Motivation to participate in an online citizen science game: a study of Foldit

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Abstract

Online citizen science projects have the potential to engage thousands of participants with scientific research. A small number of projects such as Foldit use an online computer game format. Motivation to participate in Foldit was investigated in a group of 37 players using an online survey, semi-structured interviews and participant observation. Results suggest that contributing to scientific research and an interest in science were among the most important motivations for participation. Interaction with others within the community of participants and the intellectual challenge of the game were also key for the continuing involvement of this group of regular contributors.

Keywords
online citizen science, motivation, computer games, Foldit

Introduction

With the expansion of the Internet and a greater availability of digital tools, there has been a rapid growth in citizen science projects over the past decade (Gura, 2013; Hand, 2010). Improvements in information and communication technologies have made it easier for scientists to manage projects, recruit and communicate with volunteers, collate data, and disseminate research findings more widely (Newman et al., 2011). A growing number of citizen science projects are now conducted entirely through the Internet and participants help to analyse large sets of data that have been provided by the project scientists. These projects have been referred to as online, or virtual, citizen science (Holliman & Curtis, 2014; Reed, Rodriguez, & Rickhoff, 2012).

Online citizen science consists of tasks that have granularity, that is, the work consists of much smaller units that can be easily distributed among the participants (Nov et al. 2011). Individual tasks, may not take very long to complete, which means that participants can make a contribution whenever they have a small amount of free time or are in between other activities. This ability to make small contributions has been referred to as 'microvolunteerism' and it allows individuals the

flexibility to vary the amount they contribute during any one visit, and to tailor their contribution according to other commitments (Paulos et al. 2011).

Most online citizen science projects have forums where participants can interact with each other and with those managing the project. Indeed, some have thriving online communities, where participants can acquire in-depth scientific and technical knowledge (Jennett, Kloetzer, Gold, & Cox, 2013). Over the past decade, online citizen science has attracted many thousands of participants (Krebs, 2010; Simpson, 2014; World Community Grid, 2013). Some projects have produced important results or discoveries that would not have otherwise been possible (Cardamone et al., 2009; Khatib, DiMaio, et al., 2011; Lintott et al., 2009).

Online citizen science takes a variety of formats and the task required of the participant may vary in its level of complexity. The earliest examples of online citizen science are distributed computing projects (*e.g.* SETI@home*,* Folding@home), in which the participant runs project software that automatically analyses 'work units' provided by the project team. These projects utilise the power of volunteer's PCs and games units to analyse large datasets, or to run simulations that would otherwise require the power of a supercomputer (Beberg et al., 2009). Some believe that distributed computing does not constitute citizen science as involvement is passive, however, these projects can offer the opportunity for informal science learning and online interaction with other participants.

Other online citizen science projects however, require greater cognitive involvement and participants may be asked to classify or annotate images or graphical data. For example, in Galaxy Zoo (www.galaxyzoo.org), participants are asked to classify images of galaxies according to their shape. Many hundreds of thousands of classifications have been made since this project's inception in 2007 (Cardamone et al., 2007). Projects like Galaxy Zoo have been referred to as 'volunteer thinking' or 'distributed thinking' projects (Grey, 2009; Haklay, 2011). As an extension of a distributed thinking approach, a small number of scientific research problems have been repackaged into online multi-player computer games (*e.g.* Foldit, Phylo, Eyewire and EteRNA) that use dynamic and stylised graphical interfaces, and have some features in common with mainstream computer games such as awarding points for tasks, competition between participants and performance ranking (Bowser et al., 2013; Curtis, 2014; Kawrykow et al., 2012). These games can be difficult to learn and play, and multiple game tools have to be mastered (Andersen et al., 2012). The participant usually has to complete a number of tutorial levels before they can take part in the actual game.

Motivation to participate in online citizen science projects

Participation in online citizen science has only begun to be explored in detail. Of particular interest is the motivation to participate. Some citizen scientists are volunteering their time for several hours every day, and in some cases, over many months or years. Understanding how to attract and retain participants is key to the long-term success of a project and to the realisation of its research goals (Reed et al., 2013; Rotman et al., 2012). Understanding motivation to participate also informs the design of new online citizen science projects, and helps researchers consider both the short-term and long-term goals of their project.

A small number of studies and surveys have explored motivation to participate in distributed computing projects such as SETI@home, the World Community Grid and MalariaControl.net (Holohan & Garg, 2005; Krebs, 2010; Nov, Arazy, & Anderson, 2010; SETI@home, 2006; World Community Grid, 2013). These studies have generally found that participants are motivated to take part because they want to contribute to research, and place a high level of importance on the research goals of a particular project (Holohan & Garg, 2005; Krebs, 2010; World Community Grid, 2013). Some participants in distributed computing projects have an interest in computer hardware and are motivated by their desire to develop technical skills that enable them to push their computers to the limits (Bohannon, 2005). In most distributed computing projects, points are awarded for the number of 'work units' completed, and some participants are also motivated by the competitive aspects of these projects (Holohan & Garg, 2005).

There have been a small number of studies that have explored motivation to participate in distributed thinking projects. Two studies have been carried out on Galaxy Zoo participants by Raddick et al. (2010, 2013). The first study explored the motivations of 22 participants through individual interviews, and the second study surveyed over 10 000 Galaxy Zoo participants using a quantitative questionnaire. Making a contribution to research as well as a background interest in the science were the two most important motivators for involvement (Raddick et al., 2010; 2013). A study of participants in Stardust@home, a project in which participants try to find traces of inter-stellar stardust, found that volunteers are motivated by the perceived importance of the research, and their personal enjoyment in taking part (Nov, Arazy, & Anderson, 2011a). Also, the more the participant enjoyed taking part, the more they contributed to the project. In a second study on Stardust@home the motivations of participants was compared with those of SETI@home participants relative to the effect of task granularity (Nov, Arazy, & Anderson, 2011b). Low granularity tasks were more 'passive' and involved less participant input (such as running a distributed computing programme like SETI@home), whereas higher task granularity was

defined as more 'active' including tasks such as image classification. Results of this study suggest that task granularity is positively correlated with motivation levels (Nov, Arazy, & Anderson, 2011b).

So far, there have not been many studies looking at motivation to participate in citizen science games. Iacovides *et al*. (2013) undertook a small study exploring whether four Foldit participants and four Eyewire participants were attracted to these projects because they were packaged as games. Their results suggest that the game format was not the most important motivating factor, and that participants were most attracted to the projects because they were interested in the science. Given the small number of previous studies, further work examining the motivations of those who take part in citizen science games is of interest and may illuminate what approaches, features and designs work well in attracting and retaining participants. Whether there are differences in motivation between citizen science games and other types of distributed thinking projects is also of interest, and has yet to be investigated. In undertaking this study, the wider literature on motivation has been considered and used to inform the research design and by providing a framework for the analysis of the results.

Models of motivation and their relevance to online citizen science

There is a large body of work on motivation and a number of models have been developed by those exploring motivations to volunteer, to learn, and involvement in social movements. Some of these models have been considered by other researchers investigating citizen science (Krebs, 2010; Nov et al., 2011b; Rotman et al., 2012).

Work by Clary *et al*. (1998) suggests that people are motivated to volunteer because it allows them to express values that are important to them. In the case of online citizen science, those values may be associated with the importance placed upon science, and scientific research by the participants. This has been reflected in previous research that has identified an interest in science as an important motivator for participation (Raddick et al., 2010, 2013). Other work on volunteering suggests that altruism is an important motivating factor (Batson, Ahmad, & Tsang, 2002; Sproull, 2011). This too may be relevant for online citizen science as participants are giving freely of their time in order to advance science. Research that may not otherwise have been carried out is made possible by the goodwill of citizen scientist volunteers.

In addition to studies on general volunteering, work has been carried out on motivation within an educational context, for example, the work of Ryan and Deci (2000, 2009) on intrinsic and extrinsic motivations for learning. Intrinsic motivation involves carrying out an action because it is inherently interesting or enjoyable. When intrinsically motivated, an individual is moved to act for the fun or

challenge of an activity, rather than because of external 'prods', pressures or rewards. Some of the previous studies examining online citizen science have shown that participants tend to choose projects that are in an area of science that is inherently interesting to them (Nov et al., 2011a; Raddick et al., 2010). Extrinsic motivation is engaged when doing something leads to a separable outcome such as a reward, or a desirable reaction from a significant other to whom they feel a connection (*e.g.* family, peer group, wider society). For example, the points system within some distributed computing projects has been identified as an important motivation for participation (Holohan and Garg, 2005).

The work of Klandermans (2003) on the motivation to join social movements also highlights an area that may be of relevance to online citizen science – one of '*collective identification*'. This type of motivation occurs when individuals identify with a social group and its practices (Klandermans, 2003). The importance of the online community has been highlighted by participants in both distributed computing projects and distributed thinking projects (Holohan and Garg, 2005; Raddick et al, 2010, World Community Grid, 2013). Individuals who take part in Galaxy Zoo projects occasionally refer to themselves as 'Zooites', while participants in Stardust@home refer to themselves as 'Dusters' (Nov et al., 2011b; Westphal et al., 2014) suggesting that some online citizen science projects can foster the development of a community identity (Clery, 2011).

While the motivations behind general volunteering, learning and involvement in social movements may provide some insight as to why people take part in online citizen science, it is important to note that these projects occur within a context which may be quite different (Reed et al., 2012). Online citizen science could be viewed as more opportunistic (*e.g.* there is flexibility with regard to time and place of participation unlike working for a charity), and projects may require less time or commitment than involvement in a social movement.

A small number of researchers have likened some online citizen science projects (particularly distributed computing projects) to other types of online collaborations such as the production of open-source software, or the production of open content such as Wikipedia (Benkler and Nissenbaum 2006). Studies examining the motivation of Wikipedia writers have shown that they tend to be motivated by altruistic reasons, which are often based upon the belief that information and knowledge should be freely available to anyone (Kuznetsov, 2006; Nov, 2007). Open-source software contributors on the other hand, are often motivated by more self-centred concerns such as establishing a reputation as a competent coder and the securing of employment opportunities (Hars and Shaosong, 2002; Lakhani and Wolf, 2005). However, altruism and an ideology centred on the free provision and access to software solutions are also strong motivations for some (Lakhani and Wolf, 2005, Oreg and Nov, 2008).

The relevance of the motivational models outlined above has been considered within the context of a citizen science game, Foldit. In addition to contributing to the small body of work examining participation in online citizen science, this study explores whether motivation to participate in a citizen science game differs significantly from motivation to participate in other types of distributed thinking projects, and if there are any similarities with other types of voluntary behaviour. The wider implications of this work for the design of distributed thinking projects, and more generally, public engagement with the sciences will be considered.

Brief background to Foldit

Foldit was selected for the focus of this study as it was one of the first online citizen science games to be developed and has an established online community of participants. There have been a number of publications acknowledging the efforts of Foldit players either collectively, or including specific teams of players as co-authors (Eiben et al., 2012; Khatib, Cooper, et al., 2011; Khatib, DiMaio, et al., 2011). Perhaps the most significant publication is based upon the efforts of Foldit participants to deduce the structure of a protein molecule involved in the simian AIDS virus. While biochemists had attempted to elucidate the structure of this molecule for a number of years using more conventional approaches, two teams of Foldit participants were able to construct an accurate model using the games interface in three weeks (Khatib, DiMaio et al. 2011).

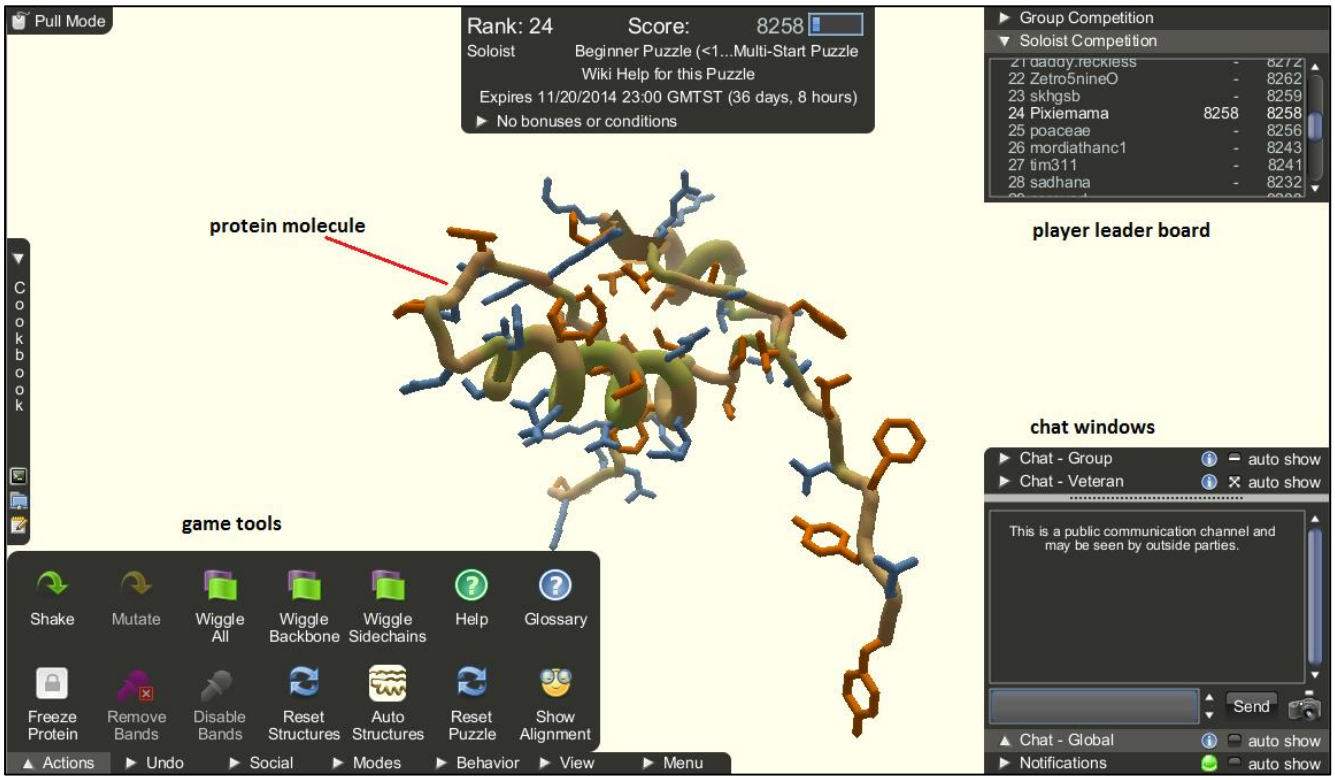
Foldit (www.fold.it) was developed at the University of Washington in Seattle by a group of biochemists and computer games developers and was released in May 2008. The rationale for its development was to harness the collective problem-solving abilities of non-experts to accelerate progress in understanding the three-dimensional structures of protein (Cooper, 2011). Foldit participants enlist problem solving skills and online tools based on computer algorithms to produce accurate models of protein structures that have previously been unknown (Khatib, DiMaio, et al., 2011). Participants can play individually or within a team, and as in other computer games, compete against one another for points. Protein structures that come closest to their 'natural' configuration (that is one that requires the least amount of energy) are awarded a greater number of points.

Despite the competitive aspect of the game, participants also work together co-operatively and collaboratively to solve the puzzles. Participants can communicate with each other via a number of different channels. They can 'talk' in real-time during the game through an internet relay 'chat' window, or they communicate asynchronously by posting messages on the project forum, or by sending private messages to each other. The project scientists and developers communicate with the playing

community via the project blog, through news updates on the homepage, and through real-time 'chats' that cover a number of issues including updates to the game, new puzzles, or new lines of research.

Foldit is a complex game and can be difficult to learn compared to other multiple–player online games (Andersen et al., 2012). Before a player can compete and work on the 'live' puzzles where the structure is unknown, it is recommended that they complete a series of tutorial or 'intro' puzzles (32 in total) that guide them through the various game tools available. These are based on proteins where the structure is already known. Once confident with the structure and function of the game, a new player is then able to play the live puzzles (Figure 1).

Figure 1*: Foldit Science puzzle. Game tools are displayed in the bottom left-hand corner. The current score and rank of the player is in the top-centre panel. The leader board for players working on this puzzle is in the top right corner. Chat windows are in the bottom right corner*



While there are many thousands of registered Foldit participants, observations of the leader boards, player profile pages, forum contributions, and in-game player statistics, suggest that there is a relatively small population of active participants. It is estimated that the active Foldit playing community is in the region of 200-300 individuals. From this playing community a small group of approximately 20-30 'core' participants have emerged. These are the participants who have been playing for a number of years and frequently participate in online discussions, write content for a game wiki, moderate the online chat,

and help to mentor and develop new participants. This pattern of contribution, in which small numbers of volunteers carry out most of the tasks, has been observed in other online communities (Preece and Schneiderman, 2009) and in other online citizen science projects such as Galaxy Zoo and Planet Hunters (Ponciano, Simpson and Smith, 2014, Luczak-Rösch et al., 2014).

Research methods

This study has taken a mixed methods approach using participant-observation, an online survey, and semi-structured interviews to explore motivation to participate in Foldit. Initial participation (in April 2012) informed the development of the online survey, while the results of the survey, as well as ongoing experiences of playing, informed the interview questions.

Being a participant observer is a direct way of obtaining data by observing what people actually do (Gillham, 2000). It can be used as an exploratory technique, as a supplementary or additional source of information (as in this research), or it can form the basis of a research project resulting in the production of a detailed ethnography (Hammersley and Atkinson, 2007). Participant observation has a number of advantages, namely, that it gives the researcher access to the 'background culture' and can enable a detailed description of behaviours, situations, intentions and events that they may not have access to otherwise (Kawulich, 2005). However, the researcher may be reliant on a small number of informants, and the experiences and views of these individuals may not be typical of the community in question (Kawulich, 2005).

As Foldit is a difficult game to master, much interaction with other participants involved learning how to play and applying the tools introduced in the tutorial puzzle to the science puzzles. After a few weeks of playing, I was invited to join one of the Foldit teams, and much of my subsequent interaction was with fellow team members. My team mates were aware of my research interests and these were communicated more widely to other Foldit participants through the Foldit forum when the online survey was launched. I kept detailed notes of my playing experience, observations of the interactions between other participants, and between participants and the project scientists and developers.

The online survey contained 28 questions which were a mixture of closed questions relating to the demographic characteristics and playing habits of the respondents, and open-ended questions that sought feedback relating to general views about Foldit. In addition to participant-observation, the survey questions were informed by previous research in this area. An effort was made to gather detailed information (not always collected in previous studies) relating to motivation, patterns of participation and demographic data. This survey had a greater reliance on qualitative questions than in

some previous work on online citizen science in order to provide respondents freedom to express their views (Carifo & Perla, 2007; Jamieson, 2004).

An online survey package used to conduct student feedback surveys at the Open University was used for this research. The questionnaire was piloted before its launch on the Foldit website, and the content was approved by the scientists and developers involved in managing the project. A link to the online survey was placed on the Foldit player forum, with some background information about the research, and a link was also placed in the start-up menu of the game which meant that every player would have seen it as they loaded the game. The survey was launched in June 2012 and was kept open for approximately 2 months. In total there were 37 responses.

Respondents were asked to provide their email address if they were willing to answer further questions about their involvement in Foldit. Of the twenty respondents who provided this information, ten agreed to take part in a semi-structured interview. Previous work in ecology-based citizen science projects has highlighted the dynamic nature of motivation, and illustrates that motivations may change over time (Rotman et al., 2012). So in addition to focussing on their reasons for playing Foldit, I asked interviewees why they continued to play Foldit over many months (or years). Participants were also asked questions about how they interacted with other participants including the scientists and developers who managed the project, and if they felt they had developed any skills as a result of their participation.

The Foldit participants who agreed to be interviewed were based in North America, Europe, and in Asia. Given the constraints imposed by time differences, participants were offered the choice of being interviewed by email (asynchronously) or via Skype. The use of Skype in conducting interviews is becoming increasingly common, and offers some advantages over phone interviews as it enables some visual cues to be picked up (if a video link is used), and it is free to use (Bertrand and Bourdeau, 2010; Hanna, 2012). However, only one participant wanted to use Skype, while the others opted to be interviewed via email.

While asynchronous email interviews do not have the immediacy of a Skype interview, they may offer some advantages. Researchers exploring online communities have argued that giving interviewees this flexibility may mean that they take more time to consider their responses, as there is no pressure to complete the interview in a specific time frame, and the fact that the interviewer isn't present means that they have less of an effect on the responses given by the participant (Debenham, 2007; O'Connor, Madge, Shaw, & Wellens, 2008).

Data analysis

Responses to closed survey questions were collated automatically by the survey tool, while the qualitative feedback from the open-ended survey questions was subjected to a content analysis. This analytical approach involves a close examination of textual data which is explored inductively for emerging themes relating to the same central meaning (Graneheim & Lundman, 2004). These themes were grouped into content or coding units, counted and illustrated graphically. It was hoped that some statistical analysis would be possible and relationships between motivating factors and other quantifiable parameters could be explored using a Chi-squared test. However, given the small sample size (n=37) numbers within sub-groups were too small to generate results of any statistical validity (Richardson, 1994).

Interview responses were collated and subjected to a thematic analysis. This is a widely used method for identifying, analysing, and reporting patterns (or themes) within data inductively (Guest, MacQueen, & Namey, 2012). In this study, the approach of Braun and Clarke (2006) has been closely followed. My experience as a participant observer was recorded in the form of field notes and internet screen shots. This material was reviewed and examined for emerging themes.

Integrating multiple strands of data is one of the challenges of using a mixed-method approach (Thomas, 2011). However, a mixed methods approach also introduces potential for methodological triangulation, and the inferences and results from each method employed in this study were used to confirm and corroborate (or confound) each other, thus providing a strategy for 'cross-checking' (Symonds and Gorard, 2010). Triangulation can help to reduce the particular limitations that are associated with any one method, and can make a dataset more robust (Jensen and Holliman, 2009). Once emerging themes had been identified, they were explored through the lens of relevant motivational frameworks, with the aim of exploring their significance within the context of a citizen science game.

Sampling and representativeness

One of the main problems with online surveys is that the response rate can sometimes be poor (O'Brien & Toms, 2010). Indeed the number of responses to this survey was only 37. However, given that the active playing population is 200-300, the response rate to this survey is somewhere in the region of 12-18.5%. While this response rate may be better than that obtained in other studies exploring online citizen science projects, it must be emphasised that the survey respondents may not be representative of the total population of active participants. Those who participated in the survey are a self-selected

sample, and some individuals are more likely to respond to a questionnaire than others (Sterba & Foster, 2008; Tourangeau, Rips, & Rasinski, 2000). This survey could be also described as an example of 'convenience sampling', as it is composed of individuals who were available and chose to make themselves accessible to the researcher (Castillo, 2009). The number of those agreeing to take part in the interviews was also small (n=10) and this sample may be skewed towards those who have stronger opinions about the game and wanted to provide more detailed feedback.

Results

Participant observation

Shortly after joining Foldit, I was invited to join a team ('Go Science'), and I received help from two of my team mates with the introductory puzzles, and with the general parameters of the game. It took several weeks (playing most days) to complete 30 of the 'intro' puzzles and move on to the 'science' puzzles. According to one of the Foldit developers, the number of individuals completing each tutorial puzzle significantly decreases with each successive puzzle therefore acting as a filter to keep the playing population relatively small (Cooper, 2014). Even if an individual has an interest in the science and wanted to make a contribution to the project, there is a relatively high threshold to participation, hence the small number of active participants in comparison to the overall number of 'registered' participants.

As a new participant, the importance of the Foldit community soon became apparent. Observations of the content of the interactions of more experienced participants on the 'global' chat window (where all participants can interact), as well as on the team chat windows (where only members of the same team interact) showed that the player community often work together to share strategies and solutions to the puzzles. Some participants were highly visible and appeared to have forged friendships with others. My own interaction with fellow team members was enjoyable and became an important motivation for continuing to play the game. Wanting to contribute to the success of Foldit also become important over the course of my involvement, and motivated the continuing development of my skills.

Observations of the global chat also highlighted the importance participants place on the potential research outcomes of Foldit (namely the increased understanding of certain diseases and the eventual development of treatments) and many participants mentioned loved ones who were affected by diseases caused by protein mis-folding. Participants were regularly observed using technical language relating to protein biochemistry (Table 1), demonstrating that informal learning was an important component of their playing experience.

Table 1: Example of a technical discussion among Foldit participants in the general forum (July 2014)

Participant 1	I think we need more background information about the protein such as the species it comes from, its function, the kind of protein which can interact with it, and other experimental data. In the Arabidopsis puzzle we have gotten useful information. If we get more information about the protein, we can search similar proteins, look for motifs in the structure etc. It's REALLY helpful to build a structure close to the native one.
Participant 2	I think it might be useful too. Knowing the function of the protein can shed light on the problem, plus it can be an interesting thing to know.
Foldit scientist	This is great feedback and I have passed it on to our scientists and developers.

The online survey

While one of the main aims of the online survey was to explore motivation to play Foldit, it provided an opportunity to explore some of the demographic characteristics of participants, providing some insight on who the game appeals to. The survey also provided an opportunity to question participants about their general level of commitment (*e.g.* how many hours a week they play, how long they have been playing Foldit).

The majority of respondents were male (78%), from developed countries, and most (68%) were aged over 40. The over-representation of men has been observed in other online citizen projects, particularly distributed computing projects (Estrada, Pusecker, Torres, Cohoon, & Taufer, 2013; Holohan & Garg, 2005; Krebs, 2010; Raddick et al., 2010; World Community Grid, 2013). This group of respondents was very well educated; seventeen (46%) had an undergraduate degree as their highest educational qualification, and an additional nine participants (24%) had a postgraduate degree as their highest qualification. Most (93%) of those with a university education were qualified in a STEM subject (science, technology, engineering, mathematics). Despite this, only two respondents were professional scientists, although there appeared to be a high proportion in IT-related professions and engineering (38%).

Approximately half of respondents had tried other citizen science projects. All respondents reported taking part in other types of science-based activities such as watching science television programmes, reading science magazines, attending science centres/museums, reading online science content or

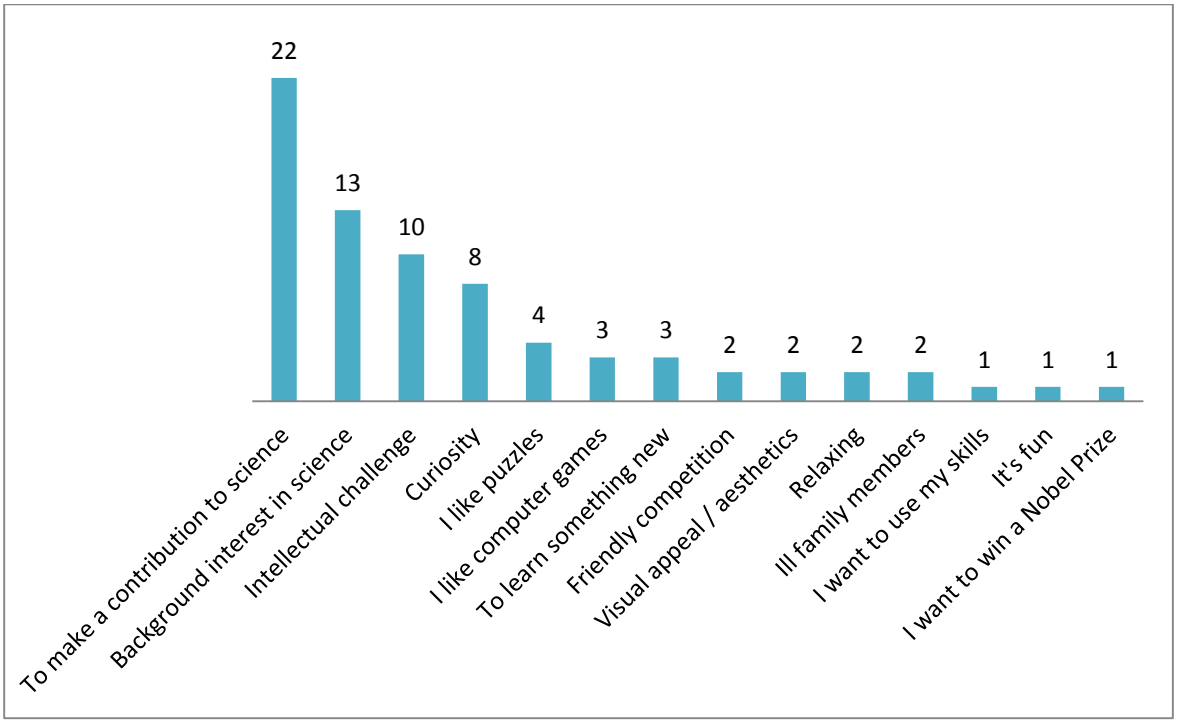
reading popular science books during the previous year. Just over half of respondents (59%) stated that Foldit was the only computer game they played.

Respondents appeared to be highly committed to Foldit. Nearly three quarters of respondents had been playing for six months or more. Seven respondents had been playing Foldit for more than three years. Overall, this group spent a considerable amount of time playing, with nearly half (49%) playing for more than 15 hours a week.

Survey responses relating to motivation to participate

Respondents were asked in an open-ended question why they play Foldit. The responses to this question are illustrated in Figure 2. Practically all of the respondents give more than one reason for trying the game but it is clear that several key motivations predominate.

Figure 2: *Reasons why respondents participate in Foldit (the number of respondents providing each response is at the top of each bar)*



Over 60% of respondents stated that they participate in Foldit is the opportunity to make a contribution to science. Over a third of respondents were motivated by a background interest in science, which may be related to the fact that many have a formal STEM qualification, and take part in a number of science related activities in addition to Foldit.

The intellectual challenge of playing attracted 10 respondents, while eight tried Foldit after their curiosity was aroused by media coverage. Only a small number of participants (three) were attracted to Foldit as an opportunity to learn something new, while a similarly small number were drawn to Foldit because it was a game.

Respondents were asked in an open-ended question what they liked best about Foldit. This question was used to further identify factors that motivated their participation. Over a third of respondents highlighted the interaction with others and the sense of community. Learning something new and developing new skills was important for approximately a quarter of the respondents. These new skills related to mastering aspects of the game, as well as learning more about the related science of protein biochemistry. Only three respondents mentioned specifically that they thought Foldit was fun to play, although the enjoyment of playing can be inferred from other comments – particularly those that refer to the community aspect of the Foldit.

Respondents were asked if they thought participants should be rewarded for playing, and if so, what would be the most appropriate way. Of the 35 respondents who provided an answer to this question, 23 stated that they did not think that Foldit participants should be offered an extra incentive. The view that rewards could harm the cooperation within the Foldit community was expressed by several respondents.

Interview feedback

Of the ten individuals who agreed to be interviewed seven stated that being part of a diverse community with a shared goal was one of the most enjoyable aspects of their participation and contributed towards their continuing participation in Foldit: *"Being in a group, team play and contributing to the benefit of the group is important to me."* (Player 1)

Some interviewees talked about the pride they have in the Foldit community and in its achievements, about the friendships they had formed and about the respect they had for their fellow team mates (one respondent referred to his team as his "*folding family*"). Three interviewees enjoyed the intellectual challenge of the game, and the opportunity to develop their skills.

Half of the interviewees expressed a desire to help the project scientists, and a few had been personally affected, or knew someone who had been affected by a disease caused by protein mis-folding (such as Alzheimer's disease). These individuals felt that Foldit may be able to shed more light on such diseases in the future, and they wanted to be actively involved in helping to find a cure.

Another important motivation highlighted by half of the interviewees was the opportunity to take part in authentic scientific research and to contribute to a project with tangible outcomes. The fact that this could be achieved without a scientific qualification was very important to one player: *"..the real point is that Foldit simply allows us folks without the proper CVs, and would crawl over broken glass to participate given half the chance, an opportunity to do this stuff. It's that simple."* (Player 4)

Interview feedback has highlighted another important issue: how participants view their contribution to Foldit. A participant's perception of their impact and importance to a project may affect their motivation to continue participating. Among the participants interviewed, there are differing views on this. Most (seven) of the interviewees felt that they were making an important contribution, and actively participating in scientific research. However, one interviewee described the role of Foldit participants as similar to that of other 'support staff': *"We help scientists to solve a problem like many other technicians useful in scientific research: the one who makes the instruments or takes care of animals in a lab for example or the communication team…all these people are useful parts of the scientific work but are not scientists."* (Player 5)
The other respondents were less sure about their contribution to science: *"For me it doesn't feel like I'm doing science. It is a game and that's also the idea the team want to promote."* (Player 7) Regardless of the degree to which interviewees felt they were contributing, some use language that is associated with scientific methodology and speak of developing and testing their "*theories and assumptions*"; "*theorycrafting*" with other participants; and suggesting directions that the project may take. The games interface was also a powerful draw for three participants who liked the combination of scientific research and a computer game. However, only one interviewee stated that the system of points and ranking was a motivation for participating.

Another theme that emerged during the interviews relates to who Foldit may ultimately appeal to, and conveys the concept of an essential skill set that is required to be a good Foldit player. One respondent referred to this as the "*right stuff*". This wider skill set can be described as comprising of intellectual attributes such problem-solving skills, intellectual curiosity, and pattern recognition skills. It may also comprise of science-related skills including a background interest in the related science, or a formal qualification in a STEM subject. However, the attributes most commonly referred to by interviewees were personal or character attributes such as perseverance, obsessiveness, patience, 'people skills', determination, and dedication. Several of the interviewed participants stated that it is a combination of these qualities that makes a successful Foldit player: *"By far the two attributes that help Foldit participants are an obsessive personality and scientific inquisitiveness. With these, a player will eventually figure out strategies that help him to do well."* (Player 1) Respondents also alluded to a '*state*

of mind' or an '*attitude*' that was required by successful Foldit participants. Several of the interviewees are within the Foldit 'core' community, and play for several hours every day, as well as managing Foldit teams or moderating player discussions. Such a skill set may therefore be more relevant to those who are within this group of highly committed participants.

Discussion of findings

The results from both the survey and interviews have shown that the desire to make a contribution to scientific research and a background interest in science are important motivators for this group of Foldit players. These motivations are also important for participants in other online citizen science projects (Holohan & Garg, 2005; Krebs, 2010; Nov et al., 2011a; Raddick et al., 2010; Raddick et al., 2013; World Community Grid, 2013). This work also suggests that the opportunity to work and collaborate with others is highly valued and has kept some participants involved in Foldit over many months and years. My own experience of Foldit suggests that interaction with others is crucial when learning how to play, and is an important motivator for sustaining participation.

In an attempt to integrate various motivational models with the findings of this research, a new framework has been developed (Table 2). While no single motivational model could be applied to all of the observed motivations, the work of Ryan and Deci (2000, 2009) on extrinsic and extrinsic motivations was perhaps the most relevant to my findings, and was used to underpin this new framework. According to Ryan and Deci (2000), intrinsic motivation exists when an activity is enjoyable, or when it promotes feelings of fulfilment and competence. There is no need for an external reward because the activity is inherently interesting. Foldit participants derive enjoyment from working with others, and taking part in a task which is related to underlying scientific interests.

Extrinsic motivation is in operation whenever an activity is done in order to attain some separable outcome. However, extrinsic motivation is not merely a question of punishment or reward and it exhibits a range of expression that is related to the degree of autonomy experienced by an individual. This is also known as 'self-determination theory', which maintains that although an activity may not be appealing (or easy), it is personally endorsed in some way and the individual has a feeling of choice (Ryan & Deci 2009). This is in contrast to compliance, when an individual carries out an activity because of an external control (*e.g*. avoiding punishment). Motivations based on compliance are not relevant when it comes to participation in online citizen science, however, extrinsic motivation based on ego involvement (*e.g*. a desire for points or a high rank in the game) or the desire for approval from others (*e.g*. being named a co-author on a scientific paper), and identification, where an individual has identified the value of the activity, do appear to be important.

While the approach of Ryan and Deci (2002, 2009) was relevant for some of the motivations articulated by study participants, not all were explained by this framework. For example, one of the most commonly cited reasons for participation, the desire to help and to make a contribution to scientific or medical research, is based on an altruistic motivation or empathy that has more in common with other types of more general 'community-based' voluntary behaviour as detailed by Clary *et al.* (1998) and Batson *et al.* (2002). In addition to altruism, another important internal motivation is the desire to be a part of a community; to cooperate and collaborate as part of distributed social group. This motive has been identified in those who write open source software (Hars & Ou, 2002), and those who join social movements (Klandermans, 2003).

Previous work on open-source software has also highlighted an important external motivator that relates to 'expected future returns' (Hars and Shaosong, 2002). There appears to be a parallel to this motivation among some Foldit participants, particularly those who have a more personal stake in the outcome of the research. For example, some survey respondents stated that their involvement in the project was the direct result of a loved one being affected by one of the diseases being researched by the Foldit scientists. While there is no guarantee that any of these participants will see these things in the near future, this remains an important motivator for some. Such a motivation could also be considered 'enlightened self-interest' (Hars and Shaosong, 2002).

Table 2 Motivational framework based on feedback to Foldit online survey and semi-structured interviews

Level 4	**Level 3**	**Level 2**	**Level 1 task granularity**
Internal Factors	Intrinsic motivations	Enjoyment	Relaxing Visual appeal Fun
		Fulfilment	Background interest in science Participation in authentic research Allows creativity Learning opportunity
		Competence	Intellectual challenge Using skills Formal qualifications not required
	Altruism	Making a contribution	Contributing to scientific research Helping scientists
	Community	Interaction with others	Work with others toward common goal Make friends
External factors	Extrinsic motivations	'Ego enhancement' (introjection)	Points Rank Positive feedback from scientists (*e.g.* recognition on papers)
		Identification	Goals of the project are important
	'Expected future returns'	Medical / scientific breakthroughs	New drug therapies Cures for self and loved ones

At the highest level (Level 4), motivations can be classified as either internal factors, which are rooted within the individual, or they can be classified as factors that are external to an individual (Hars & Ou, 2002). At Level 3, internal factors can be subdivided into intrinsic motivations, altruism and community, while external factors can be divided into extrinsic factors and expected future returns. These can be further sub-divided (Level 2) into a number of elements that have been identified by Ryan and Deci (2000, 2009) as the components of intrinsic and extrinsic motivation. Level 2 includes a further breakdown of altruism, community involvement and expected future returns, reflecting feedback from respondents. Level one represents the lowest 'granularity' of motivation, where motivations cannot be categorised or broken down further. Study participants articulated motivations that were in Level One or Level Two.

Results from previous studies, particularly work on Galaxy Zoo (Raddick et al., 2010, 2013) and some distributed computing projects (Holohan and Garg, 2005, Krebs, 2010, World Community Grid, 2013) suggest that this model is able to describe the motivations reported by these study participants. This model may therefore be of relevance to those considering setting up an online citizen science project, and could help to inform the design of a project. For example, it could help project designers decide how to reward participants, the nature of the project task, and whether they want to add features that enable collaboration. This framework may also be of use when considering motivations to participate in other types of citizen science project, and understanding the wider context of those motivations.

Conclusions

In addition to investigating motivation to participate in more detail, the results of this study have implications for the design of future distributed thinking projects. The features of Foldit that stimulate interaction between participants such as the online forum, internet relay chat, and the regular chats with the scientists and developers, may be more motivating than the traditional games features such as the point system and the leader boards. This suggests that projects that make use of features that promote interaction and sociability may motivate more sustained participation from volunteers. Having a task where participants can collaborate may also motivate sustained participation. However, while the level of difficulty associated with Foldit stimulates co-operation and collaboration, it also presents a high barrier to participation and only those with the 'right stuff' are able to progress through the tutorial puzzles and develop the skills to make a contribution to the research. Project designers seeking high numbers of participants may need to strike a balance between offering participants an intellectually stimulating experience, and making their project accessible to as many participants as possible.

The fact that most of this group have either an undergraduate or postgraduate qualification in a STEM subject and participate in other science-related activities suggests that Foldit appeals to those who are more confident engagers with science, or 'fans of science' (Priest, 2009). A high prevalence of those in the computing profession among this group may also suggest that Foldit may be more appealing to those who are comfortable with computer technology. Whether this group is representative of the wider Foldit population, or indeed, whether this demographic pattern would be observed in participants of other citizen science projects, is unknown but warrants further investigation.

The number of online citizen science projects has increased significantly over the past 10 years (Gura, 2013). They have great potential to engage non-specialists with authentic scientific research, and feedback from these Foldit participants suggests that such an opportunity is highly valued. However, the level of difficulty of the project task, and technical parameters (*e.g*. those that promote online

interaction) should be considered by those setting up a project. Online communities of citizen scientists need to be supported and future projects need to ensure that volunteers are involved and acknowledged in ways that are meaningful to them.

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