Pokémon Go and Physical Activity: A Multilevel Study in Asia

Ben V Ma a, Sai Leung Ng a,*, Tim Schwanen b, John Zacharias c, Mudi Zhou d, Ichiro Kawachi e, Guibo Sun f

a Department of Geography and Resource Management, The Chinese University of Hong Kong, Hong Kong
b Transport Studies Unit, School of Geography and the Environment, University of Oxford, UK
c College of Architecture and Landscape, Peking University, Beijing, China
d Department of Mathematics, Imperial College London, UK
e Department of Social and Behavioral Sciences, Harvard TH Chan School of Public Health, Boston, USA
f Faculty of Architecture, The University of Hong Kong, Hong Kong

* Correspondence to Sai Leung NG slng@cuhk.edu.hk +852 39436527 short-term

Background: Physical activity has long been considered an important component of a healthy lifestyle. Although many efforts have been made to promote physical activity, there has yet to be an effective global intervention in physical activity promotion. Some researchers suggest that Pokémon GO, a location-based augmented reality game, was associated with a short-term increase in player’s physical activity on a global scale, but the details are far from clear.

Objective: To study the relationship between Pokémon GO and players’ physical activity, and how it varies across players with different physical activity levels.

Method: We conducted a field study in Hong Kong to investigate if Pokémon GO is associated with physical activity. Pokémon GO Players were asked to report their demographics through a survey, and their Pokémon GO behaviours and daily walking and running distance were collected from their mobile phones. Participants (n=210) were residents of Hong Kong, aged 13 to 65 years old and playing Pokémon GO using iPhone 5 or 6 series in five selected types of built environment.

We measured the average daily walking and running distance over a period of 35 days, from 14 days before to 21 days after game installation. Multilevel modelling was used to identify and examine the predictors – including Pokémon GO behaviours, weather; demographics and built environment – of Pokémon GO’s relationship with daily walking and running distance.

Results: Average daily walking and running distance increased 18.1% (0.96 km, approximately 1200 steps) in the 21 days after participants installed Pokémon GO compared with the distance over the 14 days before installation (P < .001). However, this association attenuated over time and is estimated to disappear after 24 days.

Multilevel models indicate that Pokémon GO has a stronger and more lasting association among less physically active players than physically active ones (P < .001). Playing Pokémon GO in green space has a significant positive relationship with daily walking and
42 running distance ($P = .03$). Moreover, results show that play Pokémon GO or not, days
43 played, weather (total rainfall, bright sunshine, mean air temperature, and mean wind
44 speed), and demographics (age, gender, income, education, and body mass index) –
45 were associated with daily walking and running distance.

46 **Conclusions:** Pokémon GO was associated with a short-term increase in players’ daily
47 walking and running distance, this association is especially strong among less physically
48 active ones. Pokémon GO has the potential to build new links between humans and
49 green space to encourage people to do physical activity. The results show that location-
50 based augmented reality games, such as Pokémon GO, have the potential to be a public
51 health intervention tool on a global scale.

52 **Keywords:** physical activity; Pokémon Go; public health intervention; exergame; weather

53 **Introduction**

54 As a Pokémon GO player, the first author of this paper has walked 1526 km on five
55 continents (Asia, Africa, Europe, North America, South America) through the game,
56 resulting in a huge increase in his walking activity. His case may be an outlier, but the
57 increase in walking is very common among Pokémon GO players. Pokémon GO is a
58 location-based augmented reality (AR) game which launched in July 2016. Impressively,
59 it received 65 million monthly active players, and recorded more than 650 million app
60 downloads within six months [1]. Pokémon are virtual creatures that inhabit the fictional
61 Pokémon World. Pokémon GO allow players to locate, capture, and battle Pokémon on
62 their mobile devices if they were at the same real-world location as the players. As
63 players move around their real world, their avatars in the game will move within the in-
64 game map based on the real world geographical location. The in-game map contains
65 many features such as ‘gyms’ and ‘stops’ where players can get Poké ball and other
66 items to catch and battle with pokémon. To play this game, players need to move around
67 in the real world other than being sedentary. Nearly 9% of the global population had
68 installed Pokémon GO, and traveled more than 15.8 billion km until May 2017 [2]. In this
69 study, we aim to measure the relationship between Pokémon GO and players’ physical
70 activity, and how it varies across players.

71 Physical activity has long been considered an essential component of a healthy lifestyle
72 [3–5]. Although many efforts to promote physical activity [5–7] have been undertaken,
73 there has yet to be an effective global intervention in physical activity promotion [8].
74 Physical inactivity is the second leading cause of preventable death worldwide, next to
75 smoking [5].

76 Literature indicates that physical activity was affected by various variables, such as
77 demographics [9–11], body mass index (BMI) [12,13], weather [14–16], and built
78 environments [17–19]. Recently, a growing body of research suggests that new
79 technologies, especially the gamification of physical activity interventions, could be used
80 for promoting physical activity [20]. But it was not until 2016 that Pokémon GO provided
81 the first glimpse of how to intervene to promote physical activity on a global scale.
Some studies found that Pokémon GO is associated with a short-term increase in player’s physical activity. The existing literature can be mainly divided mainly into two groups. Objectively collected data of physical activity reported that there is an increase of the daily number of walking steps among the Pokémon GO players after the installation of the game [21,22]. Studies using self-reported data indicate that players spent more time outside and did more physical exercise because of Pokémon GO [23–26]. Other research includes studies on the Pokémon GO player’s motivation [27, 28], experiences playing Pokémon GO [29], and potential harmless brought by the Pokémon GO [30, 31].

However, there are two major research gaps. Firstly, physical activity on each day is not only determined by players demographics and Pokémon GO behaviours (such as play Pokémon GO or not, and days played), but also related to the weather and built environment. Inclement or extreme weather has been regarded as a barrier to participation in physical activity [15]; And built environment is the essential element to location-based AR game, since the game is built based on the environment of physical world. However, existing research failed to take them into account when investigating the relationship between Pokémon GO and physical activity.

Secondly, although some researchers suggest that the association between Pokémon GO and physical activity may vary among different populations [24, 25, 32, 33], little research to date has studied this differentiation among players. In recent studies, Howe et al. focused on young adults [21]; Althoff et al. studied the Microsoft wearable products users [22]; Kogan et al. focused their study on dog owners [34]; Wong et al. researched university students [26]. Asia has 60% of the world population [35], even though Pokémon GO has been suspended in Mainland China, there are still considerable numbers of Pokémon GO players in other parts of Asia. However, most studies were conducted in western countries, there has yet to be an objective study on Pokémon GO and physical activity in Asia.

Therefore, we used a multilevel modelling approach in this study to answer two main research questions:

- What is the relationship between Pokémon GO and players’ physical activity?
- How does the association between Pokémon GO and physical activity vary across players with different physical activity levels?

Methods

Research Design

We conducted a field survey in August 2016 over the period of the first month after Pokémon GO launched in Hong Kong. In five study sites that represent five typical types of built environment, Pokémon GO players were intercepted while they were playing the game. Their sex, age, income, education level, BMI (kg/m2) and the start date of
Pokémon GO were collected using a questionnaire. Participants' physical activity data, specifically daily walking and running distance, were captured from their iPhone 'health' app pages. Eventually, we compiled a data set covering the period from 14 days before and 21 days after the installation of Pokémon GO. Weather data were collected from Hong Kong Observatory, including total rainfall (mm), bright sunshine (hours), mean air temperature (deg. C), and mean wind speed (km/h). Participants received a Pokémon toy as a token of appreciation for joining the study.

### Study Population and Sites

10 Pokémon GO players were included in this study, Table 1 shows the profile of the participants. To ensure the reliability and consistency of data, only iPhone 5s or 6 series users with qualified daily walking and running distance in their iPhone 'health' app were included in this study. 2964 players were identified as Pokémon GO players while they were playing Pokémon GO on our study sites, 1248 of them answered our questionnaire. Among 1248 respondents, 1028 players were excluded because they are not iPhone 5s or 6 users, or they are iPhone users but unable to provide their daily walking and running distance data. Among 220 qualified iPhone users, respondents who did not complete the questionnaire (n=7) were excluded. We also exclude respondents that their level of Pokémon GO was not sufficient to unlock the primary functions of the game (n=3). The primary function of the game is referred to reach level 5 to gain access to the Gyms.

**Table 1. Characteristics of Pokémon GO players (N=210).**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Participants*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD) age (years)</td>
<td>26.1 (8.7)</td>
</tr>
<tr>
<td>Age group (years)</td>
<td></td>
</tr>
<tr>
<td>13-17</td>
<td>25 (11.9)</td>
</tr>
<tr>
<td>18-23</td>
<td>67 (31.9)</td>
</tr>
<tr>
<td>24-29</td>
<td>43 (20.5)</td>
</tr>
<tr>
<td>30-35</td>
<td>35 (16.7)</td>
</tr>
<tr>
<td>36-50</td>
<td>21 (10.0)</td>
</tr>
<tr>
<td>&gt;50</td>
<td>2 (1.0)</td>
</tr>
<tr>
<td>Female</td>
<td>71 (33.8)</td>
</tr>
<tr>
<td>Education</td>
<td></td>
</tr>
<tr>
<td>High school or lower</td>
<td>70 (33.3)</td>
</tr>
<tr>
<td>College or higher</td>
<td>118 (56.1)</td>
</tr>
<tr>
<td>Monthly income (HKD)</td>
<td></td>
</tr>
<tr>
<td>&lt;5000</td>
<td>65 (31.0)</td>
</tr>
<tr>
<td>5000-10000</td>
<td>12 (5.7)</td>
</tr>
<tr>
<td>10001-15000</td>
<td>41 (19.5)</td>
</tr>
<tr>
<td>15001-20000</td>
<td>30 (14.3)</td>
</tr>
<tr>
<td>20001-30000</td>
<td>18 (8.6)</td>
</tr>
<tr>
<td>&gt;30000</td>
<td>18 (8.6)</td>
</tr>
</tbody>
</table>
Site

- Office (Central): 33 (15.7)
- Mixed Use (Wan Chai): 48 (22.9)
- Green Space (Victoria Park): 46 (21.9)
- Accommodation (Wong Tai Sin): 55 (26.2)
- Retail Premises (Causeway Bay): 28 (13.3)

BMI (kg/m²)
- Underweight (BMI < 18.5): 57 (27.1)
- Normal (18.5 ≤ BMI < 25): 121 (57.6)
- Overweight and obese (25 ≤ BMI): 16 (7.6)

Mean (SD) daily walking and running distance in two weeks before installation of Pokémon GO (km): 5.4 (3.5)

*Note: numbers are ‘value (percentage)’

Five study sites represented five typical types of built environment in Hong Kong – namely green space, office area, accommodation area, mixed use area, and retail premise (Table 2). For each built environment, we selected a 200m radial zone based on the surrounding land use [36] and set ≥60% of the surrounding land use belonging to that type of built environment as the criterion for the site selection through a GIS platform [37].

Table 2. Study sites description.

<table>
<thead>
<tr>
<th>Type of built environment</th>
<th>Study site</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Area</td>
<td>Central</td>
<td>Land used for administration, or clerical, technical, professional or other like business activity.</td>
</tr>
<tr>
<td>Mixed Use Area</td>
<td>Wan Chai</td>
<td>Land used for mixed uses.</td>
</tr>
<tr>
<td>Green Space</td>
<td>Victoria Park</td>
<td>Integrated park consisting of playgrounds, sitting-out areas or public/mini sports grounds.</td>
</tr>
<tr>
<td>Accommodation Area</td>
<td>Wong Tai Sin</td>
<td>Land used to accommodate persons.</td>
</tr>
<tr>
<td>Retail Premises</td>
<td>Causeway Bay</td>
<td>Land used to: a) sell goods by retail, or by retail and wholesale; b) sell services; or c) hire goods.</td>
</tr>
</tbody>
</table>

Daily Walking and Running Distance

Daily walking and running distance data in this study are representing the daily physical activity condition of Pokémon GO players. To compare players’ physical activity before and after installation, we used the average walking and running distance each day over a period of 35 days (14 days before to 21 days after the game installation). We estimated 95% confidence intervals through a bootstrap with 500 resamples of daily walking and running distance. If there is no data in a day, that means the player probably didn’t touch their phone at all, or there are some problems with the phone, we will ignore that datum. 15 observations were excluded from the analysis because their data value is empty.
Multilevel Modelling

Multilevel modelling was employed to investigate the difference of association between Pokémon GO and daily walking and running distance across players. We have nested observations of daily walking and running distance within the same individual (from 14 days before to 21 days after the game installation), based on this cluster data structure, multilevel modelling was applied to investigate the relationship between the Pokémon GO and physical activity. At observation-level, each observation has its own observation-level attributes, including Pokémon GO or not, days played, total rainfall (mm), bright sunshine (hours), mean air temperature (deg. C), and mean wind speed (km/h). At player-level, age, income, gender, education, BMI (kg/m²), and built environment variables were added. Further, interdependencies among different levels were taken into account through multilevel modelling. We transferred parts of variables into dummy variables based on questions we intended to investigate (the organization of variables as shown in Table 3). MLwiN V.3.0 was used to conduct the multilevel modelling analysis.

Results

Daily Walking and Running Distance Before and After the Game Installation

Figure 1 shows the change of average daily walking and running distance of the Pokémon GO players in the period from 14 days before to 21 days after the game installation. We found that the average distance increased 18.1% (0.96 km), from 5.30 km (SD=2.12) (before installation) to 6.26 km (SD=2.45) (after installation). A comparison of means shows that Pokémon GO was associated with an increase in daily walking and running distance (F= 33.825, P < 0.001). We observed a decrease of the daily walking and running distance in the period from the 5th to 8th day after installation. During that period, Hong Kong’s weather deteriorated due to the influence of typhoon Nida.
Figure 1. Average daily walking and running distance before and after the installation of Pokémon GO. Error bars correspond to bootstrapped 95% confidence intervals.

Pokémon GO and Physical Activity across Players

Results of multilevel models are shown in Table 3. A null model, which is the model without any variances input and can simply describe the variance at each level, was conducted first. We found that 22.5% of the variance was explained at the observation-level, which provided justification for proceeding to the subsequent analysis. Model 1 was the result of the model which contains observation-level variables. In model 2, the player-level variables were added and analyzed together with the observation-level variables (Table 3-1). In model 3, assuming that all other variables in the model are held constant, the relation between Pokémon GO behaviours and dependent variables were investigated. In model 4, based on model 3, the interactions of Pokémon GO or not and
Results of multilevel models show that observation-level variables (including Pokémon GO or not, days played, total rainfall, bright sunshine time, mean air temperature, and mean wind speed) are significantly related to daily walking and running distance. Playing Pokémon GO or not \((P = .005)\), and bright sunshine time \((P = .01)\) are significantly associated with an increase in daily walking and running distance. On the other hand, days played \((P < .001)\), total rainfall \((P = .003)\), mean air temperature \((P = .01)\), and mean wind speed \((P = .04)\) were negatively correlated with daily walking and running distance. At the player-level, results indicate that players who are male, have high school or lower education, and with normal BMI \((\text{kg/m2})\) are likely to have a higher daily walking and running distance (Table 3-2). Furthermore, playing Pokémon GO in green space was associated with a higher daily walking and running distance \((P = .03)\).

Playing Pokémon GO was significantly associated with an increase of the daily walking and running distance \((P = .005)\), while days played was significantly associated with a decrease of daily walking and running distance \((P < .001)\). The results showed that the association between Pokémon GO and daily walking and running distance attenuated over time, and is estimated to disappear after players have played Pokémon GO for 24 days (Table 3-2).

Most importantly, results indicate that players with less daily walking and running distance have a stronger association between their daily physical activity and Pokémon GO, and the association lasts longer than other players with relatively more daily walking and running distance. Holding other variables at a fixed value, it is shown that when daily walking and running distance decreases \(\text{estimate} = -8.2 \times 10^{-3}\), the association between Pokémon GO and daily walking and running distance will increase \(\text{estimate} = 1.7 \times 10^{-2}\); and when daily walking and running distance increases \(\text{estimate} = 5.9 \times 10^{-5}\), association between days played and daily walking and running distance will decrease \(\text{estimate} = 237-5.7 \times 10^{-5}\).

Table 3-1. Multilevel models of Pokémon GO and daily walking and running distance (km) model 1, 2.

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Observation-level</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pokémon GO or not(^1) (refer=not)</td>
<td>(0.085) (&lt;.001) (***)</td>
<td>(0.084) (&lt;.001) (***)</td>
</tr>
<tr>
<td>Days played(^2)</td>
<td>(-0.003) (&lt;.001) (***)</td>
<td>(-0.004) (&lt;.001) (***)</td>
</tr>
<tr>
<td><strong>Weather</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total rainfall</td>
<td>(-0.001) (0.013) *</td>
<td>(-0.001) (0.012) *</td>
</tr>
<tr>
<td>Bright sunshine time</td>
<td>(0.003) (0.013) *</td>
<td>(0.003) (0.013) *</td>
</tr>
</tbody>
</table>
### Mean air temperature

-0.012 0.020 * -0.013 0.016 *

### Mean wind speed

-0.001 0.010 ** -0.001 0.009 **

#### Player-level

**Age (refer= '>35')**

- 13-17: -0.087 0.019 *
- 18-23: -0.016 0.320
- 24-29: -0.016 0.316
- 30-35: -0.065 0.028 *

**Income (HKD)(refer= '>30000')**

- <5000: -0.011 0.385
- 5000-10000: -0.111 0.012 *
- 10001-15000: -0.028 0.223
- 15001-20000: 0.050 0.096 *
- 20001-30000: 0.030 0.223

**Gender (refer=Female)**

- Male: 0.039 0.026 *

**Education (refer=High school or lower)**

- College or higher: -0.077 0.036 *

**BMI (refer= normal) (kg/m2)**

- Underweight(BMI<18.5): -0.069 0.004 **
- Overweight and obese(25≤BMI): -0.050 0.045 *

**Built environment (refer=Office)**

- Mixed use area: 0.026 0.207
- Green space: 0.041 0.094
- Accommodation area: 0.001 0.491
- Retail premises: -0.003 0.469

* P < 0.05; ** P < 0.01; *** P <0.001

---

246Table 3-2. Multilevel models of Pokémon GO and daily walking and running distance (km) model 3, 4.

<table>
<thead>
<tr>
<th></th>
<th>Model 3</th>
<th></th>
<th></th>
<th></th>
<th>Model 4</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\beta)</td>
<td>(P)</td>
<td>(\beta)</td>
<td>(P)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Observation-level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pokémon GO or not(^1) (refer=not)</td>
<td>0.093</td>
<td>&lt;.001</td>
<td>***</td>
<td>0.072</td>
<td>0.005</td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days played(^2)</td>
<td>-0.004</td>
<td>&lt;.001</td>
<td>***</td>
<td>-0.005</td>
<td>&lt;.001</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weather</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total rainfall</td>
<td>-0.001</td>
<td>0.003</td>
<td>**</td>
<td>-0.001</td>
<td>0.003</td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bright sunshine time</td>
<td>0.003</td>
<td>0.011</td>
<td>*</td>
<td>0.003</td>
<td>0.012</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean air temperature</td>
<td>-0.013</td>
<td>0.010</td>
<td>*</td>
<td>-0.013</td>
<td>0.011</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean wind speed</td>
<td>-0.001</td>
<td>0.037</td>
<td>*</td>
<td>-0.001</td>
<td>0.036</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Player-level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (refer= '&gt;35')</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13-17</td>
<td>-0.068</td>
<td>0.048</td>
<td>*</td>
<td>-0.067</td>
<td>0.047</td>
<td>*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
18-23 -0.007 0.414 -0.007 0.415
24-29 -0.010 0.380 -0.009 0.389
30-35 -0.061 0.031 * -0.061 0.031 *

**Income (HKD) (refer= ‘>30000’)**

| <5000 | -0.024 0.263 | -0.024 0.265 |
| 5000-10000 | -0.122 0.005 ** | -0.122 0.005 ** |
| 10001-15000 | -0.041 0.123 | -0.040 0.125 |
| 15001-20000 | 0.044 0.112 | 0.046 0.103 |
| 20001-30000 | 0.027 0.239 | 0.028 0.227 |

**Gender (refer=Female)**

| Male | 0.040 0.019 * | 0.041 0.017 * |

**Education (refer=High school or lower)**

| College or higher | -0.075 0.037 * | -0.073 0.040 * |

**BMI (refer=normal) (kg/m2)**

| Underweight (BMI<18.5) | -0.074 0.002 ** | -0.073 0.002 ** |
| Overweight and obese (25≤BMI) | -0.052 0.036 * | -0.051 0.038 * |

**Built environment (refer=Office)**

| Mixed use area | 0.032 0.195 | 0.028 0.191 |
| Green space | 0.044 0.068 | 0.001 0.494 |
| Accommodation area | -0.001 0.490 | -0.018 0.309 |
| Retail premises | 0.003 0.460 | 0.001 0.491 |

**interactions**

| Pokémon GO * Mixed use | 0.006 0.437 |
| Pokémon GO * Green space | 0.068 0.028 * |
| Pokémon GO * Accommodation | 0.027 0.210 |
| Pokémon GO * Retail premises | -0.010 0.406 |

* P < 0.05; ** P < 0.01; *** P < 0.001

248 If the data belongs to the date before participant play Pokémon GO, this value would be 0. If the data belongs to the date before participant plays Pokémon GO, this value would be 0. Otherwise, it would be 1.

250 If the data belongs to the date before participant plays Pokémon GO, this value would be 0. Otherwise it would be the number of days they played.

252 The value is equal to the value of Pokémon GO or not multiples built environment. If the participant played Pokémon GO on a day in the related built environment, the value would be 1. Otherwise it would be 0.

Discussion

Principal Results and Comparison with Prior Work

This study reported that after the installation of the game, average daily walking and
running distance of Hong Kong Pokémon GO players increased 18.1% (0.96 km, approximately 1200 steps) when compared with the period before installation, over a period of 35 days. The results were largely consistent with previous studies conducted in the USA. For example, Howe et al. found that the daily average steps for Pokémon GO players during the first week of installation increased by 955 additional steps [21]. Althoff and his colleges indicated that Pokémon Go led to significant increases, more than 25%, 261473 steps per day in physical activity over a period of 30 days [22]. These US studies and our Asia study showed that the Pokémon GO was associated with a 20% increase in physical activity after players installed the game within one month, and provided support for the idea that Pokémon GO may improve public health by promoting physical activity [32, 33, 38, 39].

Our results show that the increase of daily walking and running distance attenuates over time, that is also congruent with previous studies in the USA [21, 22]. However, the speed of attenuation is different between our Asian study and USA ones. While Howe et al. [21] reported that the association was no longer observed after six weeks (42 days), our study indicates that the association is estimated to disappear faster, in 24 days, with players in Hong Kong. That may be because Hong Kong has a relatively fast pace of life [40], which probably also makes it easier for people to lose interest in a game. The high-density built environment lacking spacious places for playing location-based AR games could also be another reason for this difference. If we would like to maximize the positive benefit from the game, initiatives should be taken to find ways to slow down attenuation.

From multilevel models, we find that total rainfall, bright sunshine time, mean air temperature and mean wind speed are significantly related to Pokémon GO players’ physical activity. The link between weather and physical activity is well established. Increased bright sunshine time could increase daily walking [41] and outdoor activities [42]; higher rainfall and wind speed is likely to be associated with lower physical activity level [43-46]; temperature could have different impacts on physical activity across areas and seasons [47]. For the season during which we conducted our study in Hong Kong, we found that bright sunshine time was significantly associated with an increase in players’ daily walking and running distance, while total rainfall, mean air temperature, and mean wind speed were negatively correlated with the distance. To the best of our knowledge, this is the first study that controlled the weather variables to provide a more precise relationship between Pokémon GO behaviour and physical activity. On Dec 7th, 2017, the new version of Pokémon GO has introduced weather features into the game, in addition to the in-game weather visual map, weather near Pokémon players will impact Pokémon in a variety of ways. This update made weather even more important for the players [48].

The relationship between physical activity and built environment has been well investigated in recent decades [17]. As a location-based AR game, Pokémon GO is highly connected with built environment, both of them could be associated with players’ physical activity. In previous studies, however, built environment has not been taken into consideration or showed little impact on physical activity [21, 22]. In this study, we took Pokémon GO together with the built environment, and found that green space has a significant positive relationship with daily walking and running distance (Table 3-2). This
result indicates that Pokémon GO may have encouraged players to use green space around them to do physical activity. Nature-based recreation has decreased 25 percent in the last 40 years [49], which puts us in danger of losing health benefits brought by nature and green space [50]. To solve this problem, Pokémon GO shows a great potential to build the connection between green space and physical activity.

By controlling the weather variable at the observation-level, as well as demographics and built environment at the player-level, results show that players with less daily walking and running distance received stronger association with Pokémon GO, and the association has lasted longer compared with players with relatively more distance before installation. This result confirms the previous intuitions from Hong Kong and the USA, that Pokémon GO is able to reach low activity populations [22, 26]. Governments and public health agencies may consider the possibility of using location-based AR technology to improve physical activity and public health of the society.

Contributions

To the best of our knowledge, this study was one of the earliest and the only field study conducted during the Pokémon GO craze (July to August 2016). There are three main contributions. Firstly, this study combined field survey with automatically recorded physical activity data from mobile devices. The field study could give us the idea of who is playing the game outside and doing the physical activity. Secondly, this paper was the first paper that has investigated the relationship between Pokémon GO and physical activity with weather and built environment added as covariances. Thirdly, the difference of associations between Pokémon GO and physical activity among different players has been investigated in this study. Such information is important to enhance the positive impact brought by games or other interventions in the future. Further, as the first objective physical activity study on Pokémon GO in Asia, this study provides evidence together with other previous studies that Pokémon GO was associated with a short-term physical activity increase worldwide.

Limitations

Our study also has limitations. Firstly, our study population is representative of active Pokémon GO players, it is not a random sample of Hong Kong population. It cannot represent all the Pokémon GO players of Hong Kong. It is possible that some players may only play it at midnight which is not within our survey time, or some people may only play it in a place not similar at all to our study areas. However, it is reasonable to assume that our study population is a representative sample of most Pokémon GO players in Hong Kong. Because participants were randomly picked within five areas represents five typical built environment types, and to play the game, players must go out and move
Secondly, in this one group pretest-posttest design study, we acknowledged that we are missing the control group, but on the other hand, we can’t think of the reasons other than Pokémon GO that brought the physical activity change to participants. During the study time, there is no campaign, parade or other big physical activity-related event happened in Hong Kong, and there is no dramatic change in weather that will lead to a physical activity increase. Further, we used daily walking and running distance as a proxy measurement of physical activity. But we should notice that some other physical activities (e.g., swimming, basketball, etc.) may not be recorded if the players didn’t carry the phone with them when doing those activities.

Conclusions

This research studies 210 Pokémon GO players in Hong Kong during the Pokémon GO craze in 2016. Results indicate that after the installation of the game, the average daily walking and running distance increased 18.1% (0.96 km, approximate 1200 steps) when compared with that before the installation. However, this association attenuates over time and is estimated to disappear after 24 days. Results of multilevel models indicate that weather should be considered in this kind of research, and the association between Pokémon GO and physical activity was stronger among less physically active people than physically active ones. Furthermore, we found that game like Pokémon GO has potential to build new links between humans and green space, to encourage people to do physical activity outside. Having a better understanding of the relationship between Pokémon GO and physical activity may cast light on the global promotion of public health in the future.

Abbreviations

BMI: body mass index
AR: augmented reality

Contributors

BVM is the first author, and SLNG is the corresponding author. BVM, GBS, and SLNG designed the project. BVM, SLNG and GBS collected data. BVM, TS and MDZ analyzed the data. BVM and SLNG wrote the manuscript. All authors contributed to the manuscript. TS, GBS, IK, and JZ provide methodological guidance. SLNG provided financial support for the data collection.

Acknowledgments

The authors thank Hui Lin for advice on the field study.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflicts of Interests
All authors declare: no financial relationships with any organizations that might have an interest in the submitted work and no other relationships or activities that could appear to have influenced the submitted work.

**Ethical approval**

This study was approved by Survey and Behavioral Research Ethics Committee at The Chinese University of Hong Kong on 4 August 2016.

**Data sharing**

The statistical code and dataset are available from the corresponding author.

**Reference**


Blair SN, Church TS. The fitness, obesity, and health equation: is physical activity the common denominator? Jama. 2004;292(10):1232–1234. PMID: 15353537


Blair SN, Church TS. The fitness, obesity, and health equation: is physical activity the common denominator? Jama. 2004;292(10):1232–1234. PMID: 15353537


Howe KB, Suharlim C, Ueda P, Howe D, Kawachi I, Rimm EB. Gotta catch’em all! Pokémon GO and physical activity among young adults: difference in differences study. BMJ. 2016;355:i6270. PMID: 27965211


Lindqvist AK, Castelli D, Hallberg J, Rutberg S. The Praise and Price of Pokémon GO: A Qualitative Study of Children's and Parents' Experiences. JMIR Serious Games. 2018 Jan 3;6(1):e1. PMID: 29298750


McCartney M. Margaret McCartney: Game on for Pokémon Go. BMJ. 2016;354:i4306. doi: https://doi.org/10.1136/bmj.i4306


Wise J. Pokémon Go’s health benefits seem short lived. BMJ. 2016;355. doi: https://doi.org/10.1136/bmj.i6684


Currie JL, Develin E. Stroll your way to well-being: a survey of the perceived benefits, barriers, community support, and stigma associated with pram walking groups designed for new mothers, Sydney, Australia. Health Care Women Int. 2002;23(8):882–893. PMID: 12487703


