Does It Matter How You Play? The Effects of Collaboration and Competition Among Players of Human Computation Games

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Human computation games (HCGs) harness human intelligence through enjoyable gameplay to address computational problems that are beyond the power of computer programs but trivial for humans. With the popularity of crowdsourcing, different types of HCGs have been developed using various gameplay mechanics to attract online users to contribute outputs. Two commonly used mechanics are collaboration and competition. Yet there is little research examining whether HCGs perform better than nongame applications in terms of motivations and perceptions. Thus, this study investigates the effects of collaborative and competitive mechanics on intrinsic motivation and perceived output quality in mobile content sharing HCGs. Using a within-subjects experiment, 160 participants were recruited from 2 local universities. The findings suggest that the nongame application was perceived to yield better quality output than both HCGs, but the latter offered a greater satisfaction of motivational needs, which may motivate individuals to continue playing them. Taken together, the present findings inform researchers and designers of HCGs that games could serve as a motivator to encourage participation. However, the usefulness of HCGs may be dependent on how one can effectively manage the entertainment–output generation duality of such games. This article concludes by presenting implications, limitations, and future research directions.

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Introduction

Human computation (HC) refers to the phenomenon of harnessing human intelligence to address computational problems that are beyond the power of computer programs but trivial for humans (von Ahn & Dabbish, 2008). The use of HC originated in collecting metadata of online content such as images and music videos. With smart mobile devices enriched with GPS and wireless connectivity, HC has been employed to the context of geo-referenced data collection. One well-known example is OpenStreetMap (Haklay & Weber, 2008), which has amassed over 2 million voluntary users who contribute information about real-world locations. The collected crowdsourced data are available for use by other location-based applications.

Traditionally, human computation systems (HCSs) employ paid human experts or volunteers through crowdsourcing to gather user-generated information. However, hiring such experts is costly and volunteerism is dependent on individuals' willingness to devote their time and effort to such a project (Yuen, Chen, & King, 2009). One recent approach is recruiting participants through crowdsourcing markets such as Amazon's Mechanical Turk (AMT), which is believed to be cost-effective and offer a diverse subject pool (Mason & Suri, 2012). However, even if users are paid for tasks performed, a more engaging experience may encourage them to generate high-quality outputs (Eickhoff, Harris, de Vries, & Srinivasan, 2012; Siu, Zook, & Riedl, 2014). Here, games represent one among many useful ways to encourage human computation. Accordingly, HCSs utilize games, and they are termed human computation games (HCGs), where players contribute their computational intelligence to a given endeavor through gameplay (Goh, Ang, Lee, & Chua, 2011). The game-based approach to HC is promising, given that games have amassed over 700 million players worldwide (Spil Games, 2013). Furthermore, over 56% of gamers play games with friends and family members, either collaboratively or competitively (ESA, 2015). These statistics imply that games can attract the attention of a vast number of people around the world.

In essence, HCGs are built upon the desire of individuals to be entertained while generating useful output as a byproduct of gameplay (von Ahn & Dabbish, 2004). As such, enjoyment and output are the most striking features of HCGs. This characteristic indeed distinguishes HCGs from pure entertainment games, in which enjoyment is considered to be the most important goal. The *ESP Game* is one of the earlier examples of HCGs that aimed to collect metadata for online images (von Ahn & Dabbish, 2004). In this game, two unrelated players are tasked with creating matching labels for randomly presented images within a given time limit. The collected image labels are then used to improve the performance of the image search engines. Another example is *EyeSpy* (Bell et al., 2009), where users contribute images and descriptions about the most visible and significant locations within a city. The crowdsourced data of *EyeSpy* are useful to support navigation or to create tourist maps. Since then, various types of HCGs have been developed in different problem-solving contexts, including music annotation, website indexing, natural language processing, ontology building, protein folding in biological science, geospatial knowledge collection, and many others (e.g., Cooper et al., 2010; Ho, Chang, Lee, Hsu, & Chen, 2009; Procyk & Neustaedter, 2014).

Given the dual nature of HCGs, one important challenge in designing HCGs is how to incentivize players to generate meaningful outputs. Accordingly, HCG developers have utilized different game mechanics to engage players. Two commonly used gameplay mechanics are collaborative and competitive (Pe-Than, Goh, & Lee, 2015; von Ahn & Dabbish, 2008). Prior research has argued that collaboration can promote positive behaviors, whereas competition can lead to negative behaviors (Peng & Hsieh, 2012; Tauer & Harackiewicz, 2004), and hence, these mechanics may influence players' motivation and perception differently. However, little attention so far has been given to the differences in players' motivations and perceptions afforded by collaborative and competitive mechanics in HCGs. In the present study, we address this gap by examining the following research question: Are players' motivations and perceptions affected by different types of HCG play mechanics?

In addressing this research question, we consider the effects of collaborative and competitive mechanics on two factors—players' intrinsic motivation and their perceived output quality. The former is important to HCGs because games are known to attract players by intrinsically motivating them (Liu, Li, & Santhanam, 2013). Since HCGs utilize games to increase players' engagement, these games should afford intrinsic motivation. According to self-determination theory (SDT), the levels of intrinsic motivation vary depending on three psychological needs—autonomy, competence, and relatedness (Deci & Ryan, 2000). Previous studies on entertainment-oriented games found that the fulfillment of these needs was related to players' enjoyment, which is the important determinant of intrinsic motivation (e.g., Peng, Lin, Pfeiffer, & Winn, 2012; Przybylski, Rigby, & Ryan, 2010).

Another factor important to the success of HCGs is output quality. Since HCGs are designed such that players generate output as a byproduct (Goh et al., 2011), output is one of the striking features of such games. Accordingly, how well players perceive the quality of output produced by HCGs may have a significant impact on their behaviors and attitudes toward these games. Such an impact has been found in previous research on information-oriented applications that had no game elements (e.g., Kim & Han, 2009). Further, prior studies used multiple dimensions to access output quality including accuracy, completeness, relevancy, and timeliness (e.g., Alkhattabi, Neagu, & Cullen, 2010; Lee, Strong, Kahn, & Wang, 2002).

To summarize, this study aims to investigate the differences in motivations and perceptions of output quality among HCGs with different gameplay mechanics (collaborative vs. competitive vs. nongame) in the context of location-based content sharing. Using a within-subjects experiment, 160 participants were recruited from two local universities. Each participant used all three applications on three different days and completed questionnaires for the respective application. Findings of this study are essential not only to enhance the theoretical understanding of the motivational process in HCGs but also to provide design guidelines for games that are not purely meant for entertainment.

Literature Review

We begin by reviewing the theoretical aspects underlying this work, followed by relevant literature on intrinsic motivation, output quality, and human computation games for location-based content sharing in collaborative and competitive contexts.

Human Computation Games

Human computation games (HCGs) are dual-purpose artifacts, generating computations and offering entertainment at the same time. They can hence be called "games with a purpose" (GWAPs), as defined by von Ahn and Dabbish (2004). Here, computation refers to the process of mapping some input representation to some output representation using an explicit, finite set of instructions (Law & von Ahn, 2011). Similarly, humans are considered to be performing computation when they process inputs and generate outputs following given instructions. In this regard, computational contributions made by humans may include, but are not limited to, contextual reasoning such as image and music video annotation, aesthetic judgment, intuitive decisions, creativity, spatial knowledge, and other forms of cognitive processing (Krause & Smeddinck 2011; Michelucci, 2013). Hence, HCGs can be broadly termed as a genre of crowdsourcing that enlist online players to perform certain forms of computation (Doan et al., 2011).

Although HCGs initially emerged as web-based casual games, more sophisticated forms of HCGs have emerged on mobile platforms as mobile technology advances. Location-based HCGs are typical examples of HCGs on mobile platforms that collect geospatial knowledge about real-world locations. One example is the *Gopher Game* (Casey, Kirman, & Rowland, 2007), in which players can either create a new gopher (i.e., a game agent) and assign tasks, or pick one up and help the gopher to complete its mission by supplying situated photographic and textual content. *CityExplorer* (Matyas et al., 2008) is another example in which players conquer each city segment by placing the markers for their chosen categories, such as food, café, and so on, within this segment. To place a marker, the player needs to provide the game with a photo of the location of interest and its name. Players who create the most markers will win the game. Next, *Indagator* (Lee, Goh, Chua, & Ang, 2010) allows players to create, browse, and rate media-rich location-based information, and rewards points for performing such activities. Finally, in *GEMS* (Procyk & Neustaedter, 2014), players create a memory record with text, audio, photographs, or video clips to capture a particular experience about a place. As players create records, they earn points and access tokens that can be used to unlock secret information about the game character.

Regardless of platform, HCGs can be classified into two types according to gameplay mechanics. One type uses collaboration, which involves a group of individuals working together, and the outcomes are shared among team members (Zagal, Rick, & Hsi, 2006). The *ESP Game* and *Gopher Game* described earlier are example HCGs with collaborative mechanics. Another type of HCG utilizes competitive mechanics in which players develop strategies to outperform one another, and only one person at a time can achieve the winning condition (Peng & Hsieh, 2012). The *City Explorer* game described earlier is an example of a competitive HCG. Although most HCGs rely on collaborative mechanics, those with competition are starting to emerge because it is known to be an influential motivator of playing games (Vorderer, Hartmann, & Klimmt, 2003). However, the effects of such gameplay mechanics on players' motivation and perceptions are not well studied, and understanding such relationships is needed to make better design decisions.

Intrinsic Motivation

Motivation is an important factor that has been studied extensively in the context of games. In fact, games are known to be an intrinsically motivating activity that individuals do it for its own sake (Liu et al., 2013). Based on an observation of a discussion forum among Multi-User Dungeon (MUD) players, Bartle (1996) proposed four types players, each of whom possessed specific motivation for playing: achiever, explorer, socializer, and killers. Bartle's work provided an important foundation for understanding motivations of game players. However, Yee (2006) argued that, in general, player types are not mutually exclusive and that classifying players based on Bartle's model may limit the understanding of the motivations of online game players. Accordingly, Yee (2006) conducted a large-scale survey with 3,000 players of massively multiplayer online role-playing games (MMORPGs) and suggested that players engaged in games for three overarching reasons—achievement, social, and immersion. The results suggested that players who scored high on the achievement motivation derived satisfaction from reaching goals and competing with others in games. Those who scored high on the social motivation enjoyed socializing with others, forming meaningful relationships, and working as a team. Players who scored high on the immersion motivation enjoy exploring the game world, being immersed in the game story, and customizing the appearance of their avatars. With the motivational model proposed by Yee, players will have a score—high or low—on each factor. Hence, players can be differentiated from one another by considering a combination of both motivating and demotivating factors.

From the perspective of SDT, Deci and Ryan (2000) contended that intrinsic motivation varies depending on the extent to which an activity affords three psychological needs—autonomy, competence, and relatedness. The autonomy need within SDT concerns a sense of volition or willingness when performing an activity. For instance, when an individual performs an activity for his/her interest or personal value, perceived autonomy is high, which in turn increases intrinsic motivation. Next, the competence need refers to the urge to interact with the social environment effectively. For instance, if an individual perceives that she/he is unable to perform an activity, this person is less likely to feel motivated to do so. Finally, the relatedness need pertains to the desire to feel connected with other individuals. Therefore, if an activity allows interaction among users, they are likely to experience a sense of connectedness, thereby increasing intrinsic motivation.

As playing games is considered to be voluntary, players' intrinsic motivation through the fulfillment of the need for autonomy, competence, and relatedness is typically high (Peng & Hsieh, 2012). Prior studies on entertainment-oriented games showed that satisfaction of these needs determine players' engagement and enjoyment (e.g., Ryan, Rigby, & Przybylski, 2006; Peng et al., 2012). Therefore, these three needs can be used to assess whether a particular game achieves its primary purpose of providing intrinsic motivation. However, the potency in providing motivation may vary as a function of personal appeal, as well as game design elements and content (Ryan et al., 2006; Zagal et al., 2006). One such element to consider in HCGs is the gameplay, and the collaboration and competition are two commonly used mechanics.

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In the social psychology literature, collaboration and competition are regarded as two different goal structures (Waddell & Peng, 2014), and hence, they may evoke different behaviors and perceptions. In particular, Tauer and Harackiewicz (2004) argued that individuals in a collaborative context may feel a loss of autonomy because they need to abide by group norms and objectives. In contrast, players in competitive situations develop strategies on their own to play against their opponents (Zagal et al., 2006). This may cause players to feel more in control of their actions in the competitive game, leading to a higher level of perceived autonomy. Next, it has been suggested that competence valuation in games varies depending on the performance feedback provided (Ryan et al., 2006). For instance, players may perceive that their achievement in a competitive setting is more personal and central than in a collaborative one (Kazakova, Cauberghe, Pandelaere, & De Pelsmacker, 2014). This is because achievement in the latter setting is considered a collective contribution of all group members (Zagal et al., 2006). Accordingly, players may experience higher competence in a competitive game compared to its collaborative counterpart. Finally, individuals can derive a sense of belonging and connection from being part of a team (Przybylski et al., 2010), but such feelings are unlikely to occur in a competitive context that fosters hostility among individuals (Waddell & Peng, 2014). The study, therefore, argues that the effects of collaboration and competition on intrinsic motivation might exist in the context of HCGs, and proposes the following research hypotheses.

> Hypothesis 1A: Perceived autonomy is higher in HCGs with *competitive* gameplay mechanics than those with *collaborative* mechanics.
> Hypothesis 1B: Perceived competence is higher in HCGs with *competitive* gameplay mechanics than those with *collaborative* mechanics.
> Hypothesis 1C: Perceived relatedness is higher in HCGs with *collaborative* gameplay mechanics than those with *competitive* mechanics.

Output Quality and User-Generated Content

Another factor crucial to the success of HCGs is a player's perception of output quality, which is regarded as a judgment made "by observing intermediate or end products of using the system" (Davis, Bagozzi, & Warshaw, 1992). Prior research has underlined the vital role of individuals' perceived output quality in influencing their attitudes in user-generated content (UGC) applications (e.g., Kim & Han, 2009). As HCG players generate UGC as a byproduct of gameplay, perceived output quality is likely to be significant in determining players' attitudes and behaviors. Accordingly, achieving objective output quality has become important for location-based HCGs. The outputs generated by location-based HCGs are different from other forms of HCGs such as image tagging in that they are more open-ended. In particular, location-based HCGs garner information based on how people describe their spatial environments and events, and quality control mechanisms such as expert or peer reviews are typically utilized (Pe-Than et al., 2015). This study utilizes the peer review mechanism in which players evaluate each other's comments on a five-star rating scale. The ratings feature serves as a means to ensure content quality. Further, the extant literature suggests that output quality is a multidimensional construct, hence necessitating the use of multiple quality dimensions to capture its various aspects (Lee et al., 2002). Using a meta-analysis of existing quality frameworks, Alkhattabi et al. (2010) revealed accuracy, completeness, relevancy, and timeliness as the most frequently appearing dimensions in these frameworks.

Multiple scholars have argued that collaboration, compared with competition, should increase positive behaviors among individuals, thereby facilitating performance (e.g., Ladley, Wilkinson, & Young, 2015; Tauer & Harackiewicz, 2004). In particular, Waddell and Peng (2014) found that individuals in a collaborative setting exhibited more cooperative behaviors and trust in their partners that may, in turn, lead to higher levels of performance. Similarly, Peng and Hsieh (2012) found that collaboration led to greater effort put into the gameplay than competition. In contrast, Tauer and Harackiewicz (2004) found no differences in performance between individuals working with others collaboratively or competitively. Although inconsistent, these findings indicate potential differences in the effects of collaboration and competition on individual performance, which may further influence their quality judgment. In addition, previous research on HCGs for image tagging argues that the type and quality of outputs seemed to differ depending on gameplay mechanics, and this may induce varying levels of perceptions about output quality (e.g., Goh et al., 2011; Ho et al., 2009). Thus, this study proposes the following hypothesis:

> Hypothesis 2: There are differences in perceptions of output A) accuracy, B) completeness, C) relevancy, and D) timeliness between HCGs with collaborative and competitive gameplay mechanics.

Methods

Applications Developed for the Study

To address the proposed hypotheses, we developed two mobile HCGs with collaborative and competitive gameplay mechanics, respectively termed *Collabo* and *Clash*, and a nongame location-based application termed *Share*, which served as a baseline for comparison. The reasons for developing our own applications were that we would have better control over the look-and-feel of the interfaces and the accessibility of the generated data.

All three applications shared the purpose of creating location-based content called comments. They offer a map-based interface on which locations are marked as mushroom

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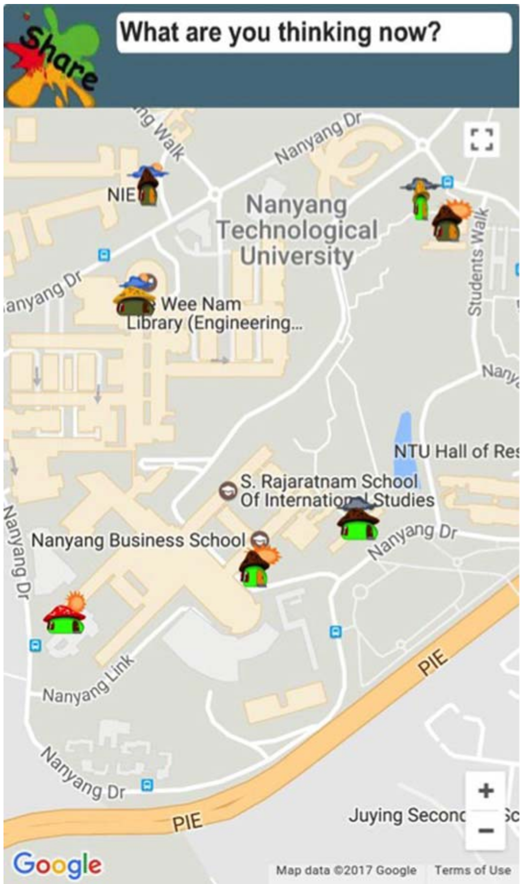

FIG. 1. Mushroom houses on the map. [Color figure can be viewed at wileyonlinelibrary.com]

FIG. 2. A list of Globs residing in a location. [Color figure can be viewed at wileyonlinelibrary.com]

houses to facilitate creating, browsing, and rating of comments (see Figure 1). More specifically, each location has a number of units, and each of these holds its respective comments. For instance, if a school is considered a location, the library inside will be one of its units that attract comments. A comment comprises five components—a title, tags, descriptions, media elements (e.g., photos), and ratings. While the comment owner creates the first four components, other users provide the ratings. In particular, players evaluate comments by giving a score on a five-star rating scale, and the aggregated rating value serves as a quality indicator.

First, *Collabo* adopts a virtual pet-based game genre and employs a collaborative mechanic by which players form a team to rescue starving pets in their vicinity. In the game, a pet represents each unit inside a location. Once a player has entered a location, the number of pets residing within this location is listed. He/she then needs to search for starving pets, which appear sad and dark in color, and are anchored by a star (refer to Figure 2). Upon selection, the information associated with the pet is retrieved, which includes a list of comments and aggregated ratings of those comments. Also, the player can see the activities of others who are trying to rescue the pet on the "Activity" tab (refer to Figure 3). To join other players in rescuing the pet, she/he needs to create new comments and/or rate comments created by others on a five-star scale. The strength of a pet is increased when new comments and rating values are added, as well as when new members have joined the team. Once a pet is rescued, the game allocates an equal amount of points to the team members.

Second, *Clash* allows players to compete with others for pet ownership. Once a player has entered a house, a list of pets residing inside is shown. The player can challenge the current pet owner to a duel (see Figure 4), and he/she will win if the total her/his strength and daily luck (i.e., a random number generated at the first login of each day) is greater than that of the challenged player. The game computes each player's strength based on the quantity, the rating value, and recency of comments. The recency value of each comment is set at 100 points when it is created, and this is reduced by 10% each day. Hence, the strength of the pet's owner will decrease if he/she is not active in creating new comments. This very feature of Clash ensures that the pet is winnable by new players. The game allows owners to securely retain the ownership status for a 15-minute period. This feature was included on the basis of the results of the pilot testing in which players reported that it was very easy to lose a pet.

In both *Collabo* and *Clash*, player-generated comments are visualized to facilitate the assessment of quality. In particular, the virtual pet and mushroom houses are used as

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FIG. 3. Activities of players performed on the GLOB. [Color figure can be viewed at wileyonlinelibrary.com]

FIG. 4. A glob owned by "GIGO." [Color figure can be viewed at wileyonlinelibrary.com]

glyphs representing four attributes of comments—quantity, quality (i.e., the rating score), recency, and sentiment. The size of pet and house varies according to the amount of comment, and the pet color and wall color of the house are subjected to comment quality. The recency of comments affects the age of the pet and house, while the sentiment is visualized as the mood of the pet and weather around the house. These features serve as a means to evaluate the quality of comments in *Collabo* and *Clash*.

Finally, *Share* is a nongame application that serves as a control. Being different from the two HCGs described above, *Share* does not have any game elements but offers the basic features for contributing and accessing location-based content. Once users have entered a location, they are presented with a number of units. Users can select their desired units to create new comments, and browse and rate those created by others. A comment in *Share* can be seen in Figure 5. Unlike the previous games, users are not awarded with any points or rewards for their activities. Instead, they can view statistics such as how many comments they have created and rated. *Share*, therefore, serves as a representative mobile content-sharing application through which to compare the perceived motivation and output quality of HCGs. The features of three implemented applications are summarized in Table 1.

Participants

In all, 160 participants with an average age of 23.20 (SD = 3.77) were recruited from two local universities. Of these, 71 (44.4%) were male and 89 (55.6%) were female. The majority of the participants (81.3%, $N = 130$) indicated that they were online gamers. Among our participants, 47.8% of them had a background in computer science, information technology or related disciplines, 38.8% were from engineering disciplines, while the remainder were from disciplines such as arts, social sciences, and business.

Of the total sample, 88.1% ($N = 141$) of the participants surfed the web via their mobile phones while 80.6% ($N = 129$) used them for map navigation. The responses also revealed that 72.5% ($N = 116$) of participants shared pictures, videos, music, and other media via their mobile phones. Next, 52.5% ($N = 84$) of participants indicated that they used the location check-in feature of social networking applications such as *Facebook* and *FourSquare* on their mobile phones. Furthermore, 59.4% ($N = 97$) of participants shared information about locations on social networking applications via their mobile phones.

Data Collection Procedure

The study was a within-subjects experimental design where participants used all three applications (*Collabo*, *Clash*,

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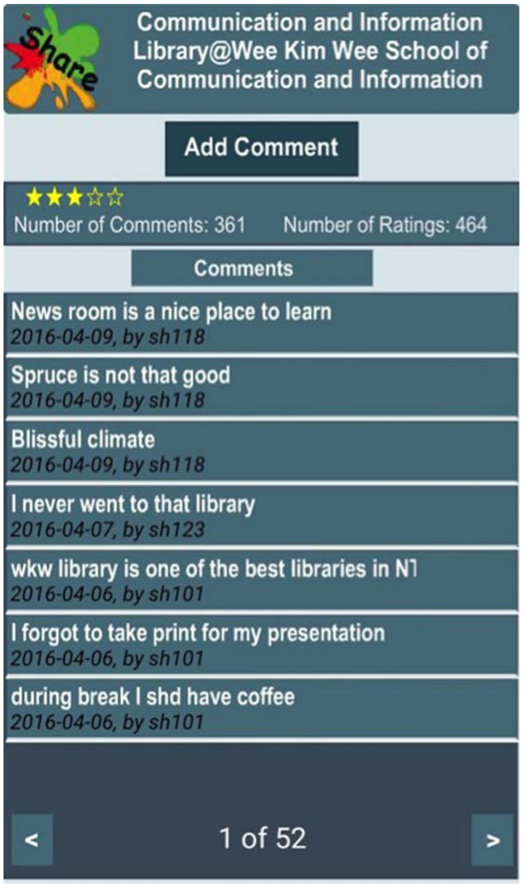

FIG. 5. A comment in *Share*. [Color figure can be viewed at wileyonlinelibrary.com]

and *Share*). The experiment was counterbalanced to reduce order effects. Participants were divided into subgroups with each performing a different combination of the applications. The experiment was conducted across separate sessions, with each session having three to nine participants. Using the same set of instructions and tasks ensured consistency across sessions. Before the experiment began, participants were given instructions on how to use the applications together with a 15-minute practice session. Participants were told that they had to use all three applications on Android-based mobile phones on 3 different days, each spaced 1 day apart.

On each day, participants were asked to follow a given usage scenario that includes joining a rescue team to save a pet (for *Collabo*), winning a pet (for *Clash*), and creating, viewing, and rating comments (for *Share*). Further, participants were advised to create content for educational or navigational purposes. More specifically, they were told that contents should be meaningful, descriptive, relevant, and useful to other players in the game. Upon task completion, participants completed a questionnaire that measured perceived motivation and information quality. These steps were repeated for all three applications. Participants were paid an incentive of $20.

Pilot Study and Manipulation Check

Before the actual experiment commenced, a pilot study was carried out with 24 graduate students. The purpose of the pilot study was to uncover deficiencies in the questionnaire and study protocol, as well as to check whether the two experimental conditions (i.e., collaboration and competition) differed significantly in a predicted direction. Participants were divided into two groups, and randomly assigned to play either *Collabo* or *Clash*, and asked to complete the questionnaire thereafter. The majority of participates reported that the questionnaire was largely clear and comprehensive. Based on the feedback, certain parts of the questionnaire were revised to improve clarity. With regard to gameplay, two participants reported the difficulty in maintaining the pet ownership in *Clash*, and hence the game was revised accordingly. The revised version of *Clash* and the questionnaire were used in the actual experiment.

This study also performed a manipulation check, which is a typical procedure used in experimental studies to ensure that the conditions of the independent variable (i.e., collaboration and competition in our study) differ significantly in the predicted direction (e.g., Bowman & Tamborini, 2012). To achieve this goal, participants in this pilot study were

TABLE 1. Summary of the features of *Share, Collabo*, and *Clash*.

Feature	Description
Content Sharing Features of Share	
Comment browsing, creating, and rating	• Facilitate content discovery, creation, and making judgement about others' comments
Usage statistics	• Show statistics such as total numbers of comment created and rated by the user
Collaboration-Supportive Features of Collabo	
Pets anchored by a star	• Indicates that other players are currently rescuing this pet • Increases the chance that players join the rescue team
The Activity tab	• Displays all activities done by players on the pet at the visited location • Facilitates a sense that the player is rescuing the pet together with other players at the same time
Group-based feedback	• Provides as a winning message
Competition-Supportive Features of Clash	
Dueling with the pet's owner	• Engages players in a situation that allows them to directly compete with another player
A Ranking list or Leaderboard	• Shows top 10 players ranked by the total numbers of pet owned • Facilitates a sense of indirect competition among players as they can compare their in-game standings against others

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TABLE 2. Factor analysis of perceived motivational needs satisfaction ($N = 160$).

Perceived motivational needs satisfaction	Factors			Alpha
	1	2	3	
Autonomy				**0.91**
This game provides me an opportunity to express my ideas and opinion freely.	0.31	0.29	**0.76**	
This game provides me with interesting options and choices.	0.27	0.32	**0.78**	
I did things in this game because they interest me.	0.12	0.25	**0.86**	
I felt controlled and pressured in certain ways.	0.10	0.04	**0.90**	
Competence				**0.92**
I felt competent at using this game.	0.28	**0.82**	0.20	
I felt that I could do activities in this game very well.	0.31	**0.84**	0.19	
I felt that I was making progress on the activities I did throughout the use of game.	0.25	**0.84**	0.21	
This game or application kept me occupied but did not overwhelm me.	0.17	**0.79**	0.22	
Relatedness				**0.93**
I felt connected with the people I played with.	**0.84**	0.22	0.18	
I felt that I was part of a group who shared similar goals.	**0.87**	0.23	0.19	
I felt comfortable with other people I played with.	**0.87**	0.26	0.16	
This game allows me to create an open channel of communication with other people that share similar interests.	**0.81**	0.29	0.20	
Variance (%)	55.37	14.43	11.29	
Eigenvalue	6.64	1.73	1.35	

randomly assigned to play either *Collabo* or *Clash*, and then asked about the extent they felt that they were competing with others in the game they played. Responses ranged between 1 (*strongly disagree*) to 5 (*strongly agree*). An independent sample *t*-test was then performed to compare the mean scores of these two groups. As expected, the results showed that participants who played *Clash* ($M = 3.80$) felt significantly higher levels of competitiveness than those who played *Collabo* ($M = 2.64$). In other words, the results suggested that these two gameplay mechanics were appropriately perceived as such by the study's participants.

Measures

The dependent variables were perceived motivational needs satisfaction and output quality. A principal component factor analysis with Varimax rotation was conducted for three different data sets associated with three applications, and factors whose eigenvalue was greater than 1 were retained. Reliability was also assessed using Cronbach's alpha. All question items were measured on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

A total of 12 question items were used to assess perceived motivational needs satisfaction. The items were adapted from the Players Experience Need Satisfaction question items (PENS) (Ryan et al., 2006) and Basic Psychological Need Satisfaction items (Deci & Ryan, 2000). Perceived output quality was assessed with 12 items that were drawn from previous studies (Lee et al., 2002; Kim & Han, 2009), and adapted to suit the study's context.

Results

Factor and Reliability Analyses

Table 2 shows the results of the factor analysis of perceived motivational needs satisfaction. As expected, three motivational factors were revealed, and they had good internal reliabilities with acceptable Cronbach's alpha values of at least 0.90. The constructs are articulated as: Autonomy—assesses one's perceived feelings of freedom in their actions and choices offered in the application; Competence—assesses one's perceived feelings of effectiveness while dealing with challenges encountered in the application; and Relatedness—assesses one's perceived feelings of connectedness with others in the application.

Next, four factors were revealed from the factor analysis of perceived output quality, and all of them had good internal reliabilities with acceptable Cronbach's alpha values of at least 0.90. Table 3 shows the results of factor analysis, and the constructs are described as: Accuracy—assesses the extent to which information generated by the application is correct, reliable, and accurate; Completeness—assesses the extent to which information generated by the application contains sufficient detail to meet one's needs; Relevancy—assesses the extent to which information generated by the application is appropriate, relevant, and useful for one's needs; and Timeliness—assesses the extent to which information generated by the application is current, timely, and up-to-date for one's needs.

ANOVA Results

Table 4 shows the means and standard deviations of the study's dependent variables. One-way analyses of variance (ANOVAs) were performed on these dependent variables to verify whether the differences in participants' ratings were statistically significant. The results indicated that there were significant differences with respect to all motivation variables—autonomy [$F(2,477) = 6.58$, $p < .01$], competence [$F(2,477) = 25.41$, $p < .01$], and relatedness [$F(2,477) = 46.88$, $p < .001$], and three output quality variables—accuracy [$F(2,477) = 15.48$, $p < .01$], completeness [$F(2,477) = 9.92$, $p < .01$], and relevancy [$F(2,477) = 15.36$,

TABLE 3. Factor analysis of perceived output quality (N = 160).

Perceived output quality	Factors 1	2	3	4	Alpha
Accuracy					**0.96**
This application provides accurate information.	0.17	0.20	**0.88**	.27	
This application provides correct information.	0.21	0.24	**0.87**	0.26	
This application provides reliable information.	0.14	0.27	**0.89**	0.21	
Completeness					**0.98**
This application provides information that covers sufficient breadth and depth for my needs.	0.20	**0.89**	0.26	0.21	
This application provides information that includes all necessary details.	0.21	**0.89**	0.23	0.26	
This application provides information that is sufficiently complete for my needs.	0.22	**0.88**	0.23	0.28	
Relevancy					**0.97**
This application provides information that is relevant to my needs.	0.25	0.26	0.28	**0.85**	
This application provides information that is appropriate for my needs.	0.26	0.26	0.24	**0.85**	
This application provides information that is useful for my needs.	0.23	0.27	0.30	**0.84**	
Timeliness					**0.97**
This application provides information that is sufficiently up-to-date.	**0.92**	0.17	0.15	0.20	
This application provides information that is sufficiently current for my needs.	**0.90**	0.18	0.15	0.24	
This application provides information I need in time.	**0.90**	0.22	0.18	0.19	
Variance (%)	62.04	13.55	10.26	8.52	
Eigenvalue	7.44	1.62	1.23	1.02	

TABLE 4. Means and standard deviations for participants' perceptions of motivational needs and output quality.

	Application types					
	Collabo (N = 160)		*Clash* (N = 160)		*Share* (N = 160)	
Variables	M	SD	M	SD	M	SD
Autonomy	3.25	0.84	2.99	0.80	3.29	0.74
Competence	3.43	0.86	3.75	0.96	3.00	1.00
Relatedness	4.02	0.90	3.40	0.96	3.01	0.94
Accuracy	2.83	0.97	3.13	1.02	3.45	0.99
Completeness	2.93	0.86	2.98	0.93	3.36	0.97
Relevancy	2.80	0.94	3.12	1.02	3.44	1.11
Timeliness	3.03	1.05	3.08	0.92	3.19	0.88

$p < .01$]. There was, however, no statistically significant difference among the three applications for perceived timeliness $F(2,477) = 1.10$, $p = .33$.

Post-hoc comparisons using Tukey's test were then conducted (see Table 5), which uncovered the following results:

- Autonomy. Participants reported that they felt more autonomous when using *Collabo* ($M = 3.25$) and *Share* ($M = 3.29$) than in *Clash* ($M = 2.99$). However, there was no significant difference in ratings between *Collabo* and the control application, hence hypothesis 1A was not supported.
- Competence. Participants felt that both *Collabo* ($M = 3.43$) and *Clash* ($M = 3.75$) could make them feel more competent than *Share* ($M = 3.29$). Furthermore, they perceived a higher level of competency in *Clash*, as predicted by hypothesis 1B.
- Relatedness. Participants reported that they felt more connected to others in both *Collabo* ($M = 4.02$) and *Clash* ($M = 3.40$) than in *Share* ($M = 3.01$). Unsurprisingly, *Collabo* was found to outperform *Clash* in fulfilling the relatedness need, which supported hypothesis 1C.

TABLE 5. Comparison between means of participants' perception of motivational needs and output quality.

Variable	Type (1)	Type (2)	Mean difference (1)−(2)
Autonomy	*Share*	*Collabo*	0.03
	Share	*Clash*	0.29*
	Collabo	*Clash*	0.25*
Competence	*Share*	*Collabo*	−0.43*
	Share	*Clash*	−0.75*
	Collabo	*Clash*	−0.31*
Relatedness	*Share*	*Collabo*	−1.01*
	Share	*Clash*	−0.39*
	Collabo	*Clash*	0.61*
Accuracy	*Share*	*Collabo*	0.62*
	Share	*Clash*	0.32*
	Collabo	*Clash*	−0.30*
Completeness	*Share*	*Collabo*	0.42*
	Share	*Clash*	0.37*
	Collabo	*Clash*	−0.04
Relevancy	*Share*	*Collabo*	0.63*
	Share	*Clash*	0.31*
	Collabo	*Clash*	−0.32*
Timeliness	*Share*	*Collabo*	0.15
	Share	*Clash*	0.11
	Collabo	*Clash*	−0.04

Note. *$p < .025$. Type (1) and Type (2) refer to the application being compared.

- Accuracy. Participants felt that the output from *Share* was more accurate ($M = 3.45$) than from *Collabo* ($M = 2.83$) and *Clash* ($M = 3.13$). Furthermore, participants recognized a higher level of accuracy in *Clash* than in *Collabo*. Therefore, in order of perceived accuracy, *Share* ranked first, followed by *Clash* and *Collabo*. Hence, hypothesis 2A was supported.
- Completeness. *Share* ($M = 3.36$) was again perceived to generate more complete output than *Collabo* ($M = 2.93$) and *Clash* ($M = 2.98$). This time, there was no significant

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difference in ratings between *Collabo* and *Clash*. Hypothesis 2B was thus not supported.
- Relevancy. Similar to completeness, participants felt that the output from *Share* ($M = 3.44$) was more relevant than from *Collabo* ($M = 2.80$) and *Clash* ($M = 3.12$), suggesting that *Share* would be better at generating more relevant output for them. Like accuracy, the ratings between *Collabo* and *Clash* were statistically significant, as predicted by hypothesis 2C.
- Timeliness. There were no statistical differences between the pairwise comparisons among the three applications. Put differently, the participants' perception of the timeliness of output was comparable across *Share*, *Collabo*, and *Clash*. Hence, hypothesis 2D was not supported by the data.

Discussion

Games represent one among many useful ways to encourage human computation. To enhance its potential in human computation, one must understand motivations afforded by both higher- and lower-level game design elements. While the former explains HCG players' motivations at the general level, the latter allows researchers and designers to ensure possible variations in motivations due to low-level design choices. This work focused on a higher-level game design element, which is the gameplay mechanic—collaboration and competition. However, the gameplay experience is a function of the responses of lower-level elements such as levels and leaderboards (Siu et al., 2014). Therefore, depending on the game elements used, players may experience a varying level of collaboration or competition, which may further influence their perceptions. This understanding is important because games are increasingly used in nongaming contexts in a form of crowdsourcing games, serious games, or gamified applications to motivate participation, thereby influencing performance and data quality. Effective designs are hence essential to achieve the intended purposes, and evaluating full-fledged HCGs may overlook the impacts of individual motivational elements afforded.

The results suggest that collaborative and competitive games differ in affording intrinsic motivation, which is evaluated by the need for autonomy, competence, and relatedness. In particular, compared to the competitive game, participants felt more self-directed and were able to behave in a manner they desired in the collaborative version. This finding is surprising, because individuals may feel deprived of freedom in a collaborative setting, which requires them to abide by rules to ensure that their actions promote the goals of the others or the group (Liu et al., 2013). Perhaps participants viewed that the gameplay of *Collabo* was not overly controlling, as it put no restriction on quantity and type of content shared (e.g., factual or emotional content). Alternatively, the competitive structure of *Clash* would have induced players to selectively perform activities to increase the chance of winning. The situation may have led players to feel that their behaviors were influenced by external factors and not self-determined, thereby diminishing perceived autonomy.

The results also revealed that participants felt more competent in HCGs than in the nongame application. This finding is unsurprising, because certain game elements, such as matching the player's skill levels and providing feedback, could foster the feeling of achievement and competence. Although *Share* allows players to view usage statistics as a form of performance feedback, it seems that this feature is not enough to support the need for competence. Compared to collaboration, the competitive game was found to significantly increase the satisfaction of competence need. Put differently, individuals felt recognized for their ability more during competition than collaboration. Perhaps as winning is important in competition, participants tried to increase their performance to outperform others (Waddell & Peng, 2014), thereby leading to a higher level of perceived competence. Here, in *Clash*, participants may have felt a sense of competence when they have won the pet by defeating the current owner.

Furthermore, *Collabo* and *Clash* were found to induce a higher level of relatedness need satisfaction than *Share*. This finding implies that participants enjoyed sharing information with others either collaboratively or competitively compared to doing it individually. In addition, participants perceived themselves as being more connected to others in the collaborative game than in its competitive counterparts. Perhaps the interdependence between reward and performance of team members in the collective game may have created a sense of belonging among players (Ladley et al., 2015). Here, *Collabo* requires players to work together as a team, and the reward is shared among team members. Such a situation may have created a sense of relatedness among players.

In contrast to the satisfaction of motivation needs, *Share* was perceived to offer higher levels of accuracy, completeness, and relevancy than both *Collabo* and *Clash* in terms of output quality. Perhaps participants felt that being able to focus solely on output generation in the nongame variant resulted in higher output quality. Further, both HCGs required players to perform gaming activities, and such extra work could have been perceived to be deviating from output generation, leading to a lack of confidence in the quality aspect. Interestingly, timeliness was perceived similarly across all three applications. Perhaps due to the assumption that online environments provide current information (Kim & Han, 2009), HCGs appeared to instill confidence that their outputs were as timely as that of the nongame application. Put differently, in the mobile context, content about current events would get noticed by other users easily, which increases the likelihood of receiving higher ratings. As such, participants may have contributed timely output regardless of the application type.

In examining the two games more closely, our results showed that the output of *Clash* was perceived to be higher in accuracy and relevancy than that of *Collabo*. It is also possible that competition that drives players to strive for victory (Peng & Hsieh, 2012) conveyed an impression that more accurate and relevant output must be generated to outperform the rivals. Perhaps in *Clash* participants were aware

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that they needed to continually improve their strength either to win or retain the pets, thereby generating more accurate and relevant outputs. Another possibility is that the nature of the relationship among team members may have affected output quality in *Collabo*. For instance, players may perform better when playing with real or social media friends (Peng & Hsieh, 2012). The lack of features that allow participants to play with their friends in *Collabo* may have been a hindrance for them to be fully involved in the gameplay, influencing their perceived accuracy and relevancy negatively.

To summarize, the present findings suggest that the non-game application was perceived to yield better quality output than both HCGs, but the latter offered a higher level of intrinsic motivation, which would, in turn, motivate individuals to continue playing them. This informs researchers and designers of HCGs and similar applications that there are certain factors such as personality that may determine an individual's preference for particular gameplay mechanics, thereby influencing their perceptions toward quality. Thus, the perceived effectiveness of HCGs may be dependent on how one can effectively manage its entertainment–output generation duality by considering human psychology and behavior characteristics in HCG design process.

Conclusion

This study provides several important implications for both research and practice. First, understanding the role played by needs satisfaction in collaboration and competition will help researchers explain the motivational process underpinning players' enjoyment in HCGs. In particular, this study found that HCGs with collaborative mechanics performed better than those with competitive mechanics in terms of providing autonomy and relatedness. The competitive HCGs supported only a higher level of competence need. The present findings, therefore, underscore the importance of HCG play mechanics, which have a differential influence on players' motivations. Second, our results suggest that gaming has an influence on players' perception of output quality. In comparing two of the HCGs, the competitive HCG was found to be more effective in influencing perceived accuracy and relevancy than its collaborative counterpart. This finding informs researchers of the need to consider the interaction between different game mechanics and output quality.

Third, our work suggests that games can be used to attract players to participate in content creation if we can leverage the differences in motivations and perceived output quality afforded by different gameplay mechanics. In particular, we found that participants in competitive HCGs experienced higher competence, and such games were perceived to produce more accurate and relevant output compared to collaborative HCGs. The more a player feels a sense of competence, the more the player will focus their efforts on the quality of their contributed output. Therefore, competition seems to be an important element for HCGs to yield better-quality output. Here, it is important to note that although collaborative gameplay mechanics outperformed their competitive counterparts with respect to autonomy and relatedness, they were perceived to produce lesser-quality outputs. As suggested by prior studies (e.g., Ho et al., 2009), players seem to take advantage of interaction afforded by the collaboration to win games, thereby generating low-quality outputs.

Fourth, although this study was conducted in the context of HCGs, the usefulness of its findings may extend to other contexts that intend to make the tasks engaging, such as crowdsourcing and gamification. For example, this study suggests that individuals will enjoy performing the tasks if games can create either a collaborative or competitive situation among players. Hence, game-based approaches to crowdsourcing could be used as an alternative incentive to monetary ones, with careful consideration of how to effectively utilize collaboration and competition to enhance users' engagement. Fifth, this study demonstrated one way to create collaboration or competition in HCGs—through team-based pet rescue or pet ownership. There may be other means to implement collaborative and competitive HCG play. This calls for future research to explore different ways to use collaboration and competition in HCGs, and investigate their effects on players' perceptions to enhance the generalizability of this study's results.

Finally, the findings of this study also contribute to the knowledge of HCG design. Our results suggest that intrinsic motivation and output quality vary between collaborative and competitive HCG play mechanics. Designers should consider strategies that could yield higher motivation and better quality output. One, features that support user empowerment are vital to facilitate autonomy in HCGs. Here, the ability to customize gameplay and players' profiles could be used. For instance, competitive HCGs may foster autonomy by having different modes of competition—direct and indirect, that could be implemented through duels and leaderboards. Two, in addition to group-based rewards, collaborative HCGs should consider integrating individual-based reward systems that may heighten a sense of competence in the collaborative setting. Three, social interaction seems to be critical to HCG players. Mechanisms that foster meaningful and purposeful social interactions should be incorporated into HCGs. For instance, location-based HCGs may consider including a feature that notifies other online users who are in the vicinity of the user. Such a feature enables the formation of location-based social networks that can bridge the gap between virtual and real social ties. Finally, HCGs should be equipped with mechanisms that ensure output quality as well as maximize the utility of output for a variety of players. The machine-based approach is a commonly used one to incentivize high-quality output but it may discourage individuals with certain personality orientations from continuing playing the games. Therefore, considering players' personality factors is important not only for incentivization but also for ranking output relevant to each individual.

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Limitations and Future Research

Although our work yields meaningful findings, it is not without limitations that offer opportunities for future research. First, this study employed a cross-sectional survey method, and participants' perceptions were collected at one time after a 60-minute gameplay session. A longitudinal study with repeated measure may be conducted to shed more light on the influence of gameplay mechanics on players' motivations. Nevertheless, our findings provide initial insights regarding how collaboration and competition influence players' motivation and their perceived output quality of HCGs.

Second, this study relied on basic, but commonly used, gameplay mechanics in HCGs. However, other alternative classification of games may exist, which include different types of game genres such as adventure and simulation, as well as hybrid games that utilize a combination of collaborative and competitive mechanics (Pe-Than et al., 2015). Therefore, future research may investigate the differential effects a larger set of gameplay mechanics on players' motivation and perceived output quality. Third, the differences in perceptions of output quality across HCGs with different gameplay mechanics call for future research to investigate whether HCGs with different mechanics attract different content types, which in turn influences players' perceptions. Fourth, this study did not consider the potential impact of individual differences on players' perceptions. For instance, players' personality characteristics may determine their preference of certain gameplay styles, which in turn may influence their perceptions. This calls for future research to explore the interaction effects of personality and gameplay styles on players' perceptions of HCGs.

Fifth, this study demonstrated one way to create collaboration or competition in HCGs—through team-based pet rescue or pet ownership. There may be other means to implement collaborative and competitive HCG play. This calls for future research to explore different ways of collaboration and competition in HCGs, and investigate their effects on players' perceptions to enhance the generalizability of this study's results. Sixth, the characteristics of the sample pose further limitations. Participants in this study were primarily undergraduate and graduate students from two local universities. It would therefore be constructive to replicate the study with people from diverse occupational and educational backgrounds to validate the findings of this study. Finally, this study was conducted on a specific human computation domain—location-based content sharing. In fact, different human computation tasks may demand varying levels of cognitive abilities, and hence they may yield different perceptions. Further studies of other domains such as image and music tagging are needed to verify the generalizability of our findings.

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