Explaining the Outcomes of Social Gamification

A Longitudinal Field Experiment

Zhang, Jun; Jiang, Qiqi; Zhang, Wenping; Kang, Lele; Lowry, Paul Benjamin; Zhang, Xiong

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If you have any questions, would like a copy of the final version of the article, or would like copies of other articles we've published, please contact any of us directly, as follows:

- **Dr. Jun Zhang**
  - School of Information Management
  - Wuhan University, China
  - Email: is_junzhang@whu.edu.cn
  - Website:
- **Dr. Qiqi Jiang**
  - Department of Digitalization
  - Copenhagen Business School
  - Frederiksberg, Denmark
  - Email: qj.digi@cbs.dk
  - Website: https://www.cbs.dk/en/research/departments-and-centres/department-of-digitalization/staff/qjdigi
- ***Dr. Wenping Zhang**
  - School of Information
  - Renmin University of China
  - Email: wpzhang@ruc.edu.cn
  - Website: http://info.ruc.edu.cn/Home/Faculty/Departments/EconomicInformationManagement/48cd198dd2f2420d9f4e7fb5c555f983.htm
- **Dr. Lele Kang**
  - Laboratory of Data Intelligence and Interdisciplinary Innovation
  - School of Information Management
  - Nanjing University
  - Email: lelekang@nju.edu.cn
  - Website: https://im.nju.edu.cn/kll1_en/list.htm
- **Prof. Paul Benjamin Lowry,** Eminent Scholar and Suzanne Parker Thornhill Chair Professor
  - Business Information Technology, Pamplin College of Business
  - Virginia Tech
  - Email: Paul.Lowry.PhD@gmail.com
  - Website: https://sites.google.com/site/professorlowrypaulbenjamin/home
  - System to request Paul's articles: https://seanacademic.qualtrics.com/SE/?SID=SV_7WCaP0V7FA0GWWx
- **Dr. Xiong Zhang**

- Beijing Jiao Tong University
- Email: xiongzhang@bjtu.edu.cn
- Website: http://en.sem.bjtu.edu.cn/show-910-443.html

*corresponding author

Explaining the Outcomes of Social Gamification: A Longitudinal Field Experiment

Jun Zhang
School of Information Management, Wuhan University, 299 Bayi Road, Wuhan 430072, China
is_junzhang@whu.edu.cn

Dr. Zhang is an Associate Professor at the School of Information Management, Wuhan University. He received his PhD degree in Information Systems from the City University of Hong Kong. His research interests include online deviant behavior, information privacy and security, e-health, and human-computer interaction. His research has been published in academic journals and conferences such as *Journal of Management Information Systems, Information Systems Research, Information & Management, Information Technology & People, Computers in Human Behavior, ICIS,* and *PACIS*. He currently serves as an AE editor for the *Communications of the Association for Information Systems.*

Qiqi Jiang
Department of Digitalization, Copenhagen Business School, Frederiksberg, Denmark
qj.digi@cbs.dk

Dr. Jiang is an Associate Professor in the Department of Digitalization at Copenhagen Business School. He received his PhD in Information Systems from City University of Hong Kong. Dr. Jiang is interested in examining the business value of emerging technology, collective intelligence, and management and economy of information and data security. His work has been published or forthcoming in *Journal of Management Information Systems, MIS Quarterly, Journal of the Association for Information Systems, Journal of Strategic Information Systems,* and others.

***Wenping Zhang**
School of Information, Renmin University of China, No. 59 Zhongguancun Street, Haidian district, Beijing 100872, China
wpzhang@ruc.edu.cn

Dr. Zhang is an Associate Professor in School of Information, Renmin University of China. He obtained his PhD in information systems from City University of Hong Kong. His research interests include machine learning, deep learning, interpretable AI, and business analytics. His work has been published in *Journal of Management Information Systems, INFORMS Journal on Computing, Production and Operations Management, Decision Support Systems*, and others.

Lele Kang
Laboratory of Data Intelligence and Interdisciplinary Innovation, School of Information Management, Nanjing University, No. 163 Xianlin Avenue, Nanjing, China
lelekang@nju.edu.cn

Dr. Kang is an Associate Professor of Information Management and Information Systems in School of Information Management, Nanjing University. He is also a member at Laboratory of Data Intelligence and Interdisciplinary Innovation, Nanjing University. He received his PhD in Information Systems from City University of Hong Kong. His current research interests include patent analysis, digital transformation, mobile commerce, and IT-enabled innovation. His research has been published in *Information Systems Research, Journal of the Association for Information Systems, Information & Management, Journal of the Association for Information Science and Technology,* and others.

Paul Benjamin Lowry
Business Information Technology
Pamplin College of Business
Virginia Tech
Pamplin Hall, Suite 1007
880 West Campus Drive
Blacksburg, VA 24061
Paul.Lowry.PhD@gmail.com

Dr. Lowry is an Eminent Scholar and the Suzanne Parker Thornhill Chair Professor in Business Information Technology at the Pamplin College of Business at Virginia Tech where he serves as the BIT PhD and Graduate Programs Director. He is a former tenured Full Professor at both City University of Hong Kong and The University of Hong Kong. He received his PhD in Management Information Systems from the University of Arizona and an MBA from the Marriott School of Business. He has published 270+ publications, including 150+ journal articles in the *Journal of Management Information Systems, Information Systems Research, MIS Quarterly, JAIS, ISJ, EJIS, JSIS, JIT,* and others. He is on the senior board of editors at the *JMIS*. He also is an SE at JAIS and ISJ, and AE at ISR. His research interests include (1) organizational and behavioral security and privacy; (2) online deviance, online harassment, and computer ethics; (3) HCI, social media, and gamification; and (4) business analytics, decision sciences, innovation, and supply chains.

Xiong Zhang
Beijing Jiao Tong University, No.3 Shangyuancun, Haidian District, Beijing 100044, China
xiongzhang@bjtu.edu.cn

Dr. Zhang is an Associate Professor in the Department of Information Management at Beijing Jiao Tong University. He earned his PhD in Information Systems from City University of Hong Kong. Prior to that, he received his bachelor's degree and master's degree from University of Science and Technology of China, and Louisiana State University in the United States. He has published in the *Journal of Management Information Systems, Journal of the Association for Information Systems, Information Systems Frontiers, Information Technology and People, Internet Research, Electronic Commerce Research and Applications, International Conference on Information Systems, Americas Conference on Information Systems, Pacific Asia Conference on Information Systems, Workshop on Information Technologies and Systems*, and so on.

*corresponding author

Abstract

Social gamification, which allows technology users to interact with each other in gamified tasks, has drawn increasing interest due to its effectiveness in facilitating users' game engagement and task efforts. In social gamification, users can compete or cooperate with other users or teams to complete game tasks and achieve game goals. However, it remains unclear how various social interaction mechanisms (SIMs), such as cooperation, interpersonal competition, and intergroup competition, influence gamification outcomes when they are separately or jointly implemented. In addition, the effects of SIMs on experiential and instrumental gamification outcomes have not been well differentiated. In this study, we systematically investigate the influences of these fundamental SIMs, as well as the possible interaction effects among them, on fitness app users' game engagement and fitness behavior. Using a fitness app custom-developed for the Chinese market, *Fitness Castle*, we conducted a longitudinal field experiment to test our proposed model and hypotheses. The results indicate that when separately implemented, cooperation and interpersonal competition can lead to differential instrumental gamification outcomes in the fitness context. We also systematically compare the differential gamification outcomes when cooperation, interpersonal competition, and intergroup competition are combined in various coopetition settings. Our study offers a theory-based framework and design principles for social gamification. Our findings help practitioners better design SIMs in their gamified technologies with the purpose of achieving optimal experiential and instrumental gamification outcomes simultaneously.

Keywords: fitness mobile application, social gamification, interpersonal competition, intergroup competition, cooperation, coopetition, social interaction mechanisms (SIMs), field experiment, game engagement, daily steps

Introduction

Gamification is the application of game design elements and mechanisms to positively change behaviors in non-game contexts, such as business, socialization, or health [66, 110]. A recent report estimated that the direct market value of gamification will reach nearly US$30.7 billion by 2025, compared to US$9.1 billion in 2020 [70]. A well-designed gamified system can increase users' learning motivation and achievement [32, 62, 104], the effectiveness of employee security training [20, 41, 97], and people's motivation to engage in health management practices [30, 54]. Completing these learning, training, job, and fitness tasks is often considered boring and effort-consuming, thus requiring sustained intrinsic motivation and strong willpower. Gamified designs are especially effective for use in tedious tasks because they increase hedonic value, engagement, and sense of achievement during task completion [34]. Gamified features, such as storytelling, role playing, points, badges, and level-ups, have been widely implemented to foster individual intrinsic motivation, leading to greater user engagement [31].

With the wide use of gamified applications (hereafter *apps*), social interaction mechanisms (SIMs) and features such as leaderboards and team-based tasks have been increasingly adopted to encourage engagement and improve task performance (e.g., amount of exercise and learning outcomes). The introduction of SIMs transforms individualistic gamification into social gamification, allowing for user interactions in the game layer. Social gamification thus converts many individual-based tasks (e.g., exercise) into social events [81], as users engage in gamified tasks with others. The design flexibility of and support for SIMs have led to gamification's increasing prevalence in managerial, educational, and healthcare contexts. Liu et al. [66] proposed the "dynamism principle" of gamification design, in which practitioners are encouraged to strengthen user–user interactions in gamified technologies. Compared to individualistic gamification, social gamification can create more immersive experiences by allowing users to interact with other users while using a gamified system [37]. As a result, SIMs in social gamification offer extra social rewards and arouse additional social motivations (e.g., receiving recognition from others) for task completion [7, 99].

Research on leveraging SIMs to improve gamification outcomes has increased recently, with the literature primarily focused on two seemingly dichotomous aspects: (interpersonal) competition and cooperation (see Table A.1 in Appendix A). In our review, we discovered that although both interpersonal competition and cooperation can improve gamification outcomes (e.g., learning performance) in specific contexts, they have serious limitations when implemented separately. For example, although fostering interpersonal competition can increase individual motivation and performance, there are undesirable side effects on teams, including conflicts, pressure on poor performers, and diminishing intrinsic motivation [24, 64]. Similarly, whereas cooperative gamification fosters users' promotive social interactions (e.g., liking and reciprocal behaviors) during task accomplishment [98], it can sometimes induce a social loafing effect (i.e., free riding) that undermines users' task efforts [15, 53]. Given these limitations, Liu et al. [66] proposes that *coopetition*, the joint use of competition and cooperation, is a promising approach to designing social gamification. Preliminary research suggests that in coopetitive settings, gamification outcomes can be maximized [76], because the joint use of competition and cooperation can be complementary and can minimize potential negative effects. However, our literature review also indicates two major research gaps regarding the effects of coopetition in the context of social gamification.

First, aside from a few studies, not all major forms of coopetition have been systematically considered, resulting in oversimplification when applied to gamification. Competition, a fundamental SIM in gamification, can be further categorized as *interpersonal competition* (i.e., competition among individual users) and *intergroup competition* (i.e., competition among groups of users). Accordingly, three different approaches can be used to establish coopetition in social gamification by highlighting the following [58]: (1) *interpersonal coopetition* (cooperation + interpersonal competition) [37], (2) *intergroup coopetition* (cooperation + intergroup competition) [76], or (3) *hybrid coopetition* (cooperation + interpersonal competition + intergroup competition). To the best of our knowledge, no study has considered these three forms or systematically investigated their gamification outcomes. It also remains unclear which type of competition, when integrated with cooperation, can lead to optimal gamification outcomes.

Second, the experiential and instrumental outcomes of coopetitive social gamification have not been well distinguished, resulting in a limited and sometimes contradictory understanding of the effectiveness of coopetition. According to the dual-outcome framework of gamification, the outcomes of gamification should be assessed from both aspects, differentiated as (1) *experiential outcomes* (game-layer outcomes) and (2) *instrumental outcomes* (nongame-layer outcomes) of gamification [66, 94]. Experiential outcomes are primarily related to the experience of playing the game, and they include users' game engagement, enjoyment, curiosity, and satisfaction [24, 61, 66]. Instrumental outcomes reflect users' task efforts toward or performance in completing the instrumental tasks behind the gamified application (e.g., learning outcomes, job performance, and training effectiveness). Many studies have focused only on experiential outcomes while neglecting instrumental outcomes, and vice versa [25, 119, 121]. Some have simply assumed that if SIMs are designed to enhance the user experience and promote technology use, then the instrumental goals of gamified technology can be achieved simultaneously [27, 76]. However, in the new context of social gamification, the influence of specific SIMs on the dual outcomes of gamification may be independent and inconsistent. For example, competition with lower-skilled users can result in improved *instrumental outcomes* (i.e., learning performance), whereas competition with equal-skilled users can lead to improved *experiential outcomes* (i.e., enjoyment, focused immersion, and temporal disassociation) [94]. Although social comparison can increase users' motivation to report phishing attacks in gamified security training (i.e., better experiential outcome), it also leads to increased incorrect reporting and a decreased accuracy rate in reporting (i.e., worse instrumental outcome) [41]. These findings serve as preliminary evidence that experiential and instrumental gamification outcomes are not always congruent. Despite initial evidence, a systematic theoretical understanding of the differential antecedents of the dual outcomes of gamification remains incomplete.

Given these two compelling research gaps, we aim to contribute to the gamification literature by systematically investigating the influence of various SIMs—including pure (interpersonal) competition, pure cooperation, and various forms of coopetition—on experiential and instrumental gamification outcomes. Experiential and instrumental gamification outcomes are integral conditions for the long-term success of gamified technologies—enjoyable experience in the game layer fosters use continuance, while a good instrumental outcome in the real-world task stimulates long-term outcome-oriented use [2]. Thus, to achieve the long-term success of gamification, practitioners need to gain a deeper understanding of the design principles that can achieve optimal experiential and instrumental gamification outcomes simultaneously.

We chose the context of gamified fitness apps (fitApps) to investigate the effects of social gamification for three reasons. First, fitApps represent a large and growing business market with substantial global health implications to which information systems (IS) researchers can contribute because of its unique business, social, and design aspects [40, 68, 101]. There were more than 206.38 million fitApp users worldwide in 2021, and this number will reach approximately 323.27 million by the end of 2026 [57]. Similarly, China had approximately 35 million monthly active fitApp users in 2021 [107]. Aside from established fitApp firms—such as Fitbit, Garmin, Nike, Under Armour, and Adidas—many startups with substantial venture capital have entered this attractive market.

Second, walking-based exercise is regarded by many people as a tedious task, and maintaining consistent exercise requires persistence and willpower [95], but gamification can increase the hedonic value of such sustained tedious tasks. Thus, fitApps can be a particularly suitable context for implementing gamification, especially because fitApp users have high discontinuance and low retention rates, where the highest 30-day retention rate is only around 16–17% for Garmin Connect and Fitbit, with all other apps having single-digit rates [8]. It is thus imperative that the industry improve its designs to motivate user engagement and performance to increase retention rates.

Lastly, walking-based exercise is traditionally "seen as an individual or even solitary practice" [3, p. 824]. This is especially true during and after the lockdowns and social restrictions caused by the COVID-19 pandemic, when people rarely conducted physical exercise with others. Social gamification provides extra opportunities for users to interact with peers in game tasks while completing fitness tasks, even in virtual settings. Hence, fitApps serve as an ideal context in which to investigate the effect of SIMs to deepen the existing understanding of whether game-layer social interactions can be further transformed into desirable outcomes of real-world-layer individual-based instrumental tasks [3].

As our theoretical foundation, we leveraged *social interdependence theory* (SIT) and developed a framework for social gamification. We proposed several ways to transform individualistic gamification into social gamification, including three ways of integrating competition and cooperation to establish a coopetition setting: interpersonal coopetition, intergroup coopetition, and hybrid coopetition. Based on this framework of social gamification, we designed and developed a six-version fitApp. Then, we conducted a longitudinal field experiment with 541 active participants for 9 weeks (63 days) to empirically test the effects of various SIMs on users' game engagement (i.e., *experiential outcome*) and daily steps (i.e., *instrumental outcome*). Our results demonstrate that the two gamification outcomes are not necessarily consistent with each other in the context of social gamification, and hybrid coopetition is an optimized solution that considers both experiential and instrumental outcomes. Our results can thus improve the design of socially gamified technologies.

Theoretical Background and Literature Review on Social Gamification

Social Interdependence Theory

To develop a design framework for social gamification, we draw on SIT, which was originally proposed to understand how individuals' efforts to achieve certain goals are affected by the "states of tension that arise as desired goals are perceived" in a social environment [45, p. 11]. SIT specifies the influence of various goal structures (e.g., competitive or cooperative) on individual- and group-level task outcomes, such as effort and performance. SIT is widely used in educational and managerial research to explain the differential effectiveness of cooperative, competitive, and individualistic tasks [46]. SIT is also used to understand knowledge-sharing behaviors in organizations and social networks [83], as well as client learning outcomes [69]. We thus propose that SIT can be adapted to our fitApps context to explain how user goal structures are shaped in the social gamification context [42, 47].

According to SIT, people are influenced by their social interdependence on others to achieve set goals. *Social interdependence* "exists when the accomplishment of each individual's goals is affected by the actions of others" [84, p. 11], and it is categorized as either positive (or cooperative) or negative (or competitive). *Positive interdependence* occurs in cooperative environments, where individuals can only reach their goals if others achieve theirs, meaning they have mutual interests and shared goals. Tensions can thus arise when people expect others to work harder and help all teammates achieve their goals. By contrast, *negative interdependence* exists when certain people or groups can only reach their goals if other people or groups fail to reach theirs, and this can be categorized as either interpersonal or intergroup negative interdependence. *Interpersonal negative interdependence* derives from conflicting interests or goals between people, whereas *intergroup negative interdependence* derives from conflicting interests or goals between groups. Tensions also emerge in competitive environments, where the desire to win against others manifests as expending more effort or enhancing task performance. In individualistic settings, people have no interdependence because they do not share mutual goals or experience conflicts of interest.

The original SIT adopts an almost one-sided view of the effects of competition and cooperation on task outcomes, where competition is negative and cooperation is positive. Cooperation leads to positive task outcomes, including increased efforts, improved relationships among team members, and better psychological health, whereas competition diminishes these task outcomes [44]. This general conclusion has been validated by a meta-analysis of 148 empirical studies on SIT [92], which demonstrated that a cooperative goal structure outperforms a competitive one in most offline task scenarios.

However, our research challenges the fundamental assumptions of SIT about competition and cooperation in our context of socially gamified fitApps for the following reasons. First, in the extant research, SIT has been widely validated in various offline cooperative settings, where there exists a high degree of task interdependence,[i] such that teammates must actively cooperate with others to complete their teamwork effectively [19]. However, in the context of gamified fitApps, physical exercise, such as walking, is normally individualistic in nature and thus does not require a team or cooperation. Second, unlike traditional offline settings, the purpose of gamification is multifaceted. Gamified app developers expect users not only to perform well in instrumental tasks but also to engage actively with the app. The original SIT does not address how these related yet competing outcomes can be simultaneously achieved. Third, researchers can now readily implement and integrate various SIM designs (i.e., cooperation, interpersonal competition, and intergroup competition) into one gamified online task. Such technological advances enable us to test the complex interaction effects among multiple SIMs not yet achieved in offline settings. We thus extend the original SIT to the gamified fitApps context by systematically revisiting the positive and negative effects of various SIMs, and their interaction effects, on multifaceted gamification outcomes.

Social Interaction Mechanisms (SIMs) in Gamification

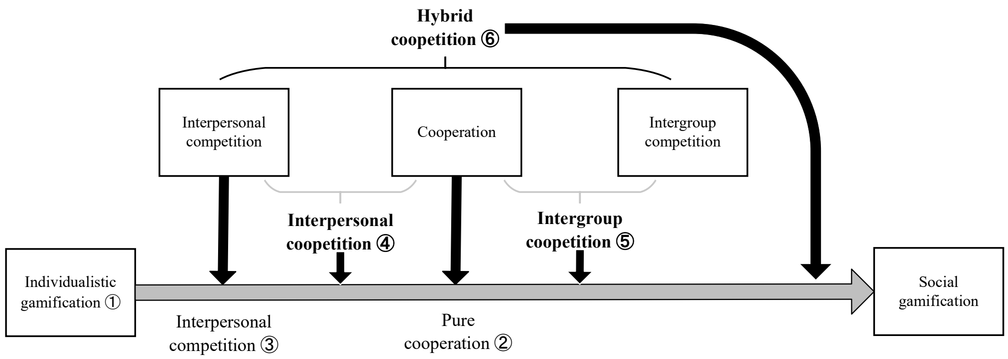
Gamified systems involve two kinds of human–computer interactions that contribute to gamification outcomes: user–system and user–user [66, 74]. Gamification design elements can be categorized as objects and mechanics [66], where the former includes the basic features of a gamified system, including visual assets (e.g., video, audio, and images), interactive components (e.g., buttons, forms, and text boxes), and items or characters (e.g., points, badges, trees, and soldiers), while the latter refers to "the rules that govern the interaction between users and game objects" [66, p. 1014], consisting of narrative mechanics, reward mechanics, and SIMs.

Reward mechanics determine the rules of giving virtual rewards (e.g., users receive one point for every 100 steps) and are supported by game objects, such as points, badges, virtual rewards, and challenges. Such mechanics provide users with timely feedback based on their task performance. *Narrative mechanics* help create an immersive game world with such design features as storytelling, roleplaying, rich graphics, and animation, enhancing engagement [28]. These mechanics represent the essential elements of gamification, and they differ from SIMs that focus on how individual users interact in gamified digital tasks, thereby improving user–user interactions [74]. Many game objects are implemented as SIMs, such as social networking, team-based tasks, and leaderboards [37]. Of the many SIMs, competition and cooperation are the most fundamental [37, 60, 76, 93].

SIT serves as the theoretical lens through which we explain how competition and cooperation can be embedded in gamified tasks. In terms of SIT, the basic SIMs in social gamification include cooperation, interpersonal competition, and intergroup competition [14, 77, 78]. In individualistic games, the design features focus on user performance,[ii] while information about others' task performance is not provided and users do not interact. In a (purely) cooperative game, the design features focus on mechanics and team-based tasks, where feedback is provided based on team members' joint efforts and goals.[iii] In a *competitive* game with either interpersonal or intergroup competition, the design features foster mechanics and tasks related to competitive goals, and feedback is provided based on user/group performance relative to other users/groups.[iv,v]

Figure 1 summarizes the design framework for social gamification SIMs. Cooperation, interpersonal competition, and intergroup competition are the three basic elements of social gamification, and there are six possible combinations for their separate or joint use (i.e., ①–⑥ in Figure 1). Individualistic gamification exists when all three elements are absent, but it can be transformed into social gamification by incorporating competitive or cooperative mechanisms. Notably, cooperation and interpersonal competition can be established independently or simultaneously, but intergroup competition cannot exist without cooperation (Figure 1). Moreover, group tasks and goals serve as preconditions for building intergroup competition, while coopetition can be established by integrating cooperation with (1) interpersonal competition, (2) intergroup competition, or (3) both.

Figure 1. Framework for Establishing Social Gamification



Review of SIM Effects on the Dual Outcomes of Gamification

We performed a literature review of the effects of SIMs on the experiential and instrumental outcomes of gamification, as detailed in Appendix A, revealing several research opportunities concerning the effects of coopetition on dual gamification outcomes.

First, the distinction between the experiential and instrumental outcomes of gamification is lacking in extant research. The terms *experiential* and *instrumental outcomes* derive from the dual-outcome framework of gamification proposed by Liu et al. [66], which suggests that gamification goals are multifaceted. Gamification was originally implemented to influence people's performance in real-world instrumental tasks, such as learning, training, and exercise. However, there has been growing recognition of the experiential values of gamified technologies, such as "fulfillment, enjoyment, satisfaction, and meaningfulness" [66, p. 1014]. Notably, enhanced experiential outcomes are often "coupled with high levels of instrumental outcomes" [66, p. 1025, 113]. However, most existing studies merely assume that the dual outcomes of gamification are concurrent and highly consistent with each other; hence, they can be simultaneously achieved with certain SIMs [27, 76], neglecting the distinct nature of the dual outcomes of gamification. Only a few empirical studies have included both [76, 93, 94, 117, 118], and little attention has been paid to illuminating the different antecedents of experiential and instrumental outcomes. Moreover, in extant studies, game engagement—the most widely recognized experiential outcome—is primarily measured by subjective perceptions, with few studies employing objective behavioral data as a proxy for game engagement. To address these research opportunities, we aim to differentiate the effects of SIMs on the dual outcomes of gamification, including the behavioral experiential outcomes (i.e., users' engagement) and behavioral instrumental outcomes (i.e., daily steps) of fitApp use.

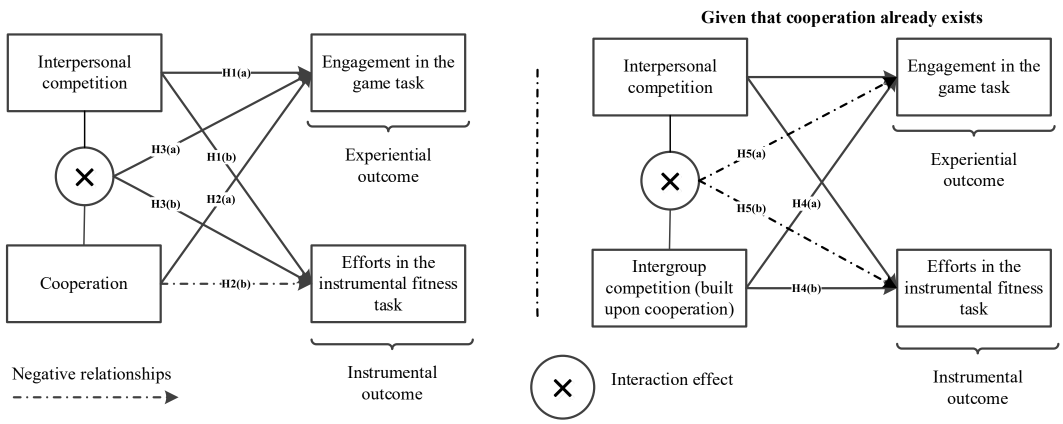
Second, as detailed in Appendix A, most extant studies have focused on gamification outcomes when competition and cooperation are used separately. These studies found mixed effects (both positive and negative) of pure cooperation and pure interpersonal competition on gamification outcomes [88]. There is a lack of empirical evidence and no theoretical explanation for whether competition and cooperation are complementary in minimizing each other's potential negative effects. By considering the mixed effects of pure interpersonal competition and pure cooperation, we further explore the interactive effects when competition and cooperation are jointly used to determine whether their positive or negative effects dominate gamification outcomes in a coopetitive setting.

Third, although competition and cooperation have been widely examined as fundamental SIMs, the various complex SIMs designed for coopetition have not been systematically investigated, especially in the context of gamified fitApps. Interdisciplinary research on SIMs has emphasized the role of coopetition in facilitating task participation and performance [5]. However, few gamification-related studies have examined coopetition, and none have been conducted in the context of fitApps [37, 60, 76, 93]. In these limited works, only one form of coopetition was studied—neglecting the holistic examination of variations in coopetition (i.e., coopetition that emphasizes interpersonal competition or intergroup competition) or differential implications in gamification research. It remains unclear whether interpersonal or intergroup competition should be highlighted in a coopetitive setting and which form of coopetition can generate optimal gamification outcomes. To address this research and practice opportunity, we theoretically distinguish three types of coopetition (interpersonal, intergroup, and hybrid) and conduct an in-depth investigation into their different gamification outcomes.

Theoretical Model and Hypothesis Development

Using our SIT-based framework of social gamification, we derive theory-based hypotheses concerning the direct and interaction effects of the three SIMs on the experiential (i.e., game engagement) and instrumental (i.e., efforts in the instrumental fitness task) outcomes of a socially gamified fitApp, as depicted in Figure 2. Generally, the SIMs in gamified fitApps attempt to facilitate user game engagement and fitness behaviors by establishing individual-based competitive game goals, as well as group-based cooperative and competitive game goals. [vi] Individual users have two options to improve their game performance (individual- or group-based): by exercising or by playing the game more. Thus, cooperative and competitive goals in game tasks are expected to influence users' game engagement and efforts in doing fitness activities.

Figure 2. The Research Model



Specifically, H1–H3 address the direct and interaction effects of cooperation and interpersonal competition, two independent SIMs. H4 addresses the direct effect of intergroup competition, and H5 addresses the substitution effect between intergroup and interpersonal competition. Notably, both H4 and H5 are based on the presumption that cooperative SIMs already exist, because cooperation is the precondition for establishing intergroup competition.

Effects of Interpersonal Competition

Interpersonal competitive elements and mechanisms have been widely adopted in gamified systems to increase users' task engagement and technology use [34, 110]. A competitive mechanism is established when users have conflicting goals, engage in competitive tasks, and receive competitive feedback.

Interpersonal competition can effectively motivate people when there are explicit rules and reasonable chances of winning [44], which applies to almost every instance of rule-based gamification. Compared to pure cooperative gamification experiences, coopetitive gamification can stimulate individual motivation more effectively by highlighting individual achievements, known as *social comparison*, where prior research argues that tend to compare themselves with those having better or similar skill levels[vii] for self-improvement purposes [106]. With the presence of a reference group (e.g., peers on an individual-based leaderboard), users are motivated to devote more effort to competitive tasks to win, perceive a sense of achievement, attempt to improve rankings, and maintain a positive self-image [10]. Hence, competitive environments encourage people to set higher goals [12, 13], further resulting in greater task engagement and efforts [73].

Similarly, interpersonal competition has been leveraged in many fitness gamification designs (e.g., competitive goals, leaderboards, and competitive feedback) to persuade users to compete with each other individually in completing the gamified task [e.g., 38]. When using interpersonal competitive design elements (e.g., competitive goals, leaderboards, competitive feedback) in the fitApp context, users are motivated to adopt social comparison strategies when assessing their task performance [e.g., 38]. Such comparisons arouse the desire for self-improvement and the motivation to defeat others, thereby increasing task effort [101]. In the gamified fitApp context, reward mechanics (e.g., users receive one point for every 100 steps) link users' game performance with both their game playing and their real-world fitness behavior. There are two major approaches to increasing individual-based game performance: (1) playing the game more frequently (e.g., actively collecting virtual items in the game and completing game tasks on time) and (2) performing more exercises in the real world. With a stronger motivation to win an individual-based competition, users are expected to adopt both approaches to increase their game performance. Thus,

H1(a). Compared to individualistic gamification, interpersonal competition leads to an increase in fitApp users' engagement in game tasks.

H1(b). Compared to individualistic gamification, interpersonal competition leads to an increase in fitApp users' efforts in instrumental fitness tasks.

Effects of Pure Cooperation[viii]

In the following sections, we first address the mixed positive and negative effects of pure cooperation on effort and engagement in gamified tasks, and then distinguish the differential effects of pure cooperation on experiential and instrumental gamification outcomes.

Mixed Effects of Constructive and Destructive Cooperation

Competition has been studied much more extensively than cooperation in gamification research; thus, Liu et al. [66] advocated further investigation into the role of cooperation in gamification design. Cooperative SIMs are formed when multiple users share the same tasks and goals and when cooperative feedback is provided. Here, we leverage SIT, which explains three potential beneficial effects of constructive cooperation on task effort and task engagement: (1) promotive interactions and positive cathexis, (2) high inducibility, and (3) psychological health.

First, cooperation leads to *promotive interaction* among cooperators, which occurs when people have mutual goals and interests, and this manifests as an increased likelihood of mutual encouragement for task completion, help, advice, and the exchange of needed resources [45]. To improve team performance, members must behave altruistically by dedicating more effort to the task [48]. When a fitApp offers constructive cooperation, users will expect and encourage each other to make stronger contributions to team-based cooperative tasks, because they maximize users' likelihood of achieving team-based goals [45]. Similarly, constructive cooperation results in *positive cathexis*—that is, a person's "investment of psychological energy in objects outside of oneself" [42, p. 935]. In a cooperative environment, individual users' efforts to complete tasks are substitutable, and users can improve their success by offering social support and encouraging teammates. Thus, cooperative efforts can lead to better task performance than individualistic efforts, as long as cooperation is established constructively [49, 103].

Second, constructive cooperation leads to higher *inducibility*, which is defined as "the openness to being influenced by and to influencing others" [46, p. 366]. When fitApp users have shared goals and interests, they can establish better relationships with each other [42, 45, 46]. A strong bond among users encourages them to "act in trusting and trustworthy ways" [46, p. 368], which can increase trust, empowerment, and social cohesion and inclusion [4]. This bond helps users act in the manner expected by other team members, given that they desire social inclusion. Such conditions can facilitate social learning and influence among teammates, encouraging them devote greater energy to cooperative tasks and expectations [30].

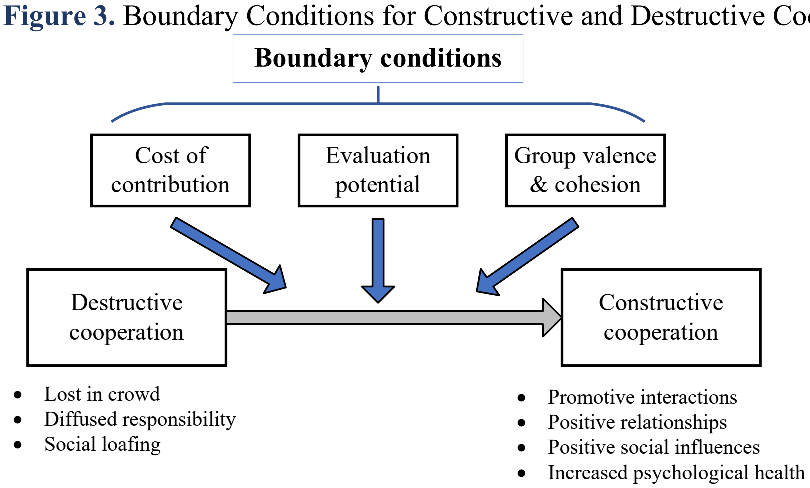
Third, people can build greater self-esteem through constructive cooperation than when completing an individualistic task [6]. A common goal cannot be achieved without coordinating individual efforts.

Thus, each task effort of each individual is potentially conducive to collective performance. Such a setting can encourage fitApp users to identify their self-worth, because their task contributions benefit other teammates, motivating them to maintain self-worth by continuously contributing to cooperative tasks.

However, cooperation can be destructive, because it often leads to *social loafing*, which is an individual's tendency to expend less task effort in a collective setting than in an individual setting [53]. In most cooperative tasks, cooperators share the responsibility for achieving team-based goals, and performance is evaluated at the team rather than the individual level; thus, the responsibility for achieving team-based goals is diffused [112]. People contribute less when task performance is evaluated at the group level, because contributors and free riders share the outcome [55].

In summary, cooperation can be beneficial to team members' task efforts if social loafing is thwarted. Based on this conceptual review, we summarize three boundary conditions for the occurrence of social loafing relevant to the design of fitApps, as depicted in Figure 3. On this foundation, we propose H2–H4.

Figure 3. Boundary Conditions for Constructive and Destructive Cooperation in FitApps



Differential Effects of Pure Cooperation on Game Engagement and Physical Activity

Here, we examine the potential experiential and instrumental outcomes of pure cooperation. Online games (e.g., massively multiplayer online role-playing games [MMORPGs]) and gamified technologies have widely deployed cooperative mechanisms to promote both IT use and associated instrumental outcomes; however, the effects are inconsistent [36, 65, 120]. We posit that an improved understanding of the two distinct outcomes of gamification will lead to a clearer account of such inconsistent effects.

As Figure 3 shows, the cost of contribution can determine the effectiveness of pure cooperation when individuals' inputs are combined with those of other teammates. In a purely cooperative setting, members contribute to the team in exchange for intrinsic rewards or psychological benefits, such as self-esteem, perceived self-worth, and a sense of social inclusion. Thus, when the cost of contribution is low, members are more willing to participate; conversely, when the cost of contribution is high, members have a stronger tendency to become free riders [17, 63, 86].

In the context of fitApps, when pure team-based cooperative game tasks are established, users have two ways to increase their app performance and contribute to the team: (1) engage in the game task more frequently—promoting the *experimental* outcomes of game engagement; or (2) conduct more fitness activities (e.g., walk more steps)—promoting the *instrumental* outcomes of increased physical exercise. Users can choose either or both methods of team contribution; however, the costs differ considerably between the two approaches. Playing the game and collecting the game rewards by simply tapping the screen is much simpler and less time-consuming than physical exercise. Hence, a cooperative setting will increase fitApp users' willingness to use the app and play the game more to improve their performance, because with simple efforts (e.g., playing the game, clicking), they can gain a stronger sense of self-worth; however, when they are required to devote more time and physical strength to improve their game performance, they will be more likely to become free riders on a pure cooperative virtual team. Thus,

H2(a). Compared to individualistic gamification, pure cooperation leads to an increase in fitApp users' engagement in game tasks.

H2(b). Compared to individualistic gamification, pure cooperation leads to a decrease in fitApp users' efforts in instrumental fitness tasks.

Interaction Effects between Interpersonal Competition and Cooperation

The extant literature has investigated the distinct influences of interpersonal competition and cooperation on task effort and performance [49, 65, 94]. Although competition and cooperation are often "conceptualized as two extremes or polar opposites," some researchers have suggested that they "should not be viewed as mutually inconsistent" but instead as partners [115, p. 337] that coexist as parallel motivations and behaviors [115]. For instance, users can be motivated to complete team-based tasks in a gamified context while simultaneously pursuing success in individual performance and high rankings. We refer to this condition as coopetitive gamification.

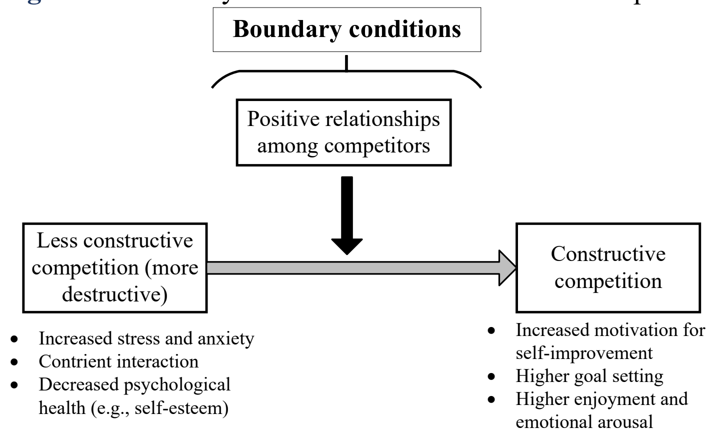
Recall that we focus on three ways to establish coopetition: (1) interpersonal coopetition, (2) intergroup coopetition, and (3) hybrid coopetition. Next, we posit that interpersonal coopetition can positively influence the experiential and instrumental outcomes of gamification through the positive interaction effect between interpersonal competition and cooperation treatments. We assert that the potential negative effects of interpersonal competition and cooperation can be mitigated by combining them in a cooperative setting, and we posit that the integration of these mechanisms is complementary and minimizes the potential negative effects of competition and cooperation.

Cooperation Facilitates Constructive Interpersonal Competition

Substantial research has shown that the influence of interpersonal competition on task efforts and performance is not always positive. [ix] *Destructive interpersonal competition* (or less constructive competition) emerges when relationships among competitors are not positive, leading to various negative behavioral outcomes occurring under three conditions: (1) high performance goals cause emotional distress for users with lower competency and self-efficacy [1, 33]; (2) *contrient interdependence*—in which the actions benefitting some can hurt others—exists among competitors, thus incentivizing them to obstruct "each other's efforts to complete tasks, achieve, or produce" [45, p. 13]; and (3) competition is infused with social harm and failure, which can undermine self-esteem, psychological health, and task engagement [96].

Considering the potential effects of competition, it is crucial to promote constructive and thwart destructive competition in fitApps. Figure 4 summarizes the potential positive and negative outcomes of interpersonal competition and their boundary conditions. Tjosvold et al. [108] explain that interpersonal competition can be constructive when "a strong positive relationship [exists] among competitors" (p. 63). Individual competitors demonstrate respect for and guide each other [96, 108] instead of demonstrating mutual discouragement and obstructing other users. In summary, positive interrelationships and mutual respect among individual competitors can foster proactive, respectful, and constructive interpersonal competition [109]. Thus, the introduction of cooperative mechanisms should promote intimacy among otherwise competitive team members because collective action from collaboration toward a common goal

Figure 4. Boundary Conditions for Constructive Interpersonal Competition



can strengthen interpersonal relationships.

Interpersonal Competition Facilitates Constructive Cooperation

Here, we propose that cooperation can become more constructive when interpersonal competition is incorporated into fitApps. As Figure 3 shows, the second contingency for constructive cooperation is *evaluation potential*, which is the degree to which one perceives their contribution to the team as identifiable and assessable by other team members. When team members believe that their other team members cannot see or evaluate their contributions to the team, they tend to feel lost in the crowd and are reluctant to contribute [53]. Consequently, people tend to reduce their contributions to the team "when their contributions cannot be identified" [43, p. 145], leading to social loafing.

Social loafing can easily take place in a purely cooperative gamified fitApp, because without individual competitive mechanisms, it is difficult to evaluate the contributions of specific team members. However, this downside can be mitigated by leveraging interpersonal competition. The combination of competitive mechanisms and cooperative mechanisms (e.g., adding an individual leaderboard) renders users' game performance visible to other team members, strengthening their sense of social accountability concerning their competency and team performance. An interpersonal competitive environment can also promote self-awareness and inhibit social loafing [53, 87].

Summarizing the above arguments, the combination of interpersonal competition and cooperation in a coopetitive gamified fitApp can lead to less destructive and more constructive competition. Therefore,

H3(a). In interpersonal coopetition settings, there is a positive interaction effect between interpersonal competition and cooperation on fitApp users' game engagement.

H3(b). In interpersonal coopetition settings, there is a positive interaction effect between interpersonal competition and cooperation on fitApp users' efforts in instrumental fitness tasks.

Effects of Intergroup Competition

Intergroup coopetition can be established by integrating competition with cooperation. Although practitioners have widely adopted intergroup competition in gamified technologies, only a few preliminary studies have considered its effects [76]. Notably, intergroup competition should be built on cooperative mechanisms. First, people should be assigned to distinct groups with cooperative, team-based tasks and goals. Second, a competitive mechanism should be provided to encourage competition with other teams.

We posit that because cooperative mechanisms already exist, further incorporating intergroup competition can be beneficial to both the experiential and instrumental outcomes of fitApps for two reasons. First, group-based incentives serve as extra motivation for individuals to exert more effort when playing the game and exercising, because people will receive an additional scarce reward when they help their team outcompete other teams [35].

Second, intergroup coopetition can lead to more constructive cooperation among teammates by inhibiting social loafing in instrumental fitness tasks. Recall that, as Figure 3 shows, the third contingent factor of constructive cooperation is *group valance* (i.e., the extent to which an individual perceives the group as important to their success) [53], or *group cohesiveness* (i.e., "the degree to which group members work together smoothly as a unit and share common goals") [59, p. 269]. Intergroup competition is among the most common approaches to inducing group cohesiveness. In intergroup coopetitive settings, users from the same team share interests and have mutual competitors (i.e., other groups), highlighting collective group goals and shaping a common group identity more effectively [9, p. 130], which can increase group valance and cohesiveness [53].

In summary, in the fitApp context, although performance is assessed on a team basis, when group members perceive the group as important to them, or when the team is highly cohesive, people are more likely to cooperate actively with other members and to contribute by playing the game or exercising more. Consequently, social loafing can be minimized when intergroup competition is added to cooperation:

H4(a). Intergroup competition, which is built on cooperation, is positively related to fitApp users' game engagement (i.e., users demonstrate higher game engagement in intergroup coopetition than in purely cooperative settings).

H4(b). Intergroup competition, which is built on cooperation, is positively related to fitApp users' efforts in the instrumental fitness task (i.e., users engage in more fitness activity in intergroup coopetition than in purely cooperative settings).

Substitution Effects between Interpersonal and Intergroup Competition

As Figure 1 shows, it is possible to create a hybrid coopetitive environment by integrating both interpersonal and intergroup competition with cooperation. MMORPGs, such as *World of Warcraft*, contain both interpersonal and intergroup competitive mechanisms, according to which individual players can fight other individuals, or multiple players can form a team and fight other teams [89, 90]. However, there is little empirical evidence of interaction effects between interpersonal and intergroup competition in hybrid coopetition. We posit that a negative interaction effect (i.e., a substitutional effect) exists between these two types of competition when they are jointly incorporated with cooperation in a hybrid coopetitive setting.

First, this counterintuitive interaction results from the different mechanisms by which the two types of competition (interpersonal and intergroup) facilitate constructive cooperation. Even though purely cooperative settings do not foster social loafing, interpersonal competition accentuates individual evaluation, whereas intergroup competition enhances group cohesion. However, evaluating the individual contributions of team members may undermine team cohesiveness, especially if deviances from expectations are revealed [71] or negative status evaluations ensue [114]. For example, low-ranked users could perceive themselves as a hindrance, while high-ranked users might question the commitment of low-ranked members. This could lead to in-group tensions (or dissatisfaction) and might be detrimental to group cohesion and undermine constructive cooperation in a hybrid coopetition setting.

Second, from a motivational perspective, we argue that interpersonal and intergroup competitive goals can be viewed as two substitute motives. Moreover, two interventions (i.e., interpersonal and intergroup competition) that stimulate two different (and substitute) motives cannot fully exert their effects simultaneously. As discussed previously, people naturally adopt a relatively high self-interest focus during interpersonal coopetition, which further motivates them to pursue competitive interpersonal goals. By contrast, individuals naturally adopt a relatively high collective interest focus in intergroup coopetition and are motivated by intergroup competitive goals [82]. However, hybrid coopetition creates a hybrid reward structure that highlights both collective and self-interests [82]. Under this hybrid-reward structure, individuals value personal and team-based achievements differently [9, 82]. Some users adopt a relatively collectivistic rationale and focus more on collective goals (i.e., helping the team achieve a high rank), while others adopt a relative self-interest rationale and focus more on individual goals (i.e., achieving a high personal ranking) [116]. In our case, intergroup competition can only effectively motivate users who adopt a collective motivation to put more effort into gamified tasks. However, intergroup competition is less effective at motivating users with a self-interest rationale. By contrast, although interpersonal competition works by motivating users with a self-interest rationale, it is relatively ineffective for users with a collective rationale. Hence, we argue that the two competitive goals in hybrid coopetition settings are substitutes for each other due to the individual selective focus on two divergent interests (i.e., individual vs. collective), leading to a lack of cooperation (i.e., "1+1 < 2") in fostering task efforts. In summary,

> **H5(a).** In hybrid coopetition settings, there is a negative interaction effect between interpersonal competition and intergroup competition on fitApp users' game engagement.
>
> **H5(b).** In hybrid coopetition settings, there is a negative interaction effect between interpersonal competition and intergroup competition on fitApp users' efforts in fitness tasks.

Methodology

Using our custom-designed fitApp, *Fitness Castle*, we conducted a series of field experiments to test our hypotheses. We created six experimental groups: the control group used the fitApp without social interaction (i.e., individualistic gamification, Group 1), and five groups (Group 2–6) used various gamified versions of *Fitness Castle* that manipulate the social interactions of cooperation, interpersonal competition, and intergroup competition (see Table 1 and the subsequent section "Field Experiment Design"). Objective usage data from log files were collected in a natural and unobtrusive setting for 9 weeks (63 days), and a post-experiment survey was conducted to gain insight into the underlying mechanisms. The dependent variables measured gaming engagement (frequency of using gamified features) and fitness performance (daily steps) per user per day. Namely, for gaming engagement, we counted the number of clicks on all game-related features (e.g., browsing game rules, collecting cannonballs, and using cannonballs to attack and occupy castles), and we elaborate on our gamification and game-related features in the subsequent section and in Appendices B2–B4.

Table 1. Summary of Experimental Groups

Group number	Cooperation	Interpersonal competition	Intergroup competition	Summary of SIMs	Sample size
Group 1	No	No	No	Individualistic	93
Group 2	No	Yes	No	(Pure) interpersonal competition	83
Group 3	Yes	No	No	(Pure) cooperation	92
Group 4	Yes	Yes	No	Interpersonal coopetition	91
Group 5	Yes	No	Yes	Intergroup coopetition	91
Group 6	Yes	Yes	Yes	Hybrid coopetition	91

Note: As shown in the dotted borders, Groups 1–4 constitute a 2×2 design to test H1–H3, and Groups 3–6 constitute a 2×2 design to test H4–H5.

Prototype and Pilot Test of *Fitness Castle*

We designed *Fitness Castle* for field experimentation, starting with our theoretical foundation and the literature on IT artifact design and evaluation. Similar to most other step-tracking fitApps, *Fitness Castle* can record users' daily physical exercise (steps, active minutes, calories burned) and provide summary statistics of users' physical activities.

Fitness Castle utilizes a story-based game to facilitate users' task efforts and gaming engagement. In this game, users can collect more cannonballs by walking more steps and using virtual items to occupy more castles. The background of the overall story is as follows: The players endeavor to occupy more territorial castles. To do so, it is imperative to search for more cannonballs. The more players walk, the more likely they are to find more cannonballs. When users' daily steps reach a predefined milestone, they receive a corresponding number of cannonballs with which they can attack and occupy territorial castles.

Inspired by other studies [39, 75, 85], we employed a narrative storytelling approach to engage gamification users. To create an immersive story, we employed the think-aloud protocol methodology in usability design research [52, 80]. Appendix B.1 details such procedures in the "Think-Aloud Protocol" section. Ultimately, we reached three key design principles of *Fitness Castle*: "throw-and-take," "multiuser compatibility," and "established elements and stories," which helped us derive the baseline story for *Fitness*

Castle. The overall story is a simplified version of *Clash of Clans*™, where players are required to collect cannonballs to seize territorial castles. To integrate the story into the fitness context, those who walk more can collect more cannonballs. To avoid introducing confounds to the field experiment, *Fitness Castle* has three primary interfaces: basic statistics of daily exercise, a gamification page, and a user account page.

Following prior research [cf. 52], we then created a paper prototype version that we tested with potential end users during a one-day design workshop (see "Paper Prototype Process" in Appendix B.2). We then developed our first app prototype with all functional features by referring to the resulting paper prototype and session notes, and it was advanced artistically by a graphic designer who attended our workshop. We hosted another one-day workshop with newly recruited potential end users to refine the design and confirm the prototype. We then incorporated styling elements into our functional prototype to finalize the development of *Fitness Castle*. Lastly, we recruited another six people as a reviewer panel to conduct a functional pilot test for one week. We processed all the feedback—including bug reports, suggestions for improvement, and complaints—to further improve the *Fitness Castle* design.

Field Experiment Design

We conducted a factorial design with six groups in a longitudinal field experiment with multiple versions of *Fitness Castle*. Rather than using a 2×3 design, we used two 2×2 designs because cooperation serves as a prerequisite for intergroup competition, as detailed in Table 1. Table B.2 details group-level manipulations, and Appendix B provides more gamification design details on *Fitness Castle*. Users in the individualistic group (Group 1; individualistic gamification; control group) had a basic task goal: to occupy more territorial castles by walking more and getting more cannonballs. In the *(pure) interpersonal competition group* (Group 2), users had the same task goal but were also encouraged to improve their individual rankings, and design features, such as individual leaderboards and medals, were adopted to support these goals. In the *(pure) cooperation group* (Group 3), users were encouraged to cooperate with their teammates and complete the basic task goal at the team instead of the individual level; thus, users were allowed to help their teammates collect cannonballs, and the number of occupied castles was determined by the joint efforts of all team members. In the *interpersonal coopetition (cooperation + interpersonal competition) group*

(Group 4), users could see their own rankings but were encouraged to complete the basic task goals at the team level (in cooperation with teammates) and to improve their personal rankings; thus, the features of Groups 2 and 3 were jointly present in Group 4. In the *intergroup coopetition (cooperation + intergroup competition) group* (Group 5), users could see their team rankings and were encouraged to complete the basic task goals at the team level; thus, compared with Group 3, Group 5 had team-based leaderboards that supported competitions among distinct groups. In the *hybrid coopetition group* (Group 6), users could see both their own and the team rankings, and they were encouraged to complete the basic task goals at the team level as well as to improve their personal rankings; thus, such features as team-based tasks, individual-based leaderboards, and group-based leaderboards were jointly present in Group 6.

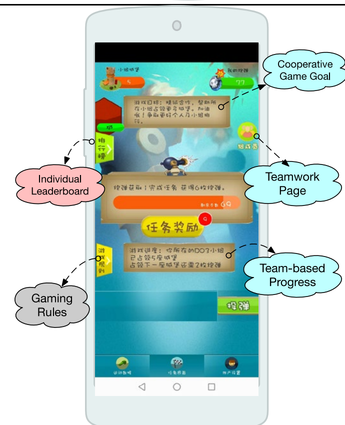
For Groups 3–6, users cooperated with team members in playing the "occupying castles" game. Each team consisted of 4–5 members (based on our randomization algorithm), because according to prior literature on team cooperation, a group size of four to seven is optimal for maximizing cooperative performance [51, 91]. Table 2 presents the factorial design matrix with screenshots of various gamification pages. For brevity, we summarize the steps users take when using *Fitness Castle* and the translation of key buttons ("Process Flow" in Appendix B).

Field Experiment Procedures

To recruit participants, we collaborated with a nonprofit national youth association in China, whose subscribers were mostly recent college graduates or undergraduate and postgraduate students from universities across more than 30 provinces in China. Hence, most potential participants were 18–24 years old. The field experiment was conducted from June–August 2020 (9 weeks, 63 days). The longitudinal design allowed us to collect a rich dataset with 63 day-level repeated observations of the variables of interest, which significantly increased the statistical power for testing the treatment effects of SIMs [29].

This experimental window was also selected to mitigate the potential contamination effect of COVID-19 for two reasons. First, China fully reopened its society in early April 2020. From that time until the first day of our field experiment, the number of new daily cases was under 20; thus, the influence of the pandemic on people's exercise behavior was minimized. Second, the June–August university summer break

Table 2. Factorial Design and Presentation of *Fitness Castle*

<table>
<tr><th></th><th>Without Interpersonal Competition</th><th>With Interpersonal Competition</th><th></th></tr>
<tr><td>Without Cooperation</td><td>
</td><td>
</td><td rowspan="2">Without Intergroup Competition</td></tr>
<tr><td rowspan="2">With Cooperation</td><td>
</td><td>
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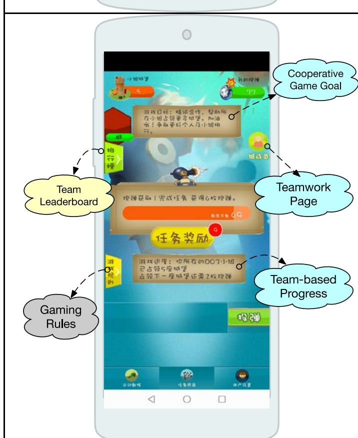
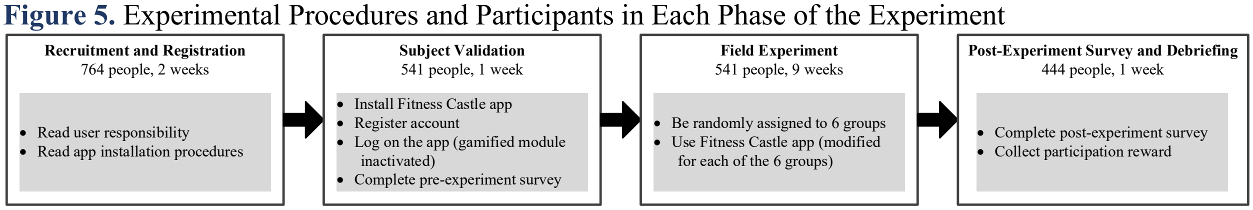
<tr><td>
</td><td>
</td><td>With Intergroup Competition</td></tr>
</table>

minimized other potential confounds in the field experiment. Given that most of our participants were university students, it should have been possible for friends attending the same university to notice each other exercising and possibly communicate about it. However, due to the pandemic, most students did not return to campus until later in January 2020, and a few students returned during the summer break. Thus, conducting the experiment during the summer break minimized these potential experimental confounds.

Figure 5 summarizes the procedures we followed. One week before starting our experiment, the youth association sent advertisement emails to all its mailing list subscribers. The advertisement email included a registration link that redirected potential participants to our registration website. Each participant was presented with an introduction page that contained a description of participant responsibilities and app-installation procedures. On the introduction page, we did not reveal the full purpose of our field experiment. We informed the participants that they were invited to help us with the usability testing of a beta-version fitApp. After the participants installed the app, it presented them with a registration page that contained a pre-experiment survey questionnaire requesting basic demographic information (e.g., height, weight, gender, and experience using fitApps) and asking several psychometric questions [22, 72]. At the end of the pre-experiment survey, an automatically generated random number was presented as the participant's unique identifier, and it was used to randomize the participants into different treatment groups. Starting on June 8, 2020, all participants used *Fitness Castle* for 9 weeks (63 days). At the end of the experimental period, we sent a notification message to all participants via *Fitness Castle* and invited them to complete a post-experiment survey. Lastly, we debriefed the users about the actual purpose of the experiment and transferred their rewards (equivalent to US$30) via Alipay.

Figure 5. Experimental Procedures and Participants in Each Phase of the Experiment



As Figure 5 shows, 764 respondents completed the preregistration, but only 541 respondents were selected as valid participants after they completed a series of required actions (e.g., app installation, account registration, account validation, and logging onto the app one day before the experiment).[x] These 541 participants were evenly distributed into six groups for the longitudinal experiment that took place over 9 weeks. In the end, we obtained 444 complete post-experiment survey responses, which we used for manipulation checks and post hoc analysis. A post hoc statistical power analysis showed that a sample size of 541 for the main hypothesis testing was sufficient to ensure a statistical power of 0.8.

Sample Description

The final sample, used for hypothesis testing, consisted of 541 participants who had installed and registered for *Fitness Castle* and used it for the duration of the 9-week experiment. Among our participants, 252 (46.58%) were male and 289 (53.42%) were female. Most participants were students from over 50 universities across China or people who had graduated from university in the past few years. Approximately 96.49% of the participants were 18–24 years old. As noted, most of the students lived off campus during the experimental period (summer break). We collected the location data of the participants through the app during the experiment and found that the participants lived across 31 different provinces in China. Figure D.1 in Appendix D presents the geographic distribution of our participants. Given that the participants attended different universities or organizations and lived in different cities across China, the possibility of communication among them was minimal.

Data Analysis and Results

We empirically validated the hypotheses by jointly using the self-reported data collected in the pre-experiment survey and objective data reflecting daily fitApp use and physical activity (541 participants × 63 days). Again, the users completed an in-app survey when they installed *Fitness Castle*. For the objective data—gaming engagement (measured by the frequency of using gamified features) and physical activity (measured by daily steps)—we implemented internal tracking middleware to record them, the data for which were uploaded to our server daily [79, 105]. We included the basic demographic and psychometric information of each participant collected pre-experiment as control covariates. We also tracked and validated individual longitudinal and latitudinal geographic data, which helped control for city-level information, such as the daily COVID-19 cases and weather conditions in each city inhabited by the participants. Table D.1 summarizes the definitions of all variables and the descriptive statistics.

Randomization and Manipulation Checks

Before testing the hypotheses, we ran a randomization check of all control covariates (Table D.2). The results from the comparison test revealed no significant differences among the 11 control covariates across the six groups. Table D.3 provides the correlation matrix. Most correlation coefficients were well under 0.6, which indicated that multicollinearity was not a major concern in the regression analysis. The only exceptional cases were the correlations among weight, height, and gender. As expected, males had much higher height and weight than females, and height and weight had a strong positive linear relationship.

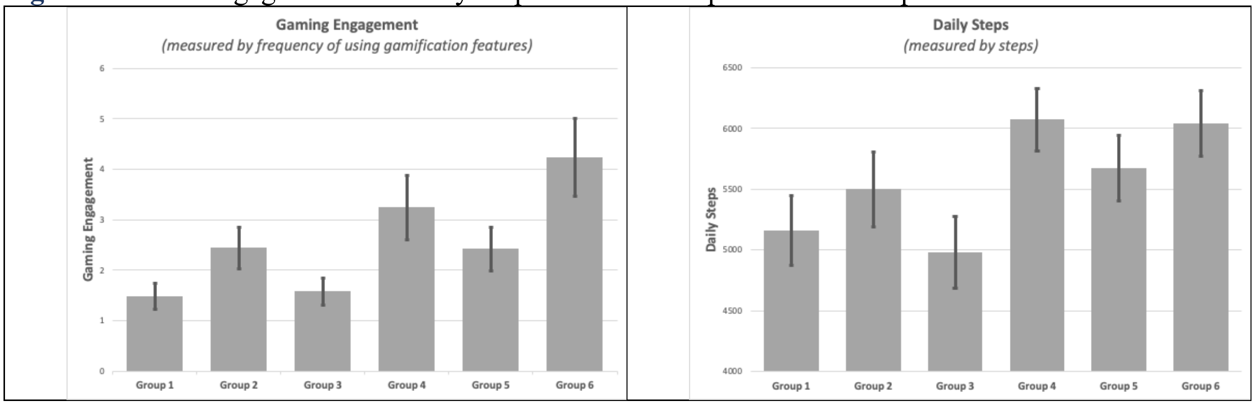
We then conducted a manipulation check to confirm the success of our treatments for cooperation, interpersonal competition, and intergroup competition. In the post-experiment survey, we asked participants to report their perceived degree of negative interdependence at both the individual and group levels[xi] and their perceived positive interdependence (perceived cooperative climate) [50, 111]. We then performed a series of independent sample t-tests to ensure that significant differences in these perceptions were present—and in the correct direction—between the treatment and control groups. These were confirmed, as predicted; thus, we concluded that our manipulations of interpersonal competition, intergroup competition, and cooperation were effective, as detailed in Table D.4.[xii]

Hypothesis Testing

To interpret the estimated percentage change in the two dependent variables—frequency of using gamification features ($game\_engage_{it}$) and daily steps ($step_{it}$)—we logarithmically transformed them, as denoted by $\ln game\_freq_{it}$ and $\ln step_{it}$. We first conducted a bivariate analysis and calculated the mean values of the dependent variables for each individual participant over the experimental period. We then used a one-way ANOVA to compare the differences among the dependent variables across the six groups. The results indicated a significant difference among the six groups in terms of the frequency of using gamification features (F = 4.48, p = 0.0005) and daily steps (F = 2.58, p = 0.025). Table D.5 shows the univariate analysis results, which indicate that both the frequency of gamification feature use and daily steps in Group 1 (individualistic gamification) were well below those in the other five groups. This finding confirms our overarching assumption that social gamification contributes to user engagement and instrumental goals. Figure 6 provides box graphs illustrating the differences across the groups.

Next, we included several control covariates in the regressions to test the hypotheses. Time-invariant control covariates include participants' self-reported gender, height, and weight ($weight_i$, $height_i$, and $gender_i$), prior experience using a fitApp ($prior\_app\_exp_i$), prior daily walking intensity ($prior\_steps_i$), and

Figure 6. Game Engagement and Daily Steps across Six Experimental Groups



dispositional traits. Time-variant control covariates include the city-level COVID-19 pandemic intensity, weather conditions, and a weekend dummy ($covid\_case_{it}$, $rain_{it}$, $avg\_temperature_{it}$, and $weekend_t$). Lastly, we included a continuous variable, day_t, which ranges from 1 to 63, to control for the temporal effect over the experimental period.

We ran the overall analysis in two steps. As depicted in Table 1, two 2×2 factorial designs were proposed to test all hypotheses. Groups 1–4 constituted the first 2×2 factorial design (with vs. without interpersonal competition; with vs. without cooperation), and we used this factorial design to test H1–H3, namely, the main effects of interpersonal competition, interpersonal cooperation, and their interaction on gaming engagement and daily steps. Group 1 (individualistic gamification) was the control group. In addition, as shown in Table 2, Groups 3 to 6 constitute another 2×2 factorial design (with vs. without interpersonal coopetition; with vs. without intergroup coopetition), and they were used to test H4 and H5. Group 3 (pure cooperation gamification) is the control group in the second 2×2 factorial design. We tested the hypotheses with two independent regression models and reported the estimated coefficients.

To test H1–H3, we coded the treatment conditions, interpersonal competition and cooperation, using two dummy variables, $\mathrm{Interpersonal\_comp_i}$ *and* $\mathrm{Coop_i}$, which were marked 1 or 0, depending on whether the participant, i, received treatments on interpersonal competition and cooperation, respectively, yielding the following regression equation (samples are from Groups 1–4):

$$\begin{cases} ln\ game\_engage_{ijt} \\ ln\ step_{ijt} \end{cases} = \beta_1 Interpersonal\_Comp_i + \beta_2 Coop_i + \beta_3 Interpersonal\_Comp_i * Coop_i + \beta_k X_{ijt} + \mu_t + \epsilon_{it}, (k = 4,5,6...) \quad (1)$$

where X_{ijt} is a vector of control covariates and μ_t is the time-fixed effect. Clustered robust standard errors were used in the ordinary least squares (OLS) estimation.

Similarly, to test H4–H5, we coded two treatment conditions, interpersonal competition and intergroup competition, using two treatment dummies, $Interpersonal\_Comp_i$ and $Intergroup\_Comp_i$, yielding the following regression equation (samples are participants in Groups 3–6):

$$\begin{cases} ln\ game\_engage_{ijt} \\ ln\ step_{ijt} \end{cases} = \beta_1 Interpersonal\_Comp_i + \beta_2 Intergroup\_Comp_i + \beta_3 Interpersonal\_Comp_i * Intergroup\_Comp_i + \beta_k X_{ijt} + \mu_t + \epsilon_{it}, (k = 4,5,6...) \quad (2)$$

In Equations (1) and (2), the treatment dummies were exogenous and randomly distributed; thus, our estimations were free of endogeneity issues and randomization bias. Based on the results of Models 1 and 2 in Table 3, we found that the influence of gamified interpersonal competition on gaming engagement and daily steps was positively significant (H1a and H1b supported). The cooperation mechanism also increased gaming engagement but decreased daily steps (H2a and H2b supported). Further, a positive interaction effect was found between interpersonal competition and cooperation on gaming engagement and daily steps (H3a and H3b supported).

Based on the estimated coefficients, compared with the individualistic setting, when participants were given the gamified feature of interpersonal competition in the app, their gaming engagement and daily steps increased by 20.68% and 16.30%, respectively. Providing the cooperative feature increased individual gaming engagement by 3.35% but decreased daily steps by 8.42%. However, when interpersonal competition and cooperation were jointly provided, gaming engagement and daily steps increased by 30.47% and 34.58%, respectively, compared with the individualistic setting. Based on the estimated coefficients in Models 3 and 4 from Table 3, the remaining hypotheses are supported, except for H5a.

Table 3. Main Results of Hypothesis Testing

Dependent Variable	**ln($game\_engage_{it}$)**	**ln($step_{it}$)**	**ln($game\_engage_{it}$)**	**ln($step_{it}$)**
Variables	Model 1 (Groups 1–4) (obs = 22,617)	Model 2 (Groups 1–4) (obs = 22,617)	Model 3 (Groups 3–6) (obs = 22,995)	Model 4 (Groups 3–6) (obs = 22,995)
	Coef. (Robust Std. Err)	Coef. (Robust Std. Err)	Coef. (Robust Std. Err)	Coef. (Robust Std. Err)
$Interpersonal\_Comp_i$ (H1a–b)	0.188** (0.004)	0.151*** (0.004)	0.247*** (0.012)	0.404*** (0.007)
$Coop_i$ (H2a–b)	0.033*** (0.002)	-0.088*** (0.004)	--	--
$Interpersonal\_Comp_i * Coop_i$ (H3a–b)	0.045* (0.013)	0.234*** (0.011)	--	--

$Intergroup\_Comp_i$ (H4a–b)	--	--	0.152** (0.013)	0.336*** (0.012)
$Interpersonal\_Comp_i$ * $Intergroup\_Comp_i$ (H5a–b)	--	--	-0.010 (ns) (0.016)	-0.316*** (0.002)
$weight_i$	-0.005 (0.006)	-0.001 (0.002)	-0.001 (0.006)	0.004 (0.003)
$height_i$	-0.006 (0.005)	-0.008 (0.006)	-0.005$^+$(0.005)	-0.011* (0.003)
$gender_i$	-0.092 (0.113)	0.015 (0.102)	-0.069 (0.078)	-0.053 (0.082)
$prior\_app\_exp_i$	0.024 (0.016)	0.015 (0.011)	0.047* (0.015)	0.009 (0.011)
$prior\_steps_i$	0.001 (0.004)	0.030$^+$ (0.011)	-0.010 (0.015)	0.043* (0.009)
$approach_i$	0.061 (0.031)	0.016 (0.013)	0.012 (0.026)	0.005 (0.025)
$avoidance_i$	-0.007 (0.028)	-0.028 (0.024)	0.023$^+$(0.009)	-0.003 (0.012)
$s\_concept_i$	-0.003 (0.015)	0.040 (0.034)	0.011 (0.022)	0.025 (0.030)
$weekend_t$	1.571 (2.312)	-0.104$^+$ (0.040)	-0.218 (3.131)	0.011 (0.010)
$covid\_case_{jt}$	0.002 (0.002)	-0.002 (0.002)	0.002 (0.002)	-0.003 (0.002)
$rain_{jt}$	0.042 (0.029)	0.022 (0.036)	0.043 (0.030)	0.021 (0.040)
$avg\_temerature_{jt}$	0.003 (0.005)	0.004 (0.002)	0.003 (0.006)	0.001 (0.003)
day_t	-0.044 (0.038)	0.087 (0.041)	-0.014 (0.052)	0.116* (0.021)
constant	2.306** (0.382)	9.089** (1.075)	1.984* (0.570)	9.363** (0.668)
Time FE[a]	Yes	Yes	Yes	Yes
R^2	0.076	0.063	0.063	0.077

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ns: not significant; a. day dummies were included but not reported.

Given that cooperative features already exist in team-based tasks on the fitApp compared with purely cooperative settings, adding intergroup competition further contributed to 16.42% and 39.93% increases in gaming engagement and physical activity, respectively (H4a and H4b supported). As posited, a substitution effect exists between intergroup competition and interpersonal competition when the gamified cooperative feature is provided. However, this effect was found only for physical activity (H5b supported), not for gaming engagement (H5a not supported). Specifically, using the pure cooperation setting (Group 3) as the reference group, the contribution from interpersonal competition to daily steps decreased dramatically from 49.78% to 12.87%, which is equivalent to the decrease in the positive contribution from intergroup competition to daily steps (from 39.93% to 3.02%). Figure 7 depicts the interaction effects.

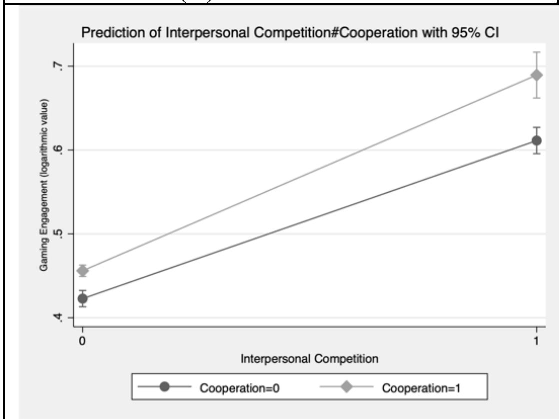
Robustness Checks and Post-Hoc Analyses

For additional insights and to rule out potential counter-explanations, we conducted a robustness check and multiple post-hoc analyses. We first used the original value of gaming engagement and daily steps as the dependent variables instead of the logarithmic values and applied Poisson and negative binomial regression models. Table D.6 in Appendix D details these results (see Model D6-1 to Model D6-8), which are consistent with our main analysis (the one exception was the statistically insignificant influence of the interaction between interpersonal competition and cooperation on game engagement).[xiii] Moreover, we used time spent using *Fitness Castle*, denoted as dur_{ijt}, as an alternative proxy for game engagement.

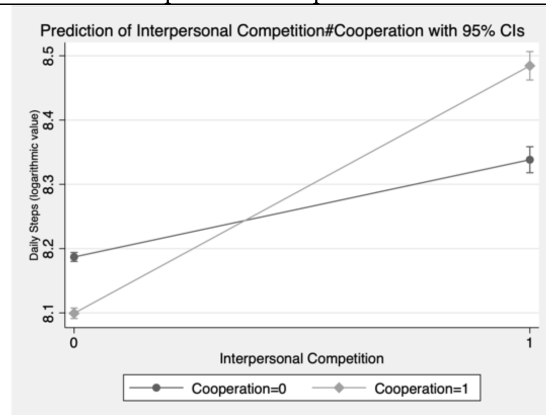
Although

Figure 7. Visualizing the Interaction Effects

(A) Interaction Effect between Cooperation and Interpersonal Competition

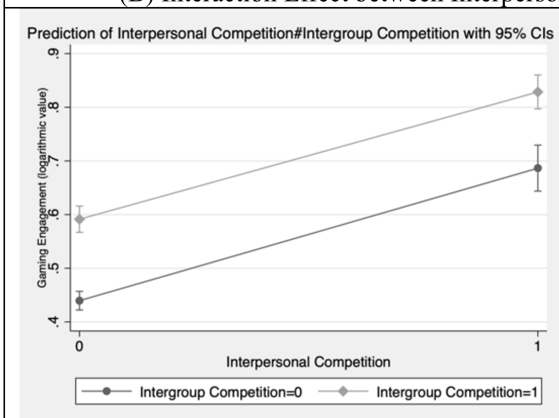


(significant)

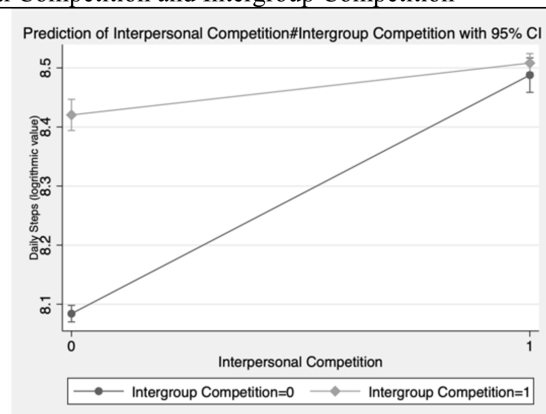


(significant)

(B) Interaction Effect between Interpersonal Competition and Intergroup Competition



(insignificant)



(significant)

our original measurement, the frequency of using gamified features, could more precisely manifest engagement stemming from gamified features, this alternative proxy, dur_{ijt}, reflected how users engaged in gamification in *Fitness Castle* as a whole [79, 105]. Similarly, we logarithmically transformed this alternative proxy, denoted as $ln(dur_{ijt})$, and applied the same model in our main analysis. Table D.6 details these results (see Model D6-9 and Model D6-10), which are consistent with our main analysis, in which H1(a)–H4(a) were supported but H5(a) was not.

Next, we used the data collected from the post-experiment survey to verify the underlying mechanisms related to the "cooperation" mechanism, because its effect on game engagement is subject to the presence of competition. Specifically, we propose that the presence of cooperation alone might incite social loafing behaviors, thereby demotivating individual engagement. However, when cooperation was properly integrated with competition, there was promotive social interaction that facilitated engagement. To untangle the potentially contradictory role of cooperation in game engagement, we analyzed and interpreted the respective psychometric data. We first measured social loafing (four measurement items), group identification (three measurement items), and social recognition (three measurement items) by referring to the prior literature (see detailed measurement in Appendix C), respectively.

Second, ANOVA revealed that social loafing in Group 3, the pure cooperation treatment group (mean = 3.507, SD =1.291), outweighed ($F_{(3,195)} = 9.48$, $p < 0.001$) that in the other groups with cooperative gamification treatments (Groups 4, 5, and 6). No other significant differences manifested among the remaining treatment groups. These findings confirmed our presumption that participants are more likely to perform free riding behaviors if their contributions cannot be identified in the gamification mechanism.

Third, to confirm the existence of promotive social interaction, we applied two-way ANOVA to estimate potential nuanced effects on group identification and social recognition in Groups 3–6. Prior research suggests that gaining social recognition is a major motivation for individuals engaging in reciprocal behaviors [105], and group identification is related to individuals' mutual helping behaviors and willingness to contribute [11, 56]. The results revealed that compared with the pure cooperation setting (Group 3), interpersonal coopetition significantly reduced perceived group identification ($F_{(1, 297)} = 10.0$, $p = 0.002$) and social recognition ($F_{(1,297)} = 11.27$, $p = 0.001$). However, intergroup coopetition significantly contributed to building group identification ($F_{(1, 297)} = 43.01$, $p = 0.0001$) and social recognition ($F_{(1, 297)} = 50.32$, $p = 0.0001$). Moreover, a significant interaction effect was identified between interpersonal and intergroup coopetition on group identification ($F_{(1, 297)} = 4.38$, $p = 0.037$) and social recognition ($F_{(1, 297)} = 4.04$, $p = 0.045$). This nuanced relationship between group identification and social recognition across the four groups (Groups 3–6) aligned with our theorization concerning promotive social interaction. The results indicate that promotive social interaction was positively correlated with group identification and social recognition, implying the importance of a "team-based" concept in shaping positive experiences in the design of social gamification. In summary, we find that cooperation serves as a key mechanism in designing social gamification by engaging users but only when contributions to such cooperation are explicit.

Discussion

Based on SIT, we investigated how cooperation, interpersonal competition, and intergroup competition in SIMs can be effectively designed to optimize the outcomes of a socially gamified fitApp. To this end, we considered both experiential and instrumental outcomes and performed a combination of psychometric and objective measurements in a longitudinally controlled field experiment using a customer-designed app (*Fitness Castle*), so that we could experimentally control for various gamified design mechanisms.

Findings Summary

We found that in our fitApp context with young adult Chinese participants, pure interpersonal competition facilitates both game engagement and daily exercise (**H1a and H1b supported**); however, implementing pure cooperation without competitive mechanisms leads to the positive experiential outcome of increased game engagement but also to the negative instrumental outcome of decreased daily steps (**H2a and H2b supported**). We found that when interpersonal competitive and cooperative design elements are jointly integrated (resulting in interpersonal coopetition), game engagement and physical activity dramatically increase (**H3a and H3b supported**). Intergroup competition combined with cooperation (i.e., intergroup coopetition) was positively related to game engagement and physical exercise (**H4a and H4b supported**). However, when interpersonal competition and intergroup competition were combined in a hybrid coopetition setting, we observed a substitution effect (negative interaction) between the two types of competition in influencing users' daily steps but not their game engagement (**H5a not supported, H5b supported**). Table 4 summarizes our key findings and the underlying mechanisms.

Contributions to Theory and Research

Our primary theoretical contribution is the explanation and demonstration of the differential effects of using three key SIMs in a socially gamified fitApp in a controlled longitudinal field experiment setting. Drawing on SIT, we propose a theoretical model for designing SIMs in the context of social gamification. We theorize and explain the interaction effects among the three SIMs, which we empirically demonstrate, in which all but one of the hypotheses is supported. Thus, our study makes several contributions to the extant research on social gamification and SIT.

Table 4. A Summary of the Key Findings and the Underlying Mechanisms of SIMs on Outcomes

SIMs	Experiential outcome (game engagement, measured by the amount of game clicks)	Instrumental outcome (fitness activity, measured by daily steps)
Pure interpersonal competition (H1a–b)	Compared with individualistic gamification, interpersonal competition aroused constructive social comparison and thus led to increased *game engagement* (H1a supported) and increased *daily steps* (H1b supported).	
Pure cooperation (H2a–b)	Pure cooperation led to increased game engagement (H2a supported). The cost of contribution to the gamified task was low; thus, *social loafing* was not observed in the game layer.	Pure cooperation led to decreased daily steps (H2b supported). Doing exercise required a higher contribution cost, such that a *social loafing* effect was observed in the real-world instrumental task.
Interpersonal coopetition: the joint use of cooperation and interpersonal competition (H3a–b)	The joint use of cooperation and interpersonal competition had a positive interaction effect on *game engagement* (H3 supported) and *daily steps* (H3b supported). Cooperation created positive relationships among teammates, leading to more constructive interpersonal competition. Meanwhile, interpersonal competition increased the evaluation potential, which minimized *social loafing* and increased *constructive cooperation* among teammates.	
Intergroup coopetition (H4a–b)	Compared with pure cooperation, intergroup coopetition (integrating intergroup competition with cooperation) resulted in increased *game engagement* (H4a supported) and *increased daily steps* (H4b supported). Intergroup competition induced group cohesiveness and thus led to more *constructive cooperation* among teammates.	
Hybrid coopetition: the joint use of interpersonal and intergroup competition (H5a–b)	A negative/substitute interaction effect between interpersonal and intergroup competition was not observed on *game engagement* (H5a rejected). The positive influence of interpersonal and intergroup competition can accumulate when the contribution cost is low in game tasks.	A negative/substitute interaction effect between interpersonal and intergroup competition was observed on *daily steps* (H5b supported). We surmise that this substitution effect is more likely to occur in real-world instrumental tasks than in game tasks.

First, this study contributes to the gamification literature by clarifying the role of user–system interaction and user–user interaction in influencing gamification outcomes. User–system interaction is primarily shaped by narrative mechanics and reward mechanics, while user–user interaction is shaped by SIMs. Most of the existing literature has investigated the influence of gamified systems as a whole (e.g., with vs. without gamified design elements) while lacking attention to the design of SIMs. We reveal that although SIMs are optional components for gamification (e.g., individualistic gamification does not contain any SIMs and user–user interaction), they play a salient role in determining users' behavioral outcomes. We suggest that SIMs serve as the lubricant between the game task and the real-world instrumental task—the tensions and relationships shaped by the SIMs in the game layer could not only influence users' game engagement but also influence their task efforts and performances in the real-world layer.

Second, we contribute to the social gamification literature by proposing a theoretical model for designing SIMs for gamified apps. As Figure 1 depicts, we enumerate three basic elements of SIMs (i.e., cooperation, interpersonal competition, and intergroup competition) as well as five different combinations of such elements in establishing social gamification (i.e., ②–⑥ in Figure 1). To the best of our knowledge, this study is the first to systematically examine the effects of all SIM elements and their complex interaction effects in a single empirical study (see Appendix A). Our study compares the effects of three distinct types of coopetition—interpersonal, intergroup, and hybrid—which has not been done previously.

Third, we contribute to the social gamification literature by deepening our understanding of the dual-outcome framework of gamification [66]. Extant studies have largely assumed that experiential and instrumental gamification outcomes are highly correlated and consistent with each other and are often achieved or failed simultaneously [27, 76]. However, in our study, the various experiential and instrumental outcomes of gamification were treated as independent outcomes for separate analyses, and our findings reveal that certain SIMs may lead to different experiential and instrumental outcomes. For example, compared to individualistic gamification, pure cooperation resulted in increased game engagement but decreased fitness activity. Such inconsistent experiential and instrumental outcomes can be attributed to the different contribution costs between the game task and the fitness task; for example, social loafing is more likely to occur during exercise than during game play. Our findings highlight opportunities for future research to differentiate the influence of certain gamified features on different gamification outcomes.

Our study also yields several theoretical contributions to SIT and other related competition and cooperation theories. First, we argued that the original dichotomous view of competition and cooperation in the original SIT [44, 92] cannot be fully adapted to the gamified fitApp context. Rather than simply assuming that competition in group settings is "bad" and cooperation is "good," or vice versa, our theorization allows for nuanced explanations that better illuminate research and real-world results. For instance, considering that task interdependence is low in individual-based fitness tasks (e.g., walking and running), the influence of interpersonal competition on completing the gamified instrumental task could be positive rather than negative. In addition, considering the multifaceted outcomes of gamification, the effect of cooperation is not purely positive—it improves experiential outcomes but diminishes instrumental outcomes in the fitApp context. By integrating SIT with the dual-outcome framework of gamification, we develop a more dialectical view of the effects of competition and cooperation.

We also contribute to SIT and related theories by developing a systematic, theoretical explanation of the boundary conditions for when competitive and cooperative settings are either constructive or destructive, as depicted in Figures 3 and 4. Our theorizing of these boundary conditions can help explain why experiential and instrumental outcomes sometimes cannot be achieved simultaneously. For example, due to the different contribution costs in the game task and the instrumental fitness task, social loafing is more likely to occur in the instrumental task than in the game tasks [17, 63, 86]. Our theorizing of boundary conditions can also explain the complex interaction effects among SIMs in various coopetition settings. For example, we empirically confirmed a positive interaction effect when interpersonal competition and cooperation were combined. Interpersonal competition makes cooperation more constructive by increasing the evaluation potential among teammates [53], whereas cooperation makes interpersonal contributions more constructive by establishing positive relationships among competitors [109].

Contributions to Applied Research and Practice

We contribute to the interdisciplinary gamification design discourse, especially regarding gamification design with explicit instrumental goals, such as fitApps. Our findings yield three primary implications for such a design. First, we demonstrated that gamification with social features can outperform individualistic gamification in terms of both experiential and instrumental outcomes. In practice, many popular gamification apps and platforms (e.g., *Duolingo* for language learning gamification or *Keep*, the most popular fitApp in China) primarily rely on individualistic gamified features, such as milestones or badges, to motivate users to achieve instrumental goals [16]. Such gamified systems can thus likely foster further user engagement and performance while decreasing discontinuation by introducing social interaction features focused on engagement and achieving goals.

Second, our study contributes to the extant practice of social gamification design. Individual-based leaderboards, representing interpersonal competition, play a dominant role in the design of social gamification today. Despite advantages in promoting instrumental outcomes, such as performing more exercise or a better training effect [27], the adverse effects of competition, such as mental stress, are noticeable. Liu et al. [66] defined the primary goal of gamification as facilitating meaningful engagement, constituting both experiential and instrumental outcomes. Accordingly, competition as a gamified social interaction feature can be further improved in terms of experiential outcomes. Our findings reveal that adding cooperation to competition can better engage users experientially and produce the same or even better instrumental outcomes. Such a finding is important because it offers an alternative mechanism for gamification designers to choose a validated social interaction feature for their gamified applications.

Third, we examined the nuanced implications of coopetition for gamification performance. Coopetition is a social interaction that combines the benefits of cooperation and competition. Therefore, coopetition can be designed at the individual level, the group level, or both, adding complexity to gamification design. From our experimental results, we did not find evidence that coopetition, including all types of competition, outperformed coopetition with a single form of competition. A key takeaway from integrating coopetition into social gamification design is that "more is not always better," which departs from the customary practice in mobile app design of increasingly adding new features. Per our theoretical inference, when introducing coopetition features, gamification designers should avoid mechanisms that might violate constructive cooperation and engender dysfunctional motives.

Finally, we propose a unified design-focused approach that combines design, theory, method, and measurement to inform actual design practices. Our resulting hypothesis-based guidelines can guide practitioners toward the appropriate design of social gamification to fit different SIMs.

Limitations and Future Research

This study has several limitations that point to compelling future research opportunities. First, the field experiment was conducted using a custom-developed fitApp, *Fitness Castle*, which has unique competitive and cooperative features that were carefully designed for the context—that is, Chinese young adults—and for experimental control. As a result, some of the research findings might not be fully generalizable to other gamification contexts. Cultural differences will likely affect the outcomes of any group task, including gamified fitness tasks. For example, at the national level, Eastern technology users tend to be more collectivistic, whereas Western users are more individualistic [67], and this difference may be reflected in the different attitudes toward competitive and cooperative gamified designs. However, it is crucial to avoid assessing such differences only at the national level, as this is typically too dichotomous, and instead to measure differences in addition at the individual level [e.g., 67, 102]. Although China, for example, is said to be more culturally homogeneous than the US, individual-level differences can be vast, even within China. Even among our seemingly homogeneous young adult Chinese sample, we observed differences related to gender and approach and avoidance orientations. Consequently, cultural differences among individuals must be considered at the individual and group levels, especially for future research on cross-cultural effects.

Second, the field experiment was conducted soon after the COVID-19 pandemic in China was under control and China's economy was reopened internally (prior to the recent omicron wave). Although we took extraordinary measures to mitigate the confounding effects induced by the pandemic (e.g., adding the number of new COVID-19 cases as a city-level control variable), the individual-level effects of the pandemic cannot be ruled out. Certainly, the timing may have provided extra motivation for all participants to get outside and enjoy exercise after a challenging lockdown. Further, social distancing during the pandemic exacerbated many people's need for social interactions, which may have made them more sensitive to the social interaction features in the fitApp. However, some people became more withdrawn and had more difficulty with social interactions following the lockdowns, but we expected such motivation differences to have an equal distribution through randomization.

Third, to ensure valid sample randomization and prevent potential cross-sample contamination in the longitudinal field experiment, we randomly assigned our participants to different experimental groups and cooperative teams. Hence, people on the teams did not know each other prior to the experiment, which may have influenced the effectiveness of the cooperation. In addition, the effects of cooperation in self-generated groups of real-world friends may differ due to the cohesion effect in social games [23]. We expect this to be true of high-functioning, long-term groups of friends versus newly formed groups.

Fourth, we provided detailed explanations of why cooperation and competition can lead to different behavioral outcomes in different situations. However, these underlying psychological mechanisms are only preliminarily validated. Future research could employ alternative methodological designs, especially highly controlled traditional laboratory experiments and various neuroscience techniques, to further understand and measure the underlying psychological causal mechanisms.

Fifth, our focus was on one particular fitApp context of increasing user engagement and performance by increasing daily walking (steps). However, the fitApp industry has exploded into several different innovative segments that are finding new ways to blend physical and virtual elements to promote a range of fitness activities [8]. These require further research to better understand the experiential and instrumental goals involved and how gamified features can help or thwart the achievement of these goals, as well as the effects of features that promote individualism, cooperation, and coopetition. We thus call for research into these innovative segments and associated designs, including [8]: (1) **gym apps** (where traditional gyms, such as Planet Fitness, provide apps to support their gym users and include virtual workouts); (2) **fasting apps** focused on helping people with intermittent fasting (e.g., *Fastic*); (3) **calorie counters + meal planner apps** for weight loss (e.g., *MyFitnessPal* and *Weight Watchers*); (4) **individualized workout apps** (e.g., *FitOn Workouts & Fitness Plans* and *Betterment*); (5) **fitness tracker apps** that do not have their own hardware, such as Fitbit or Garmin, but integrate into existing platforms (e.g., *Strava*, *Nike Run Club*, *Map My Run*, and *Google Fit*); (6) **meditation apps** (*Calm*, *Headspace*, and *BetterMe: Meditation and Sleep*); and (7) **mental health apps** (e.g., *BetterHelp* and *Talkspace*).

Conclusion

In this study, we investigated the effects of various SIMs on gamification outcomes in the context of fitness technology. We compared the differential effects of cooperation, interpersonal competition, intergroup competition, and various forms of coopetition on the experiential and instrumental outcomes of gamification. The results indicate that interpersonal competition can lead to an increase in both users' game engagement and their daily fitness activities. However, we observed that when a gamified fitness app was purely cooperative, there was an increase in game engagement but a decrease in users' fitness activity. In addition, when competition—either interpersonal or intergroup—and cooperation were jointly offered in a coopetition setting, both game engagement and fitness activity increased significantly compared to pure cooperation. Finally, we found that in a coopetition setting, the roles of interpersonal competition and intergroup coopetition act as substitutes for each other in promoting users' fitness behavior. Based on our findings, developers of gamified applications can implement different SIMs to meet their personalized gamification goals. Meanwhile, our findings provide practical solutions for practitioners to optimize experiential and instrumental gamification outcomes simultaneously.

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[i] *Task interdependence* refers to the degree to which individuals must coordinate with others to complete a certain task more effectively [18], or the amount of interaction between individuals required to complete a certain task [26].

[ii] Such design messaging (or artifacts) emphasizes the individual user without reference to others. Examples of this messaging could include: "You earned a new badge," "You have completed three challenges in total," and "You are doing an excellent job and are now at the silver level."

[iii] Such design messaging only emphasizes individual users with respect to the overall team's accomplishments or performance. Examples of this include "Your team earned a new badge," "Your team has completed three challenges in total," and "Your team is doing well and has achieved the bronze level."

[iv] Such design messaging only emphasizes individual users with respect to the performances of other users. Examples would include "You have three badges in total, which is more than 60% of users" and "You are in the top 25% of app users for daily exercise achievement."

[v] Such design messaging only emphasizes the group with respect to the performances of other groups. Examples could include "Your group has earned 20 points and is ranked second of 10 groups" and "Your group is consistently in the bottom 25% of all groups for daily exercise achievement."

[vi] The following is an example of individual-based competitive game goals: "you need to perform better than other users in the game," while "you need to help your team perform better and win against other teams in the game" is an example of group-based cooperative and competitive game goals.

[vii] Such people to whom one compares oneself are referred to as one's *comparative reference group* [100].

[viii] By *pure cooperation*, we refer to the situation where cooperative mechanisms are provided without any competitive mechanisms (including both interpersonal and intergroup competition).

[ix] For instance, Domínguez et al. [21] suggested that students' offline learning activities decreased along with the use of gamified e-learning systems, which can be to some extent attributed to poorly designed competitive mechanisms in the system. Hanus and Fox [34] also found that user satisfaction and learning performance diminished with the use of an individual leaderboard in an e-learning program.

[x] Before the experiment, we conducted an a priori statistical power analysis for repeated-measures ANOVA, which assumes a reasonable effect size (f = 0.2) for our treatment effects with a correlation of 0.5 among the longitudinally observed dependent variables. This result suggested that a total sample size of approximately 180 (e.g., 30*6) was needed for all six experimental groups to ensure a statistical power of 0.8 to detect such a small effect size. Hence, we stopped participant recruitment when we had approximately three times the required sample size of participants who completed the registration and fitApp installation.

[xi] These respectively correspond to the perceived competitive climate among individual users and the perceived competitive climate among groups.

[xii] As shown in Table C.4, users in the treatment groups with cooperation (Groups 3–6) had a significantly higher degree of perceived positive interdependence (perceived cooperative climate; mean = 5.006, SD = 1.301) than those in the groups without cooperation (Groups 1, 2) (mean = 4.309, SD = 1.664), with $t = 6.37$ and $p < 0.001$. Similarly, users in the treatment groups with interpersonal competition (Groups 2, 4, and 6) reported a significantly higher degree of perceived negative interpersonal interdependence (perceived competitive climate at the individual level; mean = 4.632, SD = 1.363) than those in the groups (Groups 1, 3, and 5) without interpersonal competition (mean = 4.018, SD = 1.649), with $t = 4.28$ and $p < 0.001$. Lastly, users in the treatment groups with intergroup competition (Groups 5, 6) reported a significantly higher degree of perceived negative intergroup interdependence (perceived competitive climate at the group level; mean = 5.052, SD = 1.175) than those in the groups without intergroup competition (Groups 1–4; mean = 3.465, SD = 1.791), with $t = 11.14$ and $p < 0.001$.

[xiii] The only exceptional case is the interaction term in Model D6-5. Despite insignificance, the p-value is 0.112, which is very close to the level of marginal significance. This may result from relatively low variance in the original value, which cannot be precisely estimated in negative binomial models. We leave this issue for open discussion.

Explaining the Outcomes of Social Gamification: A Longitudinal Field Experiment

Appendix A. Literature Review

Table A. Literature Review on the Effects of SIMs on Cognitive and Behavioral Outcomes of Gamification and Gaming

Study (Outlet)	**Social interaction mechanisms (SIMs)***					**Cognitive and behavioral outcomes of SIMs****			**Method**	**Major findings or contributions**
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**		
Featherstone and Habgood [3] (IJHCS)	Yes (+/-)	No	No	No	No	Yes	Yes	No	Experiment and interview	Competitive gamified features have both positive and side effects on motivation and game engagement.
Fotaris et al. [4] (EJL)	Yes (+)	No	No	No	No	No	No	Yes	Field experiment	Compared with traditional learning, learning supported by competitive gamification results in greater class attendances and fewer delays.
Huang and Zhou [6] (IR)	Yes (+)	Yes (+/-)	No	No	No	Yes	Yes	No	Survey	Both competition and cooperation increase social recognition, which further facilitate use of gamified technology. However, cooperation also increases social overload, which inhibit the use of gamified technology.
Leclercq et al. [10] (JIM)	Yes (+)	Yes (+)	Yes (-)	No	No	Yes	No	No	Lab experiment	Both competition and cooperation increase users' subjective engagement in gamified co-creation, but there is a negative interaction between competition and cooperation.
Morschheuser et al. [14] (CHB)	No	Yes (+)	No	No	No	Yes	No	No	Survey	Cooperative gamified features lead to increased we-intention to play the game.
Morschheuser et al. [13] (IJHCS)	Yes (base)	Yes (base)	No	Yes (+)	No	Yes	No	Yes	Field experiment	Intergroup coopetition leads to greater crowdsourcing participation than pure competition or cooperation.
Riar et al. [17] (HICSS)	No	Yes (+/-)	No	No	No	Yes	No	No	Survey	Cooperative gamified features lead to increased we-goal but decreased I-goal.
Sailer and Homner [18] (EPR)	Yes (n/s)	Yes (n/s)	Yes (+)	No	No	Yes	No	Yes	Meta-analysis	The joint use of cooperative and competitive gamified features can lead to better leaning outcomes.
Santhanam et al. [20] (ISR)	Yes (+/-)	No	No	No	No	Yes	No	Yes	Lab experiment	Competition with low-skilled competitors can increase perceived efficacy, while competition with equally skilled competitors can increase task engagement.
Sheffler et al. [21] (EJIS)	Yes (+/-)	No	No	No	No	No	No	Yes	Field experiment	Only for frequent riders, competitive feature (i.e., relative goals) leads to higher ridership.
Wouters et al. [23] (JEP)	No	Yes (+)	No	No	No	No	No	Yes	Meta-analysis	In serious game, collaborative gameplay can lead to better learning outcomes than individual gameplay.
Wu et al. [25] (ICIS)	Yes (+)	No	No	No	No	Yes	No	Yes	Survey	Social comparison and competitive climate supported by leaderboard positively influence exercise attitude and behavior.

Study	Social interaction mechanisms (SIMs)*					Cognitive and behavioral outcomes of SIMs**			Method	Major findings or contributions
	A	B	C	D	E	F	G	H		
Wu et al. [24] (IJMLO)	No	Yes (+)	No	No	No	Yes	No	Yes	Quasi-experiment	Compared with F2F cooperative learning, cooperative gamification leads to better learning outcomes.
Our study (JMIS)	Yes (+)	Yes (+/-)	Yes (+)	Yes (+)	Yes (+/-)	Yes	Yes	Yes	Field experiment	Compared with prior studies, we are the first to systematically investigate all the SIMs, as well as the complex interaction effects among them. Moreover, compared with prior studies, we systematically differentiate the effects of SIMs on the various different experiential and instrumental outcomes of gamification.

Note: (base): the baseline condition; (+): positive effects; (-): negative effects; (+/-): mixed effects.

*[A = competition; B = cooperation; C = interpersonal coopetition; D = intergroup coopetition; E = hybrid coopetition].
**[F = game-layer cognitive and motivational outcomes; G = game-layer behavioral outcomes; H = nongame-layer behavioral outcomes; F and G are experiential outcomes, while G is instrumental outcome.]

CHB = *Computers in Human Behavior*; EJEL = *Electronic Journal of e-Learning;* EJIS = *European Journal of Information Systems;* EPR = *Educational Psychology Review;* HICSS = *Hawaii International Conference on System Sciences;* ICIS = *International Conference on Information Systems;* IJHCS =*International Journal of Human–Computer Studies*; IJMLO = *International Journal of Mobile Learning and Organisation;* JMIS = *Journal of Management Information System*; IR = *Internet Research*; ISR = *Information Systems Research;* JEP = *Journal of Educational Psychology;* JIM = *Journal of Interactive Marketing*;

Appendix B. Design Support Details

Think-Aloud Protocol

Although we have theoretically explained the importance of narrative storytelling in the design of a gamification [16], few articles explicitly articulate how to do this for gamification. To create a story that is able to immerse the users, we employed the think-aloud methodology, which is widely used in usability design to understand user demand for product design and development [8, 15]. We recruited five people to participate in our think-aloud session. They were undergraduate and graduate students from one of the largest public universities located in the east coast of China. The session took around 30 minutes, which was hosted by two of the authors. After a brief introduction and practice session, the hosts presented a set of cards to the subjects. Each card presented one gaming category[i] that was from the gaming categories used on Google Play™. We asked the subjects to recall their mobile gaming experiences and sort the cards based on their preferences according to the nature of the mobile game. The concepts of action, adventure, arcade, casual, puzzle, role playing, and strategy games received the highest votes. This closely aligns with the rankings of the *categories* of top games in the Google Play during July 2018. [ii] Next, we asked the subjects to express their general opinions toward mobile games, the story, in-game operations, how they feel about using them, and so on—all so that we could further distill the key elements in designing our mobile game story. Given the prevalence and success of Pokémon GO (which was highly popular when we conducted this think aloud session), all the subjects named this mobile game during the think-aloud session. As one subject stated, "*I have watched the Pokémon when I was young. I am very fascinated with the story…*;" another subject concurred with it and stated, "*It is great experience to play as a character (from Pokémon) in the real world.*" Such observations supported our contention that the storyline and quality of storytelling are crucial in fostering user engagement in this context. Aside from Pokémon GO, other key games that were addressed included Candy Crush, Angry Birds, Bubble Shooter, and Clash of Clans. Several key words, such as "sense of accomplishment," "sense of conquest," or "feel relaxed," were also frequently mentioned in the think-aloud.

After the think-aloud session, we transcribed the interview logs and reviewed the responses. These kinds of casual games were found to be popular for use on mobile devices, which aligned with the findings in the previous literature [11]. Given that most casual games like Candy Crush or Bubble Shooter were designed to complete a set of simple mechanical operations like "swapping" or "matching," the stories in such games were not immersive to the subjects. As one subject stated, "*Is there a story in the Crush Candy? I think I only focused on swapping (the candies) to make a match of (three of more of) the same color...*"

We thus further studied the responses about the games with immersive storylines, which included Pokémon GO, Angry Bird, and Clash of Clans. An interesting finding was the commonality that all three games shared similar operations during game play, which was summarized as "throw-and-gain." Namely, the players needed to throw an object to another object to gain a return. For instance, in Pokémon GO, the players need to throw a Poké Go to a Pokémon and catch it; in Clash of Clans, the player mobilizes troops to throw stones or rockets at buildings or other objects to acquire desired resources. To this end, our first idea to improve our in-gamification story was to center it around "throw-and-take" game play. Moreover, given that we needed to implement SIMs, the story also needed to be compatible with a multiuser setting. Last, given the evidence from the think-aloud session that player resonate with familiar stories or elements, we concluded that introducing brand new elements or stories would be unwise. These constituted our three derived design principles that we followed.

Accordingly, considering these three principles—"throw-and-take," "multiuser compatibility," and "established elements and stories"—we further explored Pokémon GO, Angry Birds, and Clash of Clans for further design inspiration, and finalized the story for our app design. We named our gamified fitness mApp as *Fitness Castle*. Briefly, the overall story is a simplified version of Clash of Clans in which players are required to collect cannonballs to seize territorial castles. To integrate the story into the fitness context, those who walk more can have more cannonballs for collection and use. The detailed explanation regarding the game rules, conversion among steps, cannonballs, and castles, is given in the subsequent section of "Instructions for Fitness Castle."

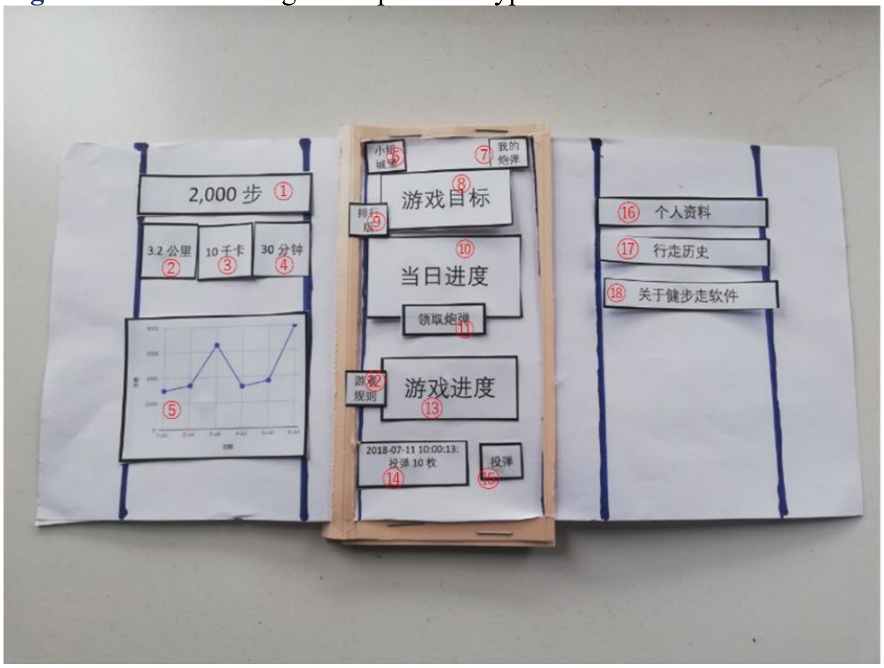
We finalized the manipulations of social interaction with two think-aloud sessions. Each session was followed by a paper prototype design workshop with newly recruited participants, which is elaborated in the next section of Appendix B ("Paper Prototype Process"). In the first session, we conceptualized the foundations of social interaction, which includes: (1) *competition*, where users directly compete with others; (2) *cooperation*, where users cooperate with other players as a team; and (3) *coopetition*, where users cooperate with other players and engage in competition as well. Building on these three general types of social interaction, we conducted another round of think-aloud protocols to further materialize the manipulations in our experimental application, *Fitness Castle*. Before the second session, we conducted a comprehensive extent of review on both literature and some prevalent gamifications with the social interaction identified in the first session. We recruited new five participants for the think-aloud session and concluded the manipulation of social interaction in *Fitness Castle*. More specifically, we segmented the social interactions into the individual and team level, and we formulated the respective rules. We derived five manipulations of social interactions from individualistic gamification, as follows: (1) *interpersonal competition*, (2) *(pure) cooperation*, (3) interpersonal coopetition, (4) *intergroup coopetition*, and (5) *interpersonal and intergroup coopetition*. We present the detailed manipulation and game mechanics of each social interaction in the section entitled, "Gamification Design for Fitness Castle."

Paper Prototype Process

As described in Appendix A, we conducted two design workshops to construct a paper prototype. Each workshop followed the think-aloud session of social interaction design. The first workshop involved three new participants and an experienced graphics designer of mApps. Each participant was given prototyping materials, including a mobile phone frame with a sliding panel of paper screens, a pen, pieces of blank paper, scissors, and scripts indicating basic buttons, functional features, graphics and the like. The graphic designer sketched prototype designs based on the insights from the group discussion and evaluated the feasibility of ideas proposed in the workshop. The participants were asked to discuss the ideal design of *Fitness Castle* to the different forms of social interactions. The discussants first determined the number of main screens (three main screens) and their order (daily exercise record → gamification page → account page). Next, we asked discussants to independently design their ideal layout of the screen of the daily exercise record by either drawing or positioning our prepared objects like "line chart," "bar chart," and "daily steps." Afterwards, the discussants shared their designs and ideas, with each presenting their work. Meanwhile, the graphic designer applied his professional expertise to evaluate the feasibility or practical insights about certain design elements. In the end, all these four participants reached a consensus after an iterative process. We applied similar methods to determine the designs of the gamification page and user account page. After all discussants concurred with each other, we finalized the design of all three main screens and crafted it in a cardboard mobile phone (Figure B.1).

The second workshop was held after the second think-aloud session of social interaction design, where there were another three newly recruited participants. We first presented the paper prototype from the first workshop, as well as the background information (e.g., concepts of social interaction and the idea of "*Fitness Castle*"). None of three participants expressed objection to the design output delivered from the first workshop, which well confirmed the validity of the interface design. Afterwards, we explained five refined social interaction mechanism, from *interpersonal competition* to *hybrid coopetition*, derived from the think-aloud session to the participants, and encouraged them to discuss how to represent those five mechanisms based on the design output in Figure B.1. All participants reached a consensus that it was necessary to display the information of other teammates in the team-based scenarios. As stated by one participant, "It will be weird to say 'cooperation' if your teammate is just a name in the scroll bar." Another participant echoed this opinion, "It (teammate's name displaying in the scroll bar) makes me feel like playing with a fictional character." Therefore, they suggested creating a subpage showing the teammates in the gamification page. The finalized prototype is presented in Figure B.2 below, where a new button (indicated by blue circle) was added to display a list of teammates (if there is). In addition, the participants provided an extraordinary suggestion for us to improve the cooperative mechanism in both *cooperation* and different *coopetition*, which was beyond our expectation because they were only invited to improve of user

Figure B.1. Initial Design in Paper Prototype Form

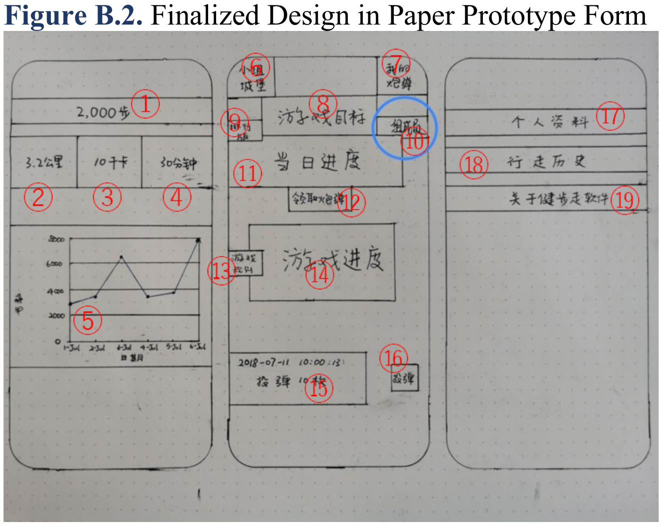


① Daily step (e.g., 2000 steps)
② Distance (e.g., 3.2 KMs)
③ Calories (e.g., 10K Cals)
④ Active minutes (e.g., 30 minutes)
⑤ Line chart for daily- and weekly-based steps
⑥ Number of castles occupied by my team
⑦ Number of my (collected) cannonballs
⑧ Game goals
⑨ Leaderboard (button)
⑩ Daily-based progress bar
⑪ Collect cannonballs (button)
⑫ Game rules (button)
⑬ Overall progress of game task
⑭ Activity records of teammates (scrolling display)
⑮ Attack using cannonballs (button)
⑯ User profile
⑰ History of exercise
⑱ About "Fitness Castle"

interface design. Their suggestion was to create a proactively cooperative mechanism in lieu of the current one (i.e., constantly displaying teammates' activities in the scroll bar). **More specifically, a user can help her/his teammate to collect the cannonballs if there were cannonballs left for her/his teammate to collect. Based on our game rules, the uncollected cannonballs are to be cleared the next day.** Such setting can motivate individual users perform promotive social interaction behaviors, namely helping her/his teammates and contributing to the collective goals or group-based accomplishment. More details are presented in the next section.

Last, we recruited another group of people as a review panel to conduct a functional pilot test for one week (i.e., 7 days). Accordingly, they evaluated every experimental version of *Fitness Castle*, respectively. In the end, they were asked to report bugs, improvement suggestions, and complaints, which helped us further improve the *Fitness Castle* prior to the field experiment.

Figure B.2. Finalized Design in Paper Prototype Form



① Daily step (e.g., 2000 steps)
② Distance (e.g., 3.2 KMs)
③ Calories (e.g., 10K Cals)
④ Active minutes (e.g., 30 minutes)
⑤ Line chart for daily- and weekly-based steps
⑥ Number of castles occupied by my team
⑦ Number of my (collected) cannonballs
⑧ Game goals
⑨ Leaderboard (button)
⑩ Teamwork page (button)
⑪ Daily-based progress bar
⑫ Collect cannonballs (button)
⑬ Game rules (button)
⑭ Overall progress of game task
⑮ Activity records of teammates (scrolling display)
⑯ Attack using cannonballs (button)
⑰ User profile
⑱ History of exercise
⑲ About "Fitness Castle"

Gamification Design for Fitness Castle

Again, we designed *Fitness Castle* as a gamified fitness mobile application. The user can collect "cannonballs" based on the steps she/he walks. We deployed the Android Sensor API to read the step data.[iii] The steps are automatically converted to the corresponding number of available cannonballs. Next, we further elaborate each prominent gamified design feature in *Fitness Castle*, including storytelling, reward mechanics, level up, and features supporting SIMs (e.g., leaderboard, the cooperative mechanics). In Table B.2., we summarize the mechanics, gamified design features elements and the exemplar tasks, goals, and feedback by experimental groups.

Storytelling (Narrative Mechanics) in Group 1-6

Storytelling is a gamified element that helps construct an immersive environment for users. We narrated the story of Fitness Castle by two means—an explicit approach and an implicit approach. In the explicit approach, we narrated the game scenario when users log on. For example, we start our narratives as "You are a warrior living in a destroyed land…Rescue the people from the evil Castles…" In an implicit approach, we used the animated text and motion graphics in the gamification page to produce an immersive storytelling. For example, when user clicks "Throw a Cannonball," a cannonball is fired from the bottom of the screen and follows a locus to hit somewhere with an animated explosive effect. As argued in the manuscript, storytelling is a fundamental element required to gamify an application. Therefore, the storytelling is a universal element for all the groups. That means, users assigned in any six groups, from "*individualistic group*" to "*hybrid coopetition*" were given the same storyline.

Reward Mechanics (The Rules That Link Daily Step with Virtual Rewards) in Group 1-6

We deployed the approach of *difficulty progression* to design the conversion mechanism, which is presented in Table B.1. For example, a user can have one cannonball ready for collection after walking 10 steps. If this user walks another 10 steps (20 steps in total), she/he can have another additional two cannonballs ready for collection, yielding three cannonballs ready for collection. Progressively, if she/he walks more than 33,000 steps in total in the same day, there will be 120 (15*(15+1)/2) cannonballs ready for collection. The daily upper limited number of cannonballs is 120. Moreover, a user needs to click a "collect" button to collect the ready-for-collection cannonballs into her/his personal "arsenal" in the same day. Those uncollected ready-for-collection cannonballs will be reset in a new day. Such rules motivate users to proactively use the app and play the game every day.

Table B.1. Rewards (Step-to-Cannonball Conversion Rule) Applied to All Experimental Groups

Steps	10	20	50	100	200	500	1000	2000	4000	7000	11000	15000	20000	26000	33000
Balls	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

For example, suppose a user walks 12,000 steps in one day, there will be 66 (11*(1+11)/2) cannonballs ready for collection. If this user does not click the "collect" button in that day, the user cannot have these 66 cannonballs in the next day because the uncollected cannonballs will be reset. However, if the user collects these 66 cannonballs in the same day, these 66 cannonballs will be stored in her/his own "arsenal," which can be used in the future. A user can collect the available ready-for-collection cannonballs whenever she/he wants as soon as it is in the same day. That is, a user can collect the cannonballs from her/his morning walk and continue collecting the rest from the afternoon activities. The number of cannonballs from the daily steps will be calculated accumulatively. In groups with cooperative mechanisms (i.e., Group 3-6), a user can help her/his teammate to collect cannonballs and store in her/his teammate's "arsenal," which will be elaborated in the subsequent paragraphs.

Level Up in Group 1-6

The level up is manifested by the "number of occupied castles," which is displayed in the top left corner in the gamified page. We employed the "number of occupied castles" as a mandatory gamified element in *Fitness Castle* to better engage teams, thereby highlighting the team-based progress. Therefore, all users across six groups (Groups 1–6) were exposed to this level-up element, "number of occupied castles." Specifically, each team, composed of 4–5 people, needs to fire 50 cannonballs to occupy one castle.

Therefore, the achieved level reflects team-based performance, namely "number of occupied castles" by a team.

Individual-Based Leaderboard (in Group 2,4,6) and Team-Based Leaderboard (in Group 5-6)

We used the leaderboard, as well as the associated prompts about the competitive goals and feedback to manifest the competitive mechanism in coopetition. The leaderboard ranks individual user or group by the number of fired cannonballs. The leaderboard displayed both daily rank and accumulative rank and were only available for users assigned into the groups with coopetition manipulation. The individual rank is only available for the "*interpersonal coopetition*" group (Group 2), "*intergroup coopetition*" group (Group 4), and "*hybrid coopetition*" group (Groups 6). Similarly, the team-based rank is available for the groups of "*intergroup coopetition*" (Group 5) and "*hybrid coopetition*" (Group 6). Therefore, for Group 6, "*hybrid coopetition*" group, there are four rankings—individual daily, individual accumulative, team-based daily, and team-based accumulative ranks— in the leaderboard. Moreover, the top-three players were spotlighted by three medals (Gold, Silver, and Bronze) based on her/his/their daily rank and accumulative rank, respectively.

Cooperative Mechanism: Mutual Help (in Group 3-6)

The cooperative mechanism is universal for both the "*pure cooperation*" group (Group 3) and three forms of "*coopetition*" groups (Groups 4–6). Every user is affiliated to a particular team where team member can see the identity (nickname in Fitness Castle) of her/his teammates. The team size is 4–5 people by considering the variation in number of subjects per manipulated group. Finally, we had 92 people (three, four-person teams and 16 five-person teams) in "*pure cooperation*" group and 91 people (4 four-person teams and 15 five-person teams) in all three "*coopetition*" groups (Groups 4–6). More group-level information is given in Table of Randomization Check (Table D.2.). Inspired by the second paper prototype workshop, we enabled mutual assistance as a manifestation of cooperative mechanism. As described in preceding paragraphs, a user needs to collect the "ready-for-collection" cannonballs every day. Those uncollected cannonballs will be reset in the next calendar day. Therefore, an individual user can help her/his teammate, a particular person, to collect the uncollected ones to the teammate's personal "arsenal," which conduces to both teammate(s) as well as the entire team. For example, suppose user A and user B are teammates and B has some uncollected cannonballs on day t, A can help B collect such cannonball, thereby resulting a one unit increase in A's record of mutual help. With A's help, B can get those uncollected cannonballs and use them in the team-based cooperative tasks, but A's own cannonballs will not increase.

Table B.2. Experimental Groups' Tasks

Groups	Game mechanics	Gamified Design Features				Examples of tasks, goals, and feedback*
		Storytelling, reward mechanics, and level-up	Individual Leaderboard	Team-based Leaderboard	Mutual help	
Group 1 (Individualistic)	1) A user earns cannonballs by walking and uses the collected cannonballs to occupy castles. 2) A user can see her/his achievement of accomplishment (i.e., number of occupied castles).	✓	✕	✕	✕	• You need XXX more cannonballs to occupy the next castle. • Walk XXX more steps today to get XXX more cannonballs and occupy more castles.
Group 2 (Interpersonal Competition)	1) A user earns cannonballs by walking and uses the collected cannonballs to occupy more castles. 2) A user can see her/his achievement of accomplishment (i.e., number of occupied castles). 3) We included a leaderboard with individual ranking in terms of number of fired cannonballs. 4) Medals are given to the top-three players (based on the daily rank and total rank).	✓	✓	✕	✕	• You need XXX more cannonballs to occupy the next castle. • Walk XXX more steps today to get XXX more cannonballs and occupy more castles to improve your individual ranking.
Group 3 (Pure cooperation)	1) A user earns cannonballs by walking and use the collected cannonballs to occupy more castles together with team members. 2) A user can see team's achievement of accomplishment (i.e., number of occupied castles). 3) A user can help her/his teammate to collect the uncollected cannonballs.	✓	✕	✓	✓	• Your team needs XXX more cannonballs to occupy the next castle. • Walk XXX more steps today to get XXX more cannonballs. • Cooperate with your teammates to occupy more castles.
Group 4 (Interpersonal coopetition)	1) A user earns cannonballs by walking and use the collected cannonballs to occupy more castles together with team members. 2) A user can see team's achievement of accomplishment (i.e., number of occupied castles). 3) We included a leaderboard with individual ranking in terms of number of fired cannonballs. 4) Medals are given to the top-three players (based on the daily rank and total rank). 5) A user can help her/his teammate to collect the uncollected cannonballs.	✓	✓	✕	✓	• Your team needs XXX more cannonballs to occupy the next castle. • Walk XXX more steps today to get XXX more cannonballs. • Cooperate with your teammates to occupy more castles. Collect and use more cannonballs to improve your individual ranking.

Groups	Game mechanics	Gamified Design Features				Examples of tasks, goals, and feedback*
		Storytelling, reward mechanics, and level-up	**Individual Leaderboard**	**Team-based Leaderboard**	**Mutual help**	
Group 5 (Intergroup coopetition)	1) A user earns cannonballs by walking and use the collected cannonballs to occupy more castles together with team members. 2) A user can see team's achievement of accomplishment (i.e., number of occupied castles). 3) We included a leaderboard with team-based ranking in terms of number of fired cannonballs. 4) Medals are given to the top-three teams (based on the daily rank and total rank). 5) A user can help her/his teammate to collect the uncollected cannonballs.	✓	×	✓	✓	• Your team needs XXX more cannonballs to occupy the next castle. • Walk XXX more steps today to get XXX more cannonballs. • Cooperate with your teammates to occupy more castles. Collect and use more cannonballs to improve the ranking of your team.
Group 6 (Hybrid coopetition)	1) A user earns cannonballs by walking and use the collected cannonballs to occupy more castles together with team members. 2) A user can see team's achievement of accomplishment (i.e., number of occupied castles). 3) We included a leaderboard with both individual and team-based ranking in terms of number of fired cannonballs. 4) Medals are given to the top-three teams and players (based on the daily rank and total rank). 5) A user can help her/his teammate to collect the uncollected cannonballs.	✓	✓	✓	✓	• Your team needs XXX more cannonballs to occupy the next castle. • Walk XXX more steps today to get XXX more cannonballs. • Cooperate with your teammates to occupy more castles. Collect and use more cannonballs to improve your individual ranking and the ranking of your team.

* We translated the original words from Chinese to English; XXX refers to a particular number.

B.4. Process Flow of Fitness Castle (Using Hybrid Coopetition Condition as the Example)

Note: The field experiment was conducted with a Chinese version of Fitness Castle. Here we present an English version of the app for readers' convenience.

Appendix C. Measurement Details of Pre- and Post-experiment Surveys

Table C. Measurement Details of Pre- and Post-experiment Surveys

Constructs / source	Pre- or Post (purpose)	Prompts, Measurement Items, and Scaling
Gender, height, and weight	Pre (covariate)	Please indicate your • Gender • Height • Weight
Prior daily steps [a] Adapted from Althoff et al. [1]	Pre (covariate)	On average, how many steps do you take each day (before the Covid-19 pandemic)? • 0–1000 steps • 1001–2000 steps • 2001–3000 steps • 3001–4000 steps • 4001–5000 steps • 5001–6000 steps • 6001–7000 steps • 7001–8000 steps • 8001–9000 steps • 9001–10,000 steps • 10,001–11,000 steps • 11,001–12,000 steps • 12,001–13,000 steps • 13,001–14,000 steps • 14,001–15,000 steps • 15,001–16,000 steps • 16,001–17,000 steps • 17,001–18,000 steps • 18,001–19,000 steps • 19001–20000 steps • more than 20000 steps

Constructs / source	Pre- or Post (purpose)	Prompts, Measurement Items, and Scaling
Prior fitness app use experience	Pre (covariate)	Have you used any fitness mobile apps before? • Yes • No If you have used any fitness mobile apps before, please indicate your experience regarding your use of fitness apps: • Never • 0–6 months • 7–12 months • 13–18 months • 19–24 months • 25–30 months • 31–36 months • 37 months or more.
Physical activity self-concept [b] Adapted from Marsh et al. [12]	Pre (covariate)	• I like to take things easy and avoid physical activity, games, or sports. • I like to stay away from games, sports, and other physical activity. • I dislike sports and physical activities. • I hate playing sports and doing physical activities. (R) • I don't like long periods of physical activities. (R)
Approach temperament [b] From Elliot and Thrash [2]	Pre (covariate)	• Thinking about the things I want really energizes me. • When good things happen to me, it affects me very strongly. • When I want something, I feel a strong desire to go after it.
Avoidance temperament [b] From Elliot and Thrash [2]	Pre (covariate)	• It is easy for me to imagine bad things that might happen to me. • I feel anxiety and fear very deeply. • I react very strongly to bad experiences.
Perceived positive interdependence [c] Adapted from Johnson and Norem-Hebeisen [7] and Van Der Vegt et al. [22]	Post (manipulation check)	• I have to cooperate with other users as a team in order to have a good performance in the "occupying castles" task. • I have to work closely with other users as a team to do ensure my performance in the "occupying castles" task. • In order to complete the "occupying castles" task well, I have to collaborate with other users. • I depend on other users for the completion of the "occupying castles" task.

Constructs / source	Pre- or Post (purpose)	Prompts, Measurement Items, and Scaling
Perceived negative interpersonal interdependence [c] Adapted from Johnson and Norem-Hebeisen [7] and Van Der Vegt et al. [22]	Post (manipulation check)	• I have to compete with other users in order to have a good performance the “occupying castles” task. • I have to perform better than other users in completing the “occupying castles” task well. • I have to outperform other users to do ensure a good performance in the “occupying castles” task. • In order to complete the “occupying castles” game well, I have to beat other users in the game.
Perceived negative intergroup interdependence [c] Adapted from Johnson and Norem-Hebeisen [7] and Van Der Vegt et al. [22]	Post (manipulation check)	• My team has to compete with other teams in order to have a good performance the “occupying castles” task. • My team has to perform better than other teams in completing the “occupying castles” task well. • My team has to outperform other users to do ensure a good performance in the “occupying castles” task. • In order to complete the “occupying castles” game well, my team has to beat other teams in the game.
Social Loafing intention [c] Adapted from George [5]	Post (post-hoc analysis)	• My team has to compete with other teams in order to have a good performance the “occupying castles” task. • My team has to perform better than other teams in completing the “occupying castles” task well. • My team has to outperform other users to do ensure a good performance in the “occupying castles” task. • In order to complete the “occupying castles” game well, my team has to beat other teams in the game.
Group Identification [c] Adapted from Sani et al. [19]	Post (post-hoc analysis)	• I feel a bond with my team. • I feel similar to the other members of my team. • I have a sense of belonging to my team.
Social Recognition [c] Adapted from Kankanhalli et al. [9]	Post (post-hoc analysis)	• Performing well in the "*Fitness Castle*" game improves my image within the user community. • Performing well in the "*Fitness Castle*" game improves other users' recognition of me. • When I perform well in the "*Fitness Castle*" game, other users will respect me.

a. China had implemented a lockdown measure to prevent the spread of pandemic before April 2020. The participants are asked to report the approximately average daily walking steps before the pandemic.
b. The prompt for this pre-experiment measure was the following: “Please indicate to what extent you agree with the following statement…;” all associated response items were anchored on a 7-point Likert-type scale from 1 = strongly disagree to 7 = strongly agree.
c. The prompt for the post-experiment measures was the following: “Please indicate to what extent you agree with the following statement based on your experience in playing Fitness Castle;” all response items were anchored on a 7-point Likert-type scale from 1 = strongly disagree to 7 = strongly agree.

Appendix D. Analysis Support

Figure D.1. Geographic Distribution of Study Participants

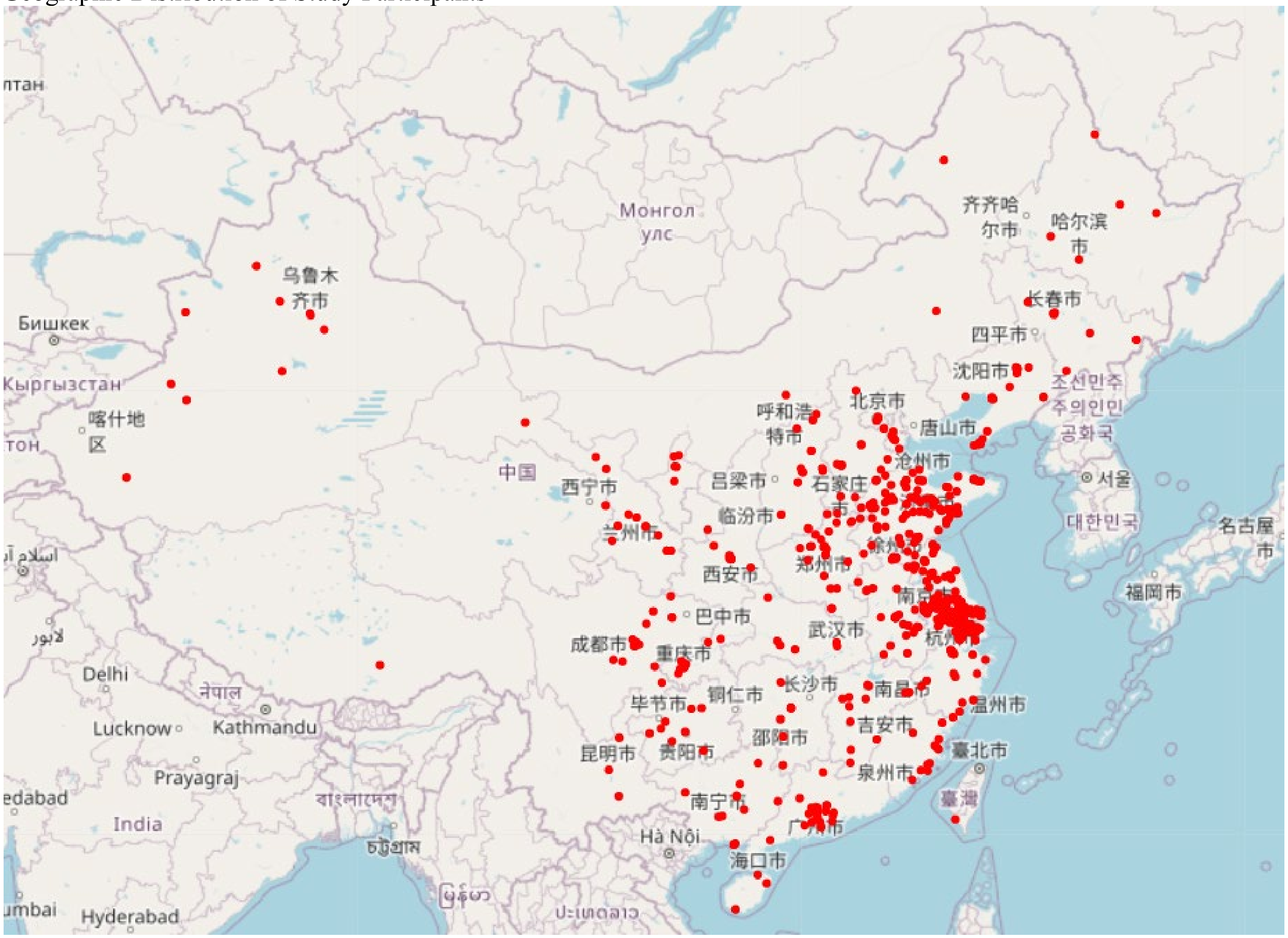


Table D.1. Descriptive Statistics of Variables in Regression Analysis with 34,083 (541*63) Observations

Variables	Definitions	Mean	Std Dev	Min	Max
$game\_engage_{ijt}$	# Of clicks to the gaming functions on *Fitness Castle* per user *i* from city *j* at day *t*	2.561	6.767	0	195
$step_{ijt}$	# Of step numbers per user *i* from city *j* at day *t*	5569.976	4502.07	102	77761
$Interpersonal\_Comp_i$	Dummy for individual competition treatment of user *i* (1 for individual competition) • $Interpersonal\_Comp_i = 0$ for Group 1, Group 3, and Group 5 • $Interpersonal\_Comp_i = 1$ for Group 2, Group 4, and Group 6	0.425	0.494	0	1
$Coop_i$	Dummy for cooperation treatment of user *i* (1 for cooperation) • $Coop_i = 0$ for Group 1 and Group 2 • $Coop_i = 1$ for Group 3, Group 4, Group 5, and Group 6	0.675	0.469	0	1
$Intergroup\_comp_i$	Dummy for team-based competition treatment of user *i* (1 for group competition) • $Intergroup\_Comp_i = 0$ for Group 1, Group 2, Group 3, and Group 4 • $Intergroup\_Comp_i = 1$ for Group 5 and Group 6	0.336	0.472	0	1
$weight_i$	Weight (kilo grams) of user *i*	59.727	11.350	40	105
$height_i$	Height (centimeters) of user *i*	168.784	8.149	150	195
$gender_i$	Gender dummy for user *i* (0 for male and 1 for female)	0.534	0.499	0	1
$prior\_app\_exp_i$	Experience of fitness mApp use prior to the experiment (ordinal value) of user *i* (0 for non-adopter)	2.081	1.946	0	7
$prior\_steps_i$	self-reported average daily walking steps prior to the experiment (ordinal value) of user *i* (scaling from 1 to 21, 1 for 0–1000 steps per day, 2 for 1001–2000 steps per day, … 20 for 19001-20000 steps per day, and 21 for 20001 steps or above per day; every interval represents 1000 daily steps)	5.575	2.914	1	20
$approach_i^a$	Self-reported approach temperament of user *i*, which is defined as the degree to which people have a disposition to be sensitive to positive stimuli in technology use. (7-point Likert scale)	5.709	0.964	1	7
$avoidance_i^a$	Self-reported avoidance temperament of user I, which is defined as the degree to which people have a disposition sensitive to negative stimuli in technology use. (7-point Likert scale)	4.137	1.262	1	7
$s\_concept_i^a$	Self-reported physical activity self-concept of user I, which is defined as individuals' beliefs about their athletic abilities. (7-point Likert scale)	4.041	1.389	1	7
$weekend_t$	Dummy for weekend of day *t* (1 for Saturday or Sunday)	0.286	0.452	0	1
$covid\_case_{jt}$	Number of daily Covid-19 cases in city *j* at day *t*	0.494	3.852	0	112
$rain_{jt}$	Dummy for weather condition of city *j* at day *t* (1 for rain)	0.465	0.499	0	1
$avg\_temerature_{jt}$	Average temperature of city *j* at day *t*	26.377	3.092	12	34.5
day_t	The *t*th day of the experiment	32	18.185	1	63

a. Three psychometric variables, $approach_i$, $avoidance_i$, and $s\_concept_i$, were measured as reflective constructs. We list the items in the Appendix E. In the regression analysis we used the means values of the items to represent the corresponding variable.

Table D.2. Randomization Check[a]

Variables	**Group 1 (n = 93)**	**Group 2 (n = 83)**	**Group 3 (n = 92)**	**Group 4 (n = 91)**	**Group 5 (n = 91)**	**Group 6 (n = 91)**	***F*-score/χ^2-score (*p*-value)**
$weight_i$	59.1461 (10.698)	59.470 (10.757)	60.356 (11.236)	57.783 (9.042)	60.964 (13.036)	60.623 (12.865)	0.98 (0.432)
$height_i$	168.457 (8.619)	167.657 (7.807)	169.924 (8.749)	169.418 (7.175)	168.852 (8.212)	168.291 (8.251)	0.88 (0.492)
$gender_i$-male	52.69%	51.81%	50.00%	54.95%	52.75%	58.24%	1.50 (0.914)
$gender_i$-female	47.31%	48.18%	50.00%	45.05%	47.25%	41.75%	
$prior\_app\_exp_i$	2.312 (2.090)	1.759 (1.574)	2.370 (1.931)	2.275 (2.071)	1.978 (1.921)	1.758 (1.974)	1.86 (0.099)
$prior\_steps_i$	5.570 (3.344)	5.916 (3.482)	5.902 (2.598)	5.505 (2.596)	5.560 (2.758)	5.022 (2.616)	1.12 (0.346)
$approach_i$	5.796 (0.836)	5.590 (1.217)	5.757 (0.823)	5.725 (0.888)	5.575 (1.230)	5.799 (0.695)	0.96 (0.442)
$avoidance_i$	4.219 (1.275)	4.265 (1.295)	4.261 (1.238)	4.095 (1.280)	3.886 (1.254)	4.103 (1.232)	1.18 (0.319)
$s\_concept_i$	4.025 (1.389)	4.064 (1.555)	4.098 (1.226)	3.879 (1.437)	4.147 (1.360)	4.033 (1.395)	0.39 (0.857)
$covid\_case_{jt}$	0.467 (1.716)	0.380 (1.331)	0.642 (2.088)	0.389 (1.278)	0.597 (1.814)	0.477 (1.726)	0.36 (0.875)
$rain_{jt}$	0.474 (0.167)	0.494 (0.150)	0.445 (0.171)	0.464 (0.177)	0.445 (0.176)	0.469 (0.159)	1.09 (0.365)
$avg\_temerature_{jt}$	26.277 (1.567)	26.629 (2.274)	26.276 (2.198)	26.525 (1.972)	26.208 (2.290)	26.372 (2.091)	0.55 (0.742)

a. We listed the mean and standard deviation for numerical variables ($weight_i$, $height_i$, $prior\_app\_exp_i$, $prior\_steps_i$, $approach_i$, $avoidance_i$, $s\_concept_i$, $covid\_case_{jt}$, $rain_{jt}$, and $avg\_temerature_{jt}$ and percentage distribution for dummy variables ($gender_i$). We compared the difference of 1) numerical variables by one-way ANOVA (*F*-score, *p*-value) and 2) dummy variable by logistic regression (χ^2, p-value), across six groups.

Table D.3. Correlations among Variables used in Hypothesis Testing

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**
(1) $Interpersonal\_Comp_i$	1													
(2) $Coop_i$	.026	1												
(3) $Intergroup\_Comp_i$	.015	.494	1											
(4) $weight_i$	-.038	.026	.067	1										
(5) $height_i$	-.037	.060	-.019	.669	1									
(6) $gender_i$ *(female)*	.033	.016	.030	-.508	-.740	1								
(7) $prior\_app\_exp_i$	-.073	.011	-.078	.003	-.004	.035	1							
(8) $prior\_steps_i$	-.036	-.038	-.069	.074	.030	-.046	.177	1						
(9) $approach_i$	-.001	.007	-.017	.006	-.051	.057	.027	.102	1					
(10) $avoidance_i$	.011	-.057	-.080	-.032	.025	-.009	-.033	.012	.024	1				
(11) $s\_concept_i$	-.036	-.001	.025	.091	.125	-.132	.180	.293	.127	-.132	1			
(12) $covid\_case_{jt}$	.020	-.026	-.012	-.039	-.025	.010	.005	-.014	.004	.020	.015	1		
(13) $rain_{jt}$	.041	-.015	-.020	-.111	-.078	-.009	-.005	-.031	-.027	.019	-.001	-.050	1	
(14) $avg\_temerature_{jt}$	-.0002	.0003	.0002	.0003	.0003	.0003	-.0002	.0002	.0002	-.132	.049	-.031	-.050	1
(15) day_t	.026	.494	.067	.669	-.740	.035	.177	.102	.024	.000	-.0003	.093	-.031	.290

Table D.4. Results of Manipulation Checks

Manipulation check on interpersonal competition vs. no interpersonal competition						
Perceived negative interpersonal interdependence (interpersonal competitive climate)	Groups 2, 4, and 6 With interpersonal competition (n = 226) (mean/SD)		Groups 1, 3, and 5 Without interpersonal competition (n = 218) (mean/SD)		*t*-statistic	*p*-value
	4.632	1.363	4.018	1.649	4.280	<0.001
Manipulation check on cooperation vs. no cooperation						
Perceived positive interdependence (cooperative climate)	Group 3, 4, 5 and 6 With Cooperation (n = 301) (mean/SD)		Group 1 and 2 Without Cooperation (n = 143) (mean/SD)		*t*-statistic	*p*-value
	5.052	1.175	3.465	1.791	11.141	<0.001
Manipulation check on intergroup competition vs. no intergroup competition						
Perceived negative intergroup interdependence (intergroup competitive climate)	Group 5 and 6 With intergroup competition (n = 148) (mean/SD)		Group 3 and 4 Without intergroup competition (n = 153) (mean/SD)		*t*-statistic	*p*-value
	5.131	1.351	4.721	1.331	2.648	<0.01

Table D.5. Univariate Analysis (mean values across six experimental groups; n=541)

Group	**$game\_engage_{ijt}$**	**$\ln(game\_engage_{ijt})$**	**$step_{ijt}$**	**$\ln(step_{ijt})$**
	Mean. (Std. Dev)	Mean. (Std. Dev)	Mean. (Std. Dev)	Mean. (Std. Dev)
Group 1	1.477 (2.472)	0.432 (0.564)	5159.08 (2775.21)	8.189 (0. 540)
Group 2	2.438 (3.707)	0.601 (0.693)	5499.03 (2835.14)	8.348 (0.417)
Group 3	1.577 (2.496)	0.451 (0.542)	4982.32 (2824.06)	8.099 (0.610)
Group 4	3.241 (6.098)	0.695 (0.808)	6073.22 (2422.17)	8.475 (0.417)
Group 5	2.422 (4.130)	0.580 (0.671)	5674.46 (2603.15)	8.431 (0.420)
Group 6	4.236 (7.285)	0.820 (0.902)	6041.00 (2553.28)	8.495 (0.378)

Table D.6. Estimation Results for Alternative Models in Post-hoc Analysis

Dependent Variables:	**Poisson Model**				**Negative Binomial Model**				**Duration as Proxy for Game Engagement**	
	$game\_engage_{ijt}$	$step_{ijt}$	$game\_engage_{ijt}$	$step_{ijt}$	$game\_engage_{ijt}$	$step_{ijt}$	$game\_engage_{ijt}$	$step_{ijt}$	$\ln(dur_{ijt})$	$\ln(dur_{ijt})$
Independent Variables:	**Model D6-1** Groups 1–4 obs=22,617	**Model D6-2** Groups 1–4 obs=22,617	**Model D6-3** Groups 3–6 obs=22,995	**Model D6-4** Groups 3–6 obs=22,995	**Model D6-5** Groups 1–4 obs=22,617	**Model D6-6** Groups 1–4 obs=22,617	**Model D6-7** Groups 3–6 obs=22,995	**Model D6-8** Groups 3–6 obs=22,995	**Model D6-9** Groups 1–4 obs=22,617	**Model D6-10** Groups 3–6 obs=22,995
	β (Robust SE)	β (Robust SE)	β (Robust SE)	β (Robust SE)	β (Robust SE)	β (Robust SE)	β (Robust SE)	β (Robust SE)	β (Robust SE)	β (Robust SE)
$Interpersonal\_Comp_i$	0.567*** (0.032)	0.044*** (0.008)	0.735*** (0.018)	0.229*** (0.007)	0.618*** (0.168)	0.077*** (0.014)	0.811*** (0.132)	0.262*** (0.024)	0.088** (0.014)	0.413** (0.017)
$Coop_i$	0.082*** (0.011)	-0.032*** (0.004)	--	--	0.120^{+} (0.064)	-0.041*** (0.012)	--	--	0.339** (0.012)	--
$Interpersonal\_Comp_i$ $*Coop_i$	0.150** (0.050)	0.171*** (0.014)	--	--	0.218 (0.141)	0.175*** (0.014)	--	--	0.303** (0.031)	--
$Intergroup\_Comp_i$	--	--	0.480*** (0.044)	0.123*** (0.011)	--	--	0.542*** (0.042)	0.141*** (0.025)	--	0.171** (0.021)
$Interpersonal\_Comp_i$ $*Intergroup\_Comp_i$	--	--	-0.183*** (0.032)	-0.130*** (0.003)	--	--	-0.243^{+} (0.130)	-0.163*** (0.025)	--	-0.029 (0.043)
$weight_i$	-0.010 (0.015)	0.002 (0.002)	-0.001 (0.011)	0.004^{+} (0.003)	-0.003 (0.014)	0.001 (0.003)	0.004 (0.014)	0.004 (0.003)	-0.016 (0.010)	-0.005 (0.012)
$height_i$	-0.006 (0.023)	-0.010^{+} (0.006)	-0.012 (0.019)	-0.011*** (0.002)	-0.023 (0.024)	-0.008 (0.005)	-0.020 (0.020)	-0.011*** (0.002)	-0.015 (0.007)	-0.026^{+} (0.009)
$gender_i$	-0.352* (0.176)	-0.020 (0.094)	-0.276^{+} (0.160)	-0.066 (0.070)	-0.259 (0.248)	-0.006 (0.093)	-0.243 (0.172)	-0.061 (0.070)	-0.242 (0.323)	-0.333 (0.201)
$prior\_app\_exp_i$	0.080* (0.033)	0.008 (0.011)	0.120*** (0.010)	0.0003 (0.010)	0.100^{+} (0.058)	0.011 (0.011)	0.121*** (0.011)	0.001 (0.010)	0.031 (0.020)	0.073 (0.033)
$prior\_steps_i$	-0.0004 (0.006)	0.031** (0.012)	-0.032 (0.035)	0.047*** (0.007)	0.025 (0.017)	0.032** (0.010)	0.003 (0.039)	0.049*** (0.008)	0.025 (0.024)	-0.008 (0.048)
$approach_i$	0.096 (0.069)	-0.002 (0.017)	-0.010 (0.072)	-0.013 (0.030)	0.055 (0.086)	-0.002 (0.016)	0.008 (0.080)	-0.005 (0.024)	0.018 (0.068)	-0.014 (0.039)
$avoidance_i$	0.006 (0.057)	-0.033 (0.026)	0.056* (0.027)	-0.012 (0.012)	0.019 (0.065)	-0.029 (0.027)	0.093* (0.043)	-0.004 (0.013)	-0.041 (0.049)	0.012 (0.020)
$s\_concept_i$	-0.001 (0.019)	0.051 (0.038)	0.014 (0.058)	0.031 (0.032)	-0.024 (0.046)	0.054 (0.036)	-0.028 (0.077)	0.039 (0.035)	0.003 (0.045)	0.014 (0.033)
$weekend_t$	-2.019*** (0.305)	-0.034 (0.043)	0.896 (8.739)	-5.031^{+} (2.647)	11.845 (15.385)	-0.025 (0.036)	4.177 (12.907)	0.103 (0.083)	-2.929*** (0.023)	-2.682*** (0.130)
$covid\_case_{jt}$	-0.002 (0.014)	-0.002* (0.001)	-0.0003 (0.010)	-0.006** (0.002)	-0.001 (0.010)	-0.002 (0.002)	0.005 (0.010)	-0.005** (0.002)	0.001 (0.005)	-0.001 (0.006)
$rain_{jt}$	0.055 (0.037)	0.017 (0.025)	0.102*** (0.017)	0.018 (0.030)	0.010 (0.042)	0.017 (0.026)	0.065 (0.044)	0.024 (0.029)	0.060 (0.075)	0.108 (0.057)
$avg\_temerature_{jt}$	-0.004 (0.014)	-0.002 (0.002)	0.002 (0.013)	-0.003 (0.002)	-0.010 (0.023)	0.0002 (0.002)	-0.001 (0.015)	-0.002 (0.002)	0.003 (0.022)	0.020 (0.016)
day_t	-0.214 (0.212)	0.095* (0.031)	-0.040 (0.145)	0.083* (0.042)	-0.226 (0.254)	0.102** (0.031)	-0.096 (0.215)	0.099** (0.035)	-0.027 (0.043)	-0.005 (0.059)
$constant$	3.393(2.967)	9.957*** (1.072)	3.617 (2.558)	9.847*** (0.482)	5.954* (2.996)	9.407*** (0.972)	4.597^{+} 2.768	9.725*** (0.499)	7.345* (1.863)	8.357* (1.599)
Time FE[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

β = beta coefficient; SE = standard error; + $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; a. Day dummies were included but not reported. R^2 Model D6-9 = .112, D6.10 = .073

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[i] Because our fitness app was going to be developed for Android devices, we browsed the subcategories of "Games" in the Google Play store and wrote down all the gaming subcategories. There are totally 17 distinct types of games in the Google Play, which include action, adventure, arcade, board, card, casino, casual, educational, music, puzzle, racing, role playing, simulation, sports, strategy, trivia, and word. Thus, each subject was given 17 cards.

[ii] https://play.google.com/store/apps/top/category/GAME [Last accessed: July 02, 2018]

The top-9 games (game category) listed in the frontpage were Temple Run 2 (Action), Magic Tiles 3 (Music), Clash of Clans (Strategy), Candy Crush Jelly Saga (Puzzle), Candy Crush Soda Saga (Casual), Bubble Shooter (Casual), Clash Royale (Strategy), Farm Heroes Saga (Casual), and Pou (Casual).

[iii] https://developer.android.google.cn/reference/android/hardware/SensorManager