Taylor & Francis
Taylor & Francis Group

Behaviour & Information Technology

ISSN: 0144-929X (Print) 1362-3001 (Online) Journal homepage: www.tandfonline.com/journals/tbit20

Gaming for good? exploring associations between game design features and self-reported sustainable behaviours in Pokémon GO

Bastian Kordyaka , Sukran Karaosmanoglu & Samuli Laato

To cite this article: Bastian Kordyaka , Sukran Karaosmanoglu & Samuli Laato (31 Mar 2026): Gaming for good? exploring associations between game design features and self-reported sustainable behaviours in Pokémon GO, Behaviour & Information Technology, DOI: 10.1080/0144929X.2026.2645884

To link to this article: https://doi.org/10.1080/0144929X.2026.2645884

Published online: 31 Mar 2026.

BEHAVIOUR & INFORMATION TECHNOLOGY
https://doi.org/10.1080/0144929X.2026.2645884

Gaming for good? exploring associations between game design features and self-reported sustainable behaviours in Pokémon GO

Bastian Kordyaka[a], Sukran Karaosmanoglu[b] and Samuli Laato[c]

[a]Åbo Akademi University, Turku, Southwest Finland, Finland; [b]Universität Hamburg, Hamburg, Hamburg, Germany; [c]University of Turku, Turku, Southwest Finland, Finland

ABSTRACT

The location-based game (LBG) Pokémon GO remains one of the most successful and widely studied video games of recent years. Designed for outdoor play, LBGs have been associated with increased physical activity and environmental awareness beyond the game context. This study examines how specific game design features in Pokémon GO are associated with players' self-reported sustainable behaviours. Drawing on a motivational framework that categorises design features into the dimensions of achievement, immersion, and social engagement, we analysed online survey data from 303 players. Results showed that (a) only immersion-related features were positively associated with self-reported positive sustainable behaviours, and (b) no significant relationships were found between the motivational dimensions and negative sustainable behaviours. Further analysis indicated that participants' country of residence was a significant factor and that the design feature *reminders, cues, and notifications* accounted for the positive association within the immersion category. Our findings highlight how immersive, human-centred design features may align with sustainability-oriented dispositions, offering new insights into the interplay between game experiences and sustainability values.

ARTICLE HISTORY
Received 24 July 2025
Accepted 5 March 2026

KEYWORDS
Location based games; motivation; sustainable behaviour; gamification; Pokémon GO

1. Introduction

When David Ulmer hid the first geocache – a waterproof container with a logbook and small exchange items – and published its GPS coordinates online, he unknowingly laid the foundation for location-based games (LBGs) (Ihamäki 2015). Unlike traditional video games, LBGs require players to move through the real world to progress, integrating digital experiences with physical spaces to encourage exploration and interaction (Baranowski and Lyons 2020; Nigg, Mateo, and An 2017). The rise of LBGs was driven by two key technological advances: widespread mobile internet access (Buchanan et al. 2001; Chae and Kim 2003) and smartphones like Apple's iPhone (2007) (Goggin 2009). These enabled satellite navigation, real-world maps, and geolocated points of interest for interactive gameplay (Colley et al. 2017; Laato, Kordyaka, and Hamari 2024b; Paavilainen et al. 2017). A defining moment came with Pokémon GO (2016), which introduced LBGs to a mainstream audience, achieving massive commercial success and global recognition. The game uses GPS, smartphone cameras, and motion sensors to place virtual objects, characters, and events in real-world locations, engaging players via an interactive map or augmented reality (AR) (Laato et al. 2024). Previous research suggests that since LBGs blend gameplay with real-world exploration, they encourage outdoor activity and can foster a growing connection to nature (Kordyaka et al. 2024). Such findings highlight the potential of LBGs not only as entertainment but also as tools for ecological and sustainable engagement (Callahan et al. 2019; Mercier, Ertz, and Bocher 2025). These characteristics make LBGs, and Pokémon GO in particular, an ideal context for examining how specific game design features and their underlying motivational categories may relate to players' sustainability-related behaviours.

One of the biggest challenges in today's urbanised societies is to manage natural resources sustainably to maintain the ecological balance i.e. a stable state in an ecosystem where living organisms, physical resources, and environmental processes interact harmoniously, allowing all components to sustain and regulate each other over time), secure the livelihoods of future generations, and minimise the negative consequences of environmental degradation (Dunlap et al. 2000; Warner

CONTACT Bastian Kordyaka bastian.kordyaka@abo.fi Tuomiokirkontori 3, FI-20500 Turku, Finland

et al. 2010). Global problems such as climate change, loss of biodiversity, environmental pollution, and scarcity of resources have prompted researchers in the field of sustainable human-computer interaction (HCI) to investigate how digital solutions can motivate people to take more responsibility for their environment (Khamzina et al. 2020; Spors et al. 2023). The explorations included fostering a sense of responsibility for one's behaviour (awareness) and opportunities to support processes (Kordyaka et al. 2024). Since LBGs are played in real-world environments, they offer the potential to actively engage players with natural spaces and support their interaction with the environment. Nevertheless, the relationship between LBGs and authentic nature experiences remains complex, as the structural and game-related mechanisms of the LBG medium always mediate these experiences. However, the extent to which LBGs resonate with sustainability-oriented behaviours (i.e. concrete, observable actions that contribute to ecological sustainability such as reducing waste, using public transportation, conserving energy, or participating in conservation activities Neher 2018) remains underexplored. Addressing this gap is particularly valuable, as it can clarify whether LBG use is associated with environmental behaviour beyond its relationship with sustainable awareness (Kordyaka et al. 2024).

To understand the interaction between LBGs and sustainable behaviours, we draw on the concept of *gamification*, which emerged in HCI research just over a decade ago and has steadily gained importance (Deterding, Dixon, et al. 2011; Deterding, Sicart, et al. 2011). Gamification is typically defined as the use of game design features in non-game contexts to improve user experience and engagement. In this study, we therefore use gamification research as a conceptual lens to analyze the motivational affordances of *Pokémon GO* as a fully fledged game, rather than claiming that it is itself a 'gamified' system. Prior work has applied gamification concepts to LBGs as platforms for movement and social interaction (Albertarelli et al. 2018; Orji, Nacke, and Marco 2017), highlighting how concrete game design features can scaffold desired behaviours (Kordyaka et al. 2024). An established framework for organising such features is the 'Motivations to Play' model, which distinguishes achievement, immersion, and social dimensions of player motivation (Kordyaka et al. 2019; Yee 2006). Specific design features and their perceived relevance, such as rewards, points, levels, and progress systems, can thus be grouped into these three dimensions to capture players' motivation to play (Koivisto and Hamari 2019; Xi and Hamari 2019) and linked empirically to self-reported positive and negative sustainable behaviours in everyday life.

With the present study, we aim to provide an empirical answer to at least two existing research gaps. First, it is currently unclear whether LBG design resonates with sustainable behaviours of players. In contrast to previous studies that focus on players' perceptions of environmental awareness, our study investigates their self-reported frequencies of sustainable behaviours in everyday life (Kordyaka et al. 2024). Second, we address the potential impact of deceptive design in gamification and analyze the extent to which motivational dimensions of gamified design features are associated with positive and negative sustainable behaviour in different ways. In doing so, we examine the extent to which specific game mechanics and design features are associated with environmentally friendly or socially responsible behaviours, or may coincide with unintended effects linked to undesirable behaviours. In this context, we use the terms game mechanics and design features to refer to concrete features of gameplay (e.g. virtual objects, virtual currency) that structure player in-game behaviour and may resonate with real-world sustainable behaviours as well. To address these two research gaps, we conducted a cross-sectional study with players of Pokémon GO. We focus on Pokémon GO as the most widely adopted and long-standing location-based game, offering a strong case for studying how LBG design may resonate with sustainability-oriented behaviours. We use the gamification concept and game motivation as a theoretical framework, which allows us to divide specific design features into three categories: achievement, immersion, and social interaction. Based on earlier work, we first formulate deductive hypotheses regarding potential relationships between game mechanisms and design features and sustainable behaviours of players, which we then test using survey data and methods of covariance-based statistics. We use the term predict in line with the statistical structure of regression models, without implying causal inference due to the cross-sectional nature of our data. In summary, our study answers the following research question:

- ***Research Question:*** *How are motivational design features (achievement, immersion, social) associated with players' self-reported positive and negative sustainable behaviours?*

Our results indicate that (a) only immersion-related features were associated with positive sustainable behaviour, and (b) none of the feature categories showed significant associations with negative sustainable behaviour. Additional analyses indicated that only the design feature *reminders, cues, notifications* was responsible for the positive relationship between the immersion category and positive sustainable behaviour. These findings contribute to ongoing HCI discussions on gamification, sustainability, and digital engagement, and highlight the potential relevance of immersion-related design features for supporting ecological engagement beyond the game context. Accordingly, with our findings, we provide a first step toward understanding how playful technologies might align with sustainability values, while investigating causal effects between design features and sustainability-related behaviours remain as a future direction.

2. Background

To better understand the background of our study, we will illustrate the context of our study Location-Based games in Section 2.1, the framing approach Sustainable HCI in Section 2.2, and the relevant approach with regard to motivational game design Gamification in Section 2.3. Following Deterding, Dixon, et al. (2011) and Deterding, Sicart, et al. (2011), we distinguish between *game* (system) and *play* (activity). For us, *Pokémon GO* is a game; points, levels, AR mechanics, and social functions are game design features (and, where relevant, motivating affordances). We use 'gamification' only to refer to the related research field.

2.1. Location-based games

Location-based games (LBGs) such as *Pokémon GO* combine digital gaming with real-world movement by integrating geolocation, augmented reality, and progression systems into everyday environments. Since its global release in 2016, *Pokémon GO* has brought the LBG genre into the mainstream and inspired new research in HCI, health, and education on location-based interaction and mobile play (Baranowski and Lyons 2020; Laato, Kordyaka, and Hamari 2024a; Paavilainen et al. 2017). Because LBGs embed play in physical places through sustained spatial interaction, ongoing progression, and rule-based mechanisms, they provide a particularly suitable context for studying long-term engagement and environmentally relevant behaviour.

Previous research has examined multiple aspects of location-based AR games, with *Pokémon GO* often serving as the central example. In terms of health and mobility, studies have found that playing *Pokémon GO* can increase walking and physical activity, change everyday movement patterns, and support more active lifestyles (Laato, Kordyaka, et al. 2022; Laato et al. 2024; Rasche, Schlomann, and Mertens 2017). Other work has emphasised social and community dimensions, reporting how the game facilitates prosocial behaviour, local encounters, and community events that can strengthen social ties (Evans et al. 2021; Lawler-Sagarin, Sagarin, and Pederson 2025; Livingston 2022; Pourmand et al. 2017; Riar et al. 2020). A smaller but growing body of research links *Pokémon GO* to environmental or sustainability-related outcomes, suggesting that play can be associated with greater environmental awareness and participation in nature-related activities (Kordyaka et al. 2024); for instance, community day events have been associated with waste collection and tree-planting initiatives that foster environmental engagement (Fernández et al. 2020), and game-related tasks have been proposed as tools for environmental education among young people (Kogan et al. 2017). However, these studies typically treat the game largely as a black box and focus on awareness, physical activity, or participation in specific events rather than systematically relating concrete game design features to patterns of everyday sustainable behaviour, including potentially negative behaviours. Our study builds on this literature by decomposing *Pokémon GO*'s motivational design into achievement, immersion, and social categories and examining how these categories are associated with players' self-reported positive and negative sustainable behaviours across different country contexts.

2.2. Sustainable HCI

Sustainable HCI examines how digital technologies can foster awareness, reflection, and collective engagement around environmental sustainability (Bremer et al. 2023; DiSalvo, Sengers, and Brynjarsdóttir 2010; Knowles et al. 2014). Within this field, research has explored how technological design can support sustainable practices through feedback, persuasion, and participation rather than purely technical optimisation. A central strand of this work is eco-feedback systems, which provide users with real-time information about their environmental impact to encourage more conscious decision-making (Jensen et al. 2021). Closely related are gamified and gameful systems that employ points, challenges, and social comparison to engage users in sustainability-oriented actions, such as conserving energy or reducing waste (Boncu, Candel, and Popa 2022; Janakiraman, Watson, and Watson 2018; Ro et al. 2017). These studies highlight how playful interaction and motivational design can enhance users' environmental awareness and stimulate reflective engagement with sustainability values.

While most sustainability-oriented games are likely to be custom-designed interventions or serious games with explicit ecological goals, the present study shifts attention to a commercial mainstream game – Pokémon GO. By analyzing how its design features – organised into the motivational dimensions of achievement, immersion, and social engagement relate to players' self-reported sustainable behaviours, we extend Sustainable HCI discussions to entertainment contexts. Understanding how everyday digital play aligns with sustainability values requires bridging Sustainable HCI and player motivation frameworks, thereby linking game design research with broader efforts to promote environmentally responsible mindsets.

2.3. Motivational design features in games

Research on gamification has provided valuable insights into how motivational design features can engage users and relate to attitudinal and behavioural outcomes. In line with Deterding, Dixon, et al. (2011) and Deterding, Sicart, et al. (2011), we understand gamification as the use of game design features in non-game contexts. In this study, we build on this conceptual foundation while recognising that *Pokémon GO* is not a gamified application but a fully developed game that incorporates diverse motivational design features. Accordingly, we use concepts from gamification research as an analytical lens to examine *in-game* design features that afford motivation, rather than as indicators of gamification itself. We refer to these in-game features as game design features or motivational affordances of *Pokémon GO*, and we understand these affordances as part of a broader motivational design process that supports playful, meaningful experiences (Hamari, Koivisto, and Sarsa 2014). Previous work has demonstrated the potential of motivational design to enhance user engagement and environmental awareness (Anggarendra and Brereton 2016; Boncu, Candel, and Popa 2022; Kordyaka et al. 2024; Ro et al. 2017), while also cautioning that persuasive or motivational design can entail unintended consequences, such as deceptive or exploitative features that steer users toward undesired behaviours (Bogost 2015; Hadan et al. 2024). For example, loot boxes in video games have been discussed as design features that combine progress rewards with variable reinforcement schedules to encourage repeat purchases (Macey and Hamari 2019; Wardle and Zendle 2021).

The present study focuses on three motivational dimensions that have been widely recognised as fundamental drivers of player motivation in digital games: *achievement*, *immersion*, and *social engagement* (Ryan, Rigby, and Przybylski 2006; Yee 2006). Achievement captures players' desire for mastery and progress, immersion reflects attentional and emotional engagement with the game world, and social engagement refers to interaction and cooperation with others. In the context of *Pokémon GO*, these dimensions provide a concise framework for analyzing how motivational design features are associated with self-reported sustainability-related behaviours.

Motivational design features – often discussed in gamification research – can thus be categorised into three dimensions: (a) an achievement-related category, (b) an immersion-related category, and (c) a socially-related category (Xi and Hamari 2019). Several alternative frameworks for conceptualising game-related motivation exist, such as Self-Determination Theory with its focus on autonomy, competence, and relatedness (Ryan, Rigby, and Przybylski 2006), or broader taxonomies of game features and gamification mechanics (Koivisto and Hamari 2019). However, our study focuses on players' perceived importance of concrete design features in a specific game (e.g. points, levels, virtual objects, social networking tools), rather than on their underlying psychological needs. The achievement-immersion-social framework proposed by Yee (2006) and adapted to game design feature categories in later work (Koivisto and Hamari 2019; Xi and Hamari 2019) is particularly suitable for this purpose because it (a) groups heterogeneous features into a small number of interpretable dimensions that map directly onto our questionnaire items, (b) has been applied successfully in prior gamification research, including in the context of *Pokémon GO* and sustainability (Kordyaka et al. 2024), and (c) allows us to formulate dimension-specific hypotheses that correspond directly to our research question about how different motivational facets relate to positive versus negative sustainable behaviours. Table 1 defines these dimensions and highlights exemplary motivational features for each based on prior research (Koivisto and Hamari 2019; Kordyaka et al. 2024). On this basis, we propose several hypotheses to examine how achievement, immersion, and social motivation in LBGs are associated with players' self-reported positive and negative

Table 1. Motivations to play.

Motivation	Definition	Exemplary features
Achievement	Desire to progress, master challenges, and gain rewards	Points, badges, levels
Immersion	Desire for deep engagement through narratives, exploration, or role-playing	Avatars, reminders, exploration
Social	Desire to interact, compete, or collaborate with others	Multiplayer, social networking

Illustrates the three different motivations to play.

sustainable behaviours in everyday life. We therefore adopt the achievement–immersion–social taxonomy as our primary analytical lens and do not, for instance, organise our measures along Self-Determination Theory's autonomy–competence–relatedness dimensions, because our items target perceived importance of concrete game features rather than basic psychological need satisfaction.

Throughout this paper, we use the term *gamification* in the established sense of applying game design features in non-game contexts to enhance motivation and engagement (Deterding, Dixon, et al. 2011). By contrast, when discussing *Pokémon GO* we refer to its *game design features*, *game mechanics*, or *motivational affordances*, meaning concrete in-game features such as points, levels, reminders, or social networking tools. We use *play* to denote players' situated engagement with the game in everyday life. Finally, we use the term *sustainable behaviour* as shorthand for our two outcome constructs, *self-reported positive* and *self-reported negative sustainable behaviour*, which capture retrospective frequencies of specific environmentally relevant actions based on Dunlap et al. (2000).

In general, we may assume that all three categories of motivational design features (immersion, achievement, social) relate to a more sustainability-oriented playstyle. As a fundamental component of play, *Pokémon GO* encourages outdoor movement and social interaction. Players are exposed to their physical surroundings, and a core tenet of the Pokémon narrative, caring for one's digital creatures, echoes sustainability-related values. Yet a more detailed analysis of how engagement with specific design features corresponds to self-reported sustainable behaviours is warranted.

For the category of motivation achievement, we assume that the corresponding motivational design features, such as progress tracking, badges, or rewards, may be associated with players taking on environmentally friendly challenges in the game, which in turn could relate to sustainable orientations outside the LBG (Koivisto and Hamari 2019). Previous work on gamified systems and exergames has shown that achievement-oriented mechanics can support goal-striving and persistence in health and sustainability-related behaviours, for example by encouraging increased physical activity or repeated engagement with eco-tasks (Boncu, Candel, and Popa 2022; Hamari, Koivisto, and Sarsa 2014; Ro et al. 2017). Such mechanics can scaffold or reinforce existing pro-environmental dispositions rather than undermining them. For example, players may walk longer distances to earn rewards, potentially increasing their awareness of local environmental projects or parks. At the same time, individuals already engaged in sustainable actions may be more attracted to such features because they resonate with their existing dispositions. In line with this literature, we expect that a stronger importance placed on achievement-related features will be positively associated with self-reported positive sustainable behaviour, but will not systematically relate to negative sustainable behaviour. Accordingly, we pose the following hypotheses:

- ***Hypothesis 1a:*** *Engagement with motivational design features in the achievement category is positively associated with self-reported positive sustainable behaviour beyond the game context.*
- ***Hypothesis 1b:*** *Engagement with achievement-related motivational design features is not associated with negative sustainable behaviour beyond the game context.*

We further posit that motivational design features corresponding to the immersion category, such as storytelling, exploration, and reminder functions, may foster a stronger sense of presence and flow in the game world. Immersion in digital games is commonly understood as attentional and emotional absorption in a mediated environment and has been linked to heightened focus on in-game cues, identification with in-game goals or avatars, and positive affect during play. Prior research on exergames suggests that studies on sustained adherence and understanding of long duration play effects remain limited (Karaosmanoglu et al. 2024, 2025). In a location-based game such as *Pokémon GO*, where core activities involve walking, visiting parks, and exploring local landmarks, experiencing these activities as immersive may make them more salient, enjoyable, and meaningful, which can plausibly correspond to more positive evaluations of sustainability-aligned behaviours (Xi and Hamari 2019). For instance, in-game memory functions may prompt reflection when players visit real-world locations like nature reserves, while caring for virtual creatures can reflect or reinforce biophilic tendencies (Balmford et al. 2002). Individuals predisposed toward environmental concern may be particularly drawn to such immersive features. Based on this reasoning, we expect that higher importance placed on immersion-related features will be positively associated with self-reported positive sustainable behaviour, and will not be systematically associated with negative sustainable behaviour. Accordingly, we propose:

- ***Hypothesis 2a:*** *Engagement with motivational design features in the immersion category is positively* *associated with self-reported positive sustainable behaviour beyond the game context.*

- ***Hypothesis 2b:*** *Engagement with immersion-related motivational design features is not associated with negative sustainable behaviour beyond the game context.*

Within the social motivation category, relevant motivational design features, such as multiplayer or social networking features, may correspond to greater interaction among players, both online and offline, fostering local encounters and information exchange about sustainability topics (Hamari, Koivisto, and Sarsa 2014). Prior work on social features in games and gamified systems suggests that social support, cooperation, and social comparison can reinforce engagement with health- and sustainability-oriented activities (Hamari, Koivisto, and Sarsa 2014; Janakiraman, Watson, and Watson 2018; Riar et al. 2020). In the context of *Pokémon GO*, collaborative raids, local player communities, and shared events can create opportunities for discussing environmental issues or participating in sustainability-related initiatives outside the game. At the same time, there is little theoretical reason to expect that valuing these social features would directly promote environmentally harmful behaviours. We therefore expect that stronger importance placed on social design features will be positively associated with self-reported positive sustainable behaviour, but will not be systematically associated with negative sustainable behaviour beyond the game context. Accordingly, we state the following hypotheses:

- ***Hypothesis 3a:*** *Engagement with motivational design features in the social category is positively associated with self-reported positive sustainable behaviour beyond the game context.*
- ***Hypothesis 3b:*** *Engagement with social-related motivational design features is not associated with negative sustainable behaviour beyond the game context.*

3. Methodology

To understand the methodology, we present the Research Design in Section 3.1, Data Collection and Participants in Section 3.2, Data Analysis and Procedure in Section 3.3, and Measurement Instruments in Section 3.4 in the following.

3.1. Research design

To test the hypotheses of our study, we used a quantitative cross-sectional survey design to comprehend the relationships between game design and sustainable behaviours of Pokémon GO players. Figure 1 Research Model with Hypotheses illustrates the postulated hypotheses.

3.2. Data collection and participants

We surveyed *Pokémon GO* players using an online questionnaire (in English) administered through Prolific (https://www.prolific.com/), an online research platform that connects researchers with a large pool of pre-screened participants. Using Prolific's prescreening filters, we restricted eligibility to adults (18 years or older) who reported currently playing *Pokémon GO*. Based on these selection, the Prolific platform manages participant invitations, informed consents, and compensation via its interface. Participation was voluntary and each participant received USD 1.60 for completing the survey. No personally identifiable or sensitive information was collected, and all responses were stored in anonymised form, in line with institutional and national ethical guidelines and the authors' university data protection policies.

An a priori power consideration for multiple regression with three focal predictors and covariates (assuming a medium effect size, $\alpha = .05$, and power = .80) suggested a minimum target sample size of 250-300 participants (Caine 2016; Chow et al. 2017; Zhou, Lu, and Shallah 2023). We therefore aimed for approximately $N \approx 300$ responses. In total, 336 responses were recorded. To ensure high-quality data, we applied a predefined set of response-validity criteria. First, we removed 16 cases with missing values. Second, we embedded instructed-response attention checks (e.g. an item such as 'please add two and three and mark the corresponding answer') and excluded 17 respondents who failed at least one of these items. Third, we inspected the distribution of completion times to flag extremely short durations indicative of speeding. However, no additional cases fell below this threshold after the attention-check exclusions. Finally, we examined response patterns on reverse-coded items for systematic inconsistencies, but this screening did not lead to further removals as well. After applying these criteria, the final analytic sample consisted of 303 participants.

Table 2 summarises the sample characteristics. Participants were predominantly male (57.4%) and between 23 and 35 years old; most held at least a bachelor's degree. The largest country groups were the United States (42.6%), South Africa (19.5%), Portugal (6.3%), and Italy (4.3%). On average, participants reported having started playing *Pokémon GO* almost five years ago in 2019 ($M = 4.83$, $SD = 2.25$) and playing the game

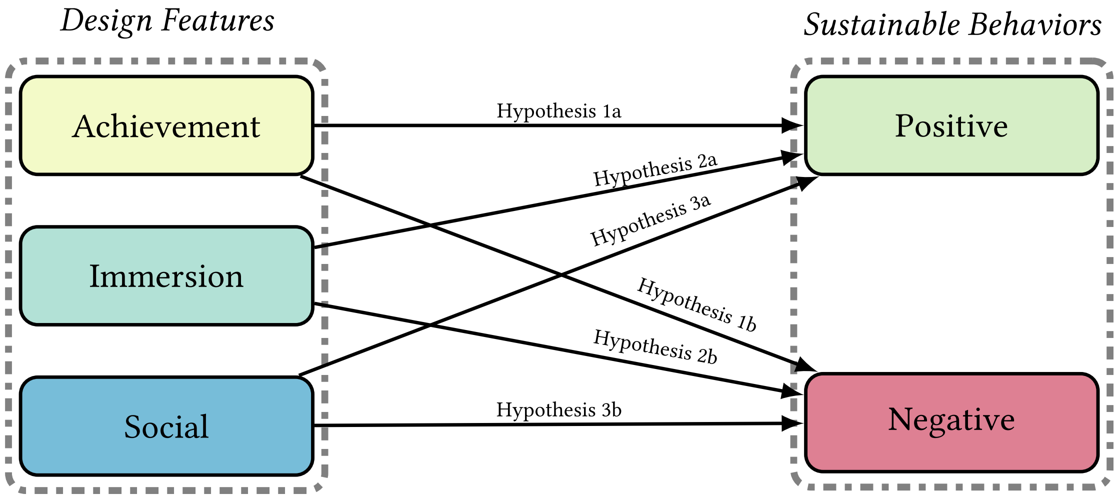

Figure 1. Research model with hypotheses.
A diagram showing the research model with labelled hypotheses arrows.

between two and three times per week ($M = 3.04$, $SD = 1.02$).

3.3. Data analysis and procedure

To test our hypotheses, we conducted a cross-sectional survey to empirically test the relationships between the motivational game design feature categories achievement, immersion, and social, concerning sustainable behaviours. For this, we collected self-reported data from Pokémon GO players using an online questionnaire. We then analysed the data using covariance-based statistics (i.e. regression analysis) and a widely used software application (i.e. SPSS 29).

Table 2. Participant demographics.

Variable	Characteristic	Number	Percentage
Gender			
	Male	174	(57.4%)
	Female	127	(41.9%)
	Other	2	(.7%)
Age			
	Between 18 and 22	33	(10.9%)
	Between 23 and 28	130	(42.9%)
	Between 29 and 35	93	(30.7%)
	Between 36 and 50	35	(11.6%)
	> 50	12	(4.0%)
Education			
	No completed school education	1	(.3%)
	Secondary school	26	(8.6%)
	2–3 years post-secondary education	37	(12.2%)
	Bachelors	164	(54.1%)
	Masters	68	(22.4%)
	Further university education	7	(2.3%)
Country			
	USA	129	(42.6%)
	South Africa	59	(19.5%)
	Portugal	19	(6.3%)
	Italy	13	(4.3%)
	Other	83	(27.4%)

3.4. Measurement model

Drawing on established practices from psychometric research, we used empirically validated scales and items from previous research, adapting them wherever needed to the context of our study. Participants were asked to report their perceptions and behaviours related to their Pokémon GO gameplay. When choosing appropriate measurements, we considered three key criteria: (1) Validity indicators: prioritising measures with established validity and reliability; (2) Contextual relevance: Ensuring that instruments minimise inaccuracies and maximise connectivity to the research context; (3) Feasibility: Factors such as resource constraints, participant burden, and ethical considerations.

To validate the measurement instrument, we examined several validity indicators. First, we evaluated the face validity of our items (Nevo 1985) by testing the instrument with a focus group of three long-time Pokémon GO players before our data collection to identify potential ambiguities in the comprehensibility of the wording and format. All focus group participants indicated that the wording and the format were understandable and clear. Next, we tested for systematic errors using Harman's single-factor test (Aguirre-Urreta and Hu 2019; Fuller et al. 2016). To do this, we entered all items of our five constructs into a factor analysis. Results indicated no single factor dominated the total variance, with the highest eigenvalue explaining only 27%. This suggests that methodological bias is unlikely in this study. In addition, we evaluated the validity of our measurement instrument consisting of motivational game design feature categories, and sustainable behaviours (Diamantopoulos 2008; Diamantopoulos and Winklhofer 2001).

To measure the formative constructs – game design features and sustainable behaviour – of our study, we used, on the one hand, a list of 15 characteristics of relevant game design features in the context of *Pokémon GO* (Koivisto and Hamari 2019; Kordyaka et al. 2024). In the questionnaire, these 15 game design features were introduced with the stem: 'Please indicate how important each of the following game design features is to you when you typically play *Pokémon GO* (1 = "not important at all", 7 = "very important")'. This stem referred to players' general, typical play and did not mention specific in-game events or sustainability-related situations; the five items that later formed the Immersion category are a subset of these 15 features and were presented with the same stem and response format. On the other hand, we used a validated measurement for positive and negative sustainable behaviour, each consisting of five items (Dunlap et al. 2000). These items were introduced with the stem: 'Please indicate how often each of the following statements has applied to you since you started playing *Pokémon GO* (1 = "never", 7 = "very frequently")'. Since (a) the game design features in their entirety define the technological system (in the context of our study, the game *Pokémon GO*) and each feature plays a unique and non-redundant role, and (b) the sustainable behaviours each contribute to a broader concept, we understand both as formative constructs (Diamantopoulos 2008; Diamantopoulos and Winklhofer 2001). To validate these, we followed existing work and conventions (Cenfetelli and Bassellier 2009; Xi and Hamari 2019) for formative measurements and proceeded in two consecutive steps. The full questionnaire, including all item wordings, stems, response scales, and construct assignments, is provided in Appendix, Table A1.

First, we were interested in the underlying dimensional structure and conducted a factor analysis. Based on recommendations from previous work, we decided to extract five factors (e.g. the three motivational game design feature categories achievement, immersion, and social and two factors for positive and negative sustainable behaviour) (Dunlap et al. 2000; Koivisto and Hamari 2019; Yee 2006). On this basis, we conducted a maximum likelihood factor analysis (ML) with varimax rotation.

In the first iteration, the gamification feature competition (*v_GF_5*), showed substantial cross-loading and the feature avatar (*v_GF_7*) a low factor loading of $\lambda = .40$. Both items were excluded from further analysis. In the second iteration of the factor analysis, the gamification feature role-play (*v_GF_9*) exhibited substantial cross-loading and was excluded. After a repeated application of the factor analysis, all items showed acceptable loadings ($\lambda \geq .57$) on one of the five specified factors without any substantial cross-loadings. Standardised composite scores were computed for each factor. Table 3 summarises the results of all formative measures. Specifically, the assignment of items to factors was as follows:

- The first factor captured all five items measuring negative sustainable behaviour (v_Beh_1, v_Beh_2, v_Beh_6, v_Beh_7, v_Beh_9).
- The second factor captured all five items measuring positive sustainable behaviour (v_Beh_3, v_Beh_4, v_Beh_5, v_Beh_8, v_Beh_10).
- The third factor loaded on the five motivational game design features narrative (v_GF_8), motion tracking (v_GF_11), virtual currency (v_GF_12), reminders (v_GF_13), and virtual objects (v_GF_15)). We label this factor *Immersion Category*.
- The fourth factor loaded on the four motivational game design features points (v_GF_1), badges (v_GF_2), levels (v_GF_3), and virtual pets (v_GF_14). We label this factor *Achievement Category*.
- The fifth factor loaded on the three motivational game design features social networking (v_GF_4), multiplayer (v_GF_6), and check-ins (v_GF_10). We label this factor *Social Category*.

Second, we conducted five multiple regression analyses using the formative indicators of the respective factor as independent variables to explain their standardised composite score as a dependent variable. Based on recommendations from previous work (Xi and Hamari 2019), we specified the following two validity criteria: (a) the variance inflation factors (VIF) of all formative indicators must be below 3.3 to rule out multicollinearity as a reference for the convergent validity of the measurement, and (b) as an indicator of convergent validity, the regression weights must be significant.

(1) **Negative Sustainable Behaviour:** The regression analysis of the five negative sustainable behaviour items and the corresponding composite score showed acceptable VIFs (≤ 2.44), and all regression weights were significant (p<.001), confirming the validity of the measurement. Following this, we calculated the mean value of the five items ($M = 4.11$, $SD = 1.60$).
(2) **Positive Sustainable Behaviour:** The initial regression analysis of the five sustainable behaviour items explaining the corresponding composite score identified one item (v_Beh_4) with a VIF of 3.47, exceeding the recommended threshold of 3.3, and was excluded from further analysis. After re-running the regression, all remaining indicators had acceptable VIFs (≤ 3.00), and all four regression weights were highly significant ($p < .001$), confirming

Table 3. Loadings, weights, and VIFs of formative measures.

Factor	Item	Load.	Sig.	VIF
(1) Negative Sustainable Behaviour				
I have never attended a meeting related to ecology	v_Beh_1	.82	$p \leq .001$	2.44
I have never joined a clean-up drive	v_Beh_2	.79	$p \leq .001$	2.04
I have never actually bought a product because it had a lower polluting effect	v_Beh_6	.67	$p \leq .001$	1.58
I do not make a special effort to buy products in recyclable containers	v_Beh_7	.66	$p \leq .001$	1.58
I have never written a politician concerning pollution problems	v_Beh_9	.79	$p \leq .001$	2.34
(2) Positive Sustainable Behaviour				
I have attended a meeting of an organisation specifically concerned with bettering the environment	v_Beh_3	.85		2.49
I have contacted a community agency to find out what I can do about pollution	v_Beh_4	.88	removed	
I have switched products for ecological reasons	v_Beh_5	.68	$p \leq .001$	1.55
I keep track of my politicians' voting records on environmental issues	v_Beh_8	.83	$p \leq .001$	1.26
I subscribe to ecological publications	v_Beh_10	.89	$p \leq .001$	2.58
(3) Immersion Category				
Narrative, storytelling (e.g. the Pokémon world and related stories)	v_GF_8	.63	$p \leq .001$	1.47
Motion tracking (e.g. completing routes and placing lure modules)	v_GF_11	.60	$p \leq .001$	1.46
Virtual currency (e.g. having PokéCoins)	v_GF_12	.69	$p \leq .001$	1.26
Reminders, cues, notifications (e.g. inventory management)	v_GF_13	.65	$p \leq .001$	1.26
Virtual objects as augmented reality (e.g. using AR features)	v_GF_15	.57	$p \leq .001$	1.26
(4) Achievement Category				
Points, score, XP (e.g. number of Pokémon caught)	v_GF_1	.68	$p \leq .001$	1.32
Badges, achievements, medals, trophies (e.g. medals, collector's badge)	v_GF_2	.73	$p \leq .001$	1.37
Levels (e.g. your trainer level and the level of your Pokémon)	v_GF_3	.73	$p \leq .001$	1.31
Virtual pets (e.g. having cute and strong Pokémons)	v_GF_14	.62	$p \leq .001$	1.07
(5) Social Category				
Social networking features (e.g. legendary raids in a team)	v_GF_4	.75	$p \leq .001$	1.35
Multiplayer (e.g. trading with friends)	v_GF_6	.72	$p \leq .001$	1.27
Check-ins, location data (e.g. leaving Pokémon at gyms)	v_GF_10	.60	$p \leq .001$	1.16

validity. Following this, we calculated the mean value of the four items ($M = 4.12$, $SD = 1.59$).

(3) **Immersion Category:** All five formative indicators had VIFs ≤ 1.47, with highly significant regression weights (p<.001). We calculated the mean value of the five items of the Immersion Category ($M = 3.57$, $SD = .76$).

(4) **Achievement Category:** All four formative indicators had VIFs ≤ 1.37 and all regression weights were highly significant (p<.001) showing sufficient values. We calculated the mean value of the four items of the Achievement Category ($M = 4.01$, $SD = .65$).

(5) **Social Category:** All three formative indicators had VIFs ≤ 1.35, and all regression weights were highly significant (p<.001) showing sufficient values. We calculated the mean value of the three items of the Social Category ($M = 3.76$, $SD = .76$).

4. Results

Below, we illustrate the results of our study, comprising the two Sections Hypothesis Testing in Section 4.1 and Additional analysis in Section 4.2.

4.1. Hypothesis testing

To test the hypotheses of our study, we conducted two multiple linear regression analyses. For this, we specified the three motivational categories *achievement, immersion, social* as independent variables to examine their association with the dependent variable *positive sustainable behaviour*. To control for potential confounds, we added the demographic (*age, gender, education, country*) and control variables (*started to play, frequency of play*) as additional independent variables. Checking linearity, residual independence, and multicollinearity, we found no indications of relevant violations in visual diagnostics; the *Durbin–Watson* statistic suggested no substantial autocorrelation ($DW = 1.88$) and *VIFs* indicated low multicollinearity ($VIFs \leq 1.93$) (Savin and White 1977). We, therefore, considered the data suitable for OLS multiple regression. The regression equation showed a significant result ($F(9; 293) = 24.77; p < .001$) that explained 42% of the variance of the dependent variable *positive sustainable behaviour*. After using the Bonferroni correction to control for multiple comparisons (Bender and Lange 2001), the predictor weights of the *immersion category* ($\beta = .24, p < .001$), and the demographics *education* ($\beta = .14, p = .03$), and *country* ($\beta = -.41, p < .001$) significantly predicted *positive sustainable behaviour* (all others $p \geq .40$). Accordingly, these results support H2a but not H1a or H3a, indicating that the immersion category is the only motivational design dimension that shows a significant positive association with *positive sustainable behaviour* over and above education and country (Table 4).

Table 4. Regression explaining positive sustainable behaviour.

Independent variables	β	t	p (uncorrected)	p (Bonferroni-corrected)	VIF
Achievement Category	−.06	−1.08	p = .29	p>.99	1.45
Immersion Category	.24	3.97	p<.001	p<.001	1.93
Social Category	.11	2.06	p = .04	p = .32	1.48
Age	.04	.85	p = .40	p>.99	1.11
Gender	.04	.90	p = .37	p>.99	1.11
Education	.14	3.03	p = .003	p = .03	1.09
Country	−.41	−8.48	p<.001	p<.001	1.20
Started to play	−.11	−2.16	p = .03	p = .36	1.27
Frequency of play	.09	1.87	p = .06	p = .09	1.07

Table 5. Regression explaining negative sustainable behaviour.

Independent variables	β	t	p (uncorrected)	p (Bonferroni-corrected)	VIF
Achievement Category	.06	.96	p = .64	p>.99	1.45
Immersion Category	−.12	−1.64	p = .41	p>.99	1.93
Social Category	−.06	−.92	p = .58	p>.99	1.48
Age	−.03	−.47	p = .56	p>.99	1.11
Gender	−.14	−2.62	p = .08	p = .09	1.11
Education	−.06	−1.05	p = .56	p>.99	1.09
Country	.32	5.70	p<.001	p<.001	1.20
Started to play	.11	1.88	p = .20	p = .61	1.27
Frequency of play	−.03	−.55	p = .61	p = .58	1.08

Second, following the procedure used previously, we specified the variables of the motivational categories *achievement, immersion, social* as independent variables to examine their association with the dependent variable *negative sustainable behaviour*. To control for potential confounds, we added the demographic (*age, gender, education, country*) and control variables (*Started to Play, Frequency of Play*) as additional independent variables. We inspected residual diagnostics to assess linearity and distributional assumptions. We found no indications of problematic multicollinearity (VIFs ≤ 1.93) and no evidence of substantial autocorrelation of residuals (Durbin–Watson = 1.81). Based on these diagnostics, we considered the data suitable for multiple regression (Savin and White 1977).

Based on those indicators, we assumed that our data appeared suitable for covariance-based regression analysis. The regression equation showed a significant result ($F(9; 293) = 9.45; p < .001$) that explained 20% of the variance of the dependent variable *negative sustainable behaviour*. After using the Bonferroni correction to control for multiple comparisons (Bender and Lange 2001), only the demographic variable *country* ($\beta = .32, p < .001$) significantly predicted *negative sustainable behaviour* (all others $p \geq .09$). Accordingly, we did not find significant relationships between any of the motivational feature categories and *negative sustainable behaviour*, providing no evidence to reject the null hypotheses for H1b, H2b, and H3b (Table 5).

4.2. Additional analysis

To gain further empirical insights based on the results of our hypothesis testing, we will now consider the two aspects of (i) Influence of Country in Section 4.2.1 and (ii) the Influence of Immersive Design Features in Section 4.2.2 below.

4.2.1. Influence of country

To further examine the significant association of the demographic variable *country*, we compared levels of *positive sustainable behaviour* and *negative sustainable behaviour* among the four most frequently represented countries in our sample: the United States of America ($n = 129$), South Africa ($n = 59$), Portugal ($n = 19$), and Italy ($n = 13$) (see Table 2). For this analysis, we treated *country* as a nominal variable in SPSS. The results of these comparisons are presented in the paragraphs below.

In the case of *positive sustainable behaviour*, we used *country* as an independent variable in an ANOVA to test group differences regarding the dependent variable *positive sustainable behaviour*. Since the Levene test of the homogeneity of variances showed a significant result, we decided to use the non-parametric Kruskal–Wallis test. The test indicated a significant difference in *positive sustainable behaviour* between the four countries $H(3) = 63.55, p < .001$. Post-hoc pairwise comparisons using the Bonferroni correction revealed that participants from the United States of America reported significantly higher values ($Mdn = 5.16, SD = 1.09$) compared to South Africa ($Mdn = 3.33$, $SD = 1.37$), Portugal ($Mdn = 2.72, SD = 1.55$), and Italy ($Mdn = 3.38$, $SD = .96$). Furthermore, no significant differences were found between South Africa, Portugal, and Italy (all of them $p > .05$). Results are shown in Figure 2 indicating that players from the United States of America reported higher levels of *positive sustainable behaviour* than those from South Africa, Portugal, and Italy, and that there were no significant differences between the remaining three of them.

For the analysis of *negative sustainable behaviour*, we followed the procedure outlined before. We treated *country* as an independent variable and conducted an ANOVA to assess potential group differences. Levene's test for homogeneity of variances was non-significant, $F(3, 216) = .51, p = .68$, indicating no violation of the homogeneity assumption. Accordingly, a parametric one-way ANOVA was conducted to examine whether *negative sustainable behaviour* varied by *country*. The analysis revealed significant differences in *negative sustainable behaviour* between the countries, $F(3, 219) = 52.04, p < .001$, the mean values are illustrated in Figure 3. Using post-hoc tests with Bonferroni correction indicated that participants from the United

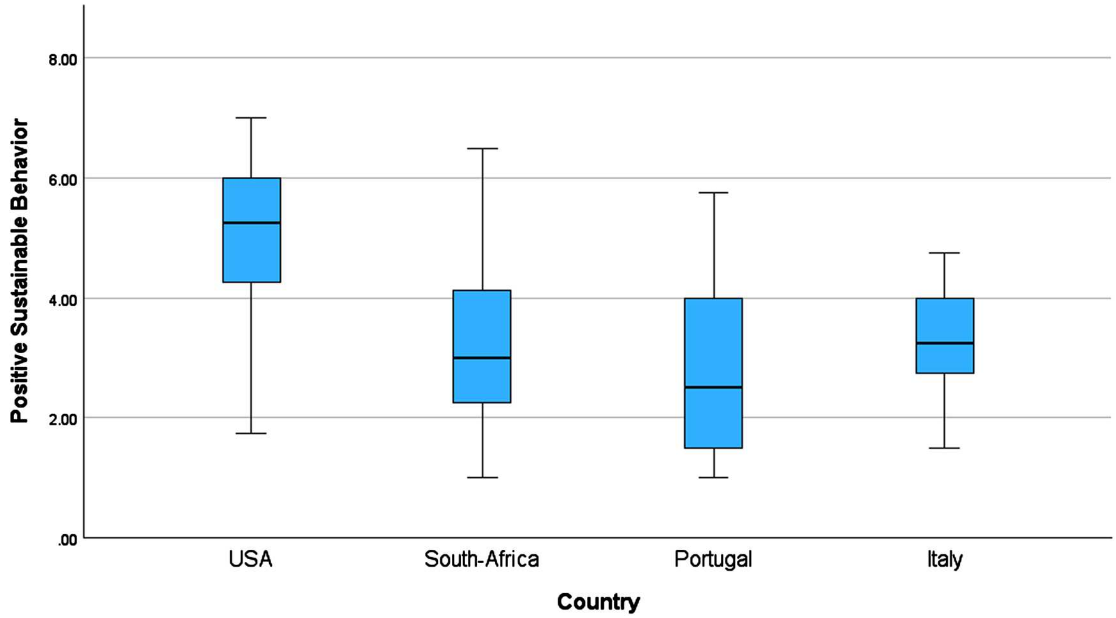

Figure 2. Kruskal–Wallis -- countries and positive sustainable behaviour.
A plot showing Kruskal–Wallis test results for countries and positive sustainable behaviour.

States of America ($M = 3.05$, $SD = 1.22$) reported significantly lower scores than those from South Africa ($M = 5.13$, $SD = 1.05$, $p<.001$), Portugal ($M = 5.31$, $SD = 1.41$, $p<.001$), and Italy ($M = 4.57$, $SD = 1.57$, $p<.001$). No significant differences were found among South Africa, Portugal, and Italy (all $p>.05$). These findings suggest that scores of *negative sustainable behaviour* were significantly lower in the United States of America compared to the other three countries, suggesting potential cross-cultural variation.

4.2.2. Influence of immersive design features

To examine the relationships between the five game design features – narrative and storytelling ($v_G F_8$), motion tracking ($v_G F_1 1$), virtual currency ($v_G F_1 2$), reminders, cues, and notifications ($v_G F_1 3$), and virtual

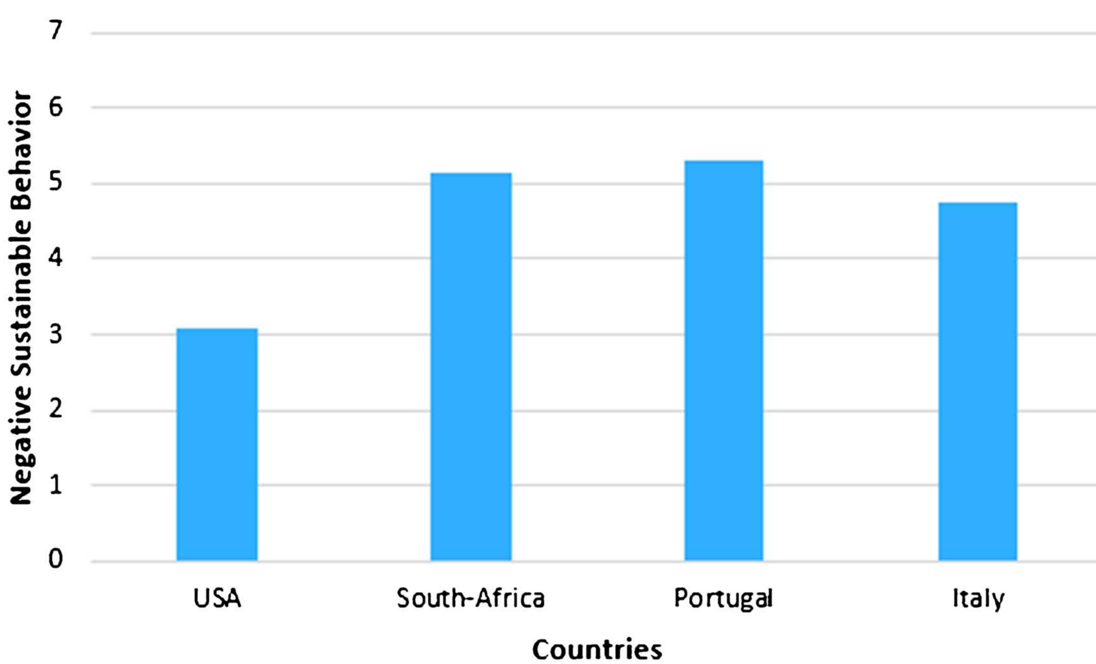

Figure 3. Mean values -- countries and negative sustainable behaviour.
ANOVA Test results for countries and negative sustainable behaviour, as shown in the figure.

objects as augmented reality ($v_G F_1 5$) – and players' *positive sustainable behaviour*, we included these variables as independent predictors in a multiple regression analysis. When testing the assumptions of linearity, autocorrelation, and multicollinearity, the scatter plots, the *Durbin-Watson statistic* ($DW = 2.03$), and the *variance inflation factors* ($VIFs \leq 1.39$) did not indicate any violations (Savin and White 1977). Based on these indicators, we assumed that our data were suitable for a covariance-based regression analysis. The regression equation yielded a significant result ($F(5, 297) = 11.89$; $p < .001$), which explained 17% of the variance of the dependent variable *positive sustainable behaviour*. After applying the Bonferroni correction to control for multiple comparisons (Benjamini and Hochberg 1995), only the variable *reminders, cues, notifications* ($\beta = .23$, $p = .005$) showed a significant association with *positive sustainability behaviour* (all others $p \geq .15$). Accordingly, the design feature *reminders, cues, notifications* appears to be responsible for the positive correlation between the immersion dimension and *positive sustainable behaviour*.

5. Discussion

The following sections outline the discussion phase, covering key findings in Section 5.1, implications for practice in Section 5.2, implications for theory in Section 5.3, and limitations and outlook in Section 5.4.

5.1. Key findings

Based on our study's results, we can now provide empirically-grounded answers to our (***Research Question:*** *How are motivational design features (achievement, immersion, social) associated with players' self-reported positive and negative sustainable behaviours?*). In the following, we summarise and discuss key findings with the following four points:

- First, for *positive sustainable behaviour*, only the immersion category significantly predicted higher levels of positive sustainable behaviour, while achievement and social categories did not. This pattern supports H2a, does not support H1a and H3a, and answers the 'positive' part of our research question by highlighting immersion as the only motivational design dimension associated with self-reported positive sustainable behaviours.
- Second, for *negative sustainable behaviour*, none of the three motivational categories showed a statistically significant relationship. This is consistent with retaining the null hypotheses H1b, H2b, and H3b and indicates that, within our model, motivational design features are not systematically associated with more frequent negative sustainable behaviours.
- Third, additional analyses showed that players from the United States of America reported significantly higher levels of positive and lower levels of negative sustainable behaviours than players from South Africa, Portugal, and Italy. This extends the main answer to our research question by suggesting that country-level context moderates overall sustainability profiles, above and beyond in-game motivational dimensions.
- Fourth, additional analyses indicated that the specific design feature *reminders, cues, notifications* was the only significant independent predictor within the immersion category for positive sustainable behaviour. This refines our interpretation of H2a by showing that the observed association between immersion and positive sustainable behaviour is primarily is likely associated with interaction-based game features rather than all immersion-related features equally.

Our findings both converge with and diverge from prior work on *Pokémon GO*. In line with studies showing that *Pokémon GO* can foster physical activity, outdoor mobility, and nature-related engagement (Kordyaka et al. 2024; Laato, Kordyaka, et al. 2022; Laato et al. 2024; Rasche, Schlomann, and Mertens 2017), we also observe positive associations between aspects of play and sustainability-related outcomes. However, rather than treating the game as a black box, our analysis decomposes its motivational design and suggests that immersion-related features,especially reminders, cues, and notifications, are most closely associated with self-reported positive sustainable behaviour. This partly contrasts with work emphasising social and community effects of *Pokémon GO* (Lawler-Sagarin, Sagarin, and Pederson 2025; Livingston 2022; Pourmand et al. 2017; Riar et al. 2020), as our social motivation category did not show direct associations with sustainability behaviours. A plausible interpretation is that social affordances primarily support community building and coordination, whereas concrete ecological actions may be more tightly cued by immersive, context-sensitive interaction mechanisms (e.g. reminders or eco-themed events) and by players' broader sustainability orientations.

5.2. Implications for practice

The results of this study provide several actionable insights for practitioners, particularly regarding the role of immersive game features in LBGs such as Pokémon GO in relation to sustainable behaviours. Four of these insights are discussed below.

First, our results showed that only the immersion category significantly predicted participants' positive sustainable behaviour. This finding suggests that immersive game features (e.g. narrative experiences) may be particularly relevant when designing LBGs aimed at supporting sustainable behaviour (Laato, Galeote, et al. 2022). In our data, this immersion category is primarily carried by reminders, cues, and notifications, which suggests that relatively small, context-sensitive prompts may be especially important leverage points for supporting sustainable behaviours. Developers can use these features to create engaging environmental experiences that may support players in connecting with nature and adopting more sustainable habits. Furthermore, the insignificant relationships of the other two motivational categories (e.g. achievement, social) suggest that (a) extrinsic incentives in the achievement category may not strongly predict real-world environmental action, and (b) merely fostering social connections in games might not be enough to support real environmental behaviour.

Second, our empirical insight that none of the three motivational categories significantly predicted negative sustainable behaviour indicates that concerns about misleading uses of motivational game design in this context (deceptive design) seem rather unfounded. Opposed to this, we argue that if gamification were manipulative in a way that would be associated with unsustainable (negative) behaviour, we might have expected a significant prediction for at least one of the three categories. However, the absence of a significant relationship indicates that the mechanics of gamification alone are not statistically associated with negative sustainable behaviour. This result challenges the notion that players in gamified systems are oftentimes nudged to act against their interests or those of society, as suggested in research on the deceptive design of gamification (Bogost 2015; Goethe 2020; Rakovic and Inal 2023). Rather, our results suggest that factors unrelated to motivation are more decisive for the development of negative sustainable behaviours outside the game. While ethical concerns about misleading gamification practices in other contexts remain relevant, our study provides no significant empirical indicator that the motivational design features of *Pokémon GO* predict unsustainable action in the real world.

Furthermore, significant differences across countries in positive and negative sustainable behaviour indicate that regional cultural factors may be associated with how players engage with sustainability in Pokémon GO. Specifically, results showed that players from the United States of America displayed more positive and less negative sustainable behaviour than players from Europe (Portugal, Italy) and South Africa. We see this as an indication that contextual factors may play an important role in shaping sustainability-related behaviours in the real world. This underscores the need for region-specific adaptations of playful interventions and underlines the added value of cross-cultural perspectives (Krishna, Sahay, and Walsham 2004; Tractinsky 1997).

Finally, our further analysis showed that the design feature *reminders, cues, notifications* was significantly responsible for the positive prediction of the immersion category on positive sustainable behaviour. This leads to the recommendation that designers of LBGs, who want to support sustainable behaviour, should not rely exclusively on immersive storytelling, but should rather integrate reminders, cues, and notifications. This suggests that micro-interventions, such as context-sensitive reminders, are potentially more effective in influencing behaviour in the context of sustainability goals than comprehensive, narrative design features.

5.3. Implications for theory

Based on the results of our study, several important implications can also be drawn at the theoretical level to refine existing HCI models for gamification and sustainable player behaviour, as well as to improve framework conditions. In the following, we discuss four of them that seem particularly relevant.

First, we understand the finding that only the immersion category significantly predicted positive sustainable behaviour in a way that emotional and cognitive engagement with the game world is a crucial factor for sustainability in the real world. This supports theories that emphasise the role of experiential and affective engagement in shaping behaviour, such as environmental psychology, which suggests that stronger connections to a virtual or augmented environment may predict greater awareness, appreciation, and sustainability-related engagement in the real world. It also refines existing gamification and motivation theories by indicating that immersive experiences – rather than extrinsic rewards (achievements) or social factors – may be more closely associated with environmentally friendly behaviour. This suggests that gamification research should move beyond traditional incentive-based models and focus more on narratives and reminders as mechanisms for behaviour change (Xi and Hamari 2019; Yee 2006).

Second, our finding that none of the motivation categories significantly predicted negative sustainable behaviour indicates that gamification mechanisms alone do not necessarily encourage unsustainable actions. This challenge concerns the misleading design in gamification, as it suggests that the categories of achievement, immersion, and social motivation are not systematically associated with harmful environmental behaviour. Instead, it suggests that external factors, such as cultural norms, infrastructure, or personal habits, may be more significant in shaping adverse outcomes. This insight refines gamification and behavioural science theories by highlighting that motivational dimensions of gamified design features alone cannot explain negative real-world behaviours, suggesting the need for broader ecological models that consider contextual influences on sustainability-related actions.

Third, the significant associations between participants' country and both positive and negative sustainable behaviour suggests that responses to gamification may vary depending on cultural and structural factors rather than being universally applicable. This calls into question individual-centred gamification theories and underscores the need for context-based models that integrate macro-level influences on player demographics. Previous research already applied Hofstede's cultural dimensions that indicate some added value in the context of our study as well (Kordyaka et al. 2023; Simon 2001). Future research should incorporate cross-cultural perspectives to understand how gamification may be related with regional sustainability norms and behaviours.

Lastly, the identification of the design feature *reminders, cues, notifications* within the broader immersion category accounts for the positive association with positive sustainable behaviour. This challenges the assumption that all immersion-related features contribute equally and enables a more differentiated understanding of the construct. It suggests that immersion is not a single, uniform driver of behaviour but a composite of distinct mechanisms that may exert varying influences. The result aligns more closely with theories of behavioural nudging and environmental cues than with concepts of deep psychological immersion, such as narrative transport or flow (Acquisti et al. 2017; Peifer et al. 2021). In this light, the explanatory power lies in the interaction-level mechanisms. Accordingly, our findings indicate that behaviour-based outcomes (i.e. sustainable behaviour) are most likely driven by interaction-based game features within the immersion category. While these features typically require active engagement with a system (e.g. by confirming a notification), other features of the immersion category (e.g. narrative, storytelling) might not necessarily need an active involvement but can be experienced through passive participation (e.g. listening).

5.4. Limitations and outlook

As with any empirical research, the present work has some limitations, which must be considered when classifying the empirical knowledge derived. In the following, some of these limitations are discussed, and we show how they can be used in future research to ensure the validity of this study's results. First, data were collected with the support of Prolific (an online research platform), which is a diverse, cost-effective, and scalable source of participants. To ensure the quality of our data, we implemented various so-called response validity indicators, such as insufficient response time, comparing backward-coded items, and using several attention tests to ensure the quality of our data. Second, we focussed exclusively on Pokémon GO as a context. This was intentional, as the game can be seen as the spearhead of LBGs, and to avoid introducing unnecessary distortions from different games into our research design. Nevertheless, we recommend prospective research to apply our results to other LBGs, such as Ingress or Zombies, Run, to examine the extent to which there are similarities and differences at a more detailed level than the empirical results of the present study. Third, we collected self-reported survey data from Pokémon GO players, which is an aspect that should be taken into account when interpreting the results of our study. This was intentional since we were interested in better understanding how specific design features are perceived by players, and self-reported surveys can be a valuable tool to capture the corresponding subjective experiences and frequencies of sustainable behaviours. Nevertheless, these measures remain retrospective self-reports and are subject to recall and social desirability biases; they should therefore be interpreted as perceived behavioural tendencies rather than verified behavioural records. Future studies should aim to triangulate our insights with behavioural data, such as location tracking or ecological behaviour logs. Fourth, while our regression analyses model directional associations from game design features to sustainable behaviours, we emphasise that the cross-sectional nature of our study precludes causal inference. The reported associations should be understood as theory-informed correlations rather than evidence of causality. We use the term 'predict' in line with the statistical structure of regression models, while acknowledging that our cross-sectional design does not allow for causal inference. However, we strongly encourage future research to employ (quasi-)experimental designs to examine alternative directionalities – such as treating sustainable behaviour as either an independent or a dependent variable. Fifth, our sample included participants from multiple countries that emerged organically through Prolific recruitment. While this provided geographic diversity, the imbalance in sample sizes, particularly the dominance of U.S. participants, limits the generalizability of our results. We see this unexpected pattern as a prompt for more cross-cultural research in HCI (Kordyaka et al. 2023). Sixth, the construct validity of our key indices warrants caution. The three motivational feature dimensions and the positive/negative sustainable behaviour indices are based on adapted item lists rather than instruments that were purpose-built and validated for the specific combination of LBG play and sustainability. Our factor-analytic results show that the empirically derived immersion dimension includes items (e.g. virtual currency, reminders) that the original taxonomy classified as miscellaneous (Koivisto and Hamari 2019), suggesting some conceptual overlap in how players perceive different game features. Likewise, the sustainable behaviour items emphasise a relatively narrow set of ecological actions (e.g. attending meetings, contacting politicians, subscribing to publications) and may not fully capture more mundane, everyday sustainability practices (e.g. transportation choices, household energy use). Future work should develop and validate richer, context-specific measures that combine broader item pools, confirmatory factor analyses across independent samples, and, where feasible, behavioural or log data to triangulate self-reports. Seventh, although our overall sample size ($N = 303$) is adequate for the specified regression models according to our a priori power analysis, it is still modest for detecting small effects and for subgroup comparisons (e.g. between countries). As such, the generalizability of our findings, particularly regarding cross-cultural differences, should be interpreted with caution, and future work would benefit from larger and more balanced samples.

6. Conclusion

Our results highlight the relevance of the immersion category of game design in its association with positive sustainable behaviour outside of the game by playing Pokémon GO. Opposed to this, the two categories, achievement and social, did not significantly predict positive sustainable behaviour. Furthermore, as we hypothesised, none of the motivational categories significantly predicted negative sustainable behaviour beyond what could be expected by chance. This suggests that other factors may play a more important role in shaping these adverse outcomes. Taken together, the results offer a nuanced understanding of how motivational design in LBGs are associated with real-world action. By demonstrating the unique role of immersion-based mechanisms, our study advances research in sustainable and green HCI and human-centred gamification. Our findings offer actionable guidance for designing location-based applications that support pro-environmental behaviour through user-centred design of technology.

Author contributions

CRediT: **Bastian Kordyaka:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing; **Sukran Karaosmanoglu:** Conceptualization, Software, Visualization, Writing - original draft, Writing - review & editing; **Samuli Laato:** Conceptualization, Supervision, Writing - review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Acquisti, Alessandro, Idris Adjerid, Rebecca Balebako, Laura Brandimarte, Lorrie Faith Cranor, Saranga Komanduri, Pedro Giovanni Leon, et al. 2017. "Nudges for Privacy and Security: Understanding and Assisting Users' Choices Online." *ACM Computing Surveys* 50 (3): Article 44, 41 pages. https://doi.org/10.1145/3054926.

Aguirre-Urreta, Miguel I., and Jiang Hu. 2019. "Detecting Common Method Bias: Performance of the Harman's Single-Factor Test." *ACM SIGMIS Database: The DATABASE for Advances in Information Systems* 50 (2): 45–70. https://doi.org/10.1145/3330472.3330477.

Albertarelli, Spartaco, Piero Fraternali, Sergio Herrera, Mark Melenhorst, Jasminko Novak, Chiara Pasini, Andrea-Emilio Rizzoli, and Cristina Rottondi. 2018. "A Survey on the Design of Gamified Systems for Energy and Water Sustainability." *Games* 9 (3): 38. https://doi.org/10.3390/g9030038.

Anggarendra, Riga, and Margot Brereton. 2016. "Engaging Children with Nature through Environmental HCI." In *Proceedings of the 28th Australian Conference on Computer-Human Interaction (Launceston, Tasmania, Australia) (OzCHI '16)*, 310–315. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3010915.3010981.

Balmford, Andrew, Lizzie Clegg, Tim Coulson, and Jennie Taylor. 2002. "Why Conservationists Should Heed Pokémon." *Science* 295 (5564): 2367–2367. https://doi.org/10.1126/science.295.5564.2367b.

Baranowski, Tom, and Elizabeth J. Lyons. 2020. "Scoping Review of Pokemon Go: Comprehensive Assessment of Augmented Reality for Physical Activity Change." *Games for Health Journal* 9 (2): 71–84. https://doi.org/10.1089/g4h.2019.0034.

Bender, Ralf, and Stefan Lange. 2001. "Adjusting for Multiple Testing—When and How?" *Journal of Clinical Epidemiology* 54 (4): 343–349. https://doi.org/10.1016/S0895-4356(00)00314-0.

Benjamini, Yoav, and Yosef Hochberg. 1995. "Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing." *Journal of the Royal Statistical Society: Series B (Methodological)* 57 (1): 289–300. https://doi.org/10.1111/j.2517-6161.1995.tb02031.x.

Bogost, Ian. 2015. "Why Gamification Is Bullshit." In *The Gameful World: Approaches, Issues, Applications*, edited by Steffen P. Walz and Sebastian Deterding, 65–80. Cambridge, MA: MIT Press. https://doi.org/10.7551/mitpress/9780262028004.003.0004.

Boncu, Ştefan, Octav-Sorin Candel, and Nicoleta Laura Popa. 2022. "Gameful Green: A Systematic Review on the Use of Serious Computer Games and Gamified Mobile Apps to Foster Pro-environmental Information, Attitudes and Behaviors." *Sustainability* 14 (16): 1–10. https://doi.org/10.3390/su141610400.

Bremer, Christina, Harshit Gujral, Michelle Lin, Lily Hinkers, Christoph Becker, and Vlad C. Coroamă. 2023. "How Viable Are Energy Savings in Smart Homes? A Call to Embrace Rebound Effects in Sustainable HCI." *ACM Journal on Computing and Sustainable Societies* 1 (1): Article 4, 24 pages. https://doi.org/10.1145/3608115.

Buchanan, George, Sarah Farrant, Matt Jones, Harold Thimbleby, Gary Marsden, and Michael Pazzani. 2001. "Improving Mobile Internet Usability." In *Proceedings of the 10th International Conference on World Wide Web (Hong Kong, Hong Kong) (WWW '01)*, 673–680. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/371920.372181.

Caine, Kelly. 2016. "Local Standards for Sample Size at CHI." In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (San Jose, California, USA) (CHI '16)*, 981–992. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/2858036.2858498.

Callahan, Mollie M., Alejandra Echeverri, Derek Ng, Chris Sandbrook, and Andrew Balmford. 2019. "Using the Phylo Card Game to Advance Biodiversity Conservation in an Era of Pokémon." *Palgrave Communications* 5 (1): 1–10. https://doi.org/10.1057/s41599-019-0287-9.

Cenfetelli, Ronald T., and Geneviève Bassellier. 2009. "Interpretation of Formative Measurement in Information Systems Research." *MIS Quarterly* 33 (4): 689–707. https://doi.org/10.2307/20650323.

Chae, Minhee, and Jinwoo Kim. 2003. "What's So Different about the Mobile Internet?" *Communications of the ACM* 46 (12): 240–247. https://doi.org/10.1145/953460.953506.

Chow, Shein-Chung, Jun Shao, Hansheng Wang, and Yuliya Lokhnygina. 2017. *Sample Size Calculations in Clinical Research*. New York: Chapman and Hall/CRC.

Colley, Ashley, Jacob Thebault-Spieker, Allen Yilun Lin, Donald Degraen, Benjamin Fischman, Jonna Häkkilä, Kate Kuehl, et al. 2017. "The Geography of Pokémon GO: Beneficial and Problematic Effects on Places and Movement." In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (Denver, Colorado, USA) (CHI '17)*, 1179–1192. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3025453.3025495.

Deterding, Sebastian, Dan Dixon, Rilla Khaled, and Lennart Nacke. 2011. "From Game Design Elements to Gamefulness: Defining Gamification." In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments (Tampere, Finland) (MindTrek '11)*, 9–15. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/2181037.2181040.

Deterding, Sebastian, Miguel Sicart, Lennart Nacke, Kenton O'Hara, and Dan Dixon. 2011. "Gamification. Using Game-Design Elements in Non-gaming Contexts." In *CHI '11 Extended Abstracts on Human Factors in Computing Systems (Vancouver, BC, Canada) (CHI EA '11)*, 2425–2428. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/1979742.1979575.

Diamantopoulos, Adamantios. 2008. "Formative Indicators: Introduction to the Special Issue." *Journal of Business Research* 61 (12): 1201–1202. https://doi.org/10.1016/j.jbusres.2008.01.008.

Diamantopoulos, Adamantios, and Heidi M. Winklhofer. 2001. "Index Construction with Formative Indicators: An Alternative to Scale Development." *Journal of Marketing Research* 38 (2): 269–277. https://doi.org/10.1509/jmkr.38.2.269.18845.

DiSalvo, Carl, Phoebe Sengers, and Hrönn Brynjarsdóttir. 2010. "Mapping the Landscape of Sustainable HCI." In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Atlanta, Georgia, USA) (CHI '10)*, 1975–1984. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/1753326.1753625.

Dunlap, Riley E., Kent D. Van Liere, Angela G. Mertig, and Robert Emmet Jones. 2000. "New Trends in Measuring Environmental Attitudes: Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale." *Journal of Social Issues* 56 (3): 425–442. https://doi.org/10.1111/0022-4537.00176.

Evans, Jocelyn, Sara Z. Evans, Daniel B. Shank, and Quinton P. Fallon. 2021. "Motivations for Social Interaction: The Case of Pokémon Go after the Fad Ended." *Social Science Quarterly* 102 (1): 547–551. https://doi.org/10.1111/ssqu.12880.

Fernández, César, María Asunción Vicente, Irene Carrillo, Mercedes Guilabert, and José Joaquín Mira. 2020. "Factors Influencing the Smartphone Usage Behavior of Pedestrians: Observational Study on "Spanish Smombies"." *Journal of Medical Internet Research* 22 (8): e19350. https://doi.org/10.2196/19350.

Fuller, Christie M., Marcia J. Simmering, Guclu Atinc, Yasemin Atinc, and Barry J. Babin. 2016. "Common Methods Variance Detection in Business Research." *Journal of Business Research* 69 (8): 3192–3198. https://doi.org/10.1016/j.jbusres.2015.12.008.

Goethe, Ole. 2020. "Gamification for Good: Addressing Dark Patterns in Gamified UX Design." In *The Digital Gaming Handbook*, 53–62. Boca Raton, FL: CRC Press.

Goggin, Gerard. 2009. "Adapting the Mobile Phone: The IPhone and Its Consumption." *Continuum* 23 (2): 231–244. https://doi.org/10.1080/10304310802710546.

Hadan, Hilda, Lydia Choong, Leah Zhang-Kennedy, and Lennart E. Nacke. 2024. "Deceived by Immersion: A Systematic Analysis of Deceptive Design in Extended Reality." *ACM Computing Surveys*56 (10): Article 250, 25 pages. https://doi.org/10.1145/3659945.

Hamari, Juho, Jonna Koivisto, and Harri Sarsa. 2014. "Does Gamification Work?—A Literature Review of Empirical Studies on Gamification." In *2014 47th Hawaii International Conference on System Sciences*, 3025–3034. Hawaii, USA: IEEE. https://doi.org/10.1109/HICSS.2014.377.

Ihamäki, Piret. 2015. "User Experience of Geocaching and Its Application to Tourism and Education." PhD thesis., University of Turku. https://www.researchgate.net/publication/277718005.

Janakiraman, Shamila, Sunnie Lee Watson, and William R. Watson. 2018. "Using Game-Based Learning to Facilitate Attitude Change for Environmental Sustainability." *Journal of Education for Sustainable Development* 12 (2): 176–185. https://doi.org/10.1177/0973408218783286.

Jensen, Rikke Hagensby, Maurizio Teli, Simon Bjerre Jensen, Mikkel Gram, and Mikkel Harboe Sørensen. 2021. "Designing Eco-Feedback Systems for Communities: Interrogating a Techno-Solutionist Vision for Sustainable Communal Energy." In *Proceedings of the 10th International Conference on Communities & Technologies -- Wicked Problems in the Age of Tech (Seattle, WA, USA) (C&T '21)*, 245–257. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3461564.3461581.

Karaosmanoglu, Sukran, Sebastian Cmentowski, Lennart E. Nacke, and Frank Steinicke. 2024. "Born to Run, Programmed to Play: Mapping the Extended Reality Exergames Landscape." In *Proceedings of the CHI Conference on Human Factors in Computing Systems (Honolulu, HI, USA) (CHI '24)*, Article 309, 28 pages. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3613904.3642124.

Karaosmanoglu, Sukran, Sebastian Cmentowski, Lennart E. Nacke, and Frank Steinicke. 2025. "ExerCube Vs. Virtual Reality: A Comparative Study of Exergame Technologies for Older Adults." *Proceedings of the ACM on Human-Computer Interaction* 9 (6): Article GAMES008, 24 pages. https://doi.org/10.1145/3748603.

Khamzina, Madina, Kaustubh V Parab, Ruopeng An, Tiffany Bullard, and Diana S Grigsby-Toussaint. 2020. "Impact of Pokémon Go on Physical Activity: A Systematic Review and Meta-analysis." *American Journal of Preventive Medicine*58 (2): 270–282. https://doi.org/10.1016/j.amepre.2019.09.005.

Knowles, Bran, Lynne Blair, Stuart Walker, Paul Coulton, Lisa Thomas, and Louise Mullagh. 2014. "Patterns of Persuasion for Sustainability." In *Proceedings of the 2014 Conference on Designing Interactive Systems (Vancouver, BC, Canada) (DIS '14)*, 1035–1044. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/2598510.2598536.

Kogan, Lori, Peter Hellyer, Colleen Duncan, and Regina Schoenfeld-Tacher. 2017. "A Pilot Investigation of the Physical and Psychological Benefits of Playing Pokémon GO for Dog Owners." *Computers in Human Behavior* 76:431–437. https://doi.org/10.1016/j.chb.2017.07.043.

Koivisto, Jonna, and Juho Hamari. 2019. "The Rise of Motivational Information Systems: A Review of Gamification Research." *International Journal of Information Management* 45:191–210. https://doi.org/10.1016/j.ijinfomgt.2018.10.013.

Kordyaka, Bastian, Katharina Jahn, Marius Müller, and Björn Niehaves. 2019. "The Comparative Self: Understanding the Motivation to Play and the Subsequent Video Game Use." In *Proceedings of DiGRA 2019 Conference: Game, Play and the Emerging Ludo-Mix*, 1–19. Kyoto, Japan: Digital Games Research Association (DiGRA). https://doi.org/10.26503/dl.v2019i1.1080.

Kordyaka, Bastian, Samuli Laato, Sebastian Weber, Juho Hamari, and Bjoern Niehaves. 2024. "Exploring the Association between Engagement with Location-Based Game Features and Getting Inspired About Environmental Issues and Nature." In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems (Honolulu, HI, USA) (CHI '24)*, Article 755, 15 pages. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3613904.3642786.

Kordyaka, Bastian, Solip Park, Jeanine Krath, and Samuli Laato. 2023. "Exploring the Relationship Between Offline Cultural Environments and Toxic Behavior Tendencies in Multiplayer Online Games." *ACM Transactions on Social Computing* 6 (1-2): 1–20. https://doi.org/10.1145/3580346.

Krishna, S., Sundeep Sahay, and Geoff Walsham. 2004. "Managing Cross-Cultural Issues in Global Software Outsourcing." *Communications of the ACM* 47 (4): 62–66. https://doi.org/10.1145/975817.975818.

Laato, Samuli, Daniel Fernández Galeote, Ferran Altarriba Bertran, and Juho Hamari. 2022. "Balancing the Augmented Experience: Design Tensions in the Location-Based Game Pikmin Bloom." In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems (New Orleans, LA, USA) (CHI EA '22)*, Article 325, 7 pages. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3491101.3519785.

Laato, Samuli, Bastian Kordyaka, and Juho Hamari. 2024a. *A Review of Studies on Location-Based Live-Service Games during the COVID-19 Pandemic: Players' Behavior and Reluctance to Return to the Pre-pandemic State* (1st ed.). Bloomsbury Academic, London, Chapter 3, 155–177..

Laato, Samuli, Bastian Kordyaka, and Juho Hamari. 2024b. "Traumatizing or Just Annoying? Unveiling the Spectrum of Gamer Toxicity in the Starcraft II Community." In *Proceedings of the CHI Conference on Human Factors in Computing Systems*, 1–18. Honolulu, USA: ACM. https://doi.org/10.1145/3613904.3642137.

Laato, Samuli, Bastian Kordyaka, A. K. M. Najmul Islam, Konstantinos Papangelis, and Juho Hamari. 2022. "Territorial or Nomadic? Geo-Social Determinants of Location-Based IT Use: A Study in Pokemon GO." *Internet Research* 32 (7): 330–353. https://doi.org/10.1108/INTR-11-2021-0863.

Laato, Samuli, Sampsa Rauti, Bastian Kordyaka, Konstantinos Papangelis, Sangwon Jung, Timo Nummenmaa, and Juho Hamari. 2024. "Gamification of Walking in Nature: A Field Experiment with Pokémon GO Routes." *Proceedings of the ACM on Human-Computer Interaction* 8 (CHI

PLAY): Article 310, 25 pages. https://doi.org/10.1145/3677075.
Lawler-Sagarin, Kimberly A., Brad J. Sagarin, and Andrew Pederson. 2025. "Enhanced Community through Augmented Reality: Social Benefits of Pokémon Go." *Psychological Reports* 128 (5): 3428–3440. https://doi.org/10.1177/00332941231197155.
Livingston, Anne S. 2022. "Technology That Inspires a Connection to Nature: Reframing the Role of Technology in Outdoor Engagement and Conservation." *Journal of Outdoor Recreation, Education, and Leadership* 14 (1): 87–94. https://doi.org/10.18666/JOREL-2022-V14-I1-11136.
Macey, Joseph, and Juho Hamari. 2019. "eSports, Skins and Loot Boxes: Participants, Practices and Problematic Behaviour Associated with Emergent Forms of Gambling." *New Media & Society* 21 (1): 20–41. https://doi.org/10.1177/1461444818786216.
Mercier, Julien, Olivier Ertz, and Erwan Bocher. 2025. ""Look at the Trees": A Verbal Nudge to Reduce Screen Time When Learning Biodiversity with Augmented Reality." *Computers in Human Behavior Reports* 18:100614. https://doi.org/10.1016/j.chbr.2025.100614.
Neher, Deborah A. 2018. "Ecological Sustainability in Agricultural Systems: Definition and Measurement." In *Sustainable Agricultural Systems*, edited by Clive A. Edwards, Rattan Lal, Patrick Madden, Robert H. Miller, and Gary House, 51–61. Boca Raton, FL: CRC Press. https://doi.org/10.1201/9780203750582-5.
Nevo, Baruch. 1985. "Face Validity Revisited." *Journal of Educational Measurement* 22 (4): 287–293. https://doi.org/10.1111/j.1745-3984.1985.tb01065.x.
Nigg, Claudio R., Desiree Joi Mateo, and Jiyoung An. 2017. "Pokémon GO May Increase Physical Activity and Decrease Sedentary Behaviors." *American Journal of Public Health* 107 (1): 37–38. https://doi.org/10.2105/AJPH.2016.303532.
Orji, Rita, Lennart E. Nacke, and Chrysanne Di Marco. 2017. "Towards Personality-Driven Persuasive Health Games and Gamified Systems." In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (Denver, Colorado, USA) (CHI '17)*, 1015–1027. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3025453.3025577.
Paavilainen, Janne, Hannu Korhonen, Kati Alha, Jaakko Stenros, Elina Koskinen, and Frans Mayra. 2017. "The Pokémon GO Experience: A Location-Based Augmented Reality Mobile Game Goes Mainstream." In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (Denver, Colorado, USA) (CHI '17)*, 2493–2498. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3025453.3025871.
Peifer, Corinna, Anita Pollak, Olaf Flak, Adrian Pyszka, Muhammad Adeel Nisar, Muhammad Tausif Irshad, Marcin Grzegorzek, Bastian Kordyaka, and Barbara Kożusznik. 2021. "The Symphony of Team Flow in Virtual Teams. Using Artificial Intelligence for Its Recognition and Promotion." *Frontiers in Psychology* 12:1–14. https://doi.org/10.3389/fpsyg.2021.697093.
Pourmand, Ali, Kevin Lombardi, Evan Kuhl, and Francis O'Connell. 2017. "Videogame-Related Illness and Injury: A Review of the Literature and Predictions for Pokémon GO!." *Games for Health Journal* 6 (1): 9–18. https://doi.org/10.1089/g4h.2016.0090.
Rakovic, Ivana, and Yasemin Inal. 2023. "Dark Finance: Exploring Deceptive Design in Investment Apps." In *Human-Computer Interaction – INTERACT 2023 (Lecture Notes in Computer Science, Vol. 14142)*, edited by José Abdelnour Nocera, María Kristín Lárusdóttir, Helen Petrie, Alessandra Piccinno, and Marco Winckler, 352–371. Cham: Springer. https://doi.org/10.1007/978-3-031-42280-5_20.
Rasche, Peter, Anna Schlomann, and Alexander Mertens. 2017. "Who Is Still Playing Pokémon Go? A Web-Based Survey." *JMIR Serious Games* 5 (2): e7197. https://doi.org/10.2196/games.7197.
Riar, Marc, Benedikt Morschheuser, Juho Hamari, and Rüdiger Zarnekow. 2020. "How Game Features Give Rise to Altruism and Collective Action? Implications for Cultivating Cooperation by Gamification." In *Proceedings of the 53rd Annual Hawaii International Conference on System Sciences (HICSS 2020)*, 695–704. Maui, Hawai'i, USA: IEEE Computer Society. https://doi.org/10.24251/HICSS.2020.086.
Ro, Michael, Markus Brauer, Kathy Kuntz, Raj Shukla, and Ingo Bensch. 2017. "Making Cool Choices for Sustainability: Testing the Effectiveness of a Game-Based Approach to Promoting pro-environmental Behaviors." *Journal of Environmental Psychology* 53:20–30. https://doi.org/10.1016/j.jenvp.2017.06.007.
Ryan, Richard M., C. Scott Rigby, and Andrew Przybylski. 2006. "The Motivational Pull of Video Games: A Self-determination Theory Approach." *Motivation and Emotion* 30 (4): 344–360. https://doi.org/10.1007/s11031-006-9051-8.
Savin, Nathan E., and Kenneth J. White. 1977. "The Durbin-Watson Test for Serial Correlation with Extreme Sample Sizes or Many Regressors." *Econometrica: Journal of the Econometric Society* 45 (8): 1989–1996. https://doi.org/10.2307/1914122.
Simon, Steven John. 2001. "The Impact of Culture and Gender on Web Sites: An Empirical Study." *SIGMIS Database* 32 (1): 18–37. https://doi.org/10.1145/506740.506744.
Spors, Velvet, Samuli Laato, Oğuz 'Oz' Buruk, and Juho Hamari. 2023. "Longing to Be the Mountain: A Scoping Review About Nature-Centric, Health-Minded Technologies." In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (Hamburg, Germany) (CHI '23)*, Article 523, 16 pages. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3544548.3581479.
Tractinsky, Noam. 1997. "Aesthetics and Apparent Usability: Empirically Assessing Cultural and Methodological Issues." In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems (Atlanta, Georgia, USA) (CHI '97)*, 115–122. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/258549.258626.
Wardle, Heather, and David Zendle. 2021. "Loot Boxes, Gambling, and Problem Gambling Among Young People: Results from a Cross-Sectional Online Survey." *Cyberpsychology, Behavior, and Social Networking* 24 (4): 267–274. https://doi.org/10.1089/cyber.2020.0299.

Warner, Koko, Mohamed Hamza, Anthony Oliver-Smith, Fabrice Renaud, and Alex Julca. 2010. "Climate Change, Environmental Degradation and Migration." *Natural Hazards* 55:689–715. https://doi.org/10.1007/s11069-009-9419-7.

Xi, Nannan, and Juho Hamari. 2019. "Does Gamification Satisfy Needs? A Study on the Relationship between Gamification Features and Intrinsic Need Satisfaction." *International Journal of Information Management* 46:210–221. https://doi.org/10.1016/j.ijinfomgt.2018.12.002.

Yee, Nick. 2006. "Motivations for Play in Online Games." *CyberPsychology & Behavior* 9 (6): 772–775. https://doi.org/10.1089/cpb.2006.9.772.

Zhou, Jing, Jiannan Lu, and Anas Shallah. 2023. "All About Sample-Size Calculations for A/B Testing: Novel Extensions & Practical Guide." In *Proceedings of the 32nd ACM International Conference on Information and Knowledge Management (Birmingham, United Kingdom) (CIKM '23)*, 3574–3583. New York, NY, USA: Association for Computing Machinery. https://doi.org/10.1145/3583780.3614779.

Appendix

Table A1. Questionnaire of the study.

Construct	ID	Wording	Ref.
Dependent variables		Please indicate how often each of the following statements has applied to you since you started playing *Pokémon GO* (1 = 'never', 7 = 'very frequently').	Dunlap et al. (2000)
Negative sustainable behaviour			
	v_Beh_1	I have never attended a meeting related to ecology.	
	v_Beh_2	I have never joined a clean-up drive.	
	v_Beh_6	I have never actually bought a product because it had a lower polluting effect.	
	v_Beh_7	I do not make a special effort to buy products in recyclable containers.	
	v_Beh_9	I have never written a politician concerning pollution problems.	
Positive sustainable behaviour			
	v_Beh_3	I have attended a meeting of an organisation specifically concerned with bettering the environment.	
	v_Beh_4	I have contacted a community agency to find out what I can do about pollution.	
	v_Beh_5	I have switched products for ecological reasons.	
	v_Beh_8	I keep track of my politicians' voting records on environmental issues.	
	v_Beh_10	I subscribe to ecological publications.	
Independent variables		Please indicate how important each of the following game design features is to you when you typically play *Pokémon GO* (1 = 'not important at all', 7 = 'very important').	Koivisto and Hamari (2019) and Kordyaka et al. (2024) Immersion category
	v_GF_8	Narrative, storytelling (e.g. the Pokémon world and related stories)	
	v_GF_11	Motion tracking (e.g. completing routes and placing lure modules).	
	v_GF_12	Virtual currency (e.g. having PokéCoins).	
	v_GF_13	Reminders, cues, notifications (e.g. inventory management).	
	v_GF_15	Virtual objects as augmented reality (e.g. using AR features).	
Achievement category			
	v_GF_1	Points, score, XP (e.g. number of Pokémon caught).	
	v_GF_2	Badges, achievements, medals, trophies (e.g. medals, collector's badge).	
	v_GF_3	Levels (e.g. your trainer level and the level of your Pokémon).	
	v_GF_14	Virtual pets (e.g. having cute and strong Pokémons).	
Social category			
	v_GF_4	Social networking features (e.g. legendary raids in a team).	
	v_GF_6	Multiplayer (e.g. trading with friends).	
	v_GF_10	Check-ins, location data (e.g. leaving Pokémon at gyms).	
Demographic variables			
	v_DV_1	Age.	
	v_DV_2	Gender.	
	v_DV_3	Education.	
	v_DV_4	Country.	
Control variables			
	v_CV_1	Started to play.	
	v_CV_2	Frequency of play.	

Survey items and constructs of the whole study with references.