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Reviews

Scoping Review of Pokémon Go: Comprehensive Assessment of Augmented Reality for Physical Activity Change

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Abstract

Pokémon Go™ (PG) is a mobile videogame that requires real-world walking to ''catch'' augmented reality (AR) virtual creatures. Media attention speculated that extensive physical activity (PA) could result from PG play, which could have public health benefit. Little is known about contextual factors related to PG play and how they may impact play initiation or duration. A systematic search of articles reporting the words PG was conducted with PubMed and Google Scholar. To understand the many possible influences on and outcomes of PG play, a scoping review was conducted by employing a conceptual model to organize the literature.
Although large numbers of people started playing PG, these were a relatively small proportion of the relevant populations, but PG may have activated some of those most in need of PA. Diverse factors predicted who initiated PG play, but they tended to emphasize anticipated fun, escapism, nostalgia, social ties, and desire for PA. Environmental factors (e.g., unavailable GPS signals, trespassing laws) limited PG play for some. Diverse factors predicted duration of gameplay, but fun appeared to be prominent. The level of increases in PA from PG among youth and young adults appeared to be small or undetected, and of a relatively short duration (<2 months). Among older adults, however, there were modest increases in PA for up to 7 months post-release. This intensity and duration of increased PA appears to be inadequate to stem the epidemic of obesity but may have mental and social health benefits. Although many adverse outcomes from playing PG were reported, these appear to be low incidence, which should primarily influence PG players to knowingly exercise caution. Many research issues were identified to specify who might play AR games and effective strategies to enhance game design to increase PA.

Keywords: Augmented reality, Games, Review, Physical activity

Background

Playing some commercial videogames has been demonstrated to have cognitive, emotional, motivational, and social benefits, besides enjoyment.[1] Substantial broad-based interest has been generated in ''games for health'' for preventing, treating, or otherwise ameliorating diseases or their symptoms. At least 1743 games for health were released between 1983 and 2016 from 23 countries.[2] A meta-analysis of the research published on 54 games for healthy lifestyle promotion revealed small positive effects on healthy lifestyles, their determinants, and even on some clinical outcomes.[3] Similar benefits have been documented for nutrition education,[4] mental health,[5] and knowledge in regard to asthma,[6] but not obesity.[7] A subcategory of videogames called exergames or active videogames, that is, those that involve physical activity (PA) to advance gameplay and might be expected to impact adiposity, have not clearly been demonstrated to promote regular PA.[8] Simply providing exergames to children produced no detectable effect on their PA.[9]

Most exergames were designed by large companies primarily for player enjoyment (and corporate profit). Increases in PA were a beneficial externality, not an intended contribution to public health. Pokémon Go™ (PG), a game that appeared in 2016, generated much media attention[10] because people were publicly playing it, and play entailed PA. PG is a manifestation of videogames called mixed, hybrid, or augmented reality (AR).[11] AR was described as ''an interactive experience of a real-world environment where the objects

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that reside in the real-world are 'augmented' by computer-generated perceptual information…''[12] Diverse AR games have appeared at least since 2001,[11,13] and AR is currently being incorporated into diverse health applications.[14] PG projects images of Pokémon, extremely popular creatures from a series of best-selling games, television shows, and movies, on the images of the actual environment by using the camera in a mobile phone or pad.[11,15]

AR, extensively used by commercial companies for games and occupational applications, has been identified as one of the exciting new technological developments in G4H.[16] More than 9944 research manuscripts or conference abstracts have been published on AR in many diverse journals covering a broad variety of subject/content categories.[17] Many articles have appeared about PG, which could be used to comprehensively evaluate the contributions and limitations of an AR game.[18] This article conducts a scoping review, that is, a broad comprehensive overview, of the literature[19] on PG. A conceptual model specifies a sequence of effects from game design through to a sequence of diverse outcomes (Fig. 1). Although this model expands on the Design, Play, Experience framework for understanding how games influence outcomes,[20] it is used here just to organize the findings in the literature.

Methods

Articles for this review were identified by inserting ''Pokémon Go'' in the search titles in PubMed and Google Scholar. Articles were included in the review that included some data on PG regarding issues in the conceptual framework (Fig. 1) or identified a comment on or critique of the game. The first author abstracted and summarized most of the articles. Each section given next reviews the relevant literature on a specific issue in this sequence of effects regarding PG. A brief statement is provided at the start of each component on why it is important. No review protocol exists.

Research on PG

Game characteristics/design

The prototype for PG was Ingress, developed by Niantic, Inc.,[21] Ingress players interacted with portals located at cultural landmarks and other places of significance and engaged the players by having them upload photos of portals and crowd-sourcing the gaming content. Ingress players could apply for portal locations. Since mostly young males played Ingress, the portals tended to be located at places of interest to young White males.[22] These portals were converted to Pokéstops (which can be added intermittently) and PokéGyms in PG. Geocaching (i.e., real-world outdoor treasure hunting game using GPS-enabled devices) is also a game element that preceded the design of PG.

PA is a side effect of PG. Playing PG, which first appeared in 2016, involves capturing Pokémon, which is superimposed on the actual image in the camera, using Pokéballs (Fig. 2). Players get extra benefits for adeptly throwing their Pokéball by using finger-swiping on the screen to hit the target surrounding the Pokémon, capturing more of the more than 300 types of Pokémon, and storing/recording them in Pokédeks. Pokémon are found throughout a neighborhood or community, but especially in parks and public places. Finding Pokémon to capture entails walking around a neighborhood, thereby accumulating PA. The game has many complexities, such as hatching and evolving Pokémon, cooperative team raids with other players, and battles against other players to intrigue and enhance players' interest.[23]

Gameplay initiation influences

Participation bias concerns who elects to engage in an intervention (e.g., a game) and who does not[24] and why. This is an important issue because it specifies the population(s) to which the findings might be generalized; may raise questions about why certain groups did not participate, and thereby require other types of intervention[25]; and expands or limits the possibilities of examining treatment by individual interaction terms to assess limits on intervention effectiveness.[26]

PG became the ''biggest mobile game in U.S. history'' only 1 week after its launch.[27] Initially, the average player was a 25-year-old (yo) White female with a college degree and an annual income of $90,000,[28] with few African Americans playing PG.[22] This soon changed to White males with similar other characteristics. In a 2016 sample of 1059 randomly sampled Costa Rican adults, 15.2% had ever played PG; 3.9% of whom were currently playing it and 11.3% of whom had stopped playing it. Most survey respondents expressed negative attitudes toward videogames in general.[29] About 82.6% of respondents to an online survey (mostly undergraduates in Texas) reported ever having played PG with males and Hispanics, reporting significantly higher percentages of players. Students who played averaged 1.36 hours of play per day. About 49.1% played alone, followed by 30.4% in a group.[30] The most commonly reported reasons for playing PG were getting exercise, social interaction, fun, and nostalgia.[30] The motivation for starting to play PG appeared to emphasize anticipated fun, escapism, nostalgia, social ties, and PA, with the motivations differing between younger and somewhat older players. Among 644 Hong Kong university students, PG players were more likely to be younger, never or rarely have stayed outdoors, and rarely walked or jogged.[31] Thus, PG appeared to activate those who needed it most. Among 93 middle-aged community health service patients, only nine

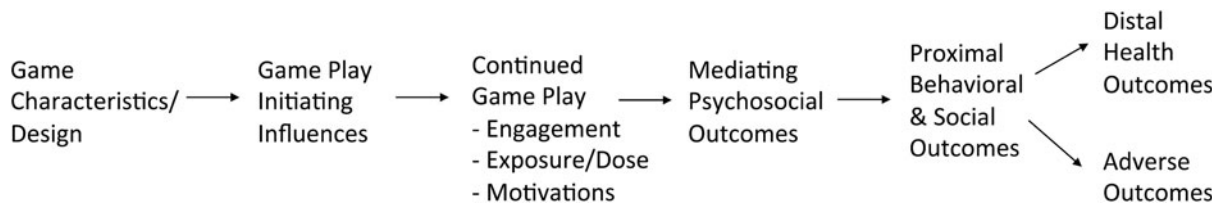

FIG. 1. Sequence of likely game characteristics that combine the published articles into meaningful categories.

FIG. 2. Screenshots from Pokémon Go™ (2019) showing walking accomplishments and rewards (left panel); Pokémon in front of the ''Old Red'' building on the University of Texas Medical Branch campus (middle panel); and an augmented reality view of a large medical campus showing gyms and Pokéstops (right panel). The circle around the avatar in the right panel shows the range in which she can capture Pokémon.

ever played PG. There were no significant differences in players versus non-players in having a smartphone, sex, or age.[32]

Using a newly developed scale with a U.S. internet-based sample of PG players ($n = 262$ adults), seven motives for playing PG were identified: exercise, fun, escapism, nostalgia, friendship maintenance, relationship initiation, and achievement.[33] A conceptual model based on the Uses and Gratification,[34] Technology Acceptance,[35] and Flow[36] theories tested among 642 German PG players identified nine factors organized into three categories: Risks: physical and data privacy; Benefits: nostalgia, enjoyment, PA, flow, socializing, and images; and Norms: social.[37] A factor analysis among 123 U.S. student PG players of nine items of reasons why someone might play PG revealed three factors: PG and videogame fans, PA seekers, and curious and social.[38] Among 621 Hungarian 18–54 yo PG players ($\bar{x} = 22.6$ yo), 10 confirmatory factors were detected from the Motives for Online Gaming Questionnaires—Pokémon Go extension: social, escape, competition, coping, skill development, fantasy, recreation, outdoor activity, nostalgia, and boredom.[39] In a UK sample of 461 mostly young adult participants, the most commonly reported reasons for playing PG were to have fun and because friends were using it.[40] Qualitative data revealed three social motive-related reasons: health benefits, family influence, and popularity; and two competition-related reasons: mastery and enjoyment (including nostalgia). Among 2612 adult Finnish respondents to an online survey, the primary reasons to start playing PG included curiosity, being a Pokémon fan, media reports, and reports from friends.[41] Thus, comparable motives for playing PG were identified from five countries, with an emphasis on motives related to expected fun, social interaction, and nostalgia.

Reasons why PG non-users and early users would not play PG included three application experience reasons: lack of interest, immature, and lack of motivation; four impact on the user reasons: felt self-conscious, preferred other applications, did not encourage vigorous PA, and not enough health benefits; and several reasons unrelated to PG: seasonal effects, priorities, lack of time, and safety concerns.[40] Among the 117 adult Finnish players who stopped playing PG, the primary reasons included boredom, difficulties in reaching higher levels, being disappointed, and technical problems.[41] Three major constraints on participation in gaming leisure activities were identified: intrapersonal, interpersonal, and structural.[22] U.S. women, especially minority women, had been harassed and unwelcome in game spaces in general, and in PG in particular.[22] Women and racial minorities in Costa Rica were also less likely to play, both due to characteristics of the game and to social harassment or discouragement when playing in public spaces.[29] Intermittent problems faced by location-based AR games included unavailable GPS signals, incomplete maps, locations that are legally prohibited to trespass, slow central processing units, physical limitations of the player (e.g., disability or fitness), and invasion of location-based privacy.[42] The renewed popularity from publisher additions

to PG of PG in 2018 may have changed the demographics of users reported in the studies in this review.[43] Unfortunately, this resurgence in popularity has only been reported in the popular press and has not yet been subjected to empirical investigation. Thus, its causes and consequences are yet unclear.

Continued game play: engagement, exposure/dose, and motivations

To have the largest health benefits, PA must be performed regularly at sufficient intensity for life.[44] A problem with lifestyle change interventions has been that there has been little maintenance of the changed behavior after the intervention period.[45] Engagement specifies the frequency, intensity (as evidenced by number of quests pursued, numbers of points earned, duration of play in a session or episode) and duration of exposure (both the time from first to last session, but also the frequency of sessions per unit of time), and maintenance of exposure over months or longer.[46] The greater the exposure to play within a session and across sessions, the more dose a player receives, and the effect exerted by the game should provide more desirable, or occasionally undesirable, outcomes. Understanding the influences on game play engagement may reveal participant, design, or location factors that could increase the frequency, intensity, duration, and/or maintenance of exposure. Experiences while playing a game could influence whether playing continues or not.

An online survey about using PG in public spaces was distributed across social media and involved 994 Australian mostly young adult PG players. Respondents did not report feeling uncomfortable or unwelcome in public spaces while playing PG (same for men and women); did feel PG encouraged them to explore public spaces; but felt only a minimal responsibility for looking after the spaces in which they played the game. There were a few small differences in these experiences by age or sex.[47] ''Ambient play'' is a term that describes the creativity and communication at the site of play. The haptic effect of ambient play concerns the experience of the site of play as part of the game experience.[48] For example, the experience of PG incorporates mobility into gameplay. Unfortunately, no user data were collected to test these propositions.

An extended version of the Technology Acceptance Model was used to review videogame acceptance (including entertainment, educational, and exergames), which is likely to be a part of game play engagement.[49] The extended Technology Acceptance Model included: perceived ease of use, perceived usefulness, perceived enjoyment, attitude, intention, and use. Within a meta-analytic structural equation model including 50 articles, the strength of relationships varied between hedonic (i.e., entertainment) and utilitarian (i.e., learning and health behavior change) games, but all variables predicted, to some extent, behavioral intention to play videogames.[49] Perceived ease of use, usefulness, and enjoyment predicted attitude, which, in turn, predicted intention.[49] Perceived enjoyment included flow, perceived satisfaction, and playfulness.[49]

In a web-based survey of active former and never users of PG, the active users were less likely to be regularly physically active than the former and never-users; active users expressed more ''fun or curiosity or recreation.'' None of the Big Five personality variables (i.e., extroversion, agreeableness, conscientiousness, neuroticism, and openness) significantly varied across the three groups.[50] An online survey of 362 mostly young Malaysian adults was recruited through social media to understand predictors of the intention to continue playing PG.[51] This study used a uses and gratification conceptual model and a structural equation model. More than half of the participants had played PG for 3 months or longer. The effects of Achievement, Challenge, Escapism, Social Interaction, and Flow on the Intention to Continue Playing PG were mediated by the Enjoyment of play.[51] This indicates the central role of enjoyment in continued gameplay. Another assessment of predictors of continued gameplay was conducted by using the uses and gratifications conceptual framework[52] including both gratification and inhibition experiences with PG. An online survey was conducted with 1190 mostly young Finnish adults. Intention to play PG again was related to Enjoyment, Challenge, Outdoor Activity, Nostalgia, and Ease of Use. This study did not test whether Enjoyment mediated the relationship of the other variables to Intention.[52]

Passion for playing PG was divided into harmonious and obsessive forms, with the latter presaging concerns for game addiction.[53] Among 621 Hungarian PG players ($\bar{x} = 22.6$ yo), the two forms of passion were highly interrelated in a structural equation model, with harmonious passion related to adaptive motives (i.e., outdoor activity, social, recreation, nostalgia) for playing PG, and obsessive passion related to less adaptive motives (i.e., fantasy, escape, boredom, competition, and coping).[53]

Among 402 mostly adult PG player respondents to an online questionnaire across 10 European countries, the personality traits of agreeableness, perseverance, and premeditation predicted continuing to play PG after 4 months from baseline, but not honesty, emotionality, extraversion, conscientiousness, openness, urgency, sensation seeking, impulsivity, need for cognition, need for closure, competitiveness, nor self-efficacy.[54] None of these personality characteristics predicted distance walked.[54]

In a complex structural equation model, the intensity of PG play was positively related to face-to-face interaction, which, in turn, was positively related to communication frequency and self-disclosure, which, in turn, were related to both bridging and bonding social capital.[55] This indicated that PG enabled players to make new contacts and new friends. In another structural equation model among 399 U.S. 18–75 yo adults ($\bar{x} = 34.5$ yo), playing PG was positively related to positive affect, nostalgic reverie, exercise, friendship initiation, and friendship intensification.[56]

Aspects of PG enjoyment varied by the three factors influencing PG play: PG and videogame fans, PA seekers, and the curious and social among 47 PG players.[38] In a web-based survey of active and former PG users, active users reported more interest in performing PA and more fun from playing PG, but no differences in many other motivations to continue playing.[50]

In a web-based survey of 199 German mostly adult active (81/199), former (56/199), and never (62/199) users of PG,[50] the only reported motivation to start playing PG that significantly differentiated active from former PG users was former users being more fascinated by the AR, suggesting

that once their interest was gratified they discontinued PG.[50] Among 230 young adult respondents to an online survey regarding parasocial relationships (i.e., close emotionally tinged relationships wherein participants perceived childhood media characters as trustworthy friends, are perceived as real [vs. pretend] with human like needs[57]), all reported having a favorite Pokémon character and the attachment was negatively correlated with the frequency of playing PG.

Qualitative research involving personal participation and observations of 100 PG users revealed that PG was an attractive user-friendly game experience requiring minimal training; and PG encouraged PA, goal setting for PA, and group interaction.[58] Among 2049 adult Finnish PG players' qualitative data, the most common reason for continuing to play PG was wanting to progress in the game.[41] Other qualitative research with 13 families revealed that although PG was exciting, enjoyable, and encouraged cooperation, there were also dangers and detriments to playing PG,[59] for example, small accidents from inattentiveness to the physical environment, increased risk of phone theft, and competitors cheating, among others.

Mediating psychosocial outcomes

Behavior change is considered the result of an intervention's impact on individual and/or environmental characteristics that are causally related to the behavior. Change in these mediating variables results in targeted behavior change.[60] Individual or environmental characteristics are called mediating variables if they have been statistically demonstrated to mediate an intervention to behavior relationship.[61] Research identifying mediating variables provides important targets for future interventions aimed at that corresponding behavior. Research determining that certain variables did not mediate an intervention to behavior change relationship either provides insight into what variables not to target in future interventions, or it employs other behavior change procedures that have a higher likelihood of influencing those variables. Variables motivating initial or continued game play could be determined to be mediating variables, but mediation needs to be tested. It is possible that factors that motivate initial and/or continued game play lead to changes in other variables that mediate outcomes. Disentangling motivating and mediating variables, for example, immersion, perceived self-efficacy, could be quite challenging.

Theoretically, variables more likely to motivate game play and proximal behavior outcomes include game-focused social psychological theory-based variables such as attitude to the game, social norms about the game, behavioral capability to play the game, anticipated emotional response from playing the game, desirability of playing the game or being PA, habit of playing the game, and intention to play the game[62]; communication theory-type variables such as interest, attention, affect, flow, cognitive absorption, immersion, presence, intervention usage,[46] and playfulness[63]; reflective, gamified, altruistic, didactic, and active types of engagement[46]; and environmental variables, such as social capital (the benefits of social relations) accumulation,[55] which possibly enable the participant to overcome barriers to participation or increase personal motivation (e.g., social support, perceived norms).

Combining measures of constructs from the Theory of Planned Behavior (TPB) (attitude, subjective norms, perceived behavioral control) with communication/game-related constructs (automaticity, immersion, and enjoyment), a six-variable model was assessed in two studies among 262 and 197 adult PG players by using a web survey. TPB variables significantly predicted intention to play a mobile game in each of the two studies, but the game variables were predictive only among younger, mostly White undergraduates, not among a somewhat older, more multicultural sample.[64]

Behavioral (PA) outcomes

Increasing PA is the primary hypothesized public health benefit from playing PG. PA outcomes from playing PG are summarized in Table 1. Simply asking college students to play PG for 60 minutes resulted in mostly moderate PA (4.9 minutes of sedentary behavior, 6.1 minutes of light PA, 48.8 minutes of moderate PA, and 0.2 minutes of vigorous PA).[65] However, when PG users of a 9-mile recreational greenway were compared with non-PG users of the greenway, the PG users took fewer aerobic steps, walked shorter distances, and burned fewer calories.[66] This was likely due to the need to stop regularly to best aim their Pokéballs to catch nearby Pokémon. Most studies among youth and young adults showed increases in PA soon after the release of PG, but activity declined to no difference from baseline or a control group within 30 days,[67] 6 weeks,[68] 24 days,[69] and 1 week.[70] Alternatively, a study among Japanese adults ($\geq$40 yo) who played PG showed increased step counts (270–583 steps per day) at 4, 5, and 7 months after the release of PG, compared with those who did not.[71] Some studies showed no differences in PA between the PG users and non-users.[31,72] Thus, playing PG can increase moderate PA, but not in everyone, and for relatively short periods, except perhaps among older adults.

Social outcomes

PG may increase face-to-face interactions among players and among other local residents. In doing so, it may increase both bridging (''…derived from casual, weak social ties that occur when individuals from heterogeneous backgrounds establish social connection'') and bonding (''…typically acquired from strong, intimate social ties when individuals render reciprocal emotional support.'') social capital.[55] Among 349 Hong Kong adult respondents to an internet survey, respondents playing PG reported both higher bridging and bonding social capital.[55]

Health outcomes

Four studies reported mental health-related outcomes. In a randomized clinical trial with one hundred ninety 12–15 yo Spanish adolescents, experimental group PG players experienced higher selective attention and concentration performance scores, but not memory.[73] In an internet survey of 50% of the 2064 subscribers of the PG subreddit who commented on PG on March 9 or 10, 2017, 370 useable responses ($\bar{x}$ = 27 yo, 85.7% male) were obtained. The self-reported distance traveled with PG was related to intellectual, emotional, and spiritual wellness, and it accounted for 33% of the

Table 1. Indicators of Physical Activity During Playing Pokémon Go

Authors (year of publication) Location of sample	*Sample characteristics (+age)*	*Design*	*Method of PA assessment*	*Comparison*	*Impact*
Althoff et al.[67] (2016) United States	792 U.S. PG players as measured by queries to Microsoft Bing	Data mining: 1420 players vs. 50,000 random selected U.S. Microsoft Band users	Step number from wrist worn 3 axis accelerometer and gyrometer	30 days of step counts before and after first PG experiential query+matched days from same start in control group	PG users increased daily steps by 192 from before to after start; 65 steps/day higher than control group; but steps declined to baseline or lower after 30 days Higher engagement with PG (as indicated by number of queries) led to more steps/day
Howe et al.[68] (2016) United States	560 U.S. survey participants in Amazon Turk (18–35 yo)	Amazon Turk survey participants who volunteered	iPhone 6	4 weeks before PG and 6 weeks after	PG users increased 955 steps/day in week 1 after PG started, but declined to +130 steps in week 6. Similar differences between players and non-players
Nigg et al.[124] (2017) United States	486 survey participants reported online ($\bar{x}$=28.6 yo)	Cross-sectional internet survey from July 28 to Aug. 31, 2016	Self-reported using Godin questionnaire	Self-reported before and after playing PG	Players increased MVPA by 50 minutes/week and reduced sedentary behavior by 30 minutes/week
Xian et al.[125] (2017) United States	167 PG players who volunteered on social media ($\bar{x}$=25 yo)	Survey research (Qualtrics)	Provided screenshots of step counts on iPhone Health	3 weeks before and 3 weeks after PG release	PG users increased 1976 steps/day: largest increases in older (>29 yo), male, overweight/obese, and non-student participants
Liu and Ligmann-Zielinska[126] (2017) United States	47 online PG players ($\bar{x}$=28.7 yo)	Cross-sectional online survey	Self-reported impact on PA	Self-reported	PG play increased player PA by 3 times of PG play, or 3 more hours on +5.6 minutes/week PG play decreased by time of the survey Safety of neighborhood influenced PG play
Barkley et al.[127] (2017) United States	358 college students ($\bar{x}$=19.8 yo)	Cross-sectional face-to-face survey	International PA questionnaire Self-reported minutes of walking and sitting	Week before PG (T_0), week after PG (T_1), current week (T_2)	Walking: +110 minutes/day at T_1 and +24 minutes/day at T_2 Sitting: −85 minutes/day at T_1 and −62 minutes/day at T_2 Played PG 5.2 days/week at T_1 and 2.1 days/week at T_2
Krittanawong et al.[128] (2017) Global	10,007 Twitter postings (no characteristic reported)	Data mining: Twitter postings from Aug. 1 to Sept. 10, 2016 mentioning PG and activity or distance	Comments in Twitter postings	Single group descriptive report	12% of tweets: walked 2–35 minutes/day playing PG 3% walked 50–150 minutes/week 16% walked daily or regularly 7.5% walked 7.5–145 minutes/week, but not timed
Wong[31] (2017) Hong Kong	644 university students (72.5% were 18–25 yo)	Cross-sectional online questionnaire	International PA questionnaire short form: vigorous intensity, moderate intensity, and walking in the past 7 days	Current PG players vs. ex-players	No difference in minutes of PA spent playing PG
Ma et al.[69] (2018) Hong Kong	210 Hong Kong residents who played PG on iPhone 5 or 6 and responded to survey ($\bar{x}$=61.1 yo)	Longitudinal from before to after PG	iPhone Health app screen shots	Measured for 35 days from 14 days before PG installation to 21 days after	Walking/running increased by 1200 steps/day Difference disappeared after 24 days

(*continued*)

Table 1. (Continued)

Authors (year of publication) Location of sample	*Sample characteristics (+age)*	*Design*	*Method of PA assessment*	*Comparison*	*Impact*
Wattanapisit et al.[72] (2018) Thailand	26 Thai medical students ($\bar{x}$ = 22 yo)	Longitudinal, questionnaire reported online at 3 time points	Self-administered global PA questionnaire v2	Baseline, 1 month, 3 months post-PG download	No significant difference in PA 11/26 students still playing 3 months after PG download.
Fountaine et al.[65] (2018) United States	27 U.S. college students	Played PG for 60 minutes	Accelerometer, ActiLife software, Troiano cut points	Single group descriptive report	6006 total steps in 60 minutes, or 100 steps/min Sedentary: 4.9 minutes Light: 6.1 minutes MPA: 48.8 minutes V: 0.2 minutes
Marquet et al.[129] (2018) United States	74 U.S. college students	Pre–post online survey	Ecological Momentary Assessment (12 p.m., 7 p.m., 10 p.m.) for 7 days and step counter on smart phone	Compared EMA responses with smart phone step counts	Non-PG players were significantly more active than players; +279 steps among PG players at noon on weekdays but not at 7 or 10 p.m.
Gabbiadini et al.[130] (2018) United States	981 respondents using Mechanical Turk	Mechanical Turk respondents	Self-reported responses to 9 items measuring recency and frequency	Correlational analysis of general physical activity	Overall PA was positively related to PG physical activity, attitudes, and sex, but it was negatively related to frequency of PG usage; model accounted for only 12.2% of the variance in overall PA
Beach et al.[66] (2019) United States	100 U.S. adult users of a 9 mi long greenway (paved path with greenery) from 7 to 9 a.m., 11 a.m. to 1 p.m., or 6:30 to 8:30 p.m. in summer	Cross-sectional single use of the greenway	Omron pedometer and Actigraph GT3X accelerometer	PG users vs. non-users PG users were significantly younger with a lower income	PG players spent as much time on the greenway as non-PG players, but took fewer aerobic steps, walked shorter distances, and burned fewer calories
Ni et al.[70] (2019) Hong Kong	65 Hong Kong medical students	Longitudinal, days after PG release	iPhone accelerometers and health app: walking distance	PG users vs. non-users for 50 days after PG release	PG players walked 1.5, 1.2, 0.9, and 0.6 km more on the 3rd, 4th, 5th, and 6th days after PG release, but not afterward
Koivisto et al.[76] (2019) Finland	1190 respondents to an online survey (9–10, 2016) (mode = 21–25 yo)	Cross-sectional	Self-reported PG play hours/day	Physical health outcomes; mental health outcomes; social health outcomes	Hours of PG play was moderately related to all outcomes
Hino et al.[71] (2019) Japan	46 PG players and 184 non-players ($\bar{x}$ = 56 yo)	Respondents to questionnaires randomly sent offering a pedometer	Pedometer step counts	PG players vs. non-players	Significant play status by time since PG release by about 270–583 steps at 4, 5, and 7 months; effects varied by subgroup (but low power to detect differences)

9–10, 2016, September–October, 2016; EMA, ecological momentary assessment; MPA, moderate physical activity; MVPA, moderate to vigorous physical activity; PG, Pokémon Go; yo, years old.

variance in overall wellness.[74] Among 2530 Japanese employed workers responding to an online survey twice, separated by a year, the 246 (9.7%) reporting playing PG for a month or longer (who were significantly younger than non-players) reported significantly less psychological distress at second report than non-players (Cohen's $d = -0.20$), but not lower physical complaints or enhanced work performance.[75] Among 1190 respondents to a global online survey (originating from Finland), hours of playing PG was moderately related to self-reported physical, mental, and social health outcomes.[76] Achievement and immersion orientation were weakly related to physical and mental health outcomes; social orientation was weakly related to achievement, immersion, and social outcomes.[76]

Other outcomes

An analysis of restaurant reviews on a prominent website before and after the release of PG in 88 neighborhoods in Houston, TX, revealed that restaurants near a game artifact (e.g., PokéGyms) did not experience more reviews, controlling for local crime and weather. However, there was an effect on numbers of reviews and star ratings for inexpensive restaurants, suggesting the mostly younger PG players patronized the less expensive restaurants when nearby.[77] Among 104 Melbourne adolescent and adult respondents to an online survey, PG players and their avatars' joint locations were charted on a city map by time of day. PG play changed the locations of players over time.[78]

Adverse outcomes

Six surveys using Clickworker crowdsourcing recruited 3492 mostly young adult PG players and 2247 non-players. Players were not significantly different from non-players in parking their car in illegal U.S. spots, venturing into unsafe places, entering someone's private property, trespassing into hospital units, breaking street crossing rules, or compromising personal safety when playing PG. Alternatively, case studies revealed that a 19 yo driver of a pickup truck became distracted trying to capture Pokémon, lost control of his vehicle, which rolled over and ejected three passengers[79]; a 13 yo male on a bicycle without a helmet entered an intersection while looking down at his cell phone and playing PG and was hit by a truck, leaving him unconscious for 30 minutes[80]; a 33 yo Japanese pedestrian was run over and dragged for 50 meters by an automobile driver playing PG[81]; and a 25 yo Italian male was hit by a van while crossing a road playing PG on a mobile phone ignoring red traffic lights.[82]

Among 100 pedestrians ($\bar{x} = 23.6$ yo) observed crossing a street in Taipei, Taiwan, more unsafe crossing behaviors were detected among those playing PG.[83] An analysis of news stories reporting PG while driving or in relation to a car was conducted to estimate driver, passenger, or pedestrian PG-reported distractions.[84] Overall, 113,993 incidents were reported on Twitter in just a 10-day period: 18% indicated a driver was playing, 11% a passenger was playing, and 4% a pedestrian was distracted. Fourteen cases indicated unique crashes (e.g., the player drove into a tree).[84] In a review of Kaiser Permanente Northern California (3.85 million members) health encounter records from July 5 through November 5, 2016, 222 reports of PG were detected: 75 (33.8%) were adverse events whereas 147 (66.2%) were benefits. Incidence of reports of both adverse events and benefits declined with time since release of PG. Most adverse events ($n = 51$, 68%) were musculoskeletal or skin injuries.[85] In the Japanese Institute for Traffic Accident Research and Data Analysis files from June 1 through August 31, 2016, regression discontinuity analysis revealed that fatal traffic injuries increased by only 0.017 deaths per million (not significantly different from zero) after the release of PG.[86] Thus, numerous case studies revealed that although substantial injuries did occur among apparently distracted PG players, the contribution to population-level injury rates or mortality levels appears to have been small to negligible.

Commentary/critiques

Right from its first appearance, PG generated extensive critiques and commentaries. Most critiques concerned possible increased risks: distracted traffic-related injury risks,[87–89] high costs associated with use of cell phones and online connections, exposure to high crime areas,[87,90] exposure to mosquito-borne diseases,[91] infectious disease spread at PokéGyms,[92] internet gaming disorder,[93] consuming high calorie foods when playing PG,[94] cigarette use and fast food intake from large companies partnering with Niantic to market products,[95] and loss of sleep.[89] Also noted were possible benefits: reduced sedentary lifestyle,[96–98] reduced obesity and diabetes from enhanced social and cognitive skills,[87,99] a model for a game to enhance the scientific assessment of biodiversity,[100] improved mental health through decreased severe social withdrawal,[101,102] and increased unusual bird sightings among parents accompanying their child playing PG.[103] The inadequacy of the public health sector to create such a creative game was pointed out, as was the need to collaborate with those who could,[104] and with behavioral change experts in both the design and evaluation of the effects of such games.[105]

Discussion

This comprehensive scoping review revealed that PG appeared to activate a modest proportion of the total population, but it may have activated some who needed it most, that is, younger individuals who rarely walked or jogged. Playing PG led to increases in mostly moderate PA, but the increases were short lived (a week to a couple of months). A diverse set of adverse outcomes included mostly distraction-related traffic accident behaviors.

Behavior change initiation

Approximately 15.2% of respondents indicated that they ever played PG in Costa Rica. This is the only estimate available for the proportion of a population ever playing PG. Apparently, most Costa Ricans did not play due to generalized negative attitudes to videogames. The motivation for starting to play PG appeared to emphasize anticipated fun, escapism, nostalgia, social ties, and desired PA, but the motivations differed between younger and somewhat older players. Women and racial minorities were less likely to play, both due to characteristics of the game and due to social harassment or discouragement for these groups playing in public spaces. Characteristics of the game, for example,

locations where Pokémon are found, could be changed to increase female and racial minority participation with PG. The social factors, that is, harassment, discouragement in public places, and generally negative attitudes to games, would require community-wide social marketing programs to change. Most of these studies did not address differences between those who elected to play PG and those who did not, and they thereby cannot address the extent to which those who did not play PG were not interested in exercising, not having fun, etc. The study reporting higher social capital among PG players cannot differentiate the direction of influence or bidirectionality. The research on motives, social cognitive and game theory, and social and personality variables provide intriguing variables to include in future research on who does and does not play AR games, and they thereby provide intervention targets for increasing initial AR gameplay.

PA change

Among youth and young adults, some increases were detected in PA within the first 2 months, but not beyond. Among adult PG players in Japan, modest increases in steps were detected at 4, 5, and 7 months after the release of PG.[71] These results are disappointing, especially in light of the media attention accorded PG. Research is needed on how to optimize the frequency, intensity, and duration of PA from players of PG and AR games. The long-term success among older adults in Japan needs to be replicated in other studies to be sure the effect was not culturally specific to the Japanese origin of the characters.

Continued behavior change, motivation, and engagement

Engagement with mHealth apps has been measured with diverse objective metrics,[106] which need to be employed in serious games research. Much of the literature has confused the psychosocial or other influences on initially starting to play a game, influences on intensity or continued game play, and influences on maintenance of behavior change resulting from game play. These need to be disambiguated in future research to inform interventionists to influence each behavior. Diverse interrelated factors appear to influence PG engagement. Future research needs to unify this approach to understanding engagement by combining constructs and perhaps differentiating which constructs separately influence or predict frequency, intensity, duration, and maintenance of engagement. The influencing factors may well vary by age, gender, socioeconomic status, ethnic group, or other demographics that influence PG game play experience, thereby requiring large samples.

Smartphone apps have been demonstrated to impact health outcomes and related behaviors,[107] but apps are not usually fun to employ. It is commonly believed that people play games to have ''fun,'' also called enjoyment, pleasure, or playfulness. One might expect that something that was fun to use would be played more frequently, intensively, and for a longer duration, having a greater health impact. That does not appear to have happened with PG. Although many of the summarized PG articles mentioned fun or enjoyment as a primary motivation for engaging in PG, the nature of what constitutes fun was not clearly specified. Videogame enjoyment has been positively related to exploratory behavior in the game, among 62 mostly adult game players.[108] Pleasure from playing a game was the strongest predictor of gameplaying time initially after a single gameplay and again 3 weeks later among 19 young adults in the Netherlands.[109] In the midst of diverse indicators of similar constructs, playfulness was measured with 17 subconstructs, which need to be more clearly delineated, and construct validity should be established.[63,110]

Fun is an understudied construct with at least three dimensions: psychosocial, embodiment, and physiological.[111] Fun could be analyzed/understood as an aspect of a game's design (game structural characteristics that lead to fun), play (the interactivity between the player and the game), and experience (also called aesthetics).[111] Flow likely plays a role in the psychosocial and physiological aspects.[111,112] However, a story or narrative with its immersion/transportation and presence experiences,[113] socializing, and nostalgia (and its remembrance of previous fun activities) may also be related to fun. Substantial research is needed to understand what fun may be in the context of AR games, and how optimally to manipulate it to optimize frequency, intensity, duration, and maintenance of AR game engagement.

Inhibition of continued PG play

Not all exposures to PG promoted continued play. One study indicated that boredom, difficulties in reaching higher levels, being disappointed, and technical problems discouraged some initiation of PG play.[11] Some reported social harassment when playing PG, especially among minority women.[22,24] And some technical difficulties were encountered, for example, unavailable GPS signals, incomplete maps, non-trespass areas, and slow central processing units.[42] Although some of these difficulties (especially some of the technical difficulties) can be redressed by the PG designers, it appears unlikely that all possible players will have similarly positive experiences, and want to continue to play. These inhibitory factors do not appear to be experienced by substantial numbers of participants, but this needs to be assessed in larger samples with close-ended questions.

Health outcomes

Whether videogames do or can prevent obesity has been addressed by several reviews. Active videogames, also called exergames, had large effect sizes on PA (ordinarily considered a key obesity preventive behavior) when compared with no game, moderate effect sizes compared with laboratory-based exercises, and mostly small or no effectiveness when compared with field-based PA.[114] Another review of games targeting diet and PA concluded that the effect sizes were mostly small, and likely not large enough to prevent obesity.[7] Given the relatively short duration of enhanced moderate-level PA from playing PG minimizes the possibility that playing PG may prevent obesity. However, hours of PG play were moderately related to self-reported physical, mental, and social health outcomes. Research is needed to increase the duration and intensity of PG play to test the desired effects on measured health outcomes. Changing long-term behavior, however, has proven largely intractable.[115]

Adverse events

A review of the literature on adverse illness and injury events from playing videogames in general (44 reviewed articles) revealed numerous fractures, dislocations, tendon and ligament injuries, head, neck, chest, abdomen, and pelvis trauma, and neurologic and behavioral health incidents.[116] Although any adverse event needs to be taken seriously, anticipated, and minimized, the population-based incidence of such problems either among the population as a whole or just among game players is small[85] and thus not a reason to discourage people from playing PG. Research on enhancing player safety while navigating a community is warranted.

Research design

An intriguing aspect of the literature on PG is the large diverse number of innovative methods for conducting the studies, especially those using big data with objective measures. The time series designs permit objective data collection (e.g., from smartphones) before the public introduction of a technological innovation (e.g., PG) and compare exposure and non-exposure groups both pre- and post-innovation. Such designs do not benefit from eliminating between-group differences from randomization, but the design permits assessment of exposure bias and correcting for such biases. Future AR research needs to capitalize on these research method innovations. Investigators developing their own AR serious game should consider consensus recommendations for their design.[117]

Comparisons to findings from other exergames

A meta-analysis of the effects of exergames in nine studies on energy expenditure indicated that the average increase was to 3.1 METS (metabolic equivalents), just barely above the criterion for moderate PA.[118] A somewhat more recent review of 27 studies of exergames in regard to increasing energy expenditure indicated that exergames generally increased energy expenditure, but the increase was in moderate, not vigorous, PA.[119]

Not much has appeared on correlates of initiation of, or maintenance of, exergame play. One study on correlates of family exergame play indicated that intention, affective and instrumental attitudes, and descriptive norms were correlated with family exergames.[120] Another study of correlates of child exergame play revealed that younger and ethnic minority children were more likely to play exergames.[121] The extensive diverse measures of correlates of initiated and continued PG play suggest that other exergame researchers would benefit from reading the PG literature. With the recent and upcoming releases of major new location-based AR mobile games (e.g., The Walking Dead: Our World, Minecraft Earth, and Harry Potter: Wizards Unite!), there will be new opportunities for research investigating specific aspects of AR gameplay and comparing AR games.

Limitations

PG has received continuous updates to its gameplay over time, several of which were highly social and highly successful in encouraging a resurgence of popular interest in the game.[122] In particular, the addition of trading, friends, sending gifts, community days, and cooperative raid battles has likely changed the social context of playing the game. Future studies should investigate whether these newer social game elements and increase in popularity have influenced player demographics, engagement, behavior, and/or health outcomes.

Conclusion

A conceptual model organized a comprehensive analysis of the influences on and results of playing PG, a popular AR game. Although large numbers of people started playing PG, these were a relatively small proportion of the relevant populations, perhaps due to negative attitudes toward videogames in the general population. Diverse factors predicted who initiated PG play, but they tended to emphasize anticipated fun, escapism, nostalgia, social ties, and desire for PA. Some environmental factors (e.g., one study identifying unavailable GPS signals, trespassing laws) limited PG play for some. Diverse factors predicted duration of gameplay, but desired/expected fun appeared to be prominent. The level of increases in PA from PG among youth and young adults appeared to be small or undetected, and of a relatively short duration. One study revealed that among older adults, however, there were small increases in PA for up to 7 months post-release. This intensity and duration of increased PA appears to be inadequate to stem the epidemic of obesity, but they may have mental and social health benefits. Although many adverse outcomes from playing PG were reported, these appear to be low incidence and should influence PG players primarily to knowingly exercise caution.

Meaningful research on PG appears to have recently evaporated. Additional research is needed on PG in its reincarnation, future releases of AR exergames, or specially designed AR games, to inform how the games may be designed to change behavior, and perhaps even to enhance mental health.[123]

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Authors' Contributions

T.B.: retrieved and abstracted the articles for review and wrote a first draft of the article. E.J.L.: wrote sections, critiqued and edited the article. Since the two authors have different approaches to games, the combination of perspectives enhanced the quality of the article.

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