franchise built around the themes of exploration and collecting, with many reporting that they had grown up playing the games and had fantasized about being a '*Pokémon* trainer in real-life.' As such, *Pokémon GO's* use of augmented reality, where play involved players venturing into the world around them to find and "catch 'em all", wasn't simply a novel experience, but something which let them live out their dreams of being part of the *Pokémon* world and living out their own *Pokémon* adventure. That is, the game became an extension of their reality and self-identity.

Centrality, which reflects whether individuals are motivated by an activity and how central this activity is to their lives, was addressed in several ways. For those heavily invested in their identity as a *Pokémon* fan, the game had particularly high centrality, given that playing the games was something they already loved to do, with some going so far as to organize their holidays around it. For those who were not, much of their motivation arose from the way the game rewarded "healthy outdoor exploration and social interaction" [19]. For many, the game became an excuse to walk around the city, a reason to spend time with friends, a method to connect with one's children, or simply a way to meet people in the local community. This last was much easier at launch, due to the sheer number of people who were out and about playing the game, with the game serving as an easy way for strangers to break the ice. This is not unlike how aficionados of *Dance Dance Revolution* would converse with one another in the arcades, with their shared interest allowing them to overcome the taboo of speaking to strangers in what is not usually seen as a social space. Finally, there is *risk*, which at launch was mostly limited to Fear of Missing Out, given how quickly the game spread by word of mouth – if

so many people were playing the game and talking about it, surely it had to be worthwhile [19, 51].

Examining *Harry Potter: Wizards Unite* and its player base with the same criteria, the reasons for its failure to live up to the commercial potential of its IP are immediately apparent. First, the gameplay, which asked players to join a Ministry of Magic force tasked with returning objects displaced from their proper time, wasn't aligned with most people's idea of what being a wizard entailed. One of the more problematic elements was the Spell Energy system, which limited how many spells one could cast and did not recharge over time. Spells are how one interacted with most items in the game, and failed spells (caused by not moving one's fingers fast enough or in a precise enough pattern) still cost energy, making many players (all except *hardcore* players) less than confident that they would be capable of playing, or raising concerns about the cost. As well, some of the trappings of the world – potions, magical beasts, characters from the books – are present, but all as lost items that do not belong in the present – nothing which makes much sense for anyone who knew much Harry Potter lore. One must remember that Harry Potter is not an IP based on a video game series – Potterheads did not grow up playing Department of Magical Accidents and Catastrophes games, wishing they could be the next Cornelius Fudge. They grew up reading about *Harry Potter,* fantasizing about discovering a hidden world of magic and having wild adventures – a notion that is quite incompatible with the design of *Wizards Unite*. This incompatibility essentially negates the effects of *sign-value,* and most of the effects of *attraction.*

Had *Harry Potter: Wizard Unite* been released in 2016 instead of *Pokémon GO*, when augmented reality games were nearly unheard of, perhaps it would have enjoyed more success than it did in 2019, coming three years after the landmark title. On the other hand, perhaps not, given that at least part of *Pokémon GO*'s claim to fame was that it got people moving, and in our study, *Harry Potter: Wizards Unite*'s performance as an exergame appears to have been poor. Strikingly, three in four participants indicated that *Pokémon GO* was the game that made them walk more, and that they found walking in *Pokémon GO* to be more be rewarding, as the in-game benefits from doing so were clear, easy-to-understand, and useful. As an example, in *Pokémon GO,* players can see exactly what they are was walking towards (i.e. a specific Pokémon) on the map, and duplicates of existing Pokémon may be valuable either for unique abilities or to trade for materials to strengthen existing Pokémon. In *Harry Potter: Wizards Unite,* players are only shown the group (i.e. Dark Arts, Quidditch, etc.) a Foundable (the name of the collectible item in the game) falls into, with players obtaining no benefit from collecting duplicates. Once again, this is an example of *Pokémon GO* being designed in accordance with known principles which drive player motivation [3].

Even with strong fundamentals behind it, however, it is unlikely that *Pokémon GO* would have retained its dominant position in the augmented reality game niche without Niantic adding new functionality to the game over time, or acting to address constraints – much as they did during the COVID-19 pandemic by making the game easier to play from home. Indeed, of the features players mentioned by name in their responses to the COVID-19 survey, including the GO Battle League, the friend system,

raids, and Adventure Sync, none were available at launch. Raids – difficult challenges which required groups of 5 to 10 players to overcome – were not implemented until July 2017 [52]. The friend system, which allowed players to send gifts to one another and trade Pokémon, wasn't implemented until June 2018 [53]. Adventure Sync, which allowed players to record distance walked while the app wasn't open, allowing them to conserve, was not implemented until November 2018 [54]. The GO Battle League, which allowed players to test themselves by challenging others around the world in real-time [55], wasn't around until January 2020. All of these updates helped to make the game a richer experience by providing more to do (relieving the *lack of interest* constraint), connecting people to the community around them (addressing the *lack of significant others* constraint) or decreasing the burden involved with playing (*lack of access/time*). This is likely why all groups of players, current and former, except for those who did not identify with any player type in our pre-COVID sample, reported a sense of behavioral loyalty to Niantic.

As such, it would be a mistake to say that simply by knowing what made *Pokémon GO* a success, someone would be able to replicate the full scale of what it managed. After all, its success came about in the world of 2016, a world in which the top augmented reality games were *Ingress* and *Zombies, Run! [56]*. Today, we all live in a Pokémon world. Matching the success story of *Pokémon GO* would be difficult at best, especially without the gameplay tying perfectly into themes of a global IP with a devoted fanbase. There are few such IPs, and fewer still whose themes would lend themselves to an augmented reality exergame. Of course, one could turn to a regional IP, like Dragon

Quest, which the Japan-exclusive *Dragon Quest Walk* [57] is based on, but then one would need to have sufficient money to negotiate with the rightsholder or be paid by them to make such a game. For most in healthcare, this is not a realistic possibility.

Zombies, Run! [56], a successful augmented reality exergame in its own right [58, 59], serves as a better example of what a good team can realistically do with a modest budget and good gameplay-*sign value* synergy, having reached over 1 million players at its peak [60]. One should note that it is a finite game, with a limited amount of content, but then the goal of an exergame isn't to force a player to constantly engage with the game. It is to allow players to change their lifestyle by way of playing the game, with augmented reality providing a powerful sense of immersion to help players achieve that.

All this, however, is dependent on a person with limited time and energy and many potential options for how to spend their time choosing to play an exergame. Thus, when creating an exergame – or any other health intervention – it is critical to know who one is designing for. This study has shown that *hardcore*, *casual*, and *in-between* players, as well as those who do not know what to classify themselves as, can experience and respond very differently to the same game. Mechanics accessible enough for *casual* players, or *no-identification* players may be too simple to hold the interest of *hardcore* players; mechanics comfortable for *hardcore* players may be seen as too complex for *casual* players. *Hardcore* players may be more exacting about their play experience, but at the same time, may engage for longer, with better physical outcomes, if the opportunity is present for that sort of play. This also appears to be the population with

least physical activity when not motivated by any intervention, so a more focused game may be warranted.

At the same time, one should be mindful of best practices in game design, with a solid understanding of how one's plans will address competence, autonomy, relatedness, mastery of controls and immersion for players, as the gaming literature has found that addressing these are far more essential for making a good game than flashy graphics or the use of sophisticated technologies such as augmented reality.

Aside from these values, it is important to consider the *attraction* and *sign-value* characteristics of players. What identities are they bringing to the table beyond being someone whose health one is trying to improve? What are they nostalgic for? What do they want? How can one use augmented reality to make their fantasies a reality in a way conducive to the change one seeks to make? How – if one is seeking to make this a longer-term intervention, will one account for social elements? And of course, should one be explicit about the fact that they are making an exergame or other health intervention, or should one call it something else to lower the burden of treatment? All these are questions to consider.

As nurses, we have an obligation to consider the whole person, and to evaluate how well the care we provide supports our patients' holistic well-being. These principles should be kept in mind when we function as nurse-designers, given that the exergames that are most successful – and most capable of retaining users – are those do not simply

address their physical health, but meet their psychological needs and support their chosen identities.

5.4 Implications for Future Research

Our study, being of an exploratory and interpretive nature, presents a number of opportunities for future research, both in terms of theory development and concept validation. More research will in fact be necessary to refine and further elaborate our novel findings.

First, while our findings suggest that differing physical activity outcomes from augmented reality exergame use are linked to player types, the gaming literature [25] only accounts for *hardcore*, casual, and *in-between* players. In the sample collected prior to COVID, we found that some players had not yet established a clear player identification. These players would likely have been classified as casual in literature, yet their physical activity outcomes were meaningfully different from casual players. This group also experienced constraints and sustainers in a unique fashion. Research should be done with other games to see if this "no-identification" type is found there and how they behave.

Second, we found that physical activity and video game play differences between the groups disappeared during the pandemic, with casual gamers increasing their play time and exercise to match that of hardcore gamers. More research needs to be done on what this implies, whether there will be a post-pandemic normalization, and if so, how long that will take.

Third, in our COVID-19 study, our qualitative results found that players were using *Pokémon GO* and *Harry Potter: Wizards Unite* to help them maintain a sense of social connection, as well as to maintain their levels of exercise during restrictions. A follow-up study, now that several other nations are undergoing lockdown, while others are quickly being vaccinated, may be of interest for comparison purposes. Niantic has also indicated that some of the changes made to the games would not be permanent, so an examination of those effects might prove interesting.

Fourth, while players stated that *Pokémon GO* made them walk more than *Harry Potter: Wizards Unite*, our survey asked players about their walking behavior before and after they began playing either of the games, as we did not consider that some players would be involved with both games. While we could ask players for screenshots showing the distance walked in each game, as well as join date, the presence of Adventure Sync, allowing the games to track steps taken when they are closed, makes this somewhat problematic.

Fifth, while we have identified involvement (attraction, sign-value, centrality, risk) as being linked to retention in augmented reality games, it is as yet unknown to what role involvement or its components may play in affecting how much individuals play, or the benefit they derive from play. Future research should look beyond retention to further examine the relationship between involvement and physical activity outcomes, as well as how this relationship is affected by differing implementations of AR

Sixth, given what our second paper reveals about the influence of constraints and sustainers on retention prior to COVID-19, an examination of exactly what barriers

players faced during the pandemic and how they were overcome – or not overcome is warranted. Were certain types of barriers related to worse mental health outcomes? Did players who overcame barriers experience better mental health outcomes?

Seventh, our surveys were also cross-sectional, and therefore we are unable to imply causality between game play and physical activity based on the current study alone. A longitudinal study may be an approach in the future.

Finally, the surveys deployed in the course of this study were conducted in the English language and only included those who played the games in English, thus excluding non-English players' experiences. Examining cultural effects on AR game use and gamers' wellbeing could be an important area for future research.

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