Bring them aboard: rewarding participation in technology-mediated citizen science projects

Abstract

Citizen science involves the general public in research activities that are conducted in collaboration with professional scientists. In these projects, citizens voluntarily contribute to the research aims set forward by the scientists through the collection and analysis of large datasets, without a preliminary technical background required. While advancements in information technology have facilitated the involvement of the general public in citizen science through online platforms, several projects still fail due to limited participation. This paper investigates the feasibility of using selected reward mechanisms to positively influence participation and motivations to contribute in a technology-mediated citizen science project. More specifically, we report the results of an empirical study on the effects of monetary and public online acknowledgement rewards. Survey indices and electroencephalographic measurements are synergistically integrated to offer a comprehensive basis for the analysis of citizens' motivations. Our results suggest that both reward mechanisms, under proper conditions, could crowd-in participants in technology-mediated citizen science projects. With this study, we seek to lay the foundations for a private-collective research model, where the focus is the intensification of participation in technology-mediated citizen science projects.

Keywords

Citizen Science, participation, rewards, intrinsic motivations, extrinsic motivations, crowd.

1. Introduction

The inclusion of contributors external to organizations' boundaries were found to be crucial for the production and sharing of knowledge (Boudreau & Lakhani, 2015; Brabham, 2010; Dahlander, Frederiksen, & Rullani, 2008; Franzoni & Sauermann, 2014; Seidel & Langner, 2015). Advancements in information technology have allowed individuals to increasingly access and collaborate with scientists through the web, overcoming geographical, social, cultural, and physical barriers (Cappa, Laut, Nov, Giustiniano, & Porfiri, 2016; Laut, Cappa, Nov, & Porfiri, 2015). In this way, private and public entities can benefit from "*crowd wisdom*" (Surowiecki, 2006), that is, the knowledge dispersed among individuals outside the boundaries of the focal organization. These participants could be involved in a wide range of scientific aims, from data collection and analysis to problem solving, in exchange of a reward or just for the pleasure of completing the task (Franzoni & Sauermann, 2014). One form of crowd participation is citizen science, which combines joint efforts of professional scientists and citizens toward the collection and analysis of data for scientific aims (Crain, Cooper, & Dickinson, 2014; Dickinson et al., 2012; Haklay, 2013; Riesch, Potter, & Davies, 2013). As the word citizen suggests, participation is open to the general public, without any particular, preliminary knowledge required. Due to the growing size of scientific datasets that can be collected and analyzed for research purposes, citizen science is rapidly emerging as a promising approach to research by involving the general public (Arcanjo, Luz, Fazenda, & Ramos, 2015; Follett & Strezov, 2015; Land-Zandstra, Devilee, Snik, Buurmeijer, & van den Broek, 2015). The recent establishment of a Citizen Science Association in USA, funded by numerous institutional partners and a related annual conference ("Citizen Science Association," 2016), offer further evidence for the growing interest around this emerging field. This interest is echoed by policymakers, as evidenced by the 2015 Crowdsourcing and Citizen Science Act, which was introduced in the USA (Coons, 2015) with the aim of fostering the integration of citizen science in federal programs.

In citizen science projects, citizens voluntarily collaborate with professional scientists in scientific research. At the same time, they have the opportunity to learn and generate knowledge (Franzoni & Sauermann, 2014), to enhance their scientific literacy and to enjoy the experience (Bonney et al., 2009; Cronje, Rohlinger, Crall, & Newman, 2011). For professional scientists, the participation of a large number of contributors potentially helps expedite research projects (Haklay, 2013; Morais, Santos, & Raddick, 2015) and reduce their overall cost (Nov, Arazy, & Anderson, 2014). In addition to benefits for researchers and citizens, citizen science represents a potential means to raise social innovation by addressing problems of social interest through new aggregations of collaborating individuals (Cappa, Facci, & Ubertini, 2015; Mulgan, 2006; Murray, Caulier-Grice, & Mulgan, 2010). In fact, citizen science is extensively leveraged in environmental monitoring where intensive data collection and analysis is needed, and citizens help is, actually, crucial to sustain the environment (Dickinson et al., 2012). Successful recent examples include "*eBird*" (Sullivan et al., 2014), "*OPen Air Laboratories*" (Silvertown, 2009), and "*Forest-Watchers*" (Arcanjo et al., 2015), where citizens help researchers in monitoring birds, air pollution, and deforestation around the world.

As citizen science requires large amount of data collection and analysis, many projects compete for attracting volunteers (Laut, Cappa, Nov, & Porfiri, 2017; Wald, Longo, & Dobell, 2016), and several online communities have failed over time (Iriberri & Leroy, 2009; Langner & Seidel, 2014). Hence, citizen participation and motivations represent major concerns for citizen science projects organizers (Nov et al., 2014; Tinati, Luczak-Roesch, Simperl, & Hall, 2017). User participation is commonly measured by the quantity of contributions and participants' engagement level (Aristeidou, Scanlon, & Sharples, 2017; Franzoni & Sauermann, 2014; Malinen, 2015; O'Brien & Toms, 2008; Preece, Nonnecke, & Andrews, 2004; Wald et al., 2016), while motivation to contribute is assessed in terms of enjoyment in performing the task (Cappa et al., 2016). Due to the benefits brought about by the involvement of citizen scientists, i.e., common citizens participating in research projects led by professionals, scholars are paying increasing attention to the study of mechanisms to foster participation and contributor motivations, as well as to increase referral intention of people who joined the projects to attract more users (Nov et al., 2014). In particular, human-computer interaction studies emphasize the importance of design elements for increasing participation in citizen science projects (Aristeidou et al., 2017; Wald et al., 2016). With the aim of contributing to such an understanding, we empirically investigated the effects of rewards offered to citizen scientists on their participation, motivations and referral intention.

The relation between rewards and volunteer activities has been studied in the literature with respect to off-line activities, while the understanding of their impact on technology-mediated projects is considered to be in need of further deepening (Dal Bo, Finan, & Rossi, 2013; Fiorillo, 2011; Rommel, Buttmann, Liebig, Schönwetter, & Svart-Gröger, 2015). Recently, a few studies have analyzed the effect of rewards on contributor participation and motivations in technology-mediated crowd-based projects, such as open source communities and crowdsourcing (Brabham, 2008; Kaufmann, Schulze, & Veit, 2011; Krishnamurthy, Ou, & Tripathi, 2014; Paolacci, Chandler, & Ipeirotis, 2010; Straub, Gimpel, Teschner, & Weinhardt, 2015), while citizen science appears to be still largely unexplored in this context. In particular, the study of rewards in the emerging context of citizen science deserves particular attention, due to its uniqueness with respect to other technology-mediated activities in terms of actors involved (i.e., the common citizens without technical background required rather than experts), different outcomes (i.e., research projects for public good rather than commercial outcomes), and data disclosure (i.e., partial disclosure rather than open access).

In order to contribute to the understanding of the efficacy of rewards in citizen science, we used an already active citizen science project, Brooklyn Atlantis (www.brooklynatlantis.org), as the experimental setting to test the effects of rewards on contributors' participation (in terms of "*number of contributions*" and "*engagement level*"), motivations ("*enjoyment level*"), and *"referral intention"* (dependent variables in brackets). Enjoyment and engagement levels were synergistically measured with surveys and electroencephalography indices, in order to offer a better comprehension of participants' motivations. The outcomes of this study offer evidence of the effectiveness of two types of rewards, i.e., monetary and public online acknowledgement, upon volunteer citizens' participation, motivations, and referral intention. While previous studies concerning volunteering and crowd based activities questioned the use of money as a reward in crowd bases projects (Fiorillo, 2011; Hertel, Niedner, & Herrmann, 2003; Krishnamurthy et al., 2014), our results contributes to the understanding of how this type of reward might be effectively offered to crowd-in participants in citizen science.

2. Theoretical background

While information technology has enabled the involvement of a large number of individuals in crowd-based projects, the failure of many online communities shows that a deeper understanding of mechanisms to increase participation and motivations is still crucial (Dahlander & Piezunka, 2014; Iriberri & Leroy, 2009; Malinen, 2015; Tinati et al., 2017). Motivations for participating in technology-mediated crowd-based projects may be divided into two main categories: intrinsic and extrinsic (Antikainen, Mäkipää, & Ahonen, 2010; Deci & Ryan, 2000). The former category is connected to self-determination in participating due to satisfaction in performing a valuable scientific task and in increasing their understanding of scientific issues, while the latter is related to the intention to contribute based on some reward. Studies have highlighted the importance of both intrinsic and extrinsic motivations for the success of virtual communities, as some people may participate mainly due to their self-interest or to contribute to a social aim, while others are primarily interested in the reward they can obtain (Füller, Hutter, & Faullant, 2011; Lakhani & Wolf, 2005; Raddick et al., 2013;

Wasko & Faraj, 2005). In the context of extrinsic motivations, one mechanism that can be used to increase participation is the offer of rewards (Boudreau & Lakhani, 2015; Bullinger, Neyer, Rass, & Moeslein, 2010; Franzoni & Sauermann, 2014; Seidel & Langner, 2015). The theoretical basis for increased number of contributions due to a reward is "*fairness expectations*": if contributors believe that the benefit distribution system of the project is fair (whereby they receive an appropriate personal reward), they are more prone to participate (Franke, Keinz, & Klausberger, 2013). A large body of research has shown that individual benefits, such as rewards, are not necessarily conflicting with higher-level social objectives, as of those of environmental concerned citizen science projects, and they can be accomplished together (Bonaccorsi & Rossi, 2003; Krishnamurthy et al., 2014). Therefore, one way to increase contributors' participation and motivations is to leverage extrinsic motivations through the proper use of rewards. The base for such an expectation in summarized in Table 1, and better explained in what follows.

Table 1 – Summary of why and how the use of rewards can benefit citizen science projects

Impact of reward	Theory	Connections with citizen science	Contribution of the study
Positive	Fairness expectation	In virtual communities (such as citizen science) if individuals belief that the benefit distribution system is fair, they are more prone to participate	↓
			Under proper conditions monetary and public online acknowledgment rewards can benefit citizen science (based on a virtual community of volunteers)
Negative	Hidden cost of rewards	In volunteering activities (such as citizen science) monetary rewards can harm intrinsic motivations	↑

One of the possible form of reward is money, which has been proposed as a promising means for increasing the quantity of crowdsourcing contributions (Brabham, 2008; Kaufmann et al., 2011;

Paolacci et al., 2010; Straub et al., 2015), a type of crowd-based project where participants are asked to collaborate in the generation of new ideas. However the impact of monetary reward was questioned in the literature regarding volunteering activities (Lepper & Greene, 1978; Titmuss, 1998). The criticism is due to the negative effect that rewards have on intrinsic motivations (Hertel et al., 2003). In particular, money could undermine intrinsic motivation resulting in a crowd-out, i.e., a reduction in the number of participants (Fiorillo, 2011; Lepper & Greene, 1978; Ryan & Deci, 2000; Titmuss, 1998). In economic theories of rewards, a common assumption is that the more a person is compensated, the higher his/her efforts will be (Festré & Garrouste, 2014). Instead, in volunteer activities it has been argued that paying for contributions, such as blood donations, might diminish willingness to participate (Titmuss, 1998). To explain how a monetary reward might have a detrimental effect on intrinsic motivations, Lepper and Greene (1978) coined the term "*hidden cost of rewards*". In fact, monetary rewards may be perceived by volunteers as a mechanisms of influence, referred as "controlling perspective" of rewards (Grandey, Chi, & Diamond, 2013), which could negatively affect their self-esteem and self-determination, thereby leading a crowd-out rather than a crowd-in effect (Deci & Ryan, 2000; Miller, Deci, & Ryan, 1988). As technology-mediated participation is changing the way in which people are involved in research projects, and crowd-based projects are seeking for new mechanisms to increase participation (Franzoni & Sauermann, 2014; Nov et al., 2014), the use of monetary rewards is currently being reexamined (Alexy & Leitner, 2011; Benabou & Tirole, 2003; Hertel et al., 2003; Krishnamurthy et al., 2014; Moller & Deci, 2014; Ryan & Deci, 2000; Straub et al., 2015; von Krogh, Haefliger, Spaeth, & Wallin, 2012). Extant studies have claimed that the phenomenon of crowd-out due to monetary rewards has not been sufficiently validated, or at least does not occur in all circumstances (Cameron, Banko, & Pierce, 2001; Cameron & Pierce, 1994; Eisenberger & Cameron, 1996; Frey & Jengen, 2001; Krishnamurthy et al., 2014; Mellström & Johannesson, 2008; Ostrom, 2000).

Citizen science is different in nature with respect to other crowd-based projects, as the participants join voluntarily to help address a societal, generally environmentally concerned, objective rather than seeking a pay or job (Boudreau, Lacetera, & Lakhani, 2011). In addition, citizen science differs from other technology-mediated volunteer projects, such as open source software communities, in terms of: i) outcomes, whereby the results of citizen science are generally contributions to research projects addressing social and environmental problems rather contributions to new commercial products or services; ii) disclosure, as the results could be partial rather than fully accessible to the community of contributors; and iii) requirements, as the participants are not experts in the field. Due to the described uniqueness of citizen science and the scarcity of studies investigating rewards in this context, a comprehensive theoretical understanding and empirical testing are needed.

In this study, we seek to demonstrate the possibility of integrating rewards in citizen science projects to bolster participation and motivations. Rewards could be useful in leveraging extrinsic motivations, but they must be designed such that intrinsic motivation levels are not concurrently harmed. To this aim, first, monetary rewards should not be offered when a personal or working relationship exists between the reward-giver and reward-receiver (Frey & Jengen, 2001). Second, although the amount of a reward may be a driver of increased participation (Gneezy & Rustichini, 2000), money offered to citizen scientists should be little such that it could be perceived as supportive rather than controlling (Frey & Jengen, 2001; Paolacci et al., 2010; Walter & Back, 2009) and it could elicit positive response in volunteers (Eisenberger & Armeli, 1997; Eisenberger & Selbst, 1994; Krishnamurthy et al., 2014). Third, participants should be offered the opportunity to devote the monetary reward they earned to other socially-concerned activities (Mellström & Johannesson, 2008). In this case, external intervention will be perceived as supportive and able to crowd-in participants, as their self-esteem and self-determination might be enhanced (Krishnamurthy et al., 2014; von Krogh et al., 2012). According to

Self Determination Theory (SDT), intrinsic motivations are negatively affected when autonomy is diminished (Miller et al., 1988; Pedrotti & Nistor, 2016). Thus, the autonomy of participants' decisions could be restored by allowing them to choose to donate the small amount of money earned (Eisenberger, Rhoades, & Cameron, 1999). Moreover, as suggested by General Interest Theory (GIT), offering money, even in small amounts, could be perceived as a signal of the importance of the task, thereby enhancing intrinsic motivations to participate (Cameron et al., 2001; Eisenberger, Pierce, & Cameron, 1999). Based on this grounding, the first research question we seek to address is: Are monetary rewards a valid reward for increasing contributors' participation, motivations and referral intention in a citizen science project? This question is addressed by ensuring that: i) no relationship exists between participants and researchers; ii) participants may only earn a small amount of money; and iii) participants are given the option to give back what they earned, devoting it to the citizen science project. We test four specific hypotheses:

H1a: Monetary rewards increase the quantity of contributions;

H1b: Monetary rewards increase citizen scientists' engagement level;

H1c: Monetary rewards increase citizen scientists' enjoyment level;

H1d: Monetary rewards increase citizen scientists' referral intention.

To attain a wider spectrum of the possible methodologies for strengthening citizen scientists participation and motivations, we also considered non-monetary rewards, which were found to be welcomed in volunteering tasks (Costa-Font, Jofre-Bonet, & Yen, 2013). Rewards related to peer recognition have always been central in scientific activities (Merton, 1976; Stephan, 2012) and online crowd-based projects (Lakhani & Von Hippel, 2003; Restivo & van de Rijt, 2012), fostering participants' self and public esteem (Hars & Ou, 2002; Maslow, 1970). Therefore, we analyze the effect of public online acknowledgement on contributors' participation and motivations, as a form of non-monetary reward connected to reputation gaining and social acceptance (Franzoni & Sauermann, 2014; Silvertown et al., 2015). Public online acknowledgement does not provide citizen scientists with a tangible benefit, as monetary rewards might. Nonetheless, community recognition enhances the visibility of individual efforts for social aims (Roberts, Hann, & Slaughter, 2006). Thus, the second research question we seek to address is: Are public online acknowledgement rewards valid methods to increase contributors' participation, motivations, and referral intention in a citizen science project? We test four specific hypotheses:

H2a: Public online acknowledgement increases the quantity of contributions;

H2b: Public online acknowledgement increases citizen scientists' engagement level;

H2c: Public online acknowledgement increases citizen scientists' enjoyment levels;

H2d: Public online acknowledgement increases citizen scientists' referral intention.

If the hypotheses are supported, the theoretical model proposed in Figure 1 will be confirmed.

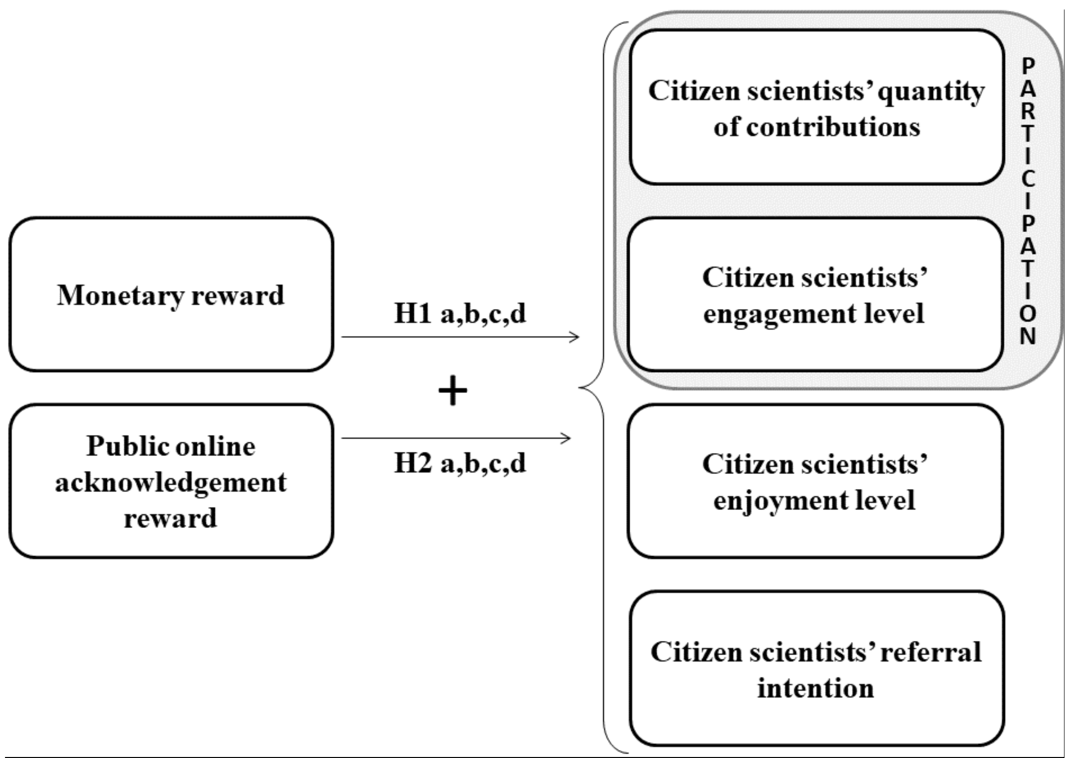

Figure 1 - Reward mechanisms effect on citizen scientists' participation (i.e., quantity of contributions and engagement level), enjoyment level, and referral intention.

3. Research methods

3.1. Empirical setting: Brooklyn Atlantis project

Brooklyn Atlantis, the empirical setting of this study, is a citizen science research initiative focused on the environmental monitoring of the Gowanus Canal in Brooklyn, New York, one of the most polluted bodies of water in USA. The aims of this citizen science project are to assess the water quality improvements over the years, to inform the community about the state of the canal, and to involve them in environmental monitoring activities. Pictures of the polluted canal are periodically collected by an aquatic robot (Figure 2a), which uploads them online on a web-based platform (Figure 2b), to be accessible for the contributors. The large amount of data collected requires citizens to help researchers in the data analysis by tagging images online through a web-based interface.

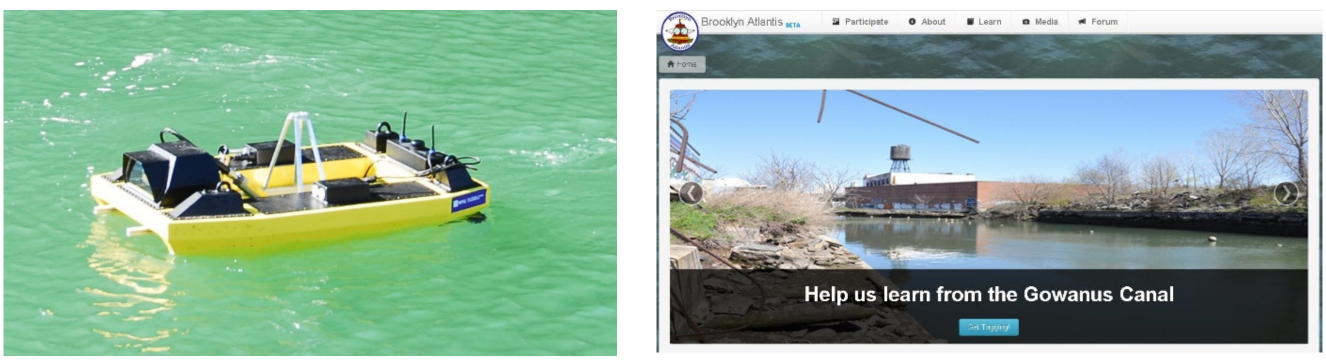

Figure 2 – (a) Aquatic robot to collect pictures and (b) web-based platform to analyze data of the Brooklyn Atlantis project.

3.2. Research design

Controlled experiments were performed in order to compare, under different conditions, citizen scientist participation (i.e., amount of contributions and the engagement level), enjoyment, and referral intention (Table 2). To measure the quantity of contributions, a counter on the web-based platform of a citizen science project was used. Referral intention data were collected through surveys. The indices to evaluate the engagement and enjoyment levels were collected through surveys, a method already used in literature to evaluate motivations (Bergendahl, Magnusson, & Björk, 2015; Gilson, Lim, D'Innocenzo, & Moye, 2012), and through an electroencephalography (EEG) device, which records brain activity and translate them into motivations measures (Duvinage et al., 2013; Palermo, Laut, Nov, Cappa, & Porfiri, 2017).

The experiments were conducted on different groups of participants, each one exposed to different rewards in a random way, as reported in Table 2. There were three reward conditions: "*No reward*" (control condition), "*Money reward*", and "*Public online acknowledgement reward*". In the first condition, no reward was offered to the participants, duplicating the modality under which all the Brooklyn Atlantis contributors normally operate. A small monetary reward was offered to the second group, with the option to donate this money for the development of new hardware components for the Brooklyn Atlantis project. The symbolic amount chosen, i.e., $2, is comparable to the amount typically earned by workers in Mechanical Turk, an online crowd-based project by Amazon, where a participant earns on average $1 per project and the payment per hour is around $1.4 (Kaufmann et al., 2011; Paolacci et al., 2010). Larger amounts of money could have been interpreted by the participants as a controlling mechanism, impinging on their autonomy of decision (Grandey et al., 2013). Since a realistic involvement in the Brooklyn Atlantis project should target a thousand of committed volunteers, this small amount of money was deemed affordable by the research team. Finally, a public online acknowledgement reward was offered to the third group of participants, in the form of acknowledgement on Brooklyn Atlantis project website.

Table 2 - Experimental set up: definition of conditions and indices

Condition	No reward	Money reward	Public online acknowledgement reward
Individuals	61	64	64
Reward	None	Money (with the option to return the small sum)	Public online acknowledgement on the website
Quantity of contributions	Number of objects tagged		
Level of engagement	Survey responses + EEG measurements		
Level of enjoyment	Survey responses + EEG measurements		
Level of referral intention	Survey responses		

3.3. Experimental set up

The experimental set-up is composed of a laptop computer, a paper-based 1-7 Likert scaled survey instrument, and the Emotiv Epoc EEG headset (Emotiv Inc., San Francisco, CA, USA) shown in Figure 3, which was already used in non-critical applications (Duvinage et al., 2013). The software used in the acquisition of EEG data from the headset device was ad hoc developed by the research team using the National Instruments LabVIEW programming environment (NI, Austin, TX, USA).

3.4. Data collection protocol

Before the arrival of each participant, a new generic user account was created on the Brooklyn Atlantis web-based platform in order to collect data anonymously. Individuals decided voluntarily to participate in the experiments. When potential participants approached the experimental setting, a researcher briefly explained the aim of the project and its functionalities to allow them to understand the scope of the activity. Only after this briefing, they decided whether to participate. In this way, we sought to replicate a typical citizen science setting, in which participants quickly learn about the project and then voluntarily decide to join or to leave. Participants were informed that all the data collected will be anonymous and in no way associated with their identity. If they decided to participate, the contributor would sit in front of the PC and wear the EEG helmet device (Figure 3).

Figure 3 - Contributor tagging images on the web-based Brooklyn Atlantis platform wearing an electroencephalography device.

Participants started the experience by receiving additional information on how the Brooklyn Atlantis website works. Then, they were randomly assigned to one of the three conditions ("*No reward*", "*Money reward*", and "*Public online acknowledgement reward*") and informed about the reward, if any. The web-based platform displayed an individual image at a time, collected by the aquatic robot, allowing participants to tag objects to be signaled to the community. In each image, there were meaningful objects to tag, in order to signal to the community the presence of unwelcomed items or other elements to be identified (e.g. green trees and cleaner water spots). Photos were from a set of images that was identical for all the participants, and participants could decide to stop the experiment whenever they wanted.

The website tracked the number of tags, while the EEG device recorded contributors' levels of engagement and enjoyment (Table 2). Participants were able to move to the next image or to stop analyzing images at any time during the experiment. On average, participants were tagging objects for about 10 minutes. Considering that Brooklyn Atlantis contributors typically participate only a few times for a total involvement of about 17 minutes, the experiment duration is comparable to a citizen scientist's first login to the website. In the presence of monetary rewards, the participants received additional information at the end of the experiment. In particular, it was explained to the participant that the project was attempting to increase the number of the aquatic robots in use and to implement an underwater camera. They could choose to donate the amount they earned to the Brooklyn Atlantis project for the development of hardware advancements. Their monetary reward could be, thus, devoted to social aims.

Finally, participants filled in a survey about their feelings (Table 3). The survey consisted of a set of questions regarding the experience in participating to Brooklyn Atlantis project, in order to measure participants' engagement, enjoyment and willingness to encourage friends to participate (referral intention). Participants graded each statement following a 1-7 Likert scale, with 1 being strongly disagree and 7 strongly agree.

Table 3 – Likert scaled survey (1= strongly disagree; 7= strongly agree)

Statement	**Mark**
I felt engaged by contributing to the Brooklyn Atlantis project.	1-7
I enjoyed tagging images for the Brooklyn Atlantis project.	1-7
I will recommend other people to participate to the Brooklyn Atlantis project.	1-7

3.5. Participants

The study was carried out on a sample of over 60 subjects for each of the three conditions ("*No reward*", "*Money reward*", and "*Public online acknowledgement reward*"), for a total of 189 individuals (details in Table 2). This sample size was tested with a power analysis and shown to be sufficient for obtaining statistically significant results. The inclusion criteria of participants were an age of 18 years or greater, no personal relationship with the researchers, and willingness to voluntarily participate. Participants were recruited among university students, in order to reduce variability of the outcomes related to unobserved variables, at the New York University Tandon School of Engineering

(USA) and LUISS University (Italy). The use of students permits the isolation of other confounding variables that could have affected the results of the study, such as age and level of education (Cappa et al., 2016). The involvement of students in experimental setting is, in fact, increasing, whereby it has been argued to not impinge on the external validity of the results (Druckman & Kam, 2011; Vanasupa, Zhang, Mihelcic, Zimmerman, & Truch, 2011). Moreover, as the students come from Universities with different technical focuses, i.e., Engineering and Management, participation is unlikely to be affected by the extent to which the scope of Brooklyn Atlantis was of interest to them (Curtis, Holliman, Jones, & Scanlon, 2017). Participants were randomly assigned to one of the three conditions.

3.6. Measures

To measure the quantity of contribution, the number of objects tagged by the participant during the experiment was recorded. Concerning participants' engagement and enjoyment levels, data relied on two methods, surveys and EEG measurements, offering a more robust analysis and, potentially, reducing common method bias (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). The EEG device evaluated brain activity through the electrode and outputs, with a proprietary algorithm, providing instantaneous engagement and enjoyment measures, each ranging from 0 to 1 at a sampling rate of 128 Hz (Mihajlovic, Grundlehner, Vullers, & Penders, 2014; Palermo et al., 2017), from which we computed the average values. Therefore, while with surveys participants declared the answers, the EEG device provided objective measurements that people could not control. Finally, referral intention was collected with the 1-7 Likert scaled survey.

3.7. Statistical analyses

The statistical analyses were conducted with SPSS software (release 17). To study the positive impact that the reward mechanisms have on the quantity of contributions (H1a and H2a), the number of images tagged in a given time was compared to the reference condition of *No reward* using a *t*-test.

Concerning the level of engagement and enjoyment, the average Likert scale marks and Emotiv Epoc EEG indices were compared between the different treatment groups in a *t*-test to assess increases associated with the rewards conditions (H1b, H2b, H1c, and H2c). For what concerns the intention of referrals to friends, survey marks were compared in a *t*-test to confront the values recorded in the treatment groups with those of the *No reward condition* (H1c and H2c). All the statistical tests were performed with an acceptance level of $p \leq 0.05$.

4. Results

Descriptive statistics of the data collected are reported in Table 4. Due to the random assignment of participants to the selected conditions, we have 61, 64, and 64 observations respectively for the *No reward*, *Money reward,* and *Public online acknowledgement reward* conditions (from a power analysis conducted prior to the experiment, these observations were expected to suffice for testing our hypotheses). The number of tags per image in the *No reward* condition is consistent with data collected during other studies conducted in Brooklyn Atlantis, where an average of 8.5 images tagged was registered in similar conditions (Laut et al., 2017). In addition, the value of enjoyment registered in the *No reward* condition is in-line with that measured in a separate experiment conducted in Brooklyn Atlantis, where participants with an equivalent age and education level displayed a value of enjoyment equal to 4.07 (Cappa et al., 2016).

Table 4 – Descriptive statistics (mean, standard deviation, and standard error) for each reward condition

	No reward			***Money reward***			***Public online acknowledgement reward***		
Number of observations	61			64			64		
	Mean	Dev. St.	Err. St.	Mean	Dev. St.	Err. St.	Mean	Dev. St.	Err. St.
Number of tags	9.23	4.77	0.61	13.75	6.50	0.81	13.98	6.73	0.84
Engagement from survey	4.57	1.12	0.14	5.64	1.07	0.13	5.50	0.89	0.11
Engagement from EEG	0.57	0.07	0.01	0.60	0.08	0.01	0.61	0.09	0.01
Enjoyment from survey	3.92	1.13	0.14	5.32	1.20	0.15	5.25	1.15	0.14
Enjoyment from EEG	0.41	0.18	0.02	0.51	0.15	0.02	0.55	0.18	0.02
Referral intention from survey	4.36	1.13	0.16	5.56	1.12	0.14	5.16	1.42	0.17

4.1. The quantity of contributions increases with the use of rewards

The average value of participants' quantity of contribution, measured as number of tags in the images, in the case of *No reward* was 9.23. When a reward was offered to the participants, the number of images tagged increased to 13.75 and 13.98 for the *Money reward* and *Public online acknowledgement* reward conditions, respectively (Figure 4). Statistical comparisons between conditions indicate a significant increase ($p<0.001$) in the quantity of contributions when a reward was offered, supporting H1a and H2a. No statistical difference was registered between the two groups to which the reward was offered ($p=0.589$).

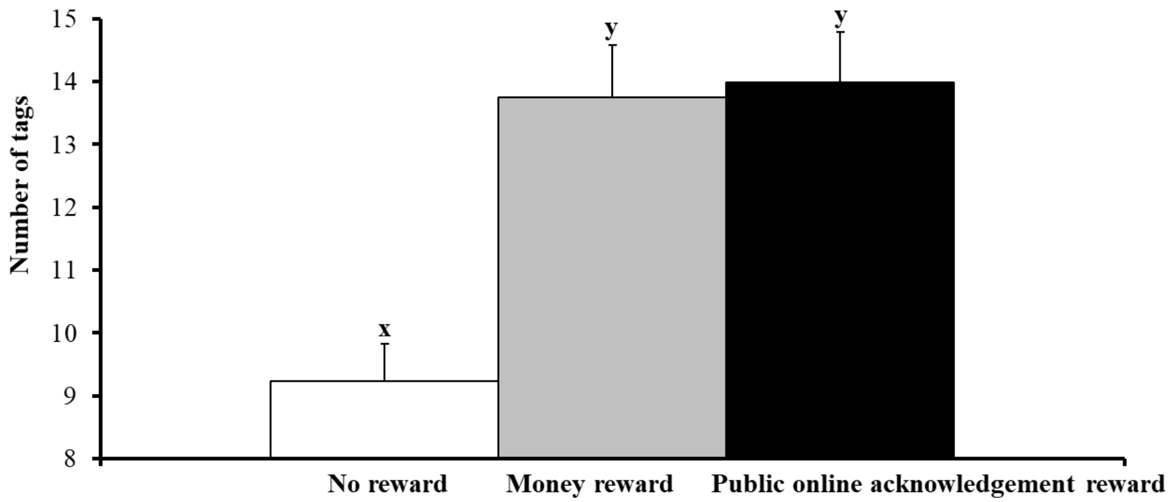

Figure 4 - Average value of "*Images tagged*" with 95% confidence interval, per condition: *No reward*; *Money reward and Public online acknowledgement reward*. Whiskers not sharing a common letter are statistically different (p<0.05).

4.2. The engagement level increases with the usage of rewards

The average value of participants' engagement measured with surveys in the *No reward* condition was equal to 4.57. When a reward was offered, either monetary or public online acknowledgement, the engagement level increased to 5.64 and 5.50 respectively (Figure 5a). Statistical comparison between the control and the *Money* or *Public online acknowledgement* reward conditions indicates a significant increase in the engagement levels (p<0.001) when a reward was offered, supporting H1b and H2b. No statistical difference was registered between the two reward conditions (p=0.211).

The engagement level was also measured using the EEG headset, which yielded values equal to 0.57, 0.60, and 0.61, for the *No reward*, *Money reward,* and *Public online acknowledgement* reward conditions, respectively. Comparing the different conditions (Figure 5b), statistically significant increases were observed when a reward is offered supporting H1b and H2b (*No reward* vs *Public online acknowledgement* p=0.012; *No reward* vs *Money reward* p=0.013) while there is not a significant difference between the two types of reward (*Public online acknowledgement reward* vs *Money reward* p=0.402).

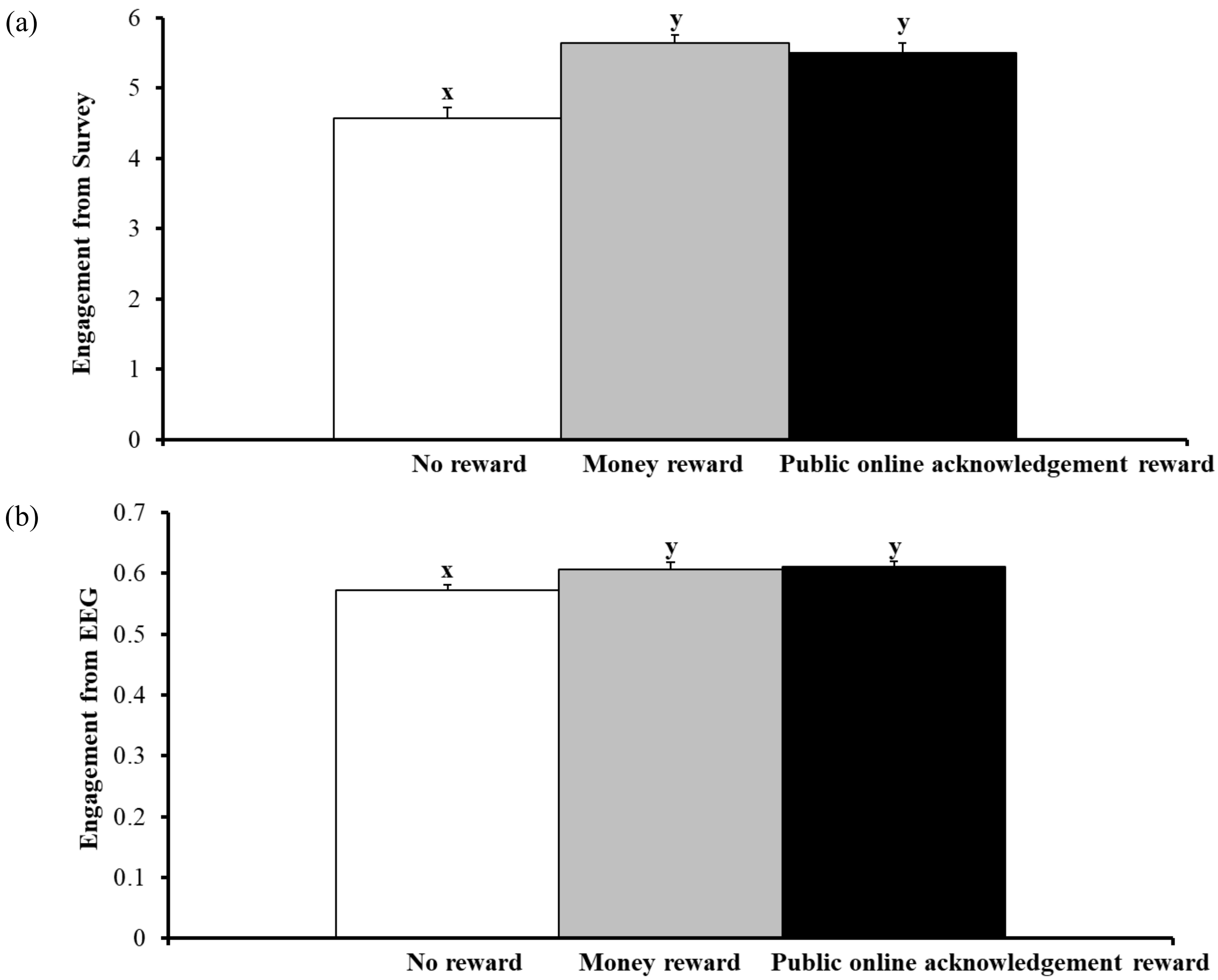

Figure 5 - Average value of "*Engagement*" from surveys (a) and from EEG device (b) with 95% confidence interval, per condition: *No reward*; *Money reward and Public online acknowledgement reward.* Whiskers not sharing a common letter are statistically different (*p*<0.05).

4.3. The enjoyment level increases with the usage of rewards

The average value of participants' enjoyment level measured with surveys in the *No reward* condition was equal to 3.92. When a reward was offered, either *Money* or *Public online acknowledgement*, the engagement rose to 5.32 and 5.25 respectively (Figure 6a). Statistical comparisons between conditions indicate a significant increase in the engagement levels ($p<0.001$) when a reward was offered with respect to the *No reward* condition, supporting H1c and H2c. No statistical difference was registered between the two reward conditions ($p=0.354$). The enjoyment level was also measured with the EEG headset (Figure 6b). The average level of enjoyment in the *Money reward* was higher than the *No reward* condition (0.51 vs 0.41, $p<0.01$), in agreement with H2b. The average level of enjoyment was also benefited by the *Public online acknowledgement reward*, with an increase from 0.41 of the *No reward* to 0.55 ($p<0.011$), in agreement with H1c. No statistical difference was registered between the two reward conditions ($p=0.110$).

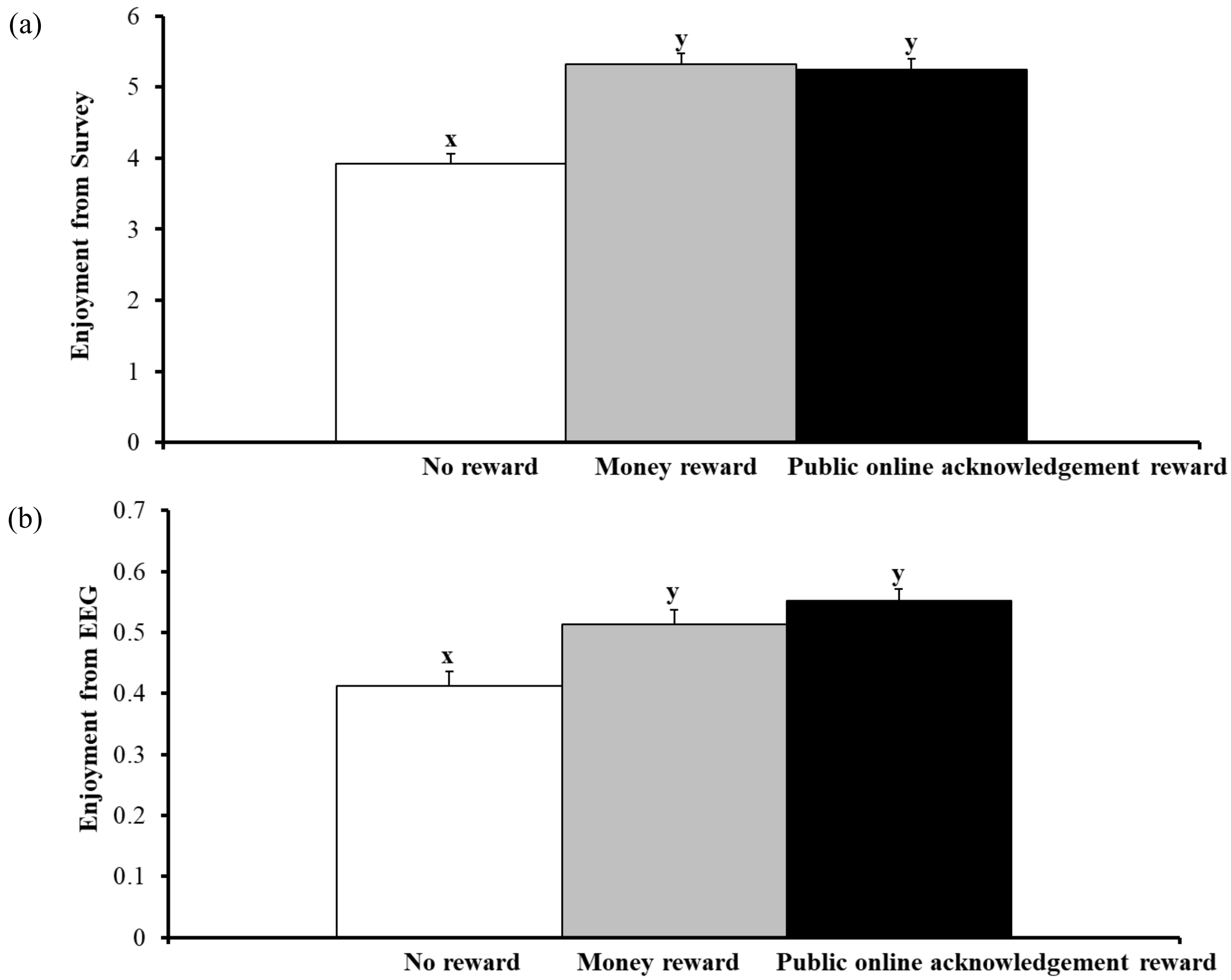

Figure 6 - Average value of "*Enjoyment*" from surveys (a) and from EEG device (b) with 95% confidence interval, per condition: *No reward*; *No reward*; *Money reward and Public online acknowledgement reward*. Whiskers not sharing a common letter are statistically different (*p*<0.05).

4.4. Referral intention increases with the usage of rewards

The referral intention of contributors was collected by survey (Figure 7). The values of *Money reward* and *Public online acknowledgement reward* conditions (5.56 and 5.16, respectively) were statistically higher (p<0.001) than the *No reward* condition (4.36). *Money reward* was found to be more effective than *Public online acknowledgement reward* in increasing referral intention (p=0.038).

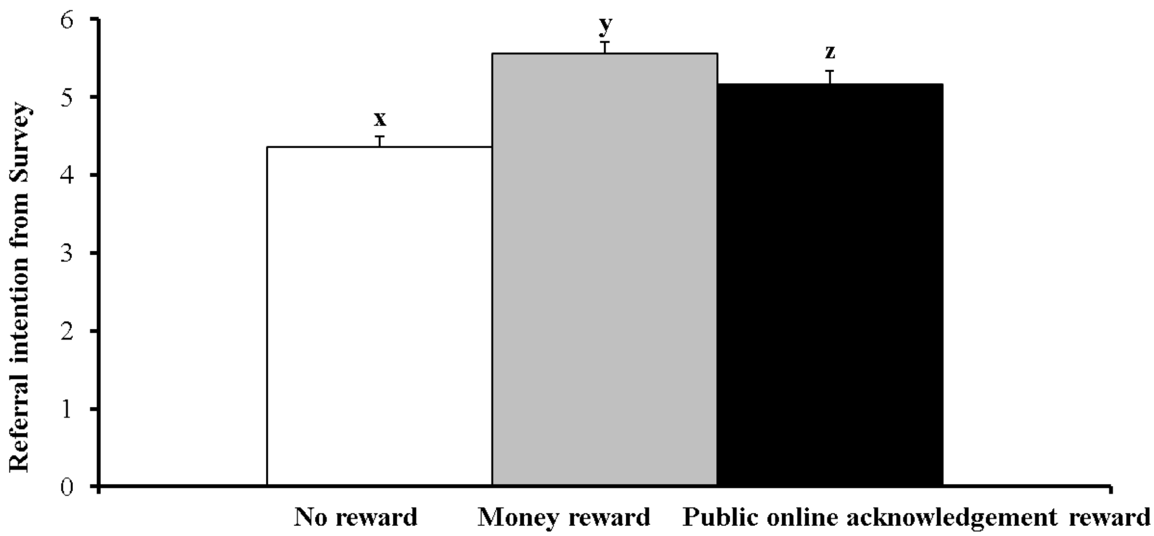

Figure 7 - Average value of "*Referral intention*" from surveys with 95% confidence interval, per condition: *No reward; No reward*; *Money reward and Public online acknowledgement reward*. Whiskers not sharing a common letter are statistically different (*p*<0.05).

5. Discussion

In this work, we experimentally assessed whether monetary and public online recognition rewards are effective means to increase participation and motivations in technology-mediated citizen science projects, operationalized by the quantity of contributions, contributors' engagement levels and enjoyment, and referrals intention levels. While recent studies have tested the implementation of citizen science in rehabilitation, face-to-face interactions with researchers and the effects of virtual competitors upon citizen scientists' participation and motivations (Cappa et al., 2016; Laut et al., 2015, 2017), this study explored the effect of rewards in such a context. Our results indicate that both monetary and public online acknowledgement rewards, under proper conditions, are successful in increasing the amount of contributions and motivations. In this research, we also assessed the positive effects of both the rewards on the referral intention, which could be interpreted as an overall assessment of contributors' intention to participate in the future (Bloemer, 2010), as well as a means to increase participation by attracting other users. Thus, this effort contributes to the state of the art of viable methods to boost citizen science participation (Cappa et al., 2016; Laut et al., 2017; Wald et al., 2016), by offering evidence for the positive outcomes obtained through rewards.

Monetary rewards, connected with extrinsic motivations, have been found to negatively impact intrinsic motivations in volunteer activities, resulting in the so-called crowd-out effect (Fiorillo, 2011; Lepper & Greene, 1978; Ryan & Deci, 2000; Titmuss, 1998). Our results extend the findings of crowd-in effect connected to monetary reward recently found in online open source communities (Krishnamurthy et al., 2014), in the context of citizen science. This crowd-in phenomenon in citizen science was found under specific modalities: i) the absence of a personal relationship among participants and researchers, ii) a small, symbolic, monetary reward, and iii) the option to devote the small sum earned to the improvement of the project components. In this way, monetary rewards are likely to be perceived as supportive means to social cause, rather than mechanisms of influence and control (Frey & Jengen, 2001; Grandey et al., 2013; Paolacci et al., 2010). In fact, following the SDT, restoring the autonomy of decision is expected to bolster individual self-esteem and self-determination, which are at the basis of intrinsic motivations (Ostrom, 2000). This finding is particularly relevant, whereby it shows that under precise conditions, a monetary reward does not trigger a crowd-out effect, but rather it reinforces intrinsic motivations in technology-mediated citizen science projects.

Public online acknowledgement reward associated with peer recognition also registered a positive impact on contributors' participation and motivations. Participants benefited in terms of reputation gaining and social acceptance (Franzoni & Sauermann, 2014; Silvertown et al., 2015). This result suggests that in the field of citizen science, money is not the only reward that can be used for increasing participation and motivations. Considering the fact that citizen science benefits from a large numbers of contributors, this form of reward could be more economically sustainable for the research institutions. This is even more relevant considering the strong link between the number of citizen science contributions and the quality of the research outcomes (Cappa et al., 2016; Nov et al., 2014).

While survey data and interviews are typically used for studying motivation for participation in citizen science projects (Aristeidou et al., 2017; Brabham, 2010; Cappa et al., 2016; Land-Zandstra et al., 2015; Laut et al., 2015; Nov et al., 2014; Tinati et al., 2017), another unique feature of this study is the integrated analysis of engagement and enjoyment levels through a portable EEG device and traditional surveys. While participants have direct control of the responses declared in the surveys, the EEG device measures motivations without participants' control. With surveys, participants can formulate the answer in order not to fail the expectations of researchers, if suffering from social desirability bias (Moorman & Podsakoff, 1992). Although this phenomenon brings people to present themselves in a favorable light regardless of their true feelings, the EEG offers a direct measure of brain activity. Therefore, the combined use of surveys and EEG could help disentangling declared from measured motivations in participants. The synergistic integration of these two evaluation methods may represent a valuable approach for avoiding common method bias and reinforcing the validity of empirical findings (Podsakoff et al., 2003). The conclusions drawn from surveys and EEG measurements are in good agreement, offering compelling validation for the EEG measurements. However, the magnitude of the positive effects of the two rewards differs between the two measurement methodologies, that is, the declared and measured values (Table 5).

Table 5 – Magnitude of the positive effect of *Money* and *Public online acknowledgement* rewards on declared and measured effect.

Declared effect		Measured effect	
Survey Referral intention	*Money reward ++*	**Images tagged**	*Public online acknowledgement reward ++*
	Public online acknowledgement reward +		*Money reward +*
Survey Engagement level	*Money reward ++*	**EEG Engagement level**	*Public online acknowledgement reward ++*
	Public online acknowledgement reward +		*Money reward +*
Survey Enjoyment level	*Money reward ++*	**EEG Enjoyment level**	*Public online acknowledgement reward ++*
	Public online acknowledgement reward +		*Money reward +*

In particular, it is possible to distinguish a stronger positive effect of the *Public online acknowledgement reward* with respect to measured EEG indices and number of images tagged. Differently, when people have the direct control of the feedback provided, as in surveys, *Money reward* was evidenced to bring greater values of referrals, engagement, and enjoyment levels. By only considering survey responses, it could have been concluded that money is more effective as a reward. This conclusion might have been associated with the fact that people, having received money, would feel more obliged to give a positive feedback to researchers, due to the social desirability bias (Moorman & Podsakoff, 1992). By examining indices for which people were not required to give a feedback in person, as for images tagged and EEG measures, the *Public online acknowledgement reward* seemed to be more effective. This result could be relevant for the organizers of citizen science projects, when designing effective rewards to motivate participants. The comparison of the two rewards in terms of their impact on participation, motivations, and referral intention of citizen science should be further investigated in future studies.

Another critical finding of our study is related to the evidence that almost all the participants to whom money was offered (60 out of 64) decided to return the small sum they received in favor of advancements in the Brooklyn Atlantis project. A similar evidence was found in the context of open source communities, but with a different magnitude: in that case around 19% of participants waived the monetary amount received (Krishnamurthy et al., 2014), while in this study the amount rise to 93%. This finding is particularly relevant in the context of citizen science, which seeks to reduce costs of scientific inquiry through massive volunteer participation. Offering a monetary reward with the option of waiving it is functional to the crowd-in phenomenon. In addition, it constitutes a feasible and economical method for organizers of citizen science projects to boost participation, whereby even minuscule monetary amounts could hamper the financial sustainability of projects with a large pool of participants. This outcome supports the view of GIT, where monetary rewards do not diminish the autonomy of people if they are free to waive it, and rather provides a sense of the importance in their contributions. In this vein, the possibility of returning the monetary rewards creates a sort of circularity around the whole idea of citizen science, with participants donating both their time (during the experiments) and their money (the returned reward) to a social cause they feel committed to.

6. Conclusions

The attention of professional researchers, policymakers, environmental regulators and funding agencies towards technology-mediated citizen science projects is rising due to the benefits they can offer to scientific progress, support for the environment, and public literacy (Bonney et al., 2009; Cappa et al., 2016; Cronje et al., 2011; Follett & Strezov, 2015; Franzoni & Sauermann, 2014; Haklay, 2013; Morais et al., 2015; Nov et al., 2014). In addition, in USA, the National Science Foundation and, in Great Britain, the Natural Environmental Research Council are increasingly seeking efforts from the scientific community to undertake project-related science outreach. In this context, sustained citizen science participation represents a promising means for massively involving the general public and for improving the appreciation of scientific research.

However, as many crowd-based projects fail over time, research in citizen science has focused on how to stimulate user participation and motivations (Butler, 2001; Langner & Seidel, 2014; Laut et al., 2017; Nov et al., 2014; Tinati et al., 2017; Wald et al., 2016). Therefore, the outcomes of this study contribute to this field of research, as it shows how to positively influence citizen scientists' participation (i.e., quantity of contributions and engagement), enjoyment, and referral intention through a proper use of rewards. In greater detail, this research demonstrated that both monetary and public online acknowledgement rewards are effective in citizen science. They can be used to sustain participation and motivations and, more in general, to create the conditions for improving the public value of science (McNie, Parris, & Sarewitz, 2016).

In addition, with this study we also contribute to the scientific debate on the effect of monetary rewards in volunteering activities such as citizen science, as intrinsic motivations can be harmed and lead to a crowd-out effect (Fiorillo, 2011; Lepper & Greene, 1978; Ryan & Deci, 2000; Titmuss, 1998). We support the claim that this negative effect does not occur in all circumstances (Cameron et al., 2001; Krishnamurthy et al., 2014; Mellström & Johannesson, 2008; Ostrom, 2000), by evidencing that monetary rewards, used under proper conditions as in this study, can be beneficial in citizen science. In so doing we provide citizen science organizers, and more broadly to volunteer activities organizers, an additional means to nurture contributors' participation and motivations.

There are several future developments that can stem from this research. Future studies should identify for which individual a particular type of reward is more valuable in order to maximize their effect. This study was performed among students to provide a homogeneous group and mitigate the role of unobserved variables; however, moderating effects brought about by age, previous knowledge, and heterogeneity in work experience, which are present in real citizen science instances, should be investigated in future research. The effects of sanctions for poor performance should also be investigated, as a means to penalize rather than reward participants on the basis of their contribution to the project (Festré, 2010). An additional step that should be undertaken is to understand the long term effects of the rewards tested in this research on the extent of contribution and the motivations level, building on previous work which has shown that he effectiveness of reward mechanisms may decrease over time (Moller & Deci, 2014). This aspect is crucial in citizen science as after motivating people to participate, it is important to keep them contributing over longer periods of time and to have them return for multiple sessions. Additional rewards may be investigated, especially those that do not impose monetary costs for citizen science project organizers, such as social media rewards that can remunerate participants with increased influence over social media by establishing new network interactions (Smailovic & Podobnik, 2016). In addition, future research should address experiments "*in the wild*", to evidence how online participation in citizen science may be affected by other phenomena, beyond those explored in the controlled conditions of this empirical, hypothesis-driven study.

To conclude, in the context of open source projects, the use of monetary rewards to crowd-in participants for innovation purposes has been considered, leading to the assessment of a model based on a mix of private and collective gains to nurture participation, known as the private-collective innovation model (Hippel & Krogh, 2006; von Hippel & von Krogh, 2003). In citizen science, efforts are focused on collecting and analyzing more data for a social purpose, such as environmental monitoring, rather than directly contributing to innovation as in open source communities, implying different motivations underpinning participation. Therefore, with this study we sought to lay the foundation for a private-collective research model, focused on the intensification of citizen participation in technology-mediated citizen science projects based on monetary and public acknowledgement rewards, whose outcome is scientific research of the public interest. In fact, as the outcomes of this research are drawn by experiments conducted in a relevant case study context, i.e., an active citizen science project, the results can be extended to similar projects to nurture participation.

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