An Investigation of Player Motivations in Eyewire, a Gamified Citizen Science Project

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Abstract

Sustained engagement of participants is essential for the success of a citizen science project. However, the motivations of why people engage with such activities can be idiosyncratic, varied, and evolving. In this article we examine player participation in Eyewire, a citizen science game. We undertake an investigation of why Eyewire players take part in the game based on responses from a large-scale survey. Our analysis identifies 4 groups of features which impact participation and long-term engagement. We draw on theories of motivation and and consider the 4 categories with respect to the intrinsic and extrinsic motivations of engagement. We assimilate our findings into a framework of volunteer participation for gamified citizen science, which draws on existing design frameworks, in order to support the design of future crowdsourced science projects.

Keywords: Citizen Science, Player Motivations, Gamification, Crowdsourcing

1. Introduction

Web-based citizen science projects enlist the help of large numbers of volunteers to solve challenging scientific research problems. In recent years, citizen science has become a reputable and scalable solution to support scientific ventures, employed by a swathe of domains, from physical and natural sciences (e.g., [1, 2]) to the humanities and arts (e.g., [3]).

As computational systems, they are human-agent collectives [4] that leverage human computation and crowdsourcing [5] to help professional scientists process huge amounts of research data to advance their work. As communities, they foster an environment for loose-knit communities to form, whose members interact via online fora [6, 7] and real-time chat systems [8]. Interactions are varied in scope and purpose, from discussions on tasks, platform features, and general topics, to calls for competition or collaboration to achieve a community-defined goal. The combination of human computation and sociality has shown to be highly effective, not only in accomplishing the original scientific objectives that were

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outsourced to the crowd, but also in yielding unanticipated discoveries initiated by members of the community [7].

Even though a significant number of success stories in citizen science exists, the behaviour of participants varies greatly across projects and platforms. Numerous initiatives had to be halted prematurely or cancelled entirely because they could not reach a critical participating mass or keep their contributors engaged [9]. And serendipitous citizen-led discoveries via forum communication serve a compelling narrative but are definitely not the norm one can naturally expect when launching a citizen science project.

One of the most critical challenges in designing successful CS systems is in recruiting and sustaining participation over time. Key to understanding it is the question of user motivation. What factors drive participants to volunteer their (free) time to support a scientific cause, that, intuitively, has no immediate benefit for them? Studies have found that in volunteer-based citizen science, contributions tend to be largely driven by intrinsic reasons, including (i) the desire to help a worthy scientific cause, (ii) a personal interest in science, or (iii) the sense of belonging to a group of like-minded people [10]. But as diverse as the systems and projects in citizen science are the people participating (or not participating) in it, which asks for further studies of user motivations to widen the examined citizen science platforms and cultural contexts.

In this paper we explore player motivations in Eyewire,[1] a Web-based citizen science game that aims to create a detailed map of the human brain by asking people to identify connected areas in 3D-transformed fMRI images. We undertake an investigation of Eyewire participant motivation based on a survey pertaining to Eyewire player participation. The survey consists of $1,505$ responses to a questions related to playing Eyewire. Our analysis draws upon a set of thematically coded responses; we develop a coding frame of 18 characteristics related to participation and engagement. We contextualise our findings against the broader literature on motivation and online communities [11, 12, 13, 14, 15] and introduce a framework for participation, which sits at the intersection between online citizen science and gamification, grounded on participant survey responses.[2].

Our insights have shaped the way Eyewire engages with its community and are part of an ongoing debate about the role of gamification in citizen science [17]. Our findings provide evidence to support the use of specific game elements, which adds to the existing gamification literature, specifically with regards to placing external rewards [17, 18, 19]. Eyewire is just one of several successful initiatives in this space which marry the two for the benefits of science and the underlying community of volunteers. We hope that the present study, one of the most complex of its kind in terms of data sources and methods, will have implications on the design of future similar systems, in particular with respect to the effective use of game elements to turn a highly specific scientific task into an entertaining and positively addictive (social) experience.

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[1]http://eyewire.org/

[2]This work builds on and extends previous studies of the Eyewire platform and the Eyewire player participation study [8, 16]

2. Related Work

2.1. Motivation Theory

There is a long history of using motivational theories to study the behaviour and participation of individuals in online communities and Web systems [20, 21, 22]. In many studies, Self-Determination Theory (SDT) has been used a theoretical framework to help understand why people take part and contribute to online communities [23, 24, 25, 26, 27]. More specifically, SDT has been used extensively in gamification research and game design [28, 29].

Self-Determination Theory [30] describes human motivation based on two types of motivations: intrinsic and extrinsic [31, 32, 22]. Intrinsic motivations are those which apply when the individual finds fulfilment in performing the activity (i.e., just for fun). Alternatively, extrinsic motivations are related to the attainment of a goal (i.e., to gain a promotion), or some external outcome (e.g., a reward such as a financial gain). Intrinsic and extrinsic motivations are closely linked [33], and studies have shown, the relationship between the two are often antagonistic [34, 35]. Attending to the intrinsic desires often have a direct impact on extrinsic rewards, which for system designers, is an important consideration when developing platforms. For example, intrinsic motivations have been found to have a positive psychological effect, improving wellbeing, and thus increasing creativity, learning outcomes, and quality of life [36].

In the context of online communities, crowdsourcing tasks, and citizen science projects, studies have investigated how facilitating the intrinsic and extrinsic motivations of participants using suitable technical and social features can help improve an individual's contribution and duration of engagement [37]. It has also been noted that the type of task which they are attempting to complete is linked to the type of motivations which individuals exhibit [38]. As suggested by Ryan *et al.* [22], and Vanstweenkiste *et al.* [39], the emphasis of extrinsic rewards should not be used to come at the expensive of the intrinsic award, which subsequently will undermine and discourage intrinsic motivations.

2.2. Citizen Science and Online Communities

We focus our discussion on studies of volunteers in the context of citizen science and 'games with a purpose' (GWAPs) [40], as a human computation design paradigm that is used in Eyewire. Related work has attributed various aspects of online participation to intrinsic, extrinsic, and social factors [34, 13]. This work also builds on existing studies pertaining to the study of the Eyewire platform [8, 16].

Brabhams's study of Web-based content production competitions, for example, found that contributors were motivated by both the ability to be creative and part of a community, but also by the ability to make money and improve their reputation and skills [31]. Moor and Serva [41] articulate motivation factors based on correlating expressions, identifying 14 different categories of motivations, which cover intrinsic and extrinsic aspects. Crowston and Fagnot [42] describe motivation arcs, which account for changes in motivation over time, and investigate the prevalence of specific factors at different stages of participation, an idea which is based on Hackman and Oldham's word design model [43]. Frameworks such as these aim to understand and model why people decide to get involved in an activity, and how their engagement continues beyond the initial contact. Another example is the Reiss profile [44], a personality-based approach to assessing motivation; their approach identifies themes such as power, curiosity, social contact, status, and tranquillity. Kraut and Resnick [13] name 16 basic desires related to personal motivations in their work on building successful online communities.

2.2.1. Gamification

The implications of game mechanics and gamification on user engagement have been an extensive subject of study and debate in numerous studies [45, 38]. Building on insights from behavioural economics, researchers and design practitioners have tried to understand how to purposefully use well-established game elements to drive participation [46], encourage sociality, and avoid potential negative effects of incentives on intrinsically motivated activities [33]. Surveys of GWAP players [47] have identified the factors of challenge and desire to learn and improve [48] alongside social interaction as conducive to developing a successful game with a purpose. As described by Spitzberg [49], motivations are often the precursor to skill acquisition, which reinforces the need to facilitate and encourage a vibrant environment, which may include aspects of community and communication [50], which have been found to be motivating factors for participation in other types of Web platforms, such as Facebook [51].

Pertaining to Citizen Science communities, Raddick et al. [10], Jackson et al. [52], and Tinati et al. [53] have discussed the role of intrinsic themes such as altruism, collaboration, personal interest, and learning in the behaviour of amateur scientists. Extrinsic motivations have been shown to drive participation as well, especially when CS is gamified [54, 55, 56]. However, the use of gamification within citizen science has been shown to be task and domain specific [57, 38], and has the danger if reducing the chance of repeat participation.

Our paper is connected to the aforementioned literature in the following way. Situated in the context of GWAPs in citizen science, Eyewire uses similar game elements as FoldIt[1] and EteRNA.[3] It features a somewhat technical user interface, which is designed as a 3D map of a neuron in the human brain which players explore in order to discover and highlight connected regions. There is no game narrative beyond the use of typical game elements such as leader boards, points, badges, and more intricate interface features [58] . On the gamification side, Eyewire is inline with a broader trend in citizen science that utilises 'motivations driven by interest in technology and rewards' [59]. However, we are still far from understanding which of the two has a higher impact on participation: the technology or the task itself; or, going further, the incentives devised through gamification.

In addition, our analysis looks at the effects of other system design features, in combination with game elements, on the behaviour of contributors. In particular, we explore those features that facilitate communication and interaction among players. We examine motivational aspects within Eyewire along three dimensions - task, community, and gamification - in order to find out whether the co-existence of the three within the same system differ-

[3]http://eterna.cmu.edu/web/

entiates it from other citizen science projects, in particular those that have been concerned about the trivialisation of user engagement through 'pointification' [18, 17].

3. The Eyewire Platform

Eyewire is a citizen science project that enlists the help of people to deduce the structure of neurons of the human brain using functional magnetic resonance (fMRI) scans. Crowd contributions are combined with machine learning classifiers to create a detailed map of the connections of neurons - the so-called 'connectomes' - at the back of the human eye. The ultimate goal of the project is to help neuroscientists to achieve a better understanding of the ways in which humans process visual stimuli. At the time of writing, Eyewire has over $130,000$ participants from 130 countries.

Contributors interact with the system via a game interface, which invites them to explore colourful 3D maps to highlight regions with specific physical properties (see Figure 1). The basic region-marking task is performed by clicking on the 2D visualisation on the right in an area that is suspected to be part of the current neuron. The 2D visualisation represents the currently selected layer from the 3D cube shown on the left, which can be rotated for easier inspection. Layers of the fMRI cube can be switched by using the up and down keys.

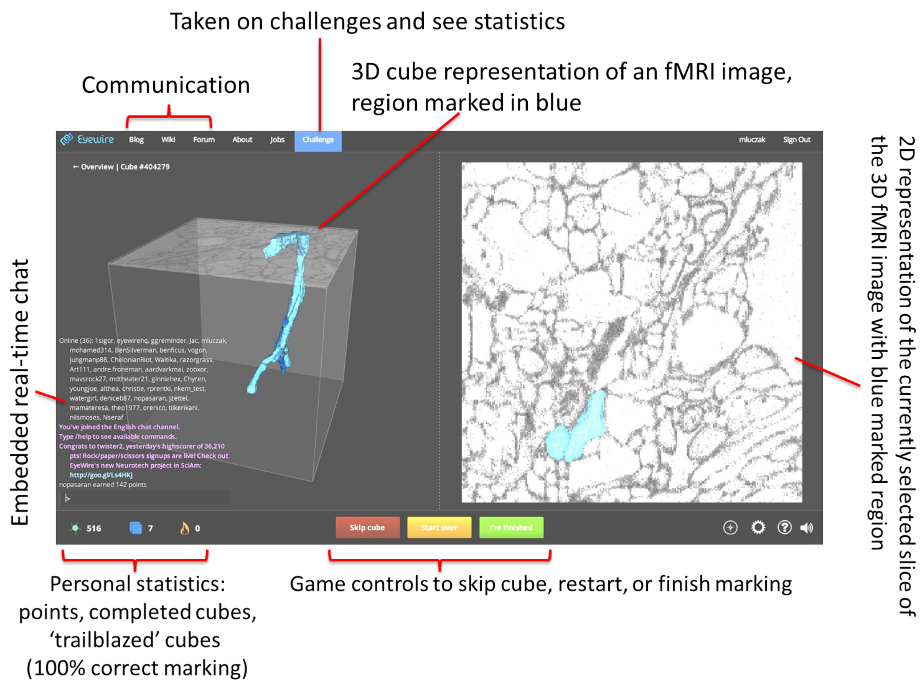

Figure 1: Eyewire Task Interface

3.1. Gamification Features

Gamification elements, including leaderboards, scoring, and competitions [29] are integral to the design of Eyewire. A complete list of these features is summarised in Table

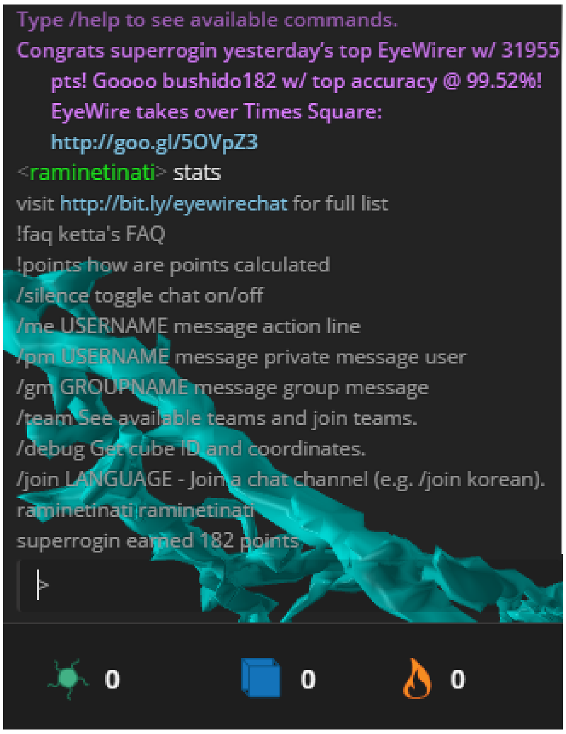

Figure 2: Embedded Chat Interface in Eyewire

1.

Completed tasks are rewarded by points. Leaderboards and activity feeds help with keeping track of one's progress and comparing with others. To further encourage participation, periodic competitions and challenges are run, often bringing the players together in teams. Such events are initiated by community managers or by members of the community themselves, who wish to compete for a specific goal or set of badges. The real-time chat, which can be accessed alongside the task interface, supports a set of game-centered commands, including individual player statistics or team formation.

UI feature	**Purpose**
Points	Players obtain points for their completion of a task. Points obtained are relative to the accuracy of the player
Leaderboard	Displays the top scoring player, or team (dependent on mode of play)
Activity feed	A real-time ticker of the current users online, games being played, and points being won
Puzzle UI overlay	A gamified layer to add a puzzle layer to the completion of marking cubes
Competitions	Community and platform-led competitions, which can be either solo competitions or team play
Real-time chat	A real-time chat mechanism is embedded within the main UI
Game commands	Game commands to enable the player to report stats, and communicate with members of teams and issue private messages

Table 1: Gamification features used in Eyewire

3.2. Sociality features

Players use the real-time chat show in Figure 2 to talk to each other and view each others' points and achievements. The chat supports several pre-defined game commands, issued by using a forward slash '/', that can be used as shortcuts to popular features. For example, the '/silence' command will mute all chat sounds and hide the corresponding window, allowing the user to focus on the actual game play. Further on, there are commands for building teams, broadcasting messages to such teams instead of the public chat feed, and publishing player statistics.

In addition to the chat, the main interface links to additional communication channels which are not part of the game (shown at the top left of Figure 1). There is the Eyewire project blog, where the community managers promote game highlights, competitions, and challenges as well as new or notably successful players. The players can also consult the Eyewire wiki, which contains information about how to play the game, and about the science behind connectome mapping. In addition to these, players are provided with a forum, which facilitates more comprehensive, asynchronous discussions on various topics around the game, including error reports.

Statistic	(All Players)	Play-only	Play and chat	Highly active	Use commands	No commands
Players	97,945	86,659 (88%)	10,705 (11%)	1,060 (1%)	3,152 (3%)	7,559 (7%)
Task entries	4,005,244	1,272,081 (31%)	2,733,163 (68%)	2,007,346 (50%)	2,024,266 (51%)	708,897 (18%)
Chat messages	835,130	-	799,338	705,680	728,380	70,958
Avg. chat messages per user	-	-	75	666	231	9
Avg. commands per user	-	-	10	95	34	-
Avg. play account length (hours)	1,641	416.2	1,641	6,513	2,511	1,278
Avg. chat account length (hours)	495.8	-	495.8	4,788	1,069	256

Table 2: *Participation overview* - Participation in Eyewire, organised by casual participants who only performed tasks ("Play-only"), casual participants who used chat and performed tasks ("Play and chat") and those who participated for more than 30 consecutive days ("Highly active"). The last two columns show the proportion of chat users who also used commands versus not.

3.3. Descriptive Statistics

For a detailed description of Eyewire, we draw on platform data between January 2012 and August 2014, which contains records of 98, 224 unique players, and their 4, 409, 998 games and 835, 732 chat messages. The data has been divided into several players sets, based on their gaming and chat behaviour, as described in related work [8].

As shown in Table 2, a large proportion of the chat and gaming activity is undertaken by only a small number of the total players. 86.2% of games and 95.6% of chat messages are carried out by 10.9% of Eyewire players. It is noteworthy that the proportion of 'active' Eyewire players - those that participate in chat and games - is lower than on other citizen science platforms [60], even though the chat interface is placed inline with the main gaming interface. Within this group of active players on Eyewire we can then observe a similar long-tail distribution of contributions per user compared to other citizen science platforms [60], Considering the subset of 'highly active' players (active for more than 30 consecutive days) Table 2 illustrates that only few more than 1% of Eyewire players produced over 50% of the total games (2 million).

Comparing players who only participated in gaming (which accounted for 88% of the population) to those who engaged in both chat and gaming (the 'active' players), we found that the average number of games completed by gaming-only players was significantly lower (15 games compared to 255). In addition to this, the number of days since the first registration of 'active' players was nearly 4 times higher.

29.5% of players used commands within their chat messages, and command use was found to be positively correlated to the number of games played. Players who used commands within their chat completed over 6 times as many games on average (642 in comparison to 94), yet this had a slight impact on their time to complete a game, taking an extra 31 seconds on average (317 seconds in comparison to 286 seconds). 60.3% of the highly active players used commands within their chat messages. In comparison to the broader category of active players who used commands, the highly active ones used three times as many commands (95 commands compared to 31), with one particular player issuing 23, 900 commands. Considering the average number of chat messages a highly active player produced (666), 14.3% of their interaction with chat involved the use of commands.

In summary, Eyewire exhibits characteristics similar to other crowdsourcing and citizen science platforms; the majority of tasks are completed by a small proportion of the users, and it is possible to identify different types of users based on their behaviour and interaction with system features (e.g. those that use chat). Of significance for Eyewire and our analysis, there are several active groups of players which are engaged, and make use of the talk and gamification features, which may indicate different types of motivation which separate these groups of players.

4. Data and Methods

A survey was conducted by the Eyewire team as part of an ongoing effort to understand their citizen science community; questions are shown in Table 3. It was ran during April 2013 and received 1, 505 responses. Demographic information, including age, gender, education, and geographic location, was asked (but not required), alongside several free-text questions, in which participants could state their reasons for playing Eyewire. The participants were free to respond to as many of the questions as they wanted, with no mandatory fields. Finally, to ensure anonymity, the results of the survey were de-referenced from the Eyewire players identifiers.

4.0.1. Methods

We used an iterative thematic coding process [61] in order to elicit the high level concepts and categories that explain why volunteers engage with Eyewire. Whilst being appreciative of existing motivation theory [31, 43] and empirical studies [62, 63, 64], we deliberately decided to examine the participants free-text responses without any pre-disposition to related work, and consult existing literature once a stable set of criteria had been identified.

The thematic coding focused on the free-text responses to the question of "Why do you play Eyewire?". 65% of survey participants completed this question, making it the most popular free-text question in the survey. The average length of a response was 15 words, and 10% of responses were over 50 words long (a short paragraph).

The coding involved three researchers. In the first phase, each researcher were given a unique random sample of the responses, and then were asked to generate a list of codes relating to motivations. Each researcher performed this task separately, and then met as a group to form an agreement on the coding schema.. Following this, each researcher recoded another random set of unique responses and confirmed the coding schema provided an inclusive and meaningful set of codes. Finally, each of the researchers were then given the total list of responses to code. During this process, the researchers was asked to select a primary and secondary motivation factor (where applicable) for each participant from the refined list. The primary and secondary motivations approach was chosen due to the length and richness of the responses. As responses were on average over 200 characters long, after several iterations of coding, researchers agreed that in order to represent the context of the responses fully, more than one code would be required.

In addition to the free text survey responses, to support our analysis, we computed descriptive statistics from the demographic information collected via the survey, and used those in combination with the qualitatively coded responses to understand if specific motivations are related to dimensions such as age, gender, education, and geographic location.

#	**Question**	**Response type**
1	Why do you play Eyewire?	Free-text
2	If you could add one feature to Eyewire, what would it be	Free-text
3	How did you discover Eyewire	Free-text
4	Anything else you would like to say	Free-text
5	Gender	Free text
6	Age	Numerical choice
7	Country	Predefined list of countries
8	Level of Education	Predefined list
9	Occupation	Free text
10	How long do you play Eyewire per week (rough estimate)?	Predefined options
11	If you play Eyewire for more than 1 hour per week, how long do you play (rough estimate)?	Free text
12	Does Eyewire inspire you to learn more about the brain?	Predefined options

Table 3: Questions asked in the 2013 Eyewire player survey

4.1. Representativeness

The survey contains responses from 10% of the total number of Eyewire players. In order to assess its representativeness, we compared the data collected via the survey to an anonymised data set containing demographics and player statistics. As we did not have detailed demographics about the players within the Eyewire player log files, we used the reported responses as a proxy. We compared the reported time spent playing Eyewire per week (Question 10, 11), against the recorded time spent of all players from the activity log. As Figure 3 illustrates, the survey responses and the log file are comparative, with a similar proportion of time spent. Although 3% of survey participants did report to play for 20 hours or more per week, none of these could be identified in the log files.

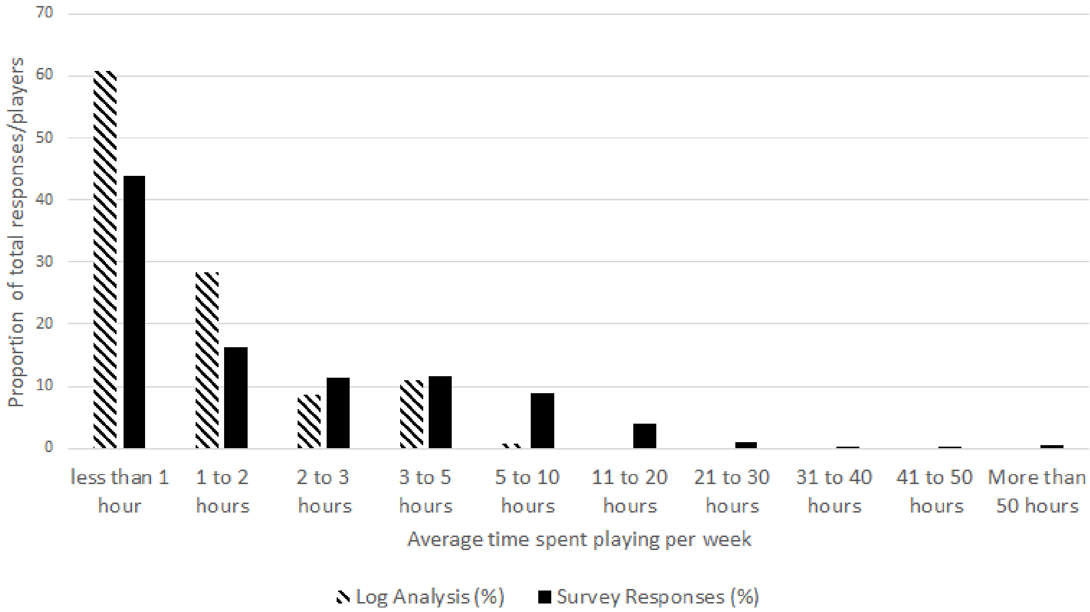

Figure 3: Comparison between Eyewire survey results and actual player log. Breakdown of reported average time spent playing the game per week, against actual time spent

4.2. Identifying Responses

In order to obtain a set of responses which represent the spectrum of survey responses, we used a word frequency analysis on the responses to question 1. The word frequency analysis was used to elicit the vocabulary and phrasing used by the Eyewire survey participants, after stemming and removing stop words we were left with a skewed distribution of word frequencies. We noted that the most common terms corresponded to the motivations identified during the coding process, including words such as “science”, “fun”, “help”, “time”, “brain”, “play”, “interesting”, “love”, and “research”.

As an initial step we constructed the common phrases used by participants, these included phrases such as “To contribute to”, “want to help”, or “it is fun”. These results were then used to narrow down and select a number of responses across the different demographic groups and motivations, in order to obtain a representative sample of the survey participants.

5. Results

5.1. Survey Results

Overall, 38% of respondents self-reported as female, 62% male, a slightly more gender-balanced userbase compared to other non-gamified citizen science projects [65]. A breakdown of responses by age, education level, and gender is visible in Table 4. We also examined the responses to the questions how often and how long Eyewire is played. More than half of male and female participants self-reported being more likely to play Eyewire for more than one hour at a time (59.6% and 53.7%, respectively). When asked whether Eyewire inspired one to learn more about the human brain, both males and females answered nearly proportionally similar to *"Yes, Absolutely"* and *"Yes, a little"*; these answers jointly account for 84.5% and 86.8% of male and female responses, respectively.

Level of Education	**(Age)**	**(Age)**	**(Age)**
	M & F	**M**	**F**
Middle school	17.5	16.7	20.10
High school - Current student	16.7	16.3	16.2
High school	32	31.7	32.9
College - Not current student	39.4	35.1	46.5
College - Current student	22	22.1	21.8
Finished college (Undergraduate)	44.1	38.70	44.9
Graduate school - Current PhD student	30.8	29.3	32
Graduate school - Current Masters student	32	31.7	32.4
Masters - Finished degree	46.5	40.29	41.5
PhD - Finished degree	59	53.5	40.29
MD/DO	43.3	41	48
Overall average age	**30.4**	**28.8**	**33.8**

Table 4: Reported level of education, corresponding to average age.

5.2. Motivation Elicitation

We now report our analysis of the free-text responses to the question, *"Why do you play Eyewire?"*. Based on the 989 participant that answered the question, we applied the coding approach described before and hand-coded the responses for motivations of participation. 18 motivation factors were found through thematic coding and each free-text response was associated to a primary and secondary motivation. One example is shown below; in this response, *procrastination* is the main focus of the response, with *contribution* being another important participation driver which we reflect upon.

"It is easy to access when you have a few minutes to kill and it is more productive than doing nothing. Moreover, it allows you to contribute to a project while learning and testing your own brain."

Table 5 lists the coding schema which was derived after several iterations of coding. The 18 codes represent the 'motivational' concepts identified. Their positioning as primary and secondary factors, and the breakdown of gender to motivation. The 12 motivations found in the first step of the thematic coding are marked by a '+'. As we discussed earlier, in a second round of coding we refined this initial list of themes with 6 additional codes identified. For

Motivations	Description of Code/Motivation	Total	Pri.	Sec.	M(count)	F(count)
Contribution+	Contributing to the project, not specifically related to helping science	286	165	121	174	112
Science+	Helping improve scientific knowledge. Direct mention of contributing to science	262	188	74	186	94
Fun+	For the entertainment value. No specific mention of games or competition	199	174	25	118	81
Learning+	To learn about science, or related learning purpose	95	61	34	74	21
Personal interest+	For some personal interest towards Eyewire, related to the scientific task	93	70	23	58	35
Interesting+	Due to a general interest in Eyewire	83	68	15	57	26
Procrastination+	To avoid doing another task, i.e. avoid doing school work	70	52	18	39	31
Relaxing+	As a way to relax from other tasks.	66	47	19	31	35
Gaming+	The ability to play a game, specific mention of gaming	56	41	15	32	24
Puzzle	Specific mention of enjoying the puzzle aspect of the task	39	28	11	22	17
Challenge+	Specific mention of the challenge aspect of the task	36	21	15	17	19
Community	Taking part, or feeling part of a community	27	7	20	20	7
Curious	An 'initial' interest in Eyewire, not specifically mentioning gaming or science	23	22	1	11	12
Beautiful+	Specific mention of the visually appealing aspects of Eyewire (e.g. 3D cube visuals)	13	1	12	2	11
Competition	The ability to compete with other players in the game	12	3	9	8	4
Interface	Specific mention of the 3D interface and actual design of the platform	7	5	2	3	4
Addictive+	The addictive nature of the task, often describing their flow or finding it difficult to stop	6	5	1	0	6
Citizen science	Specific mention of citizen science (activities or the act of contributing to citizen science)	5	4	1	4	1

Table 5: Coding schema of elicited motivational codes (primary and secondary). Motivations identified during the first iterations of coding are denoted by $^+$. Motivations by gender (M,F) are proportional to the number of responses to the survey sample.

instance, in the first iteration we identified *challenge* as an important motivational aspect; as we analysed the responses a second time, we found many were talking specifically about *solving puzzles*, rather than challenges in general, and decided to expand our framework accordingly.

As shown in Table 5, the desire to *contribute* (both as primary and secondary reasons combined) accounted for 20.4% of the answers, with the interest in *science* as a close runner-up at 18.8%, and *fun* as a slightly more remote third at 14.3%. We have also performed a co-occurrence analysis on matching pairs of motives (independently of their position as a primary or secondary); as Table 6 shows, being able to *contribute* in an entertaining way seems to be the most common combination, accounting for 13.6% of the co-occurrences, where the most important reason to participate features in 6 of the top 10 pairs.

We compared the reasons why people participate in relation to their level of education (see Table 7). Across several stages of education, we observed that the main themes identified earlier, such as to *contribution* to a worthy cause, for *science* or for *fun* both received a comparatively high number of responses compared to other motivations. Participants who identified themselves as being in high school appeared to be strongly driven by the game-like elements of the project (*fun*, *gaming*, *relaxing*), as well as by *curiosity* to engage in *science*.

Motivation Pairings	Freq.	% of Freq.
Contribution & Fun	50	13.6
Fun & Science	38	10.4
Contribution & Personal Interest	17	4.6
Contribution & Gaming	14	3.8
Fun & Learning	13	3.5
Contribution & Relaxing	12	3.3
Contribution & Procrastination	11	3
Contribution & Interesting	11	3
Learning & Science	11	3
Fun & Interesting	10	2.7

Table 6: Most frequent co-occurring primary and secondary motivations

Education	Most Frequent Motivations
Middle school	Fun, Science
High school - Current student	Fun, Science
High school	Competition, Fun
College - Not current student	Curious, Science
College - Current student	Science, Fun
Finished college (Undergraduate)	Contribution, Science
Graduate school - Current PhD student	Contribution, Science
Graduate school - Current Masters student	Science, Fun
Masters - Finished degree	Contribution, Fun
PhD - Finished degree	Fun, Contribution
MD/DO	Contribution, Relaxing

Table 7: Level of education and 2 most frequent corresponding motivating factors

Similarly, by examining learning outcomes against our motivation framework; we noted a relationship between those that responded "Yes, Absolutely" to learning new knowledge about the brain via Eyewire, and motives that are somewhat related to this desire to learn (*contribution*, *fun*, *science*). We assume that avoiding studies or work in an entertaining environment was the reason why *procrastination* has been prominent in the groups of participants who were undertaking studies (college, high school).

It appears that several qualities which are typically associated with game mechanics or good design did not play as much of a role in the decision to participate to the project. The game was not perceived as particularly *addictive*, *challenging*, or *beautiful* by many participants. At the same time, being involved with *citizen science*, as part of a larger community pursuing a scientific question, was deemed as less important than other aspects. On a related note, social features such as *community* and *competition* seemed to be particularly important among those who identified themselves as currently in high school, or those who have finished high school. The results also showed that respondents who were not attracted by the opportunity to learn something about the brain (answering the corresponding question with "No, not at all", and "Not so much") had no tendency towards a particular motivation.

6. Motivation Analysis

We now consider the question of *"Why do you play Eyewire?"* in order to unpack the motivations of Eyewire' players. The analysis draws on the coded responses described in

Table 5. Our discussion is framed by insights from related literature that studied similar phenomena in other participatory online environments.

6.1. Contribution and Science

We examined the responses that were related to *contribution* and *science*, broken down by the different demographic groups previously identified. At coding stage we deliberately opted for two separate themes to capture the participants' wish to donate their time and skills to this citizen science endeavour, as from the survey responses there was a sense that some players contributed towards Eyewire as such (and were less interested in the actual goal of the project), while others were specifically driven by the aspiration to advance science (via Eyewire or elsewhere).

Out of the 349 answers that referred to such aspects, 252 (72.2%) had one of the two themes as their only motivating factor (no secondary motivation could be identified), which speaks for their essential role in the engagement of volunteers in citizen science. We found such effects across demographic groups and gender, as well as a strong relationship to the desire to expand their knowledge about the human brain as part of the exercise (92% of the individuals who participate due to the two reasons were also interested to learn).

"I want to help science" (M, CC, learns from Eyewire)[4]
"To do what I can to help and keep a small contact with science." (F, FC, learns from Eyewire) "I play because I want to help out with any scientific research I can" (M, CHS, learns from Eyewire) "I feel in my small way I am able to contribute to something that will help all mankind." (F, FC, learns from Eyewire)

The remaining 97 responses mentioned other motivation factors in addition to *contribution* or *science*. In this group, individuals described their reasons for players for a number of different reasons, from the ability to *learn* (25.7%), to feeling part of a *community* (11.3%), and enjoy the *gaming* experience (24.7%).

"I play because I want to help further science and because it's fun. It actually is as simple as that!" (F, CHS, learns a lot from Eyewire)
"To contribute to and learn neuroscience" (F, CC, learns from Eyewire)
"It allows me to do something to contribute to academia while simultaneously acting as a stress relieving activity." (M, CC, learns from Eyewire)
"Because I want to help scientists make the most important discoveries in history so far - understanding how the human brain works. Also because I am feeling as a part of a community" (M, FC, learns a lot from Eyewire)

Few responses described their contribution to the project and science, as well as their desire to be part of a social activity or community. In an existing study [8], an analysis of the chat data revealed that the players used the communication tool for self-monitoring,

[4]For all answer quotes in this paper we use the following abbreviations: M=Male; F=Female; CC=currently in college; CHS=currently in high school; CM= current Masters student; FC=finished college; FHS=finished high school; FM=completed Masters

issuing commands, and interacting with gamification features. Furthermore only a small proportion (10%) of players engage in chat. Considering these findings, it may be that players who are motivated by the desire to contribute or help science are not engaging in discourse, instead, they focus their attention to the task element of Eyewire.

6.2. Gaming and Entertainment

As Eyewire was initially designed as a gaming environment, we expected players to be motivated by the desire to play games, and the entertainment value of the platform. In order to assess whether those motivated by the gaming and entertainment value of Eyewire answered differently from those interested in science and the project, we examined the corresponding responses using the same vocabulary analysis methods discussed before. We selected responses that were coded with *gaming*, *challenge*, *competition*, *puzzle*, and *fun*. The distinction between these codes was based upon the way the individuals described their "playing" activities and preferences with Eyewire. For instance, some responses described their love of puzzles as the reason for participating, whereas others were interested in the challenge and possibility of competing with other players using the leaderboard. From the 267 respondents that were identified with these motivations, 93 (34.8%) were solely focused on the ludic qualities of the Eyewire environment. For instance:

"Because its fun :)" (F, FC, does not learn that much from Eyewire)
"It's like a puzzle game, and I like puzzle games" (M, FM, learns a little from Eyewire)
"Well. I think this is more useful than playing angrybirds or clash of clans." (M, CC, learns a lot playing Eyewire)

The first two responses are typical for individuals playing Eyewire simply for its entertainment value. Similar views were held by players who would engage with the system as a way to procrastinate or because they had some spare time. Whilst their main motivation might not have been related to an inclination to learn or help citizen science, 85% of participants said that by playing the game, they did indeed gain more knowledge about how the human brain works, with over 30% of them assessing that these learning effects have been significant. The third response is indicative for another important feature of Eyewire (or citizen science in general): while those are the words of someone who appreciates games, upon inspection, the response also suggests that the player perceives this particular game as being more useful way to pass time than some prominent casual games that are highly popular on social networks. Yet, whether this value comes from self-fulfilment or for the greater good, is unclear.

The remaining 174 responses associated with *gaming* and *entertainment* tended to be more explicit in regards to players' motives and how these relate to additional factors. Here are some exemplars:

"It's entertaining, and I feel like I am contributing to a useful task." (M, CM, learns from Eyewire)
"It's both entertaining and satisfying, because I feel like I'm helping science as I get better at playing." (F, CHS, learns a lot from Eyewire)
"I like a challenge, find the neuroscience aspect interesting, and would rather help with a project while frittering my time" (F, FC, learns from Eyewire)

"It's much more fun than many videogames and it serves a good purpose, so I don't feel like I am wasting my time while I relax and have fun." (F, PhD, learns a lot from Eyewire)

These answers illustrate of the positive relationship between game mechanics and citizen science. While playfulness is a strong basis to attain and sustain participation, people also appreciate the fact that they are able to learn something new, contribute to the project, and use their free time to something productive. We noted that, in comparison to those that declared to be only driven by the ability to engage with a game, who tended to be in high school or just graduated from it, the group here were mostly college educated or higher. We also found that within the small set of responses that were coded with *competition*, 75% of the answers mentioned this aspect only as a secondary (though necessary) component of their involvement, for example:

"I often play browser games anyway and this actually serves some kind of purpose. The ranking is a necessary part to keep me occupied though." (M, CM, learns little from Eyewire)

These findings reflect earlier observations, 60% of responses that were coded with *competition* as their secondary motivation were associated with a primary motivation related to their desire to aid the initiative or scientific discovery. Looking back at the analysis of the platform statistics from Section 3.3, the high proportion of game commands for those that participate in chat, in particular commands used to check and report statistics of players would see to confirm that the competitive environment in Eyewire is a contributing factor of player participation.

6.3. Community

A smaller share of the respondents consistently described a strong feeling of being part of a *community.* In addition, players in this category were most likely to mention other motivations such as, a *personal interest* (16%) in the task, their wish to be *entertained* (36%), or to *contribute* and support the project (44%). Within this set of responses, we also observed a tendency for Eyewire players to see the community as a means to meet other (amateur) scientists and like-minded individuals:

"It is fun, I meet/talk to people with similar interests, and I am helping science." (M, CHS, learns from Eyewire)

"To make a difference. To do something that has value and makes an enduring contribution to neuroscience. To be involved in a group with the same goals." (F, FM, learns a lot from Eyewire)

"Love to help. Like meeting new scientists." (M, FHS, learns a lot from Eyewire)

For those primarily interested in having fun and playing the game, their engagement with the community tends to emphasise socialising, be that by chatting or competing against other fellow citizen scientists. Here are two answers that are illustrative for this attitude:

"Because it is awesome. Mostly because I am interested in community driven projects." (M, CC, learns a lot from Eyewire)

"Cuz it's addictive, for a good cause, and fun! Also the player community is great." (M,CM, learns a lot from Eyewire)

"Addiction. Its very addiction, the environment and community its great too! The purpose above." (M, CM, learns a lot from Eyewire)

Looking back at the chat statistics displayed in Table 2, only a small proportion of the players actually engage with the chat (10%), but of those, chat is used as a tool to conduct general discussion with other members of the community, rather than a mechanism for serious scientific discourse.

Finally, we noted that for those respondents who greatly valued the sense of *community* in Eyewire, thus having this as primary motivation, very often expressed their secondary reason to participate as related to a wish to contribute to the project or to help advance science, and much less to play a game or be entertained:

"I want to be a part of a community who's goal is scientific and will yield positive results." (M, CHS, learns from Eyewire)
"To help a nice community with a good cause" (M, FC, learns from Eyewire)

6.4. Learning and Personal Interests

Finally, we look at the group of contributors that were identified as being motivated by the ability to learn about the field, find the project interesting, or have some personal interest in the topic. We also include the answers mentioning *citizen science* within this, as this code was used to label responses that appreciate the possibility to find out more about this novel approach to advance science, and hence were driven by the wish to learn something new as well. Within this set of individuals, 130 out of the 203 (64.0%) were only motivated by the project itself or viewed it as a means to expand their horizons; these individuals were mostly college educated or higher (more than 80%), and represented a large proportion of those that were studying for or had a PhD (38.4%). Such responses were concerned with how Eyewire provides a resource to learn about the brain, or indirectly fulfils some personal interest, whether it is related to neuroscience, the brain, or just the platforms design and capabilities.

"Very interested in the brain." (F, CM, learns a lot from Eyewire)
"I'm interested in AI and this seems like an interesting problem. I wanted to play the game for a while before trying my own hand at an algorithm." (M, CM, learns a lot from Eyewire)
"I am very interested in the minute details of the bio-mechanics in action in the brain. I want to know literally and materially what 'memory' is, how we retrieve information from 'memory', what thinking is, and what learning is" (M, PhD, learns a lot from Eyewire)

Whilst the learning objectives of the participants were different, responses indicate that Eyewire provides an environment for a variety of purposes, including learning, which appears to be independent of the gamification aspects of the system. In respect to the remaining 73 responses, we found that 60.2% of them were also related to motivations of *contribution* and *science*, in comparison to 18% that were related to *entertainment* and *gaming*. This may indicate that those who engage with the system for academic reasons, were not particularly triggered by the game mechanics that are at the core of the design of the platform.

7. Discussion

There are several goals of a citizen science project which contribute to the primary purpose of harnessing the collective capacity of humans to complete computationally difficult and time-consuming tasks accurately and timely. Similar to other crowdsourcing systems, designing and supporting an environment, which is engaging and sustains participation, is a key challenge. Eyewire exhibits characteristics of a successful citizen science project, with a growing and sustained set of contributors, who actively engage in science with the rest of the community. The analysis of survey responses reveals a series of motivating factors which make it an attractive environment for people to stay on board beyond just a short period of initial activity. Our work is very much in-line, but also contextualises, design guidelines in the area of online communities [13]. Sustained engagement in citizen science - whether or not it uses game mechanics - relies on a suitable platform, on a task that is appealing (and people can care about, i.e., neuroscience and understanding how our vision works), and a community with some level of sociality and a shared sense of purpose.

However, successful participation is not guaranteed, and there are several factors which may affect participation. This may be due to the nature of the task itself or to interface issues which could have been avoided through a more considerate UX design. Ultimately, this requires more than technical expertise; designers require an understanding of their users, their needs, and their engagement with the community [13, 7]. The importance of these non-technical dimensions is emphasised in the light of studies looking beyond citizen science engagement, where *fun* and *entertainment* were deemed important to engagement at an early stage, alongside community belonging, the opportunity to contribute to a greater cause, and, most importantly in this case, the ability to learn and improve one's knowledge [66].

Entertainment Value. For Eyewire players, using gamification features such as points, leaderboards, and rankings was appreciated by a significant proportion of the survey respondents. Our findings support the claim that incentivising behaviour via gamification can be beneficial to participation [67], without reducing the importance of the project's scientific or crowd-based objectives. Transforming a complex task into smaller micro tasks accessible via an interface with game elements [29] has been identified as a significant factor in player participation, depending on the task domain and level of expertise required [38]. As we found from the survey responses, a great majority of the participants referred to the gamification positively. This has attracted a broad range of people who willingly spent time on the platform (from young students to professional medical practitioners).

Beyond the extrinsic motivations, this has also improved the experience of those motivated by altruistic reasons, including participants with an inclination to scientific enquiry, or interest in the medical area in question. In many of the responses, participants self-identified themselves as students who have an interest, or are studying medicine. In contrast to Eveleigh *et al.* study of participation in the Old Weather project [19], Eyewire appears to have created an environment which contains a balance between gamification elements, without removing transparency of the original scientific task. The unit of work required to be completed is substantial enough to provides players with a significant level of autonomous working to allow them to feel competent and content to fulfil their psychological needs, while at the same time, small enough to enable the Eyewire platform to form a collective decision based on the answers submitted by participants, within a certain degree of accuracy.

Community and Communication. We also found that there was strong motivations linked to engagement, included self-learning, personal interest in neuroscience or related areas, and community belonging. These insights are in-line with other studies on motivation in citizen science projects [10], though in our case the sense of community appeared to be more explicit. We trace this back to the design of interaction capabilities in Eyewire, most prominently the embedded real-time chat interface and feedback that is tightly integrated with the main game interface. Such features are suited to respond to and foster the intrinsic motivations of participants; improving their well-being through community interaction and communication. Similarly, the ability to report one's points and gaming statistics addresses extrinsic motivations, allowing participants to compete with each other, or at the very least, monitor their own performance.

Based on the system log analysis, we found players that exhibited a mix of intrinsic and extrinsic motivations, were those that participated significantly in the game as well as chat discussions, with their responses suggesting that their engagement was to further establish themselves within the community as a known player, but also to help out and encourage newly joined members. Conforming to the breakdown of motivations by Aparicio *et al.* [11] into the three game elements *autonomy*, *competence*, and *relation*, Eyewire players find a configurable, self-managed profile (autonomy), are offered feedback, points, and leaderboards (competence), and are able to chat and form groups in an ad-hoc fashion (relation).

In the context of design frameworks, providing a mechanism for communications, either as a back-channel or as a main communication mechanism helps the community feel part of a group, which in-turn, has a positive effect on the engagement of users [13]. Moreover, Spitzberg *et al.* [49] suggest that internal communication is important for building motivations, which then may lead to skill development, an arguably true observation with respect to our analysis of the relationship between gaming and chatting; players which chatted and used more commands appeared to complete more games, thus improve the performance of the system [37]. Furthermore, responses pertaining to the competitive and gamification aspects of Eyewire described the leaderboard as a feature which encouraged individuals to participate and remain active, because it stimulates the desire to maintain their status as top performing players. Przybylski *et al.* [68] described similar behaviour to this, where the "fear of missing out" helped retain users.

Contributing to Science. In addition to motivations related to entertainment and gaming, the desire to contribute to a worthy *scientific* cause appeared to be powerful motivations for Eyewire players. This was not only true for responses where in which *contribution* or *science* was identified as primary motivation, but were also found as secondary motivations, closely linked with aspects such as *personal interests*, and *learning*. Moreover, our findings suggest that motivations related to contributing to "the science" was the most probably factor to co-occur with any other motivation. To that end, our findings suggest that the desire to contribute is just as prevalent as those found in non-gamified citizen science projects [10].

From our responses, it appears that, despite the gamification aspects of Eyewire, there were still strong intrinsic motivations for individuals to participate. These findings are in-line with Bowser *et al.* [67] study, suggesting that gamifying citizen science activities draws upon motivation components found in both gamers and amateur scientists, and can thus help reach out to new audiences.

Akin to other investigations of citizen scientist motivations, we found that participants are primarily driven by the desire to contribute to a worthy scientific cause. Casting our findings outside citizen science investigations, we find that in crowdsourcing platforms like Wikipedia, contributors were instead driven by the motivations associated with learning, facilitated by the ability to create, edit, and discuss an encyclopedic article. We attribute this difference to (i) the nature of the contribution, (ii) the purpose of the system, and (iii) limitations of the system's functionality. The task inputs in online citizen science are typically atomic contributions to a more complex scientific workflow controlled by the experts managing the project. In a system like Wikipedia instead, the users are much more autonomous and far less restricted in their actions by the software system. However, this system-enabled deliberation in Wikipedia turned out to be in conflict with the emergence of highly restricting social norms, which are commonly attributed to be the cause of decline of this community-curated encyclopedia [69].

In light of this, if we consider the so-called citizen science "serendipitous discoveries", raises the question: how far can citizen science projects drive technical deliberation before similar social phenomena kick in? "Serendipitous discoveries" [6] are citizen-led scientific inquirers that go beyond the original constrained scope of the crowdsourced tasks, leveraging the more flexible and ad-hoc communication capacities of platforms [60]. In many cases, internal and external communication mechanisms such as forums and social media facilitate these discoveries, and are initiated and driven by the – potentially – non-expert participants. While these discoveries are facilitated by particular system design components, the full extend of the social processes behind them are yet to be investigated.

7.1. Motivational Framework

There are a number of trade-offs to be considered when designing online communities to match both intrinsic and extrinsic motivations [13]. The implementation of mechanisms that enable individuals to engage and take control of the system, favours intrinsically motivated behaviour, which in turn can be critically influenced by external rewards [70] such as points, leaderboards, and individual performance measures. For instance, if system designers were to implement a gamified citizen science platform that capitalises on a strong community component, then there should be features that allow for competition, as well as community discussions, hence facilitating the chances of supporting the intrinsic and extrinsic desires of participants. Such findings are similar to Jung *et al.* [37], who found that the use of points, leaderboards, and feedback provided both a competitive environment, plus helped an individuals intrinsic needs for competence.

We now synthesise our findings and structure them in accordance to the intrinsic and extrinsic motivations for participation, guided by literature associated with motivations [30, 15, 34] and the use of gamification elements for engagement [36], with an emphasis towards forming a design framework for gamified citizen science projects. This was conducted as part of a reflective process with the Eyewire team, understanding the intrinsic and extrinsic drivers can be a useful tool during the design and development stages, as well as during the growth and periodic review of how the community is performing. In several instances, we learnt from the design team that updating or even redesigning the platform played an important role in improving and managing the number of active and dormant players. Specific features, such as chat, competitions, and “grand” challenges were made more prominent, thus driving participants of with a disposition to certain motivational factors.

Based on our analysis of responses, and existing investigations of motivations and design criteria for citizen science platforms (e.g. [65, 7]), we group the motivations identified (cf. Table 5 across two categories: (1) the intrinsic component, which relates to the act of contribution, user experience, and to support a worthy cause. (2) Extrinsically oriented behaviour, which is influenced by several factors, such as using their expertise for external rewards, or to reach an elevated status in the community through superior positioning on the leaderboard, and winning competitions. Our framework has been constructed based on existing studies of gamification features in platform design (e.g., points, leaderboards, etc.) [36] and motivations [11, 14, 71, 12, 72, 28], we summarise our findings of Eyewire in Table 8. We grouped our motivations into four high-level classes, corresponding to the relationship found during the coding process [5]: (1) the desire to contribute, (2) to learn, (3) to be part of a community, and (4) to be challenged, entertained, and play. Considering the motivational themes, and intrinsic and extrinsic behaviour, we map how platform features, such as the task interface design, is able to support the type of motivations. The platform features described in Table 8 map to one or more of the gamification and interface features described in Table 1. Intrinsic and extrinsic drivers also extend across motivational themes; take for instance the intrinsic desire to fulfil altruistic needs, this extends to aspects of supporting a worthy scientific cause, or, helping new members join and feel part of a community.

Whilst our framework describes the platform features which can facilitate different player motivations, the implementation of a technology or feature should also reflect the context of the social conditions within the community. For instance, one would not develop a platform that masks the task completely with a fully gamified interface, if there are indicators that the community has a strong intrinsic motivation to help a scientific cause. Similarly, one would not develop a task workflow that is highly isolated from community interactions, if the task was collaborative by nature.

8. Conclusion

In this study, we investigated the relationship between crowdsourcing, participation, and motivations. To do this, we studied the gamified Web-based citizen science platform, Eyewire. Our work is inspired by the increasing desire by designers, scientists, and researchers to build successful crowdsourcing platforms capable of offering accurate answers to complex scientific questions, while at the same time, providing an engaging environment for participants; so much so, participants return time-and-time again. Moreover, our study focused on a particular class of crowdsourcing platforms which problematize around blending citizen science challenges with components of gamification and sociality.

[5] These are for organising purposes

Motivation Theme	Intrinsic Motivation	Extrinsic Motivation	Platform Features	Related Frameworks
Contributing and Science	Altruistic desire to support worthy cause, feel-good factor	Use contribution as means to improve status within the Eyewire community	Task interface with gamified elements, local and global stats reporting	Value-based design: emphasis on goals and 'economic' value [71]
Learning and Personal Interests	To learn new knowledge, mastering a topic, fulfil ones interest in topic, satisfy their hobby	Use knowledge learnt for personal gain, e.g., improve school grades	Feedback Mechanisms, Additional context about the task (info boxes), Blog dedicated to describing the science of Eyewire	User-centered design: Actions and Feedback Mechanisms to support learning [14, 28]
Community and Communication	To help other members within the game, answering questions, encouraging new players	To demonstrate reputation and status	Real-time Chat, Group Chat, Forums, Blogs, Integrating external social media platforms	Social-gamification design: integrating inline community features [72]
Gaming and Entertainment	Problem solving for fulfilment and success	To compete with other players, to gain recognition as a top player	Leaderboards, Points, Team play, Scheduled Competitions	Mechanics-based design: using game, points, and leaderboard elements [11, 12]

Table 8: Motivation Matrix of Intrinsic and Extrinsic Factors, Eyewire platform features, and supporting design frameworks

By working through Eyewire and its specific features and functionalities, our findings revealed that whilst gamification and game mechanics are promoted throughout Eyewire (its tagline being: "A Game to Map the Brain"), several other factors contributed to the participants' motivation. Our findings suggests that gamification, as a set of components within a citizen science platform, appeals to a broad range of participants, not only those with extrinsic drivers such as competition or external rewards.

In contrast to existing studies of gamification use in crowdsourced environments [27], and its role on attracting externally-rewarded or intrinsically-driven engagement [19], Eyewire has managed to use such elements to not only improve the quantity, and quality of work attained. For Eyewire, gamification offers a mechanism to achieve active participation, attracting individuals, independent of their gaming interest. The features of the platform fosters an environment for individuals to learn and improve their own scientific knowledge and expertise, and offers players the ability to compete if they are inclined to do so. These findings contribute to an ongoing debate about the role of (or need to resort to) game mechanisms to make citizen science projects more appealing to wider audiences and sustain engagement [17, 19, 7, 73].

While – or some people might say *despite* – the gamification of the citizen science task, the main reason to participate was dominated by the generally positive effects and outcomes of the activity: aiding a beneficial cause, advancing scientific knowledge, learning. Although participants of the survey self-reported this as the main reason for participation, our analysis of the chat data revealed that game elements, including game commands and self-performance and leaderboard monitoring were often highly used by members of the community. These appear to have provided the ability for players to *compete* with each other, forming self-defined teams and competitions. We found that Eyewire features similar player engagement characteristics to other non-gamified citizen science platforms [60], and that there are differences between the self-reported reasons for why individuals participate in Eyewire and their actual in-game behaviour.

Based on the analysis of Eyewire, we considered a general participation framework for participation, which has been inspired by literature in the space of citizen science platform design, as well as studies of participation in online systems. Our design framework outlines 4 categories of design, and contextualise them in terms of the intrinsic and extrinsic reasons for participation, the associated features of the Eyewire platform, and the design frameworks that support these motivations. The framework draws upon related literature in order to demonstrate that our findings are compatible with research on other forms of online participation, as well as with the broader study of motivation.

The four categories found in Table 8 encapsulate the 18 motivating factors identified via the analysis of the survey responses. Our findings reveal that participation has been achieved by a confluence of socio-technical design, such as blending elements of gamification with community and player communication. Our analysis revealed a complex interplay between multiple factors, including the desire to *contribute* to the project and science in general, self-*learning* and *interest* in the subject domain, *community* belonging, alongside the *entertainment* value of a *gaming* narrative.

8.1. Limitations

We consider the limitations of our paper in the context of the generalizability of our framework for designing citizen science platforms. As the focus of this paper places emphasis on the behavioural of players participating on the Eyewire system, our findings are informed by the individuals who completed the Eyewire survey. As a consequence, our findings are limited by the scope of the platform, and as discussed in Section 4.1, the population of Eyewire players who responded to the survey. In order to determine if our survey population provided a fair representation of the total population of Eyewire players, we compared the reported time playing Eyewire, with the server player logs captured within the platform. Although using play time is not the most accurate proxy to determine the representation of survey population compared to the total player population, as Eyewire does not collect demographic information about players, this was the best approximation possible.

We are also aware that our motivational framework has been led by the analysis of responses from only one gamified citizen science platform. In order to provide design framework which is less system-specific and generalizable to crowd-based platforms, we compared our findings with additional studies of citizen science projects, and also drew upon other online community design frameworks.

8.2. Future Work

Studies on citizen science to date are often restricted to single system analysis, and tend not to look across the multiple platforms for insight; this is also a limitation for this investigation. Our future work will reach out for cross-platform studies to compare the characteristics of communities constituted on different platforms as well as the tasks they perform and investigate the potential biases in citizen science that result from the specificity of the respective communities (e.g. cultural biases as a result of focusing public relation and outreach on a particular region or country).

References

[1] F. Khatib, S. Cooper, M. D. Tyka, K. Xu, I. Makedon, Z. Popović, D. Baker, F. Players, Algorithm discovery by protein folding game players, Proceedings of the National Academy of Sciences 108 (47) (2011) 18949–18953.

[2] K. Land, A. Slosar, C. Lintott, D. Andreescu, S. Bamford, P. Murray, R. Nichol, M. J. Raddick, K. Schawinski, A. Szalay, et al., Galaxy Zoo: the large-scale spin statistics of spiral galaxies in the Sloan Digital Sky Survey, Monthly Notices of the Royal Astronomical Society 388 (4) (2008) 1686–1692.

[3] D. McKinley, A cognitive walkthrough of the whats the score at the bodleian? task interface to increase volunteer participation.

[4] N. R. Jennings, L. Moreau, D. Nicholson, S. Ramchurn, S. Roberts, T. Rodden, A. Rogers, Human-agent collectives, Communications of the ACM 57 (12) (2014) 80–88.

[5] P. Michelucci, Handbook of human computation, Springer, 2013.

[6] C. Cardamone, K. Schawinski, M. Sarzi, S. P. Bamford, N. Bennert, C. Urry, C. Lintott, W. C. Keel, J. Parejko, R. C. Nichol, et al., Galaxy Zoo Green Peas: discovery of a class of compact extremely star-forming galaxies, Monthly Notices of the Royal Astronomical Society 399 (3) (2009) 1191–1205.

[7] R. Tinati, M. Van Kleek, E. Simperl, M. Luczak-Rösch, R. Simpson, N. Shadbolt, Designing for citizen data analysis: A cross-sectional case study of a multi-domain citizen science platform, in: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, CHI '15, ACM, New York, NY, USA, 2015, pp. 4069–4078. doi:10.1145/2702123.2702420.
URL `http://doi.acm.org/10.1145/2702123.2702420`

[8] R. Tinati, M. Luczak-Rösch, E. Simperl, W. Hall, N. Shadbolt, /command'and conquer: analysing discussion in a citizen science game, ACM Web Science Conference 2015.

[9] M. J. Raddick, G. Bracey, K. Carney, G. Gyuk, K. Borne, J. Wallin, S. Jacoby, A. Planetarium, Citizen science: status and research directions for the coming decade, AGB Stars and Related Phenomenastro 2010: The Astronomy and Astrophysics Decadal Survey (2009) 46P.

[10] M. J. Raddick, G. Bracey, P. L. Gay, C. J. Lintott, P. Murray, K. Schawinski, A. S. Szalay, J. Vandenberg, Galaxy zoo: Exploring the motivations of citizen science volunteers, Astronomy Education Review 9 (2010) 010103.

[11] A. F. Aparicio, F. L. G. Vela, J. L. G. Sánchez, J. L. I. Montes, Analysis and application of gamification, in: Proceedings of the 13th International Conference on Interaccion Persona-Ordenador, INTERACCION '12, ACM, New York, NY, USA, 2012, pp. 17:1–17:2. doi:10.1145/2379636.2379653.
URL `http://doi.acm.org/10.1145/2379636.2379653`

[12] I. Blohm, J. Leimeister, Gamification: Design of it-based enhancing services for motivational support and behavioral change, Business and Information Systems Engineering 5 (4) (2013) 275–278. doi:10.1007/s12599-013-0273-5.

[13] R. E. Kraut, P. Resnick, S. Kiesler, M. Burke, Y. Chen, N. Kittur, J. Konstan, Y. Ren, J. Riedl, Building successful online communities: Evidence-based social design, MIT Press, 2012.

[14] S. Nicholson, A user-centered theoretical framework for meaningful gamification, in: Games+ Learning+ Society 8.0, Madison, WI, 2012.

[15] R. M. Ryan, E. L. Deci, Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being., American psychologist 55 (1) (2000) 68.

[16] R. Tinati, M. Luczak-Rösch, E. Simperl, W. Hall, "science is awesome":studying participation in a citizen science game, ACM Web Science Conference 2016.

[17] K. Shubber, How Facebook and gaming could help scientists battle disease, online article, retrieved on 17-09-2014 (2013).

[18] C. Parr, Why citizen scientists help and how to keep them hooked, online article, retrieved on 17-09-2014 (2013).

[19] A. Eveleigh, C. Jennett, S. Lynn, A. L. Cox, “i want to be a captain! i want to be a captain!”: Gamification in the old weather citizen science project, in: Proceedings of the First International Conference on Gameful Design, Research, and Applications, Gamification '13, ACM, New York, NY, USA, 2013, pp. 79–82. doi:10.1145/2583008.2583019.
URL http://doi.acm.org/10.1145/2583008.2583019

[20] A. H. Maslow, A theory of human motivation, Psychological Review 50 (1943) 370–396.

[21] K. B. Madsen, Theories of motivation, Institute of General Psychology, The Royal Danish School of Educational Studies, 1968.

[22] R. M. Ryan, E. L. Deci, Intrinsic and extrinsic motivations: Classic definitions and new directions, Contemporary Educational Psychology 25 (1) (2000) 54 – 67. doi:http://dx.doi.org/10.1006/ceps.1999.1020.
URL http://www.sciencedirect.com/science/article/pii/S0361476X99910202

[23] O. Nov, D. Anderson, O. Arazy, Volunteer computing: A model of the factors determining contribution to community-based scientific research, in: Proceedings of the 19th International Conference on World Wide Web, WWW '10, ACM, New York, NY, USA, 2010, pp. 741–750. doi:10.1145/1772690.1772766.
URL http://doi.acm.org/10.1145/1772690.1772766

[24] Y. Zhao, Q. Zhu, Exploring the motivation of participants in crowdsourcing contest.

[25] O. Nov, O. Arazy, D. Anderson, Scientists@ home: what drives the quantity and quality of online citizen science participation, PloS one 9 (4) (2014) e90375.

[26] E. D. Mekler, F. Brühlmann, K. Opwis, A. N. Tuch, Disassembling gamification: the effects of points and meaning on user motivation and performance, in: CHI'13 Extended Abstracts on Human Factors in Computing Systems, ACM, 2013, pp. 1137–1142.

[27] E. D. Mekler, F. Brhlmann, A. N. Tuch, K. Opwis, Towards understanding the effects of individual gamification elements on intrinsic motivation and performance, Computers in Human Behavior (2015) –doi:http://dx.doi.org/10.1016/j.chb.2015.08.048.
URL http://www.sciencedirect.com/science/article/pii/S0747563215301229

[28] S. Deterding, The lens of intrinsic skill atoms: A method for gameful design, HumanComputer Interaction 30 (3-4) (2015) 294–335. doi:10.1080/07370024.2014.993471.
URL http://dx.doi.org/10.1080/07370024.2014.993471

[29] K. Seaborn, D. I. Fels, Gamification in theory and action: A survey, International Journal of Human-Computer Studies 74 (0) (2015) 14 – 31. doi:http://dx.doi.org/10.1016/j.ijhcs.2014.09.006.
URL http://www.sciencedirect.com/science/article/pii/S1071581914001256

[30] E. L. Deci, R. M. Ryan, Intrinsic motivation and self-determination in human behavior, Plenum New York, 1985.

[31] D. C. Brabham, Crowdsourcing as a model for problem solving an introduction and cases, Convergence: the international journal of research into new media technologies 14 (1) (2008) 75–90.

[32] P. Organisciak, Motivation of Crowds: The Incentives That Make Crowdsourcing Work (2008).
URL http://crowdstorming.wordpress.com/2008/01/31/

[33] E. L. Deci, R. Koestner, R. M. Ryan, A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation., Psychological bulletin 125 (6) (1999) 627.

[34] R. M. Ryan, E. L. Deci, Intrinsic and extrinsic motivations: Classic definitions and new directions, Contemporary Educational Psychology 25 (1) (2000) 54 – 67. doi:http://dx.doi.org/10.1006/ceps.1999.1020.
URL http://www.sciencedirect.com/science/article/pii/S0361476X99910202

[35] C. P. Cerasoli, J. M. Nicklin, M. T. Ford, Intrinsic motivation and extrinsic incentives jointly predict performance: A 40-year meta-analysis., Psychological Bulletin 140 (4) (2014) 980.

[36] J. Hamari, J. Koivisto, H. Sarsa, Does gamification work? – a literature review of empirical studies on gamification, in: Proceedings of the 2014 47th Hawaii International Conference on System Sciences, HICSS '14, IEEE Computer Society, Washington, DC, USA, 2014, pp. 3025–3034. doi:10.1109/HICSS.2014.377.
URL http://dx.doi.org/10.1109/HICSS.2014.377

[37] J. H. Jung, C. Schneider, J. Valacich, Enhancing the motivational affordance of information systems: The effects of real-time performance feedback and goal setting in group collaboration environments, Manage. Sci. 56 (4) (2010) 724–742. doi:10.1287/mnsc.1090.1129.
URL http://dx.doi.org/10.1287/mnsc.1090.1129

[38] N. R. Prestopnik, J. Tang, Points, stories, worlds, and diegesis: Comparing player experiences in two citizen science games, Computers in Human Behavior 52 (2015) 492 – 506. doi:http://dx.doi.org/10.1016/j.chb.2015.05.051.
URL http://www.sciencedirect.com/science/article/pii/S074756321500432X

[39] M. Vansteenkiste, C. P. Niemiec, B. Soenens, The development of the five mini-theories of self-determination theory: an historical overview, emerging trends, and future directions, Ch. 9, pp. 105–165. arXiv:http://www.emeraldinsight.com/doi/pdf/10.1108/S0749-7423, doi:10.1108/S0749-7423(2010)000016A007.
URL http://www.emeraldinsight.com/doi/abs/10.1108/S0749-7423

[40] L. von Ahn, L. Dabbish, Designing games with a purpose, Communications of the ACM 51 (8) (2008) 58–67.

[41] T. D. Moore, M. A. Serva, Understanding member motivation for contributing to different types of virtual communities: A proposed framework, in: Proceedings of the 2007 ACM SIGMIS CPR Conference on Computer Personnel Research: The Global Information Technology Workforce, ACM, 2007, pp. 153–158.

[42] K. Crowston, I. Fagnot, The motivational arc of massive virtual collaboration, in: Proceedings of the IFIP WG 9.5 Working Conference on Virtuality and Society: Massive Virtual Communities, 2008.

[43] J. Hackman, G. R. Oldham, Motivation through the design of work: test of a theory, Organizational Behavior and Human Performance 16 (2) (1976) 250 – 279. doi:http://dx.doi.org/10.1016/0030-5073(76)90016-7.
URL http://www.sciencedirect.com/science/article/pii/0030507376900167

[44] S. Reiss, Multifaceted Nature of Intrinsic Motivation The Theory of 16 Basic Desires, Review of General Psychology 8 (3).

[45] J. McGonigal, Reality Is Broken: Why Games Make Us Better and How They Can Change the World, Penguin Group US, 2011.
URL http://books.google.co.uk/books?id=yiOtN_kDJZgC

[46] G. Zichermann, C. Cunningham, Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps, 1st Edition, O'Reilly Media, Inc., 2011.

[47] L. von Ahn, L. Dabbish, Designing games with a purpose, Commun. ACM 51 (8) (2008) 58–67. doi:10.1145/1378704.1378719.
URL http://doi.acm.org/10.1145/1378704.1378719

[48] T. W. Malone, What makes things fun to learn? heuristics for designing instructional computer games, in: Proceedings of the 3rd ACM SIGSMALL symposium and the first SIGPC symposium on Small systems, ACM, 1980, pp. 162–169.

[49] B. H. Spitzberg, Preliminary development of a model and measure of computer-mediated communication (cmc) competence, Journal of Computer-Mediated Communication 11 (2) (2006) 629–666. doi:10.1111/j.1083-6101.2006.00030.x.
URL http://dx.doi.org/10.1111/j.1083-6101.2006.00030.x

[50] J. Alison Bryant, A. Sanders-Jackson, A. M. K. Smallwood, Iming, text messaging, and adolescent social networks, Journal of Computer-Mediated Communication 11 (2) (2006) 577–592. doi:10.1111/j.1083-6101.2006.00028.x.
URL http://dx.doi.org/10.1111/j.1083-6101.2006.00028.x

[51] C. Ross, E. S. Orr, M. Sisic, J. M. Arseneault, M. G. Simmering, R. R. Orr, Personality and motivations associated with facebook use, Computers in Human Behavior 25 (2) (2009) 578 – 586, including the Special Issue: State of the Art Research into Cognitive Load Theory. doi:http://dx.doi.org/10.1016/j.chb.2008.12.024.
URL http://www.sciencedirect.com/science/article/pii/S0747563208002355

[52] C. B. Jackson, C. Østerlund, K. Crowston, G. Mugar, K. D. Hassman, Motivations for Sustained Participation in Citizen Science: Case Studies on the Role of Talk, http://crowston.syr.edu/sites/crowston.syr.edu/files/MotivationinTalk(A).pdf (Submitted).

[53] R. Tinati, M. Luczak-Roesch, E. Simperl, N. Shadbolt, Motivations of citizen scientists: A quantitative investigation of forum participation, in: Proceedings of the 2014 ACM Conference on Web Science, ACM, 2014, pp. 295–296.

[54] A. Bowser, D. Hansen, J. Preece, Gamifying citizen science: Lessons and future directions, in: Designing gamification: Creating gameful and playful experiences workshop, CHI 2013, ACM, 2013.

[55] I. Iacovides, C. Jennett, C. Cornish-Trestrail, A. L. Cox, Do Games Attract or Sustain Engagement in Citizen Science? A Study of Volunteer Motivations, in: CHI '13 Extended Abstracts on Human Factors in Computing Systems, ACM, 2013, pp. 1101–1106.

[56] D. Rotman, J. Preece, J. Hammock, K. Procita, D. Hansen, C. Parr, D. Lewis, D. Jacobs, Dynamic changes in motivation in collaborative citizen-science projects, in: Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work, ACM, 2012, pp. 217–226.

[57] A. Eveleigh, C. Jennett, S. Lynn, A. L. Cox, “i want to be a captain! i want to be a captain!gamification in the old weather citizen science project, in: Proceedings of the First International Conference on Gameful Design, Research, and Applications, Gamification '13, ACM, New York, NY, USA, 2013, pp. 79–82. doi:10.1145/2583008.2583019.
URL http://doi.acm.org/10.1145/2583008.2583019

[58] D. Robinson, V. Bellotti, A preliminary taxonomy of gamification elements for varying anticipated commitment, in: Proceedings of the CHI, 2013.

[59] G. Newman, A. Wiggins, A. Crall, E. Graham, S. Newman, K. Crowston, The future of citizen science: emerging technologies and shifting paradigms, Frontiers in Ecology and the Environment 10 (6) (2012) 298–304.

[60] M. Luczak-Rösch, R. Tinati, E. Simperl, M. V. Kleek, N. Shadbolt, R. Simpson, Why won't aliens talk to us? content and community dynamics in online citizen science, in: Eighth International AAAI Conference on Weblogs and Social Media, 2014.
URL http://eprints.soton.ac.uk/363523/

[61] C. Pope, S. Ziebland, N. Mays, Analysing qualitative data, Bmj 320 (7227) (2000) 114–116.

[62] C. Lampe, R. Wash, A. Velasquez, E. Ozkaya, Motivations to participate in online communities, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM, 2010, pp. 1927–1936.

[63] J. Raddick, C. Lintott, S. Bamford, K. Land, D. Locksmith, P. Murray, B. Nichol, K. Schawinski, A. Slosar, A. Szalay, et al., Galaxy zoo: Motivations of citizen scientists, in: Bulletin of the American Astronomical Society, Vol. 40, 2008, p. 240.

[64] M. J. Raddick, G. Bracey, P. L. Gay, C. J. Lintott, P. Murray, K. Schawinski, A. S. Szalay, J. Vandenberg, Galaxy zoo: Exploring the motivations of citizen science volunteers, Astronomy Education Review 9 (2010) 010103.

[65] M. J. Raddick, G. Bracey, P. L. Gay, C. J. Lintott, C. Cardamone, P. Murray, K. Schawinski, A. S. Szalay, J. Vandenberg, Galaxy zoo: Motivations of citizen scientists, arXiv preprint arXiv:1303.6886.

[66] O. Nov, What motivates wikipedians?, Communications of the ACM 50 (11) (2007) 60–64.

[67] A. Bowser, D. Hansen, Y. He, C. Boston, M. Reid, L. Gunnell, J. Preece, Using gamification to inspire new citizen science volunteers, in: Proceedings of the First International Conference on Gameful Design, Research, and Applications, Gamification '13, ACM, 2013, pp. 18–25.

[68] A. K. Przybylski, K. Murayama, C. R. DeHaan, V. Gladwell, Motivational, emotional, and behavioral correlates of fear of missing out, Computers in Human Behavior 29 (4) (2013) 1841 – 1848. doi:http://dx.doi.org/10.1016/j.chb.2013.02.014.
URL http://www.sciencedirect.com/science/article/pii/S0747563213000800

[69] A. Halfaker, R. S. Geiger, J. Morgan, J. Riedl, The rise and decline of an open collaboration system: How wikipedia's reaction to sudden popularity is causing its decline, American Behavioral Scientist

57 (5) (2013) 664–688. doi:10.1177/0002764212469365.
URL http://dx.doi.org/10.1177/0002764212469365

[70] T. G. Gill, Expert systems usage: Task change and intrinsic motivation, MIS Quarterly 20 (3) (1996) 301–329.

[71] M. Sakamoto, T. Nakajima, T. Alexandrova, Value-based design for gamifying daily activities, in: Entertainment Computing-ICEC 2012, Springer, 2012, pp. 421–424.

[72] J. Simes, R. D. Redondo, A. F. Vilas, A social gamification framework for a k-6 learning platform, Computers in Human Behavior 29 (2) (2013) 345 – 353, advanced Human-Computer Interaction. doi:http://dx.doi.org/10.1016/j.chb.2012.06.007.
URL http://www.sciencedirect.com/science/article/pii/S0747563212001574

[73] S. R. G. K. H. M. P. K. J. M. Segal, Avi., Improving productivity in citizen science through controlled intervention, in: Proceedings of the 24th International World Wide Web Conference, Web Science Track, ACM, 2015.