"Because Science is Awesome": Studying Participation in a Citizen Science Game

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ABSTRACT

In this paper, we examine the motivations for participation in EyeWire, a Web-based gamified citizen science platform. Our study is based on a large-scale survey to which we conducted a qualitative analysis of survey responses in order to understand what drives individuals to participate. Based on our analysis, we derive 18 motivations related to participation, and group them into 4 motivational themes related to engagement. We contextualize our findings against the broader literature on online communities, and compare our findings with other citizen science platforms, in order to understand the implications of gamification within the context of citizen science.

Keywords

Citizen Science, Crowdsourcing, Online Communities

CCS Concepts

•Information systems → Collaborative and social computing systems and tools;

1. INTRODUCTION

Online citizen science projects enlist the help of large numbers of untrained volunteers to solve challenging research problems. Recent years has witnessed the release of such projects across a swathe of disciplines, from physical and natural sciences (e.g., [16, 18]) to the humanities (e.g., [22]).

Online citizen science projects can be understood as collective intelligence systems that use human computation and crowdsourcing [23] to help professional scientists process huge amounts of raw data and advance their empirical work. They form loose-knit communities, whose members interact with each other in dedicated online discussion forums [6, 43]. Collaboration is distributed and implicit, centred around either task artefacts, platform features, or general topics of interest. Yet, at scale, the two perspectives are complementary and effective not only accomplishing sought after scientific objectives, but also yielding unanticipated discoveries initiated by members of the community.

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One of the most critical challenges of designing successful citizen science systems is in recruiting and sustaining participation over time. This can be seen from the high number of initiatives that had to be halted prematurely or cancelled entirely because they could not reach critical mass or keep their contributors engaged [31]. Core to understanding why people are not participating or else fail to stay engaged with CS projects is the question of motivation.

In this paper we study this question for EyeWire[1], a Web-based citizen science game that aims to create a detailed atlas of the human brain. By using a gamified environment, EyeWire asks people to identify connected areas in 3D-transformed fMRI images, whilst offering players the chance to compete against each other. Our work is inspired by a quantitative exploration of EyeWire Player participation [42], in which we qualitatively analyse data collected from a large-scale survey pertaining to volunteer contributions to EyeWire. The main contribution of our work is the identification of 18 motivations of engagement and participation with EyeWire, and how these relate to specific platform features, such as elements of gamification, communication, and collaboration. We contextualise our findings against existing motivational frameworks [32], and compare our work with other studies of citizen science platforms, human computation, and online communities.

2. RELATED WORK

Related work has attributed various aspects understanding online participation in different types of online communities [17]. Observations and longitudinal studies are typical methods used to provide an understanding of the behaviour and interactions between individuals who participate in online communities, with specific focus on the relation between system design and user participation.

Often, motivational theories such as self-determination theory is used to understand participant motivations [5, 28, 35], which categories human participation driven by intrinsic and extrinsic motivations [10]. In such cases, studies have shown intrinsic motivations emerge from one's pleasure of performing the activity (i.e., just for fun). In contrast, extrinsic motivations have been related to external achievements or incentives (e.g., for a financial reward). The two categories are considered complementary and not mutually exclusive. Here we focus our discussion on studies of volunteers in the context of citizen science and 'games with a purpose' (GWAPs) [44], as a human computation design paradigm that is used in EyeWire.

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

[1]http://eyewire.org/

to make money and improve their reputation and skills [5]. Moor and Serva [24] articulate motivation factors based on correlating expressions, identifying 14 different categories of motivations, which cover intrinsic and extrinsic aspects. Crowston and Fagnot [7] 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 [13]. 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 [33], a personality-based approach to assessing motivation; their approach identifies themes such as power, curiosity, social contact, status, and tranquillity. Kraut and Resnick [17] name 16 basic desires related to personal motivations in their work on building successful online communities.

The implications of game mechanics and gamification on user engagement has been an extensive subject of study [21]. 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 [47], encourage sociality, and avoid potential negative effects of incentives on intrinsically motivated activities [9]. Surveys of GWAP players [45] have identified the factors of challenge and desire to learn and improve [20] alongside social interaction as conducive to developing a successful game with a purpose. Pertaining to citizen science platforms, Raddick et al. [32], Jackson et al. [15], and Tinati et al. [41] discuss the role of intrinsic themes such as altruism, collaboration, personal interest, learning in the behavior of amateur scientists. Studies have also started to documented the role of gamification on the extrinsic motivations of players and participation in particular gamified citizen science platforms [3, 14, 34].

Our paper is connected to the aforementioned studies in the following way. Situated in the context of GWAPs in citizen science, EyeWire uses similar game elements as FoldIt [16] and EteRNA[2]. It features a somewhat technical user interface and does not build a fictive game narrative around the actual task, which is designed as a 3D map of a neuron in the human brain the players explore in order to discover and highlight connected regions. On the gamification side, EyeWire seems to be perfectly inline with a broader trend in citizen science that utilizes 'motivations driven by interest in technology and rewards' [26]. However, we are still far from understanding which has a higher impact on participation: the technology or the task itself; or the incentives devised through gamification.

3. EYEWIRE

EyeWire is a citizen data-analysis project that enlists the help of people to deduce the structure of neurons of the human brain, derived from functional magnetic resonance images (fMRI) scans. Crowd contributions are combined with machine learning algorithms to create a map of the connections of neurons ('connectomes'), which reside at the back of the human eye. The goal of the project is to help neuroscientists to achieve a better understanding of the ways in which human process visual stimuli.

Players interact with Eyewire using an interface which contains gamification elements. The main 'task' requires players to examine colourful 3D maps and highlight regions with specific physical properties. The basic region marking task is performed by clicking with the cursor 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. Completed games are rewarded by points, and public leaderboards are shown, listing the top players at that current point in time. Players are also able to observe their own statistics, allowing them to keep track of their progress, and to compare themselves with other players. To further encourage participation, periodic competitions and challenges are run, often bringing the players together in teams. Figure 1 illustrates the functionality of the game interface. Competitions are either setup by the EyeWire team (usually to encourage or refresh system activity), or led by the players who wish to compete for a specific goal or set of 'badges'.

As shown in Figure 1, EyeWire contains an embedded real-time chat that allows players to talk to each other, view other players points and achievements, as well as use a number of game commands, which are issued by using a forward slash ('/'). Issuing player statistic commands are not shown on the public chat feed, unless a player issues a command such as group message ('/gm'), which posts their message to a particular team, in which they first have to join using the '/team' command. The formation of a team is an community-driven process which usually is a result of an ongoing competition between teams of players. In addition to the real-time chat, the main interface links to additional communication interfaces which are not part of the game. 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 this, players are provided with a forum that facilitates more comprehensive, asynchronous discussion on various topics around the game, including error reports.

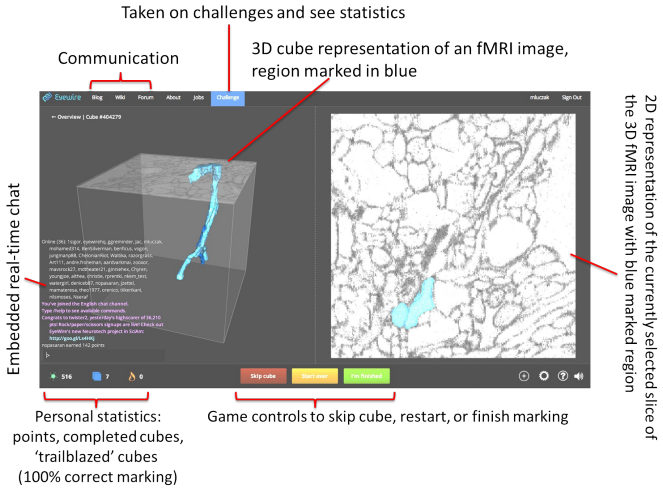

Figure 1: EyeWire Task Interface

3.1 EyeWire Platform Overview

To further describe Eyewire, we analysed platform data which contains 4, 409, 998 game actions and 835, 732 chat records, made by 98, 224 unique players, between January 2012 and August 2014. We extracted different sets of players related to their gaming and chatting behaviour. (1) casual players who only performed tasks, (2) casual players who performed tasks and chat activity, and (3)

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

highly active players who contributed at least 30 days of consecutive activity. The relative proportions of these three groups, were 88%, 11% and 1%, respectively, as visible in Table 1.A significant 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. We found that the proportion of 'active' EyeWire players - those that participate in chat and games - is lower that other citizen science platforms [19], despite the chat interface being inline with the main gaming interface. However, considering the active players, EyeWire exhibits a similar skewed distribution of contributions to other studied citizen science platforms [43]. For example, the 'highly active' players' contributions; they represent 1% of EyeWire players, yet are responsible for more than 50% of the total games (2 million).

We also focused on the impact of players that participated in chat in comparison to those that only completed games. Comparing the share of players who only completed games (which accounted for 88% of the population) to those who engaged in both chat and gaming (the 'active' players), the average number of games completed by gaming-only players was significantly lower (15 games compared to 255). In addition to this, the overall account age (that is, the number of days since the first registration) of 'active' players was nearly 4 times longer. However, with respect to the frequency to which new game rounds were started (the delta in minutes between games), those that only participated in the game spent on average 6 minutes without playing, in comparison to 65 minutes for the 'active' players.

Statistic	(All Players)	Task only	Chat and Task	Highly 'Active'
Players	97,945	86,659 (88%)	10,705 (11%)	1,060 (1%)
Games	4,005,244	1,272,081 (31%)	2,733,163 (68%)	2,007,346 (50%)
Chat Msgs.	835,130	-	799,338	705,680
Avg. Chat Msg/Player	-	-	75	666
Avg. Tasks/Player	257	15	255	297
Avg. Task Acc. (hrs)	1,641	416.2	1,641	6,513
Avg. Chat Acc. (hrs)	495.8	-	495.8	4,788

Table 1: *Participation Overview* - Participation in EyeWire, organised by casual participants who only performed tasks ("Task only"), casual participants who used chat and performed tasks ("Chat and Task") and those who participated for more than 30 consecutive days ("Highly Active")

4. DATA AND METHODS

4.1 Survey Data

The survey, with questions show in Table 2 was conducted by the EyeWire development team as part of an ongoing study to understand their players and elicit their reasons to contribute to the project. The survey was ran during April 2013 and received 1,505 responses, and asked participants demographic information such as age, gender, education, and geographic location, and also a free-text section where participants could state their motivations in playing EyeWire. All questions were optional to answer, and the results of the survey were anonymous.

We used calculated the player chat and gaming activity distribution, and also the mapping between a player's engagement with the real-time chat and their gaming activity (e.g., number of chat messages vs. the number of games completed).

Question	Response Type
Why do you play EyeWire?	Free-text
Gender	Free-text
Age	Numerical choice
Country	pre-defined list of countries
Level of Education	pre-define list of education boundaries
Occupation	free-text
How long do you play EyeWire per week (rough estimate)?	pre-defined options
If you play EyeWire for more than 1 hour per week, how long do you play (rough estimate)?	Free text
Does EyeWire inspire you to learn more about the brain?	Pre-defined options

Table 2: 2013 EyeWire Player Survey Questions

For the free-text responses, we used an inductive thematic coding approach [30, 46], in order to extract the the main motives why volunteers engage with EyeWire. Whilst being appreciative of existing motivation theory literature [5, 13], we deliberately decided to examine the participants' free-text responses without being predisposed to a set of motivation criteria or any theoretical framing, and consult these sources once a stable set of criteria had been identified. The coding process consisted of four different steps that involved the same three researchers. The first two steps were similar and resulted in a list of codes referring to motivation factors. In each of these two steps, the three researchers first coded the responses independently, then discussed their views in the group, and agreed on a common set of codes. The second coding iteration led to refinements of the list produced in the first step. In the next step we then cross-examined our findings with previous studies, mapping the set of codes we identified to existing theoretical frameworks to validate them. Finally, we went back to the survey responses to select a primary and a secondary motivation factor for each participant from the consolidated list.

4.1.1 Survey Representativeness

We calculated basic statistical measures on the demographic information collected via the survey, and used these statistics in combination with the qualitatively coded responses to understand if specific motivations are related to dimensions such as age, gender, education, and geographic location. As the survey contained 10% of the total set of EyeWire members, we wanted to ensure that the data collected and analysis performed are representative. To compare the survey with the total set of EyeWire players, we were given access to an anonymized dataset containing the details of EyeWire players, including their demographics and player statistics. We also had access to EyeWire's website analytics software to confirm the representativeness.

5. RESULTS

5.1 Overview

Overall 38% of respondants self-reported their gender as female, 62% male. A breakdown of responses to the ages of participants by education level and gender are visible in Table 3. Based on the responses, we identified a total of 96 countries from where players reside, of which the top 10 are shown in Table 4.

In addition to the demographic data, we analysed their responses to determine how often and how long they played EyeWire. 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

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 3: Education Level and Average Age Based on Gender

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.

Country	Proportion (%)
USA	47.23
Germany	5.07
Canada	4.94
UK	4.74
Poland	4.54
Australia	2.80
Italy	1.93
Brazil	1.73
Netherlands	1.73

Table 4: 10 Most frequently reported country of player's location

5.2 Motivation Elicitation

In this section we 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 used the coding approach described in section 4 and hand-coded these 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 7 lists the 18 motivations identified, their positioning as primary and secondary factors, and the breakdown of gender to motivation. The 12 motivations found in the first iteration of the coding process are marked by a '+'. During the second round of coding the three researchers refined this initial list with 6 additional codes. For 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 coding scheme accordingly.

As shown in Table 7, 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 (independent of their position as a primary or secondary); as 5 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.

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 5: Co-Occurrence of 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 6: Level of Education and Top Two Corresponding Motivating Factors

As shown in Table 6, we compared the motivation of participation against their reported level of education. Across several stages of education, we observed that the motivations identified earlier: *contribution*, *science*, and *fun*, were found to be more common than other motivations. We found that responses who identified themselves as high school students appeared to be strongly driven by the game-like elements of the project (*fun*, *gaming*, *relaxing*), as well as *curiosity*, and *science*. Similarly, examining learning outcomes against our elicited motivations; 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 for *procrastination* being prominent in the groups of participants that 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. In 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 bias towards a particular motivation.

Motivations	Description of Code/Motivation	Total	Pri.	Sec.	M(count)	F(count)	M(%)	F(%)
Contribution$^+$	Contributing to the project, not specifically related to helping science	286	165	121	174	112	37.46	26.08
Science$^+$	Helping improve scientific knowledge. Direct mention of contributing to science	262	188	74	186	94	39.49	19.21
Fun$^+$	For the entertainment value. No specific mention of games or competition	199	174	25	118	81	36.51	17.89
Learning$^+$	To learn about science, or related learning purpose	95	61	34	74	21	47.97	13.23
Personal interest$^+$	For some personal interest towards EyeWire, related to the scientific task	93	70	23	58	35	38.40	19.21
Interesting$^+$	Due to a general interest in EyeWire	83	68	15	57	26	42.29	14.69
Procrastination$^+$	To avoid doing another task, i.e. avoid doing school work	70	52	18	39	31	34.31	22.91
Relaxing$^+$	As a way to relax from other tasks.	66	47	19	31	35	28.92	28.61
Gaming$^+$	The ability to play a game, specific mention of gaming	56	41	15	32	24	35.19	22.49
Puzzle	Specific mention of enjoying the puzzle aspect of the task	39	28	11	22	17	34.74	23.33
Challenge$^+$	Specific mention of the challenge aspect of the task	36	21	15	17	19	29.08	34.76
Community	Taking part, or feeling part of a community	27	7	20	20	7	45.61	38.42
Curious	An 'initial' interest in EyeWire, not specifically mentioning gaming or science	23	22	1	11	12	29.45	20.96
Beautiful$^+$	Specific mention of the visually appealing aspects of EyeWire (e.g. 3D cube visuals)	13	1	12	2	11	9.47	22.64
Competition	The ability to compete with other players in the game	12	3	9	8	4	41.05	51.23
Interface	Specific mention of the 3D interface and actual design of the platform	7	5	2	3	4	26.39	30.74
Addictive$^+$	The addictive nature of the task, often describing their flow or finding it difficult to stop	6	5	1	0	6	0.00	46.11
Citizen science	Specific mention of citizen science	5	4	1	4	1	49.26	9.61

Table 7: Motivations (Primary and Secondary) for both Genders. 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.

6. MOTIVATION ANALYSIS

Based on the survey analysis, we now examine in more detail the content of the responses to the question *"Why do you play EyeWire?"*. The analysis draws on the quantitative analysis and the motivations identified in order to better understand the participation of EyeWire Players, and to consider their possible implications on the design of the gamified citizen science. Our discussion is framed by insights from related literature that studied similar phenomena in other participatory online environments.

The responses chosen aim to represent different the demographic groups where possible, in order to provide a set of responses which represent the spectrum of survey responses, including age, gender, education, location, and employment. In order to achieve this, we performed a simple word frequency analysis of the vocabulary and phrasing used by the EyeWire community (via the survey particiipants). 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 conducted an analysis of the common phrases used by participants. As shown in Table 7, these included phrases such as "To contribute to", "want to help", or "it is fun". These results was then used to narrow down and select a number of responses from the different demographic groups and types of motivations in order to further understand the context of the responses made.

Supporting the project/science. We examined the responses that were related to the feeling of contributing towards the Eyewire scientific endeavour. For this, we derived two codes, *contribution* and *science*. We chose to deliberately separate these into two motivations, as from the survey responses there was a sense that some people contributed towards the EyeWire project as such and appeared less interest in the actual science, while others were specifically driven by the aspiration to advance science (via EyeWire or elsewhere).

Out of the 349 responses which were labelled by such motivations, 252 (72.2%) had one of the two codes as their only motivating factor, with no identifiable secondary motivation. We found such effects across the different demographic groups, and across gender. We also compared these responses to the survey question 'Does EyeWire inspire you to learn more about the brain?', and found that 92% of the responses who were labelled with these motivations were also interested to learn. The 8% which answered they did not want to learn about the brain were identified themselves as either High School or Middle School students.

"I want to help science" (M,CC, learns from EyeWire)[3]

"To do what I can to help and keep a small contact with science." (F, FC, learns from EyeWire)

The remaining 97 of the 349 responses were identified to have a secondary motivation in addition to *contribution* and *science*. In this population, we found that responses described several motivations for why they play EyeWire, including: to *learn* about the breain (25.7%), to feel part of a *community* (11.3%), or because of 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)

"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)

Whilst survey participants appear to report that contributing to EyeWire and learning about science is a key driver to their participation, the analysis of the real-time chat log suggests a lack of scientific discussion. Instead, chat messages contained extensive use of self-monitoring commands (e.g., '/stats'), and informal discussions (e.g. 'wow, I've done enough, time for bed'). Unlike the discussion forums in other citizen science platforms[19] which were found to facilitate scientific discourse, EyeWire's chat appears to promote less formal, subject specific conversation. We also question the extent to which players who are motivated by the desire to contribute or help science are engaging in chat? Instead, they may focus their attention to the task element of EyeWire.

For Entertainment. A significant proportion of the responses contained at least one reference to the gamification, competition, or the entertainment value of participating in Eyewire. To compare the type of responses which were identified by these motivations, against responses reporting an interest in *contribution* and *science*, we analysed responses that were labelled to contain motivations

[3]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

related to *gaming*, *challenge*, *competition*, *puzzle*, and *fun*.

The distinction between the five 'gaming and entertainment' codes is based on how responses described how and why they 'play' EyeWire, and the specific features (e.g., leaderboards, points) involved. For instance, we found a responses described their love for completing puzzles, whereas others were interested in the challenge and ability to compete with other players. From the 267 respondents that were labelled with these motivations, 93 (34.8%) were solely focused on its ludic qualities of the EyeWire environment. Here is a small set of replies that illustrate this attitude:

"Because it's fun :)" (F, FC, does not learn that much 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 shown above are an illustration of responses where we identified motivations which primarily describe their engagement with EyeWire purely 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 is for self-fulfilment or for the 'greater good', is unclear.

The remaining 174 responses associated with *gaming* and *entertainment* were found to be explicitly linked to a secondary motivations, such as *learning*, or *contribution*. For example:

"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 responses are indicative of the positive relationship between the use of game mechanics and citizen science. The entertainment and playfulness value of EyeWire is a strong driver to attain and sustain participation. Furthermore, players also appreciate that they are able to learn, contribute to the project, or use their free time for something productive.

We found that in comparison to survey respondants who stated they were driven by only by the entertainment value of Eyewire, tended to be in, or just graduated from high school, or below. Those that associated themselves with learning as well as gaming self-identified themselves as college educated or higher. We also found that within the small set of responses that were coded with *competition*, 75% of the responses 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)

As observed earlier, 60% of responses with their secondary motivation as *competition* were found to have a primary motivation associated with contributing to the project, or for improving and advancing science.

To Learn. Our coding revealed a population of survey respondants who identified as being primarily motivated by the ability to learn, or stated that they had some personal interest in the topic. We also include the responses which describe their interest with the domain of *citizen science*, as these responses were describing how citizen science allowed them to learn about the medical knowledge in EyeWire.

Within this set of responses, 130 out of the 203 (64.0%) were motivated soley by the project itself. These respondents self-identified themselves as college educated or higher (80%), with a large proportion of those studying for or had a PhD (38.4%). These responses described how EyeWire provides an initial resource to learn about the brain, fulfilling personal interest, which may be associated with their studies in neuroscience, or medicine.

"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)

Although the learning objectives of the participants are unknown, these responses provide some evidence to suggest that EyeWire offers an environment where players are capable of learning about the nature of the task. In many of these causes, we found that those that discuss learning as a motivation are independent of the gamification aspects of the system.

In respect to the remaining 73 responses from the 203 responses, 60.2% were also labelled as describing motivations related to *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 the purposes of learning more were not particularly triggered by the game mechanics that are at the core of the design of the platform.

To be part of a Community. Whilst representing the smallest set of responses, being part of a *community* was identified as a primary motivation for 27 of the respondents. In all cases, *community* was found as a primary motivation in addition to *personal interest* (16%), their wish to be *entertained* (36%), or to *contribute* (44%). Cross-examining these observations with the player log analysis, 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.

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)

We also observed that in several of the responses, being part of a *community* was more than just discussion, it offered participants the chance to meet like-minded individuals, and speak to (amateur) scientists:

"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)

Finally, a small proportion of the responses labelled with a primary motivation as *community* and secondary as *gaming* or *entertainment*, we found their responses tended to depict a level of socialising, chatting, or competing against other fellow players. For example:

"Because it is awesome. Mostly because I am interested in community

driven projects." (M, CC, learns a lot from EyeWire)
"Addiction. It's very addiction, the environment and community it's great too! The purpose above." (M, CM, learns a lot from EyeWire)

7. DISCUSSION

The primary goal of a Web-based citizen science project is to use the collective capacity of humans to complete computationally difficult and time-consuming tasks, in an accurate, timely, and sustainable manner. Similar to other crowdsourcing systems, developing a socio-technical environment which is engaging and manages to maintain an active community is challenging. While this may be due to the nature of the task itself or interface issues which could have been avoided through a more considerate UX design, it ultimately involves understanding the users and their community [17, 43].

EyeWire exhibits the characteristics of a successful citizen science project, combining elements of gaming, discussion, and science. Understanding the motivation of its contributors may give hints to what made it attractive for people to stay on board beyond the initial activity driven mostly by chance and curiosity. Our work is very much in-line, but also contextualizes design guidelines in the area of online communities [17]. 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 common interest.

Gamification Elements. For EyeWire players, being able to contribute to a worthy cause via an entertaining, competitive interface was mentioned by a significant proportion of the survey respondents. Considering this, our findings support the claim that incentivising behavior via gamification can be beneficial to participation [2] without reducing the importance of the project's scientific or crowd-based objectives. Transforming a complex task into smaller (micro) tasks via a gaming interface with several of the elements associated with a gamified environment [36] has been identified as a positive motivation for a player's participation. As we found from the survey responses, participants described their experience with the gamificaiton elements as something which encouraged them to participate and remain active. The demographics of these players capture a broad range of people, from young to old, students to professionals. Such responses align with both intrinsic and extrinsic motivating factors for participation, from internal rewards and feeling happy ('entertainment'), to being able to compete and gain status within the Eyewire community (facilitated by the public leaderboard).

Scientific Contribution. The desire to contribute to a worthy cause, and/or to support scientific discoveries was a powerful incentive for EyeWire players to participate. Our findings suggest that it was the primary motivation for the majority of responses. In a number of cases, we identified a set of responses which describe how their primary focus was to be able to contribute to a worthy scientific endeavour; suggesting that their participation was entirely driven by the intrinsic desire to help. However, we also identified responses which described a secondary participation factor, with a significant proportion (more than 60%) of responses describing their participation being related to the 'entertainment' value, or to be able to 'game' and 'compete'. These responses suggest that whilst players are driven by the intrinsic desire to help, there is also an element of extrinsic-incentives, such as rewards (badges) to praise (status on the leaderboard). These findings suggest that the desire to contribute is just as important in gamified citizen science platforms as in non-gamified citizen science projects. Indeed, as Bowser et al. [2] found, gamifying citizen science activities inspire both gamers and amateur scientists, enlisting a wide range of participants.

Learning. Learning and obtaining additional knowledge with respect to the science in Eyewire was identified as a prominent motivation across many of the survey responses. Responses indicate that not only are players intrinsically motivated by the desire to learn, but also feel that by playing EyeWire, they are able to learn more about the brain. These findings are similar to existing studies on motivation in non-gamified citizen science projects, such as the Zooniverse [32, 29, 25], which suggest the intrinsic desire to learn more helps sustain participation. Considering the debate against gamification as a means to facilitate learning, specifically in citizen science, our findings suggest that EyeWire's integration of gaming elements have not distracted players from the feeling that they were able to learn, or to obtain knowledge about the scientific task. Eyewire has managed to balance a mix of intrinsic and extrinsic rewards to allow players to engage with the gaming elements, whilst learning about the scientific process. Given that the EyeWire interface only reveals limited scientific information (e.g., a player is presented with an render of the 'connectome'), we assume that players are inspired to seek additional material to read and learn about. This is in contrast the types of learning in other citizen science platforms, where citizen scientists collaboratively perform further examination on the objects they have been asked to classify [43].

Community Engagement. Whilst we only identified in a small number of responses, we found the description of how the community was an important aspect to a player's participation a noteworthy motivation. In many of the responses, the feeling of community belonging appeared key to why players engaged with the chat mechanism, offering them a chance to share their experiences, and feel part of a community of like-minded individuals. As described by Kraut et al. [17], offering individuals with the ability to communication, which may be as part of the platform interface, or as a back channel (e.g., an external discussion forum) can help individuals feel part of a group, which has a positive affect on the engagement of users. As Spitzberg [39] argues, communications are important for supporting both intrinsic ad extrinsic motivations; this can be beneficial for supporting community expansion, and helps individuals development their own skills. Given the findings in a systems analysis of Eyewire [42], this is true with respects to the relationship between gaming and chatting; players which chatted and used more commands completed more games.

Beyond studies of citizen science platforms, we identified commonalities to online behavior in other online communities, such as Wikipedia. Factors such as *fun* and *entertainment* were deemed important to engagement, alongside community belonging, the opportunity to contribute to a greater cause, and, most importantly in this case, the ability to learn [27], and and improve one's knowledge overtime [7].

Compared to EyeWire's participants who are primarily driven by the inclination to help science, Wikipedians exhibit greater motivation towards the learning effects associated with the editing of an encyclopedic article on a certain topic [1, 27]. We attribute this difference to the nature of the contribution, which is much more immediate in the Wikipedia case than in any citizen science project, in which players' inputs are just one component of a much more complex, expert-driven scientific workflow. While some platforms are very enthusiastic about so-called "serendipitous discoveries" [6], which represent citizen-led scientific inquirers that go beyond the original scope of crowdsourced task, designing functionality which encourages this form of activity is yet to be understood [19]. In

some cases, the science team responsible for initiating the project explicitly encourage the crowd to join them to investigate and contribute to scholarly publications, yet only a small proportion of participants do so.

8. REFLECTION ON METHODS AND LIMITATIONS

In this section we discuss the methodological implications associated with conducting an investigations participant motivations in citizen science – and more broadly, in online communities – as presented in this paper, and blend this with related studies of general online communities. Specifically, we discuss the relationship between the methods and findings, and how these translate to both an understanding of the social as well as the technological guidelines and frameworks.

Since the launch of the early citizen science projects, there have been numerous studies conducted to understand the motivations for why people volunteer their time on such platforms [8]. Analogous to the analysis conducted within this paper, studies have formed different sets of motivating factors via the use of surveys, data analysis, and observations (e.g., [5, 7, 32, 2]). These studies converge on the same types of motivations; citizen scientists appear to be driven by the desire to help a worthy cause, to learn more about science, or simply as a means to spend their free time.

In many cases, citizen science and 'online community' motivational studies have been associated with existing motivational theories (e.g., Self-Determination Theory, Cognitive Evaluation Theory [11]), used to help explain how different categories of motivations may be associated with different platform features and functionality. Similarly, the aforementioned methods of data collection and analysis have been used to produce design frameworks and guidelines, which describe key components for building and supporting online communities, and offer social and technical design guidelines for system builders and community managers [17, 33]. However, in both, the frameworks and motivation studies, assumptions are made due to the nature of the methods; surveys – in most cases – provide a partial account of the population's opinion, and data analysis of system logs offer an understanding of the patterns of participation interactions. Consequently, the limitations of these methods raise a number of methodological questions with regards to the accuracy and scope of the findings, and how far they can be pushed towards a generalisable set of rules and guidelines.

Whilst we are aware that these limitations are documented elsewhere in other studies of social phenomenon on the Web (e.g., social media and big data analysis [4, 40], we must be consider them in the context of citizen science research. For example, citizen science is considered as a global crowdsourcing activity, yet our findings (see Table 4, which are consistent with others [32] have show that there be a significant geographic bias in participants. A large proportion of the individual who participate on citizen science platforms are from a select number of countries, often situated within the western world.

Given the varying level of success reported in different types of citizen science projects [12, 19]), we need to ask questions pertaining to why particular demographic groups and countries do not participate in citizen science activities, which require both a sociological and technical understanding. Moreover, are such findings reflected in the motivations elicited, or present in the design guidelines for supporting online communities? We also need to evaluate the types of methods used to derive this insight, and how applicable the findings are in terms of their generalisability.

9. CONCLUSION

In this paper we conducted an analysis of EyeWire in order to consider the motivations related to player engagement and sustained participation. Our analysis was based on data collected via an online "player participation" survey, in combination with a dataset containing 3 years worth of EyeWire platform data. We primarily focused on eliciting the motivations of participation as stated by respondants in their free-text response to the question of "why do you play EyeWire?". Based on systematic qualitative coding of the survey responses and a quantitative analysis of the respondents self-reported demographics, we elicited a set of motivations which relate to their reasons for participation. Working with existing literature, we grouped these motivations into 4 categories of motivations and contextualised them with respect to the design of a gamified citizen science platform.

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. We were interested to find out whether the use of game mechanics had an impact on participants' motivation, taken into account the ambivalent links between external rewards and intrinsically driven engagement. We found one of the main reasons to participate was dominated by the generally positive effects and outcomes of the activity: aiding a beneficial cause, advancing scientific knowledge, learning. However, 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.

Our findings suggest that the inclusion of gamification elements embedded in the Eyewire workflow has facilitated players to successfully engage with the task whilst remaining aware of the scientific tasks they are supporting. Furthermore, the use of components such as leaderboards and individual points has encouraged participants to *compete* with each other, and inspired emergent behaviour such as forming self-proposed teams and competitions. We found this emergent social behaviour reflects player engagement characteristics in other non-gamified citizen science platforms [19]. Furthermore, by looking at the combination of motivations found within the responses, we found that gamification and entertainment is not necessarily independent of motivations related to contributing to science or a worthy cause, nor is it independent from participants interesting in learning. These findings contribute to an ongoing debate about the role of (or need to resort to) game mechanics to make citizen science projects more appealing to wider audiences and sustain engagement [38, 43, 37].

Considering the wider body of literature associated with online communities in general, the responses for participation, and as a product of this, our elected motivations share many commonalities with other qualitative studies of Web-based platforms. We see the further development of our work will involve the study of other citizen science platforms in order to derive a generalisable framework for understanding citizen science participation. However, as we discussed in Section 8, we are aware that in order to derive such a framework, we need to better understand the methods and theories used to collect and interpret the data under question.

As an immediate next step, we wish to enrich this current study of player participation by conducting a longitudinal study of players in order to understand how their interaction with the system changes over time, with the purpose of better understanding motivations and engagement as a dynamic process. A second line of research will strive to better understand the relationship between spe-

cific platform features (e.g., chat, leaderboards, and user engagement) and the motivations which they correspond to. This would fit into a larger set of studies which would involve a comparative analysis of participant and community behavior *across* citizen science projects, both gamified and non-gamified.

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