Exploring the impact of game framing and task framing on user participation in citizen science projects

Purpose—This paper examines how game framing and task framing influence experienced meaningfulness (eudaimonia) and perceived enjoyment (hedonia), which in turn can account for user participation behavior in citizen science projects.

Design/methodology/approach—The authors designed and implemented a citizen science system, *Citizen Sort,* and used a survey method to investigate to what extent game framing and task framing influence participation behavior. PLS-SEM was used to test research hypotheses with 76 *Citizen Sort* participants.

Findings— Analysis confirmed that game framing and task framing have a significant impact on perceived enjoyment, but showed that only task framing has a direct effect on experienced meaningfulness. The effects of experienced meaningfulness on participation were fully mediated by perceived enjoyment. Content analysis of qualitative data revealed additional insights.

Research limitations/implications—This research is limited due to its sample size and considered as an exploratory study, in which PLS-SEM was used to identify the impact of game framing and task framing as well as support the theory development regarding the dual nature of citizen science games.

Practical implications—This research provided suggestions for scientists, designers, and project initiators that game framing and task framing should be effectively integrated to provide enjoyable and meaningful experiences so as to promote user contribution.

Originality/value—This research is an initial study which explored the impact of the dual nature of citizen science games. The findings provide the groundwork for guidelines and strategies to facilitate user contribution in citizen science projects.

Keywords: Citizen science games, user participation, task design, stimulus-organism-response framework, user experience.

1. INTRODUCTION

Citizen science is a crowdsourcing approach through which members of the public are recruited to help with scientific data collection or analysis in distributed systems, often via an open call for contribution over the web (Bonney et al., 2014). Participants contribute by working on tasks such as observation, annotation, and classification (Wiggins and Crowston, 2011), and citizen science projects have become important outlets to promote science communication and education (Bonney et al., 2016, Crall et al., 2013). Citizen science projects are inherently interesting to many people, but can also be difficult, complex, or potentially tedious for others. The success of a citizen science project relies upon motivated crowds of participants, so identifying factors that motivate and engage user participation is an important question to be addressed by citizen scientists, designers, and project initiators. Many different motivations have been explored, including altruism, activism, and tangible rewards (Rotman et al., 2014, Curtis, 2015). More importantly, knowing how to design citizen science projects in a way that effectively enhances the user experience is a more proactive approach when it comes to addressing challenges such as low user retention, participation, or contribution. Games and play are therefore viewed as promising approaches for motivating citizen science participants (Preece, 2016, Greenhill et al., 2016), and citizen science games have become a trendy form of design in extant citizen projects, such as Foldit, Eyewire, and Galaxy Zoo.

In citizen science games, scientific tasks and game features overlay and interact with each other. Traditional game elements such as reward and punishment systems, goals and achievements, chance and probability, obstacles and objectives, narrative and exploration, etc. can imbue scientific activities with hedonic, enjoyment focused characteristics (Sicart, 2008, Curtis, 2015, Bowser et al., 2013). In some cases, this is done through gamification, the application of individual game-like elements such as points or competition to non-game contexts (Deterding, 2012, Deterding et al., 2011). In others, participants may engage with science through "full-fledged" serious games, not unlike the commercial titles available in online marketplaces such as Steam or Origin. Both gamification and full-fledged game approaches are in accordance with the idea that game design can inspire participation and motivation in purposeful systems (Deterding, 2015). In this research, we use the term "game framing" to encapsulate the various game elements that lead many citizen science participants to perceive a task-oriented scientific experience as "a game," and we are interested in exploring how serious games with scientific purposes could possibly engage and motivate participation.

We further recognize that, just as play can influence perceptions of science, so scientific tasks can influence perceptions of play through values such as altruism, inquiry, and scholarly insight (Curtis, 2015). Citizen science projects are often promoted as being altruistic ("helping scientists"), educational ("improving oneself") or a mix of the two (Wiggins and Crowston, 2011). Absent game elements, citizen science projects most often attract participants through an appeal to people's desire to do something meaningful, either for others or for themselves: the science that will be accomplished, the education that the work will provide. We consider appeals of this kind to be task framing.

In recent years, many studies have investigated the impact of game elements, though in the majority of this work, attention is focused mostly on hedonic experience like fun or enjoyment (e.g., Pe-Than et al., 2014, Siemens et al., 2015) or on outcomes, for example quantity or quality of work accomplished (Suh and Wagner, 2017). Yet citizen science games also have the potential to serve a eudaimonic role for players by creating lasting meaning and insight. A few researchers have noted the importance of meaning in serious games (e.g.,Powell and Colin, 2008, Deterding, 2014, McGonigal, 2011). Game framing and task framing result in experiences that are different in important ways from hedonically-oriented entertainment games and non-game (but often richly eudaimonic) scientific activities. Such experiences have a complex, dual nature, part work and part play, and in this research, we advocate for the study of both the hedonic and eudaimonic aspects of citizen science games.

To better understand this duality, we designed and implemented a citizen science system, *Citizen Sort*, featuring two "full-fledged" citizen science games: *Forgotten Island* and *Happy Match.* We constructed research hypotheses to help explain the effects of game framing and task framing on users' hedonic and eudaimonic experiences in these two games, and we evaluated our hypotheses with a mixed-methods approach, drawing on responses collected by survey from various players of the two games. We developed a model to explore the impact of game framing and task framing on enjoyment and meaningfulness, which in turn may influence player participation behaviors. We further elaborated upon this model via a qualitative content analysis of participant's open-ended responses.

2. CITIZEN SCIENCE GAMES

2.1 *Games and gamification*

There is a long tradition of leveraging the motivating, enjoyable qualities of gaming for non-entertainment purposes, an approach labelled in various ways by various researchers depending on context and the scope of implementation. In this work we draw a distinction between two of the most common terms, "gamification" vs. "serious games". Gamification is commonly referred to as the application of game-like elements to non-game contexts, usually with imposed limits on the scope of implementation that make the resulting experience something different than a "full-fledged" or "serious" game (Deterding et al., 2011, Deterding, 2015, Michael and Chen, 2005). Both serious games and gamified systems can be used to leverage the benefits of play for practical, motivational outcomes.

Extant studies have generally found that game features, whether implemented in the context of gamification or in a full-fledged game implementation, can have a positive impact on user motivation and engagement (Morschheuser et al., 2017, Pe-Than et al., 2014), attitude and user satisfaction (Hamari, 2015), learning outcomes (Santhanam et al., 2016), participation behavior (Ding et al., 2017, Hamari, 2013), and task performance (Landers et al., 2017, Buckley and Doyle, 2017). Of the two approaches, gamification design tends to be more commonly implemented in various contexts, such as crowdsourcing (Mekler. et al., 2017), marketing (Bittner and Shipper, 2014), and education (Landers and Armstrong, 2017), possibly because of the extra challenge of developing a full-fledged game vs. incorporating just a few specific game mechanics into a non-game experience (for example leaderboards, badges, or achievements). In addition, game researchers have frequently expressed concerns about the sometimes shallow understanding of gamification in disciplines where it is used (Deterding, 2014, Bogost, 2011) and designers and researchers alike tend to argue strongly for the importance of games as dynamic systems, where the interaction of individual elements produces the most strongly perceived effects (e.g., Schell, 2008, Hunicke et al., 2004). With this in mind, our investigation favors full-fledged "serious games" and treats game framing as more than individual game features, but rather as a complex, holistic construct, with an emphasis on game dynamics and patterns evolved through the integration of individual game elements.

2.2 *Dual nature of citizen science games*

A number of citizen science projects use games and/or gamification as a motivational tool, including world class projects such as *Zooniverse*[1], *Eyewire*[2], and *Foldit*[3], and many others. The dual nature of citizen science games – the possibility for spending large amounts of time playing while also engaging with a scientific task – seems to create a strong potential for satisfying more than just hedonia needs. Prior studies on gamification or serious games have traditionally focused on fun, limited to investigations of hedonic experiences such as enjoyment, immersion, and flow, even when play and work are intertwined (Santhanam et al., 2016, Morschheuser et al., 2017, Greenhill et al., 2016).

From a player standpoint, there are two interconnected ways of understanding such experiences, e.g., as either *games* (setting aside, for the moment, distinctions between gamification and serious games) or as *tasks*. These player perspectives are not mutually exclusive, as prior studies show that playing games not only leads to the enhancement of hedonic experience such as fun or enjoyment, but can also stimulate more complex feelings in

[1] http://www.zooniverse.org

[2] http://eyewire.org

[3] http://fold.it

players, e.g., striving for greater insight, meaning, and purpose in life (Oliver et al., 2016, Oliver and Bartsch, 2010). This type of gratification is dubbed "eudaimonia" gratification (Waterman, 1993, Oliver and Bartsch, 2010), indicating fulfillment through meaningfulness and appreciation. Several researchers have advocated the power of eudaimonic needs in producing human well-being (Ryan and Deci, 2001). In game related studies, researchers have also specifically argued for rethinking game design as a critical, transformative design practice to serve human flourishing (Deterding, 2014), contributing to "something that has lasting significance beyond our own individual lives" (McGonigal, 2011, p. 50).

The dual nature of citizen science games makes it possible to afford experiences that are both playful and meaningful. Though major attention has been given to design for enjoyment and fun, several studies have also identified the importance of meaning, helping, and contribution in motivating participation in science activities (Curtis, 2015, Chandler and Kapelner, 2013, Tinati et al., 2017). Contribution to a project and contribution to science were the most frequently mentioned motivational factors for participation in citizen science projects such as Eyewire (Tinati et al., 2017) and iSPEX (Land-Zandstra et al., 2016). However, these studies are mostly based on descriptive analysis and do not specifically touch upon either the distinctive conceptualization of hedonia and eudaimonia or how they relate to the design components of citizen science games. In this research, we aim to address this gap by using citizen science games to study how game framing and task framing can lead to players' hedonic and eudaimonia gratifications and their subsequence behaviors.

3. CITIZENSORT OVERVIEW

We developed *Citizen Sort*[4] in 2013 to facilitate research on citizen science games. *Citizen Sort* is an online platform that supports a real-world science task: taxonomic species classification. It was developed in partnership with life science domain experts from several scientific institutions, and was tailored to support information science, human-computer interaction, and user experience research. Since its release, more than 5,000 participants have signed up for *Citizen Sort* accounts. *Citizen Sort* includes two "full-fledged" serious games: *Happy Match* and *Forgotten Island*. Both use game framing and task framing to shape the user experience and encourage participation.

3.1 *Happy Match* and *Forgotten Island*

In *Happy Match* and *Forgotten Island*, players are shown photos of moths and answer questions that help taxonomically classify the moths to species (see Fig. 1). Questions and

[4] https://citizensort.org

answers are organized around biological "characters" and "states." Each question asks about a specific character, e.g., "shape at rest," "forewing main color," "forewing highlight color," or "wing pattern." There are several possible answers, or states, that players can select, e.g., (for shape at rest) "arrow," "spread," "tent," etc.

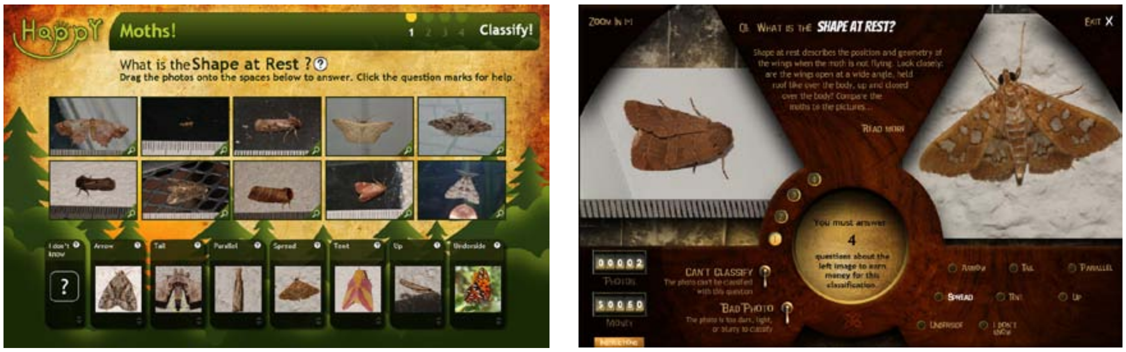

Fig. 1. Classification screens for *Happy Match* (left) and *Forgotten Island* (right). *Happy Match* players answer questions by dragging and dropping photos into the bins at the bottom of the screen. *Forgotten Island* asks players the same character-state questions and provides the same answer choices as *Happy Match*, but differs aesthetically and is themed around the adventure world of the game.

The correct answers to most photos in the games are not known. Participants produce metadata about the images through their answers, helping to produce accurate identifications to species. Occasional images are gold standard photos that have been previously classified by experts. These are used to estimate data quality and to generate performance feedback. From a standpoint of task, *Happy Match* and *Forgotten Island* function nearly identically.

In previous work (Prestopnik and Tang, 2015), we embraced the differences between *Happy Match* and *Forgotten Island* to conduct comparison studies and unpack distinctions in game framing between these two games. In this study, we adopt a different level of analysis, evaluating the two games as instantiations of the same fundamental idea: the use of game framing and task framing to encourage participation in crowdsourced scientific activities.

3.2 *Game framing*

Happy Match and *Forgotten Island* both present the embedded scientific task as play, e.g., as fun, engaging, entertaining, challenging, artistic, and escapist. Task performance is connected to quantitatively defined variable reward outcomes, e.g., reinforcement learning and the so-called "dopamine loop" (Howard-Jones et al., 2011, Eyal, 2014, Koepp et al., 1998). As shown in Fig. 2, *Happy Match's* reward system is points-based. Players earn high scores, including bonuses, which are used on the *Citizen Sort* website to rank players. *Forgotten Island* includes far more content than the classification interface alone, and so twists the notion of points, rewarding players with in-game currency instead. Monetary rewards are used to purchase equipment that will progress the game, unlock new map areas to explore, and advance the story. While *Forgotten Island* is a story-based adventure that offers the aesthetic and experiential attributes of many commercial games, *Happy Match* is a more limited experience, essentially a quiz organized around points and performance. However, *Happy Match* and *Forgotten Island* are both full-fledged games, in that they each offer a complete play experience, including victory conditions, goals, obstacles, etc.

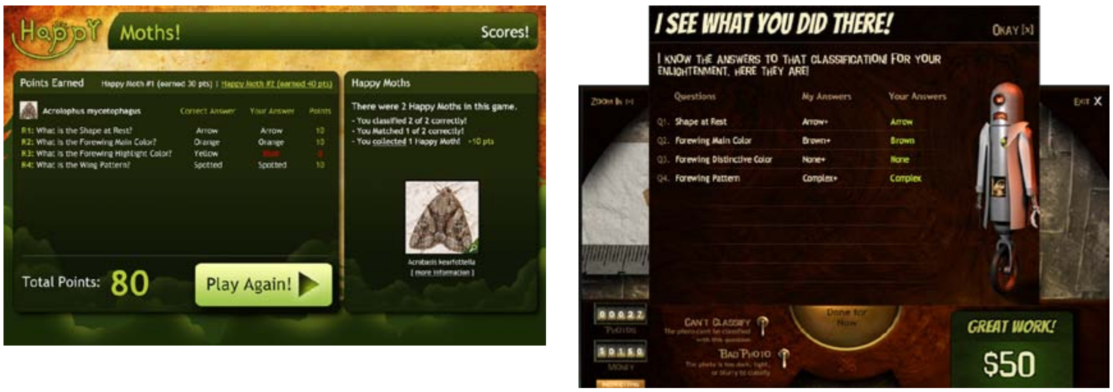

Fig. 2. Feedback and reward screens from *Happy Match* (left) and *Forgotten Island* (right). Players are briefly shown either a green reward pop-up graphic or a red punishment graphic, depending on how well they have classified the photo.

3.3 *Task framing*

Happy Match and *Forgotten Island* emphasize task in order to make their science content noticeable and meaningful (see Fig. 3). In both games, players are given information to establish and reinforce the scientific value and purpose.

It is tempting to worry that task framing could undermine the playful aspects of each game *as* a game, or that game framing might undermine the serious intent of the embedded science. We suggest that it is equally plausible that game framing and task framing complement one another. When framed as a fun and altruistic undertaking, the convergence of play and task may help attract players to the game, supporting both hedonia and eudaimonia gratifications.

Fig. 3. Task framing screens from *Happy Match* (left) and *Forgotten Island* (right). *Happy Match is framed as a game for good.* At the beginning of Forgotten Island, comic-book pages directly inform players of the game's scientific purpose, and urge players to help scientists, work carefully, and do as well as they can.

4. RESEARCH HYPOTHESES DEVELOPMENT

Game framing elements and task framing elements should both be significant predictors for user experience and behavior in citizen science systems (Preece, 2016). The stimulus-organisms-response (S-O-R) framework (Mehrabian and Russell, 1974) from environmental psychology establishes an overarching framework that enhances our understanding of how environmental stimuli can affect a person's affective states and behavioral responses. This framework has gradually evolved to explain the interrelationships among design characteristics, user evaluations of the design, and user reactions in different contexts (Kim and Lennon, 2013, Cyr and Head, 2013). It has also been used in gamified crowdsourcing research to denote how game framing elements impact users' psychological and behavioral outcomes (Morschheuser et al., 2017). Participants respond to task framing and game framing elements based on the nature of these stimuli and their own internal characteristics and states, and their responses could be reflected by behaviors such as participation sign-ups, participation rates, and participant retention. Therefore, we use the S-O-R model as a meta-framework to develop hypotheses about the effect of game framing and task framing on participant experiences and behavior in citizen science games. Fig. 4 shows our proposed research model, which depicts how game framing and task framing, two layers of design characteristics, contribute to perceived enjoyment (hedonia) and experienced meaningfulness (eudaimonia) and then subsequently impact user participation in citizen science projects. The following subsections provide more details on our research hypotheses.

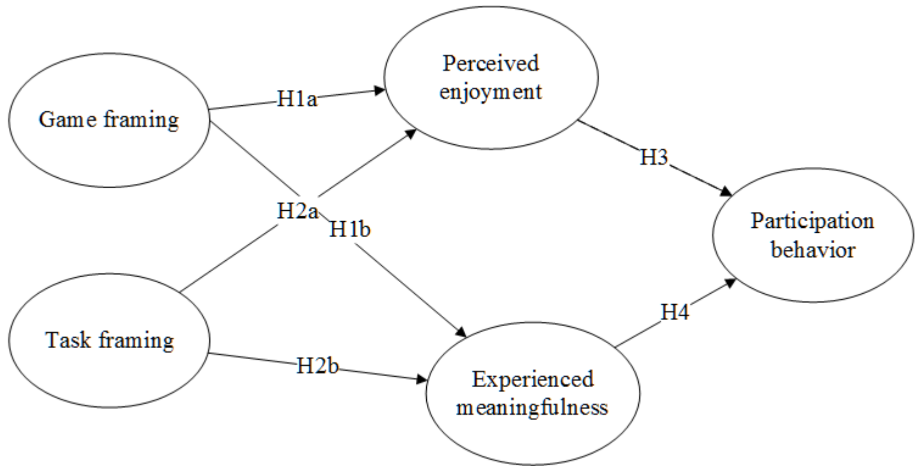

Fig. 4. Research Model.

4.1 *Game framing and task framing*

Game framing is the imposition of playful structure upon experience, compelling players to learn mechanical systems and to engage with the game world. For example, many games take advantage of outcome uncertainty (Costikyan, 2013), game spaces (Schell, 2008), reward cycles (Howard-Jones et al., 2011), competition (Santhanam et al., 2016) and other mechanics because they are known to be motivating from a psychological or experiential perspective. Game designers also gravitate toward story as a tool for engagement, for example, focusing upon the “epicness” of games (McGonigal, 2011) or the role of fantasy in motivation (Malone and Lepper, 1987, Rieber, 1996). Game framing is seen as immersive and entertaining, primarily serving the hedonic interests of players.

In a prior study on website perception, the way tasks were framed was found to impact consumers’ perceptions of a shopping website and their viewing behaviors (Cyr and Head, 2013). In exercise research, framing a goal as intrinsically motivating lead to higher performance than framing it as extrinsically motivating (Vansteenkiste et al., 2007). Studies on gamification also have shown how task framing can influence user activation and engagement (Lieberoth, 2015, Kundisch and von Rechenberg, 2017). Therefore, though most participants will naturally consider working on scientific tasks to be serious and valuable, it is important to specifically articulate the significance and meaning of tasks and to note the value of a participant’s scientific contribution.

4.2 *Experienced meaningfulness and perceived enjoyment*

Perceived enjoyment refers to hedonic experiences associated with fun elements in citizen science games. Prior studies have explored the effects of game design on users’ level of enjoyment and engagement in serious work (Santhanam et al., 2016, Bittner and Shipper, 2014). In the context of crowdsourcing, designed features like incentives, rewards, points, leaderboards, and stories, can influence a player's psychological experiences, such as motivation, fun/enjoyment, and engagement (Morschheuser et al., 2017). In gamified citizen science systems, adding game elements to repetitive or monotonous tasks can make participation more fun and enjoyable (Flatla et al., 2011). Therefore, we hypothesize:

Hypothesis 1a: Game framing has a positive impact on perceived enjoyment.

Researchers have found that players may gain meaningful insight through playful activities (Oliver et al., 2016, Oliver and Bartsch, 2010). Many game elements are purpose-built from knowledge of human psychology and brain chemistry to enable interaction dynamics that immerse and engage users (Howard-Jones et al., 2011). Other kinds of game framing, such as exploration, allow players to try new things, experience novelty, and guide higher-order aspects of play. Reward systems provide instant and meaningful feedback about performance, satisfying the human need to feel competence and enhancing player self-efficacy, which may help players to feel that what they have accomplished is worthwhile. With this in mind, we see a connection between game framing and experienced meaningfulness as well:

Hypothesis 1b: Game framing has a positive impact on experienced meaningfulness.

Task framing describes how tasks are presented to audiences. In the context of citizen science, mentioning the science value of task is an effective way to communicate its importance; how a user considers a task will influence their perceptions of that task (Cyr and Head, 2013). For participants of citizen science games, the hedonic nature of gamified citizen science systems might naturally make them feel engaged (van der Heijden, 2004). However, framing a game task with scientific value adds an additional layer of meaning, with participants understanding that they can learn and contribute to real science. Especially for people who are inherently interested in science activities, knowing the value of their work can lead to enhanced pleasure while playing. Therefore, we hypothesize:

Hypothesis 2a: Task framing has positive impact on perceived enjoyment.

Experienced meaningfulness is a critical psychological state that arises from working on significant tasks (Hackman and Oldham, 1976) with a purpose-oriented focus rather than a hedonic focus (Tims et al., 2016, Steger et al., 2012). Understanding the significance of a task has been demonstrated to have a positive impact on workers' experienced meaningfulness in organizational contexts (Hackman and Oldham, 1976, Steger et al., 2012). Conveying the scientific value of tasks in citizen science games may help to elicit more serious responses from players or make them feel more competent and connected to scientific inquiries. Task framing in the citizen science context can help players to understand the value of their contribution to science in real life, even as they play a game ostensibly for its entertainment purpose. Accordingly, we consider task framing to have an important impact on experienced meaningfulness:

Hypothesis 2b: Task framing has a positive impact on experienced meaningfulness.

4.3 *Participation behavior*

Research on user behavior in crowdsourcing has shown that a small percentage of users typically contribute the majority of scientific data, while most contributors participate only a few times and with little effort (Sauermann and Franzoni, 2015). According to the S-O-R framework (Mehrabian and Russell, 1974) and the job characteristics model (Hackman and Oldham, 1976), behavioral and working outcomes are affected by a person's experienced psychological states.

Several studies have found a positive impact of perceived enjoyment on user behavior (Curtis, 2015, Tinati et al., 2017), and experiencing something interesting and fun is a critical factor for user participation in citizen science projects (Tinati et al., 2017). In a citizen science game, when a player experiences enjoyment, they are likely to stay in the game environment, continuing to explore, interact with the game world, and participate in other ways.

Hypothesis 3: Perceived enjoyment has a positive impact on user participation.

Players will undoubtedly sense the underlying meaningfulness of playing citizen science games, such as enhanced knowledge of science, a sense of contribution to scientific inquires, and insight into life related questions (Powell and Colin, 2008, Tinati et al., 2017), and this meaningful experience has been identified as a critical factor for user participation in serious games and gamified systems (Chen et al., 2015, Land-Zandstra et al., 2016). As a player experiences a sense of self-growth and self-achievement, his or her willingness to participate will be enhanced. With this in mind, we posit that experienced meaningfulness will also positively affect user participation.

Hypothesis 4: Experienced meaningfulness has a positive impact on user participation.

5. METHOD

5.1 *Data collection*

Currently, *Citizen Sort* has attracted more than 5,000 participants. Users who sign up provide their email address and information about their interest in science, nature, and games. For this study, we reached out to former players to follow-up about their participation via an online survey. As an incentive, participants were entered into a drawing for one of ten $10 Amazon gift cards. Data collection lasted from February 2017 to March 2017.

5.2 *Measurements*

Our survey included questions about design, play experience, and participation, as well as open-ended responses about player interest and willingness to engage with science tasks or citizen science games. Respondents were explicitly asked to answer questions based on their experiences with *Happy Match* or *Forgotten Island*.

Measurements of design, player experience and participation behavior were self-developed or adapted from the literature (see Appendix A). Seven-point Likert scale questions (1=strongly disagree, 7= strongly agree) were used to record answers. We reviewed literature on game and task design, developing and testing items to measure game framing and task framing. Other constructs, including perceived enjoyment (van der Heijden, 2004), experienced meaningfulness (May, 2004, Hackman and Oldham, 1976), and participation behavior (Mehrabian and Russell, 1974) were adapted from the literature. We conducted a plot study with 41 undergraduate students to test the validity and reliability of our instruments. These undergraduate students were introduced to play *Citizen Sort* for half an hour, and then they were invited to answer our survey questionnaire based on their experiences with *Forgotten Island* or *Happy Match*. After removing items that did not load well with their relevant constructs, we finalized the survey questionnaire and sent this instrument to *Citizen Sort* players.

The survey generated 76 valid responses (we removed responses that were incomplete or from players too young to participate). Though small, this sample size meets the recommended ratio of 10 times of the maximum number of items in a construct, so the sample was adequate to validate our research model (Hair et al., 2014). Responses were analyzed through a mixed-methods approach. This included statistical analysis using PLS-SEM to validate our research hypotheses as well as content analysis to add to our understanding of our model.

6. RESULTS

We used PLS-SEM to estimate the measurement model and structural model. PLS-SEM is a component-based SEM approach that is appropriate for the early stages of theory development (Barclay et al., 1995), which fits our goal to explore and understand the impact of game framing and task framing in citizen science games. For content analysis, we used an inductive, open-ended approach to interpret participant responses, looking for additional support to understand respondent's experiences with *Citizen Sort*.

6.1 *Participant overview*

28 participants were male, and 47 were female, with 1 participant choosing not to report any demographic information. Ages ranged from 18 to 67, with a mean of 37.44. We asked participants about their highest level of educational attainment, and found that the majority (N = 47) had a graduate degree. Most of the remainder (N=23) had an undergraduate college degree. Two participants reported a high school education, and two reported a middle school education. Participants were interested in science (interested: 73, not interested: 2) and nature activities (interested: 69, not interested: 6). The majority did not consider themselves gamers (Yes: 26, No: 49), but when asked how many hours they played single-player games in a given week, the response range was between 0 and 70 hours, with a mean of 6.99 hours. Participants were equally split between *Forgotten Island* and *Happy Match* (FI: N = 36, HM: N = 40), the result of an email recruitment procedure that contacted similar numbers of players for each game.

6.2 *Construct reliability and measurement model*

Cronbach's alpha was calculated to measure construct reliability. The reliability of our five constructs ranged from 0.71 to 0.87 (see Table 1); we consider the items within constructs to have good internal consistency as they are all above the threshold 0.70 (Kline, 2011). We also checked the Variance Inflation Factor (VIF) scores of all constructs. Scores ranged from 1.22 to 1.67, less than the recommended threshold of 5 or below (Hair et al., 2014). Accordingly, multicollinearity should be not be a concern.

<<Table 1. Reliability and validity analysis.>>

We calculated and found that the AVEs of all five constructs were higher than 0.5, and the square root of AVEs were higher than the correlation coefficients between latent factors. The composite reliability of constructs was higher than 0.70. We also calculated factor loadings and cross-factor loadings for each item. Our results show that all items had the highest loadings on their designated constructs (all above 0.70), and all are much higher than their cross-factor loadings, which satisfy the requirements of thresholds (Hair et al., 2014) (see Table 2). Analysis results support that our measurement model has good convergent and discriminant validity.

<< Table 2. Factor loading and cross-factor loading analysis..>>

We performed Harman's one-factor analysis to determine whether variances of constructs were due to a common method factor (Podsakoff et al., 2003). A principal component analysis showed that the largest component accounted for 39.6 percent of the variance in the data; no single component explained the majority of data variance. We included a single method factor in the research model and followed procedures suggested in literature (Liang et al., 2007). The factor loadings of items on the common method factor were much smaller than on their designated constructs (see Table 3). Therefore, common method bias should not be a serious concern in this study.

<<Table 3. Common method bias assessments>>

6.3 *Hypotheses testing*

As hypothesized, our results showed that game framing had a significant positive effect on perceived enjoyment ($\beta = 0.33$, $p < 0.05$), supporting H1a. However, game framing did not have a significant impact on experienced meaningfulness, and therefore, H2b was not supported. Task framing was positively and significantly associated with enjoyment ($\beta = 0.26$, $p < 0.05$) and experienced meaningfulness ($\beta = 0.33$, $p < 0.05$), supporting both H2a and H2b. Our results also revealed that perceived enjoyment was positively associated with participation behavior ($\beta = 0.39$. $p < 0.05$), supporting H3. Experienced meaningfulness, however, did not significantly affect participation behavior, so H4 was not supported.

Our structural model indicates an insignificant path from experienced meaningfulness to participation, although the correlation coefficient between these is significant (β=0.39, p <.001). We analyzed whether mediating effects might exist, following procedures suggested by Preacher and Hayer (2008). We examined direct effects from experienced meaningfulness to participation without perceived enjoyment, and found the direct effect was significant (β=0.40, p <.001). We next included perceived enjoyment in our model, finding that the paths from experienced meaningfulness to perceived enjoyment (β=0.53, p <.001) and from perceived enjoyment to participation behavior (β=0.39, p <.001) were both significant. A bootstrapping approach showed that the indirect effect from experienced meaningfulness to participation behavior, via perceived enjoyment, was significant (β=0.21, $p < .05$). Therefore, we concluded that the effect of experienced meaningfulness on participation behavior is fully mediated by perceived enjoyment.

6.4 *Qualitative insights*

To further understand participant perceptions of *Citizen Sort*, we asked three open-ended questions at the end of the survey questionnaire: (1) What elements or components of the game helped to keep you interested in playing the game? How so? (2) What elements or component of the game influenced your willingness to classify pictures of living things? How so? (3) Do you have any other comments or reactions about your experience playing the game? Note that these do not ask about the specific variables of our model.

Following the content analysis method introduced by Neuendorf (2002), we used an inductive, open-coding approach to analyze qualitative data collected by the three free-text questions. Response to each question from a participant was treated as a unit of analysis. Two coders independently developed codes by using the first ten responses and generated a draft coding schema. A third coder moderated the discussion to reach consensus on the meaning of codes. Additional codes were added during the analysis procedure that followed, and the coding schema was finalized when all coders agreed it reached saturation. The coding schema has two categories of codes: design elements and evaluations. The initial inter-coder reliability was 93.82%, and then reached 100% after several rounds of discussion.

Participants typically discussed game design elements and their experiences with the games in both positive and negative tones, and the coding schema was developed to capture this. Table 4 shows the frequencies of positive or negative mentions of design elements codes, which are further divided by games. Game related elements such as story, exploration, challenge, and reward were mentioned primarily in positive terms, suggesting that these enhance players' willingness to play citizen science games. Similarly, the task related elements "science" and "classification," were also more frequently mentioned positively as elements that motivate play. Beyond game and task framing, however, we noted that other aspects of a game's design, for example technical issues, control problems, and graphics, were frequently mentioned by players as negative factors that undermined their willingness to participate.

<<Table 4. Frequencies of Design Elements Codes>>

Table 5 shows the frequencies of evaluation codes, reported either positively or negatively by participants. The most frequently mentioned evaluation codes, such as "interesting" and "enjoyment," seem related to hedonic aspects of the experience, while other frequently mentioned codes such as "meaningfulness," "learning," and "achievement" are more related to eudemonia outcomes. This finding suggests that, in line with our research model, hedonia and eudaimonia are both critical psychological states that have impact on participants' willingness to play citizen science games. Some participants also made negative evaluations, for example on the codes "interesting," "achievement," "enjoyment," and "competence."

<<Table 5. Frequencies of Evaluations Codes >>

Participant remarks illustrated important differences between *Forgotten Island* and *Happy Match*, including differences in design elements and evaluations. *Forgotten Island* players especially valued story, an element of game framing that was not factored into our model but that was identified as motivating and engaging by many players. For example, "The plot and achievements helped to keep me interested in playing the game. Also the fact that I'm helping science." *Forgotten Island* players also highly valued interesting, enjoyable, and meaningful experiences in the game. *Happy Match* players seemed motivated by meaningful and learning-oriented experiences. They remarked frequently on *Happy Match* as both an altruistic scientific activity and as an educational experience.

7. DISCUSSION

7.1 *Game framing vs. task framing in citizen science games*

Our motivation for this study was to systematically assess how game framing and task framing can influence users' experienced meaningfulness and perceived enjoyment in citizen science games. In line with previous research (Tinati et al., 2017, Greenhill et al., 2016), game framing can have a significant positive impact on participants' perceived enjoyment, which leads to enhanced user participation. Task framing also leads to significant positive effects on both experienced meaningfulness and perceived enjoyment. Against our expectations, game framing did not have a significant effect on experienced meaningfulness, nor did experienced meaningfulness directly impact participation behavior. This was surprising, as these results conflict with prior arguments about the meaningfulness and appreciation associated with game framing (Oliver et al., 2016). One possible explanation is that the literature on meaningful entertainment focuses mostly on games, novels, or movies as whole objects, without differentiating specific game framing elements. Game framing and task framing haven't been explicitly examined as two layers that overlay each other, and it is possible that this interrelationship causes effects that remain to be more thoroughly understood. We had expected many players to feel appreciation for, and derive meaning from, the game framing of the two games, and we felt it likely that experienced meaningfulness would directly influence user participation, especially given the enthusiasm for science and nature expressed by our survey respondents.

Post-hoc mediation analysis did show that experienced meaningfulness had an indirect effect on user participation through perceived enjoyment, suggesting that the scientific nature of the games – their meaningfulness to science-oriented players – might have made the games more enjoyable for the players in our sample. Prior research has also noted that when serious games are designed to align with personal goals or interests, meaningfulness experienced by individuals can be a form of intrinsic motivation and lead to enhanced enjoyment (Kawrykow et al., 2012, Mekler et al., 2013). Our players naturally had intrinsic motivations to engage with science tasks, enjoying our games not just as games, but as vehicles for science. This seems to be borne out by our qualitative data, where many participants did note how contributing in a meaningful way to "scientists" or "science" was considered very valuable and enjoyable to them.

Our participants' strong leanings toward science might also help to explain why game framing did not have a significant impact on experienced meaningfulness. For this population of players, game framing is potentially less meaningful than task framing. It is easy to imagine other kinds of players – for example, individuals who frequently play commercial video games – who might derive more meaning from game framing than from science. It is also possible that the game framing of *Forgotten Island* and *Happy Match* had no significant impact on meaningfulness because the design of these games is not moving or touching enough to produce such effects.

A third possibility is that our treatment of game framing in terms of exploration and rewards may be too narrow to fully capture any meaningfulness experienced. Our qualitative data provide some support for this possibility, especially the importance of story, and so we explore this idea more deeply in the next section.

The insignificant findings in our model underscore the unique nature of citizen science games (and perhaps other kinds of serious games and gamified experiences), wherein the duality of game framing and task framing can attract populations with particular interests and perceptions. While our findings about game framing and task framing are largely in line with current arguments regarding hedonic and eudaimonia gratifications in games (Oliver et al., 2016), we also see how play may or may not be meaningful for some kinds of players, and how serious work can similarly be enjoyable or not depending on one's intrinsic attitudes towards task.

7.2 *Story and meaning*

In this study, we treated our two games, *Happy Match* and *Forgotten Island* as instantiations of the same design concept: serious or "fully-fledged" citizen science games that are presented to players through game framing and task framing. Nonetheless, these games do have fundamental differences.

Participants noted that story – an element of *Forgotten Island* but not *Happy Match* – was an important motivator. Having finished *Forgotten Island's* ~5-hour plot, some participants also noted that this was the moment when they finally discontinued play: "I finished the plot. It turns out that was the thing that kept me playing," and, "The story line is at an end. No point in playing any longer," and "I finished it so I stopped playing." We downplayed story as an aspect of game framing for the purposes of this study, but we acknowledge that story can have a real impact on players' willingness to play and their decision to stop playing, i.e. their decision to stop participating.

Happy Match has no such stopping point, and players discontinued play at various points and for various reasons, e.g., "it became repetitive," "I forgot about it," "no follow-up to the game," "time constraints," etc. Several participants suggested that a continuous outreach effort, with reminders or incentives, might have kept them playing.

Story took on this kind of "reminder" role in *Forgotten Island*. The narrative arc provides a continuous set of goals for players, objectives that call them back to the game over time and keep them playing. The story is also linked to mechanical game framing elements, strengthening the goal-directed behavior that it encourages.

As game framing, *Forgotten Island's* story is structured around puzzles, e.g., the player is only able to unlock and access certain areas of the game and new chapters of the story by finding and using items at the right moments and in the right locations. The story also motivates mechanics like exploration and the acquisition and use of items. In its role as game framing, *Forgotten Island's* story offers significant hedonic gratifications. The finding of items, the novelty of exploration, and the creativity of self-expression all contribute extensively to player enjoyment and fun, as illustrated by our qualitative data.

From a standpoint of eudaimonia, *Forgotten Island's* story might be better considered as a standalone element. From this vantage, story is more than a mechanical system: it is also an experience structured around twists and turns, interesting characterizations, archetypes, dramatic questions, adventure, setbacks, obstacles, themes, and, ultimately, victory for the player (Vogler, 2007). Storytelling is fundamentally human, and stories can simultaneously be highly enjoyable and profoundly meaningful.

Though game framing had no significant impact on experienced meaningfulness in our structural model analysis, a respondent of *Forgotten Island* mentioned, "The choices had consequences, which mirrors life." This is just one example, but it lends some support to our argument for eudaimonia gratification associated with game framing. Still, we failed to identify much other evidence to support this relationship. One possibility is the nature of *Forgotten Island's* narrative, which is humorous, light-hearted, child-like, and not necessarily deep or thought-provoking. Given the significant impact of game framing on enjoyment, and the comments about story as enjoyable and motivating, it may be that the narrative written for *Forgotten Island* does a good job enhancing players' sense of enjoyment and fun, but is not incisive or profound enough to produce feelings of meaningfulness. It would be interesting to explore hedonic and eudaimonia gratifications in citizen games with different kinds of stories.

Happy Match lacks a story, so its players experience eudaimonia through their own inherent interest in the task. Because the matching activity and its scoring metrics are, in some ways, merely game-like mechanical crenellations layered onto task, in this and other work (Prestopnik and Tang, 2015), we find that *Happy Match* tends to attract players with an already well-developed interest in science and a basically altruistic or educationally-oriented mindset.

We can see clear advantages and drawbacks to using story (Zyda, 2005, Jenkins, 2004), including citizen science games and other game design contexts. For some players, story can be motivating, prolonging play and encouraging contribution to scientific tasks. However, story also imposes limits on play (and, therefore, participation); when a story is concluded, players lose interest. Additionally, writing compelling stories that are enjoyable and meaningful is no trivial endeavor. Storytelling is an art form, not a science, and so while great opportunities can present themselves when deploying story as a tool for motivation and engagement, so, too, can great risks. For some kinds of players – e.g., the science-oriented players of our study – it may be that story is simply not as effective for player recruitment and retention as strong, positive task framing, possibly even without game elements at all.

Not having enough data to delve into all these issues, we can only conclude that story can – at least sometimes – be a profound aspect of game framing, one worthy of further exploration. In future work we look forward to investigating the role of story as a game framing element and as a contributor to experienced meaningfulness and perceived enjoyment.

7.3 *Research and Practical Implications*

Our paper has several research and practical implications. Theoretically, we drew upon the stimulus-organism-response framework to investigate how game framing and task framing can serve as environmental factors to impact players' organismic states and behaviors in citizen science games. Our discussion showed how players expressed different insights about game framing and task framing and their effects on the play experience. We also conceptualized both hedonia and eudaimonia aspects of these citizens science play experiences, and we specifically argued for the importance of understanding this dual nature of citizen science games (and perhaps other serious games as well). Third, our findings provided empirical support that citizen science games are indeed considered a richly rewarding mix of work and play that can provide unique, worthwhile experiences for players.

Practically speaking, scientists, designers, and citizen science project initiators face many challenges when it comes to recruiting and retaining users. Though games are a promising direction for enhancing user experience, motivation, and participation, it is still uncertain how participants' experiences are shaped by the game layer and work layer of citizen science games. Our findings suggest that game framing and task framing should be effectively integrated to promote player contribution behaviors.

In future research, we will be interested in more deeply exploring game framing, and in further investigating the relationships between hedonic and eudaimonia experiences in citizen science games. Research on user behavior in crowd projects has identified that among millions of contributors, it is typical that only a small percentage will contribute the majority of scientific data. Most contributors will participate only a few times and with little effort (Sauermann and Franzoni, 2015). Similar contributor distributions have also been found in online communities and in citizen science games (Prestopnik et al., 2017). The quality and amounts of data provided by different kinds of users, the ways different users experience and appreciate the system in question, and the retention rate of participants are all important, if complicated, aspects of participation. In our future research, we will further explicate our model and to unpack participation in a more holistic sense. We would also like to investigate whether games can be an effective way to attract science non-enthusiasts or even make them more willing to contribute to citizen science activities.

8. LIMITATIONS AND CONCLUSION

In this research, we explored the dual nature of citizen science games, which are presented to players not only as games, but also as scientific activities. We conceptualized this in terms of game framing and task framing, explicating how these environmental stimuli can impact perceived enjoyment, experienced meaningfulness, and ultimately, participation.

Several limitations should be noted. First, our sample is relatively small and dominated by a population interested in science and nature. It would be interesting to explore other populations with different degrees of interest in science, nature, and games to see how they react to various game framing and task framing approaches. Second, our analysis is based on subjective responses and open-ended questions, which can impose a self-reporting bias. Therefore, beyond the subjective participation measures used to test our model, we also understand the importance of studying and understanding complex user contribution patterns in citizen science projects through more objective measures. Third, our content analysis focused on the descriptive level, providing frequency and valence information about design element and evaluation codes, yet we did not further elaborate how design element codes are associated with player evaluations or behaviors.

Our findings suggest that game framing and task framing both make important contributions to how a player perceives and reacts to citizen science games. Game framing had a strong impact on enjoyment, while, for users of a scientific bent, task framing positively impacted both meaningfulness and enjoyment. We posit that in citizen science environments, and perhaps in other kinds of serious game experiences, it is important to emphasize *both* task and game. The hedonic outcomes of game framing are useful for attracting and retaining players, but the eudaimonia of task elevates playful experiences to something truly meaningful.

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APPENDIX A Instrument

Game framing (self-developed and tested)

- The game offered possibilities for exploration
- The game offered possibilities for earning rewards

Task framing (self-developed and tested)

- The game explained why I should work on the scientific tasks
- The game explained the value of the scientific tasks

Perceived enjoyment (van der Heijden, 2004)

- My interaction with the game is enjoyable
- My interaction with the game is pleasant
- My interaction with the game is exciting

Experienced meaningfulness (May, 2004, Hackman and Oldham, 1976)

- Playing this game gave me new insights about life
- Playing this game enriched my life in some way
- Playing the game was worthwhile

Participation behavior (Mehrabian and Russell, 1974)

- I spent time playing the game
- I explored the game
- I left this game as soon as possible (R)