Citizen Science Opportunities in Volunteer-Based Online Experiments

Nigini Oliveira†‡
nigini@cs.washington.edu

Eunice Jun†
emjun@cs.washington.edu

Katharina Reinecke†
reinecke@cs.washington.edu

† Department of Computer Science and Engineering
University of Washington, Seattle - USA

‡ Department of Computer Science
Universidade Federal de Campina Grande, PB - Brazil

ABSTRACT

Online experimentation with volunteers could be described as a form of citizen science in which participants take part in behavioral studies without financial compensation. However, while citizen science projects aim to improve scientific understanding, volunteer-based online experiment platforms currently provide minimal possibilities for research involvement and learning. The goal of this paper is to uncover opportunities for expanding participant involvement and learning in the research process. Analyzing comments from 8,288 volunteers who took part in four online experiments on LabintheWild, we identified six themes that reveal needs and opportunities for closer interaction between researchers and participants. Our findings demonstrate opportunities for research involvement, such as engaging participants in refining experiment implementations, and learning opportunities, such as providing participants with possibilities to learn about research aims. We translate these findings into ideas for the design of future volunteer-based online experiment platforms that are more mutually beneficial to citizen scientists and researchers.

ACM Classification Keywords

H.5.3 Group and Organization Interfaces: Collaborative computing

Author Keywords

Citizen science; online experimentation; open science

INTRODUCTION

An increasing number of research projects involve the general public to support data collection, data analysis, and other parts of the scientific process [18]. Such efforts are broadly named citizen science projects. Besides enabling research that could not be conducted by scientists alone, an additional goal of these projects is often to teach the public about the research process and findings and to improve people's scientific understanding [33, 8, 47].

Online experiments with uncompensated samples, such as those enabled through the experiment platforms TestMyBrain [41], Project Implicit [17], GamesWithWords [12], LabintheWild [22], and VolunteerScience [38], also rely on volunteers to contribute data [34, 36, 13]. Instead of receiving financial compensation (as often the case when participating in laboratory studies or those conducted on Amazon's Mechanical Turk), participants voluntarily take part in the studies, motivated by the prospect of supporting science and/or receiving personalized feedback upon completion.

Because participants in volunteer-based online experiments are subjects rather than collaborators, these platforms are usually not considered in typologies of citizen science (see, e.g., [45]). In fact, there is currently no volunteer-based online experiment platform that supports participants' involvement beyond their data contribution. What is largely unknown, however, is whether participants have a desire to be involved in and learn about other parts of the research process: Should volunteer-based online experiment platforms provide opportunities for research involvement and learning as is common in conventional citizen science projects? Understanding whether the goals of citizen science – such as teaching the public about the research process and findings and improving people's scientific understanding – can be applied to volunteer-based online experiments can help design online experiment platforms that support collaboration between research and citizen scientists.

The goal of this paper is to understand (1) if participants want to be more involved in online experiments by doing more than contributing their data and (2) what the opportunities are for volunteer-based online experiment platforms to incorporate participants' needs. Our intent is to evaluate if volunteer-based online experiment platforms should be redesigned with more participants' needs in mind and considered citizen science projects. We analyzed feedback from 8,288 volunteers who took part in four volunteer-based online experiments on the experiment platform LabintheWild over the course of four years. By analyzing open-ended comments about participants' experiences, we were able to organically discover citizen science

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opportunities without prompting participants to think about these needs. Our analysis revealed two main findings:

- *Opportunities for research involvement:* While LabintheWild and most other volunteer-based online experiment platforms currently only offer to provide general feedback, we found that participants use this option to voluntarily contribute in a variety of ways, such as to report bugs in an experiment or to suggest analyses or follow-up hypotheses. This shows that participants in volunteer-based online experiments choose to contribute as citizen scientists. We outline opportunities, such as for involving participants in several stages of the research process, as well as needs, such as for acknowledging participants' contributions.
- *Opportunities for participant learning:* Our findings also show that participants frequently share their interest in the research projects and the larger picture of how their own data relate to the research. We discuss opportunities for participant-researcher interactions that can address the current imbalance of researchers' and participants' benefits.

Our findings suggest that volunteer-based online experiments should be considered as citizen science projects given that many participants contribute more than experiment data and given the wide-ranging opportunities for involving participants as collaborators. We present design directions that address these opportunities and could be incorporated into a future generation of volunteer-based experiment platforms.

PRIOR WORK

Contributions in Citizen Science Projects

Citizen science usually describes collaborations between researchers and non-professional volunteers who help with the data collection and other research tasks [18]. One of the largest citizen science web portals, the Zooniverse [49], hosts a number of research projects in which citizen scientists can participate by performing research activities such as annotating, classifying, and transcribing data [42]. Cornell University's eBird project is another well-established citizen science project in which people contribute bird sightings to a large openly available database [40].

While both Zooniverse and eBird are examples of projects in which citizen scientists support the data collection and annotation, other projects offer different levels of collaboration between researchers and citizen scientists. Shirk et al. [39] presented a model of public participation in science suggesting that the role of citizen scientists can range from defining a need to designing and running the entire project. In addition, Haklay [15] identified three categories of contribution: volunteer computing (e.g., Rosetta@home [9]), volunteer thinking (e.g., FoldIt [6], the Polymath project [14, 7], and Zooniverse [42]), and participatory sensing (e.g., eBird [40]).

Volunteer-based online experiments seek a slightly different type of contribution than traditional citizen science projects: By taking part in behavioral experiments, participants add to the data collection with their personal characteristics and behavior. In previous typologies and characterizations of citizen science (such as those by Shirk et al. [39] and Haklay [15] described above), volunteer-based online experiments are often excluded due to the assumption that participants in these projects are subjects rather than collaborators [45]. Nonetheless, most of these experiment platforms refer to themselves as citizen science projects (see, e.g., [34, 48]), perhaps because the platform designers realized that participants contribute more than just data. For instance, on many of these platforms, participants share the studies in social networks or other online forums, thus helping to recruit other test-takers [13, 36]. Participants have also been found to report distractions or interruptions during the test, thereby helping to ensure the data quality [36].

Motivating Participation

To encourage contributions, most citizen science projects offer participants learning opportunities to broaden their scientific understanding [18, 30]. In fact, prior work has shown that citizen science projects successfully convey facts about science to their participants [43, 4, 23]. The Crowd Research project [44], a collaboration between researchers and hundreds of people, additionally offers citizen scientists research experience—an effort that has resulted in several crowd-authored papers at premier HCI conferences (e.g. [11]).

Additionally, citizen science projects employ various strategies to support the interaction between researchers and citizen scientists. eBird [26] maintains a simplified question and answer environment where contributors can help solve each other's problems. Another project, NestWatch [27], promotes organizational chapters of contributors who are geographically close. Zooniverse utilizes a forum-like site [50] where volunteers socialize and discuss the projects and science in general. Some projects also disseminate information about results through newsletters and scientific publications [3].

While educational goals are certainly one motive for participation [37], researchers have found that there are a variety of reasons why people contribute to online communities [24, 31, 10]. Rotman et al. [37] studied the motivations of researchers and citizen scientists in a conservation-focused citizen science project called BioTracker [25]. Both groups named egoism (i.e., having the goal of improving their own welfare [2]) as a primary reason for starting to participate in citizen science. Researchers thought it was useful to advance their careers, and citizen scientists were hoping to find educational opportunities and interesting activities [37]. While other motivational factors (e.g., altruism) played smaller roles at the onset, these factors changed with time. In particular, Rotman et al. found that sustained participation was more likely if citizen scientists felt that their contributions were explicitly recognized [37].

Volunteer-based online experiment platforms usually incentivize participation with a combination of altruism, game-like features (e.g., VolunteerScience), and educational opportunities in the form of personal results (e.g., TestMyBrain and LabintheWild). While some of these platforms summarize research outcomes in blog posts or on social media, additional learning opportunities are missing.

Interaction between Researchers and Citizen Scientists

Most citizen science projects provide minimal communication and interaction possibilities between researchers and citizen scientists. In fact, 75% of citizen science projects are thought to be purely contributory (according to a typology of citizen science projects presented in [39]), while only 11% use fully cooperative patterns [32].

Perhaps as a result of the large scale and geographically distributed nature of most citizen science projects, citizen scientists might not expect the possibility of direct communication with researchers. In fact, while researchers have called for timely support from science team members (e.g., [42]), we are not aware of any research that has evaluated citizen scientists' need for interaction with researchers.

The interaction possibilities are even sparser in volunteer-based online experiment platforms. While traditional in-lab studies allow for interpersonal interaction before and after the experiment (at the very minimum), online experiments are usually conducted with anonymous participants and without any direct contact between researchers and participants. There are, of course, many ethical concerns around the anonymity, such as the difficulty of knowing whether participants understand the informed consent or whether they have any concerns after participating (see [20] and [1] for an extensive discussion). In addition, the lack of direct communication and acknowledgment of participants' contributions may negatively affect participants' motivations [37].

In summary, while most citizen science projects offer learning opportunities and involvement in multiple research stages, there is little work that has explored these needs from the perspective of participants. Furthermore, there has not yet been a discussion of how citizen science practices can be applied to volunteer-based online experiments. We contribute an analysis of such needs and focus our exploration on the design of volunteer-based online experiment platforms.

METHODS

Our aim for this study was to uncover the perceptions, questions, and needs of participants in volunteer-based online experiments. Two research questions guided our exploration:

1. What are the opportunities and needs for involving citizen scientists in volunteer-based online experiments?

2. How can researchers and platform designers address these opportunities and needs?

To answer these questions, we conducted an analysis of comments that participants entered after taking part in experiments on LabintheWild [36]. LabintheWild is an experiment platform that enables participants to receive personalized feedback on their experiment results and compare themselves to others (see Figure 2). Experiments are advertised with short slogans, such as "Test your reaction time!" or "Are your judgements similar to others?" and usually take between 5 and 15 minutes. Participants are between 5 and 99 years old, have diverse educational and occupational backgrounds, and come from more than 200 countries [36].

The choice of a comment analysis to answer our research questions has two key benefits: First, it enabled us to get a large number of perspectives from users with diverse backgrounds. Second, asking for general comments and feedback at the end of each experiment enabled us to collect needs and desires that participants revealed without being asked directly.

LabintheWild participants can provide comments in two locations (see Figure 1): (1) After finishing the experiment but before reaching the results page, participants are asked if they have any comments and if they experienced any technical issues. The location of this comment box reduces the likelihood that participants' knowledge of their personalized results biases their feedback. (2) Some experiments include a second comment box on the results page (see Figure 2) that asks participants for any additional feedback.

Data set

Our dataset included 8,288 comments that were made in response to four experiments conducted between 2012 and 2016. We included comments from the following experiments in the analysis, chosen with the goal of having a representative and diverse set of LabintheWild experiments:

A a *subjective experiment* with timed stimuli (images of websites) that participants were asked to view and then rate on a Likert scale;

B a *survey* that asked for Likert scale and open ended responses about a social situation;

C a *choice experiment* that required participants to judge fit and pair words and images;

D an *objective recall experiment* that asked participants to memorize a geometric setting and reproduce it later.

Across all four experiments, around 10% of participants who completed the study left a comment. We excluded unintelligible comments (e.g., repeated random letters), non-English comments, and comments consisting of only one word without providing an explanation or context (e.g., "fun", "boring", "interesting"), leaving a total of 6,851 comments for analysis.[1] These comments were made by roughly the same number of participants (some participants provided multiple comments).

The demographic background of participants who left comments reflects the diversity of LabintheWild volunteers. Those who entered comments came from various educational backgrounds and ages, including pre-high school teenagers, young adults pursuing graduate degrees, middle-aged adults who attended high school only, and elderly participants. The majority of participants who left comments pursued college or higher education (60% - 75% depending on the experiment). The average age was 30 (standard deviation = 16 years, range = 9 - 90). These participants came from 31 to 119 countries depending on the experiment. As we will later see, the diversity of participants can be a great advantage when it comes to opportunities for research involvement in volunteer-based online experiments.

[1]The dataset including participants' comments is available upon request.

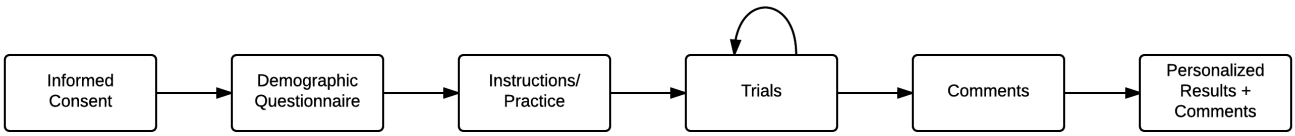

Figure 1. Overview of experiment stages in LabintheWild. Participants can provide comments on the last two pages.

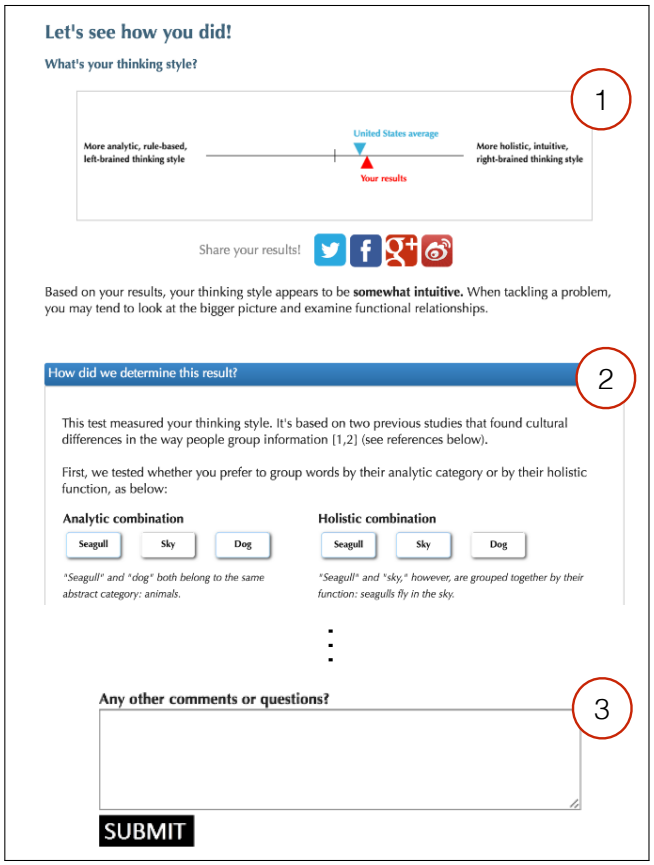

Figure 2. An example of a LabintheWild results page. The page shows (1) personalized results in comparison to others, (2) an explanation on the background of the research and how participants' results were calculated, and (3) a comment box that enables participants to leave any feedback that they did not enter on the previous comments page.

Analysis

We conducted a thematic analysis of the comments to identify emergent themes on participants' needs, questions, and desires. There were three phases to this analysis: the development of a dictionary to code the comments, the coding itself, and the analysis of codes for themes.

To develop the dictionary, one coder first reviewed the comments and extracted four general aspects that differentiated the comments: *type* (e.g., feedback, preferences, bugs, etc.), *phase* (i.e., the study phase the comment referred to, such as the demographic questionnaire), *detail* (e.g., design and user experience, emotions, and disclosure of personal information), and *other* (referring to themes discovered later in the analysis). These aspects and the resulting codes were then discussed and refined among the three authors to reconcile any ambiguities in the codes.[2]

Two researchers then independently coded the comments of four experiments and interchangeably checked each others' work. The coders switched between older and more recent comments to eliminate possible effects of experiment changes or particular populations dominating the comments. The research team met to reconcile and discuss any divergences in the codes' understanding. The coders stopped once they reached a point of saturation where coding more comments no longer provided new insights.

The research team subsequently selected codes related to technical feedback, disclosure of personal information, curiosity, and emotionally charged reactions. Using affinity diagramming [19], these codes were synthesized into themes. As a final step, the themes were confirmed by looking through comments that were not previously coded.

FINDINGS

Our analysis revealed six major themes that point to opportunities for improving the collaboration between participants and researchers. These themes can be broadly divided into (1) Opportunities for research involvement, such as involving participants in refining the experiment implementation or in the ideation of follow-up experiments, and (2) Opportunities for participant learning, such as providing participants with the possibility to learn more about the research background and findings or experimental design. In the following, we explain these themes with the help of participants' comments, annotated with the participant number and the experiment descriptor in parentheses (e.g., P#(A), see the Data set Section for a summary of the experiment descriptors).

Opportunities for Research Involvement

Participants' comments indicate that citizen scientists could be involved in various stages of the research process, such as in the experiment design stage (e.g., by pointing out flaws in the setup), in the analysis stage (e.g., by elucidating data quality issues that could compromise accurate and meaningful analysis), and by proposing future research directions and follow-up hypotheses.

Theme 1: Participants want to help improve the experiments

Our first theme revealed that participants can provide researchers with nuanced, actionable feedback on the implementation of experiments before researchers collect large amounts of data. The four main areas that these comments cover are

[2]The final dictionary contained 37 codes and is available for download at www.labinthewild.org/data/

technical issues, user experience hindrances, impairments to understanding study tasks, and presumed flaws in experimental design. Among these kinds of comments, bug reports were the most frequent. For example, P620(C)'s and P710(C)'s comments made researchers aware of problems they were able to resolve for future participants:

> *"I had to retake it part way through as I couldn't click the blue arrow."* P620(C)

> *"There didn't seem to be a way to deselect a word if you touched it by accident."* P710(C)

Feedback on bugs in the implementation can also help reveal unexpected problems regarding web browsers and Internet connections that negatively impact the user experience. Although experimenters strive to test their platforms on numerous kinds of hardware and browsers, it is impossible to test all kinds of devices, connection speeds, and browsers that participants, quite possibly located all over the world, may use.

> *"First try using Opera 12 crashed the browser on the first mock-question."* P87(A)

> *"one of the pic didnt show up, due to connection issue"* P40742(A)

> *"I do not know if it [is] because I am using a tablet no not, but it was occasionally difficult to select words. [...]"* P1874(C)

While researchers cannot control how participants access experiment platforms, participants' comments about such issues can help researchers become aware of practical problems that may systematically prevent a particular group of people from participating, hence resulting in a sample bias. This is an especially important issue for volunteer-based online experiment platforms that seek to recruit samples of participants from diverse political, social, economic, and cultural backgrounds.

Because volunteer-based online experiments attract a range of participants with varying levels of education, comments are an invaluable tool to assess barriers to volunteers' understanding and participation. Through their comments, participants share their thoughts, express their frustrations, and explain their confusion. Participants can direct researchers' attention to unclear task instructions, as P3264(C) does by saying,

> *"the phrasing of the second exercise made it difficult to determine what the question was"* P3264(C)

Comments such as this one can also cause researchers to consider if the language used in their experiments excludes any demographic group from participation because of the complexity of language, culture dependent lexical meaning of words, etc. For instance, LabintheWild translates experiments into eight different languages. Despite this, countries that speak the same language still have different lexicons. Indeed, a participant shed light on the difference between British English and American English and thereby encouraged the researchers to reconsider how experiments are translated in the future:

> *"Pant in Britain does not mean what it does to an American. It is underwear not trousers. Also in the bio information you ask for highest level of degree. College in the UK is NOT University/Bachelors level degree.[...]"* P20(C)

Furthermore, comments are insightful not only in identifying needs to provide clearer, more precise explanations of task requirements and verbal stimuli but also in detecting more complex issues around cognitive load and attention. For instance, P23288(D)'s feedback represents comments conveying that participants perceived the experiment as too long:

> *"The second test results are slightly skewed as i was losing interest, so I sped right through. I'm actually quite surprised I did so well on the second test. I know if I had taken the second first and the first second, I would have done absolutely perfect on the first, but much less so on the second."* P23288(D)

Finally, another aspect of experiments that participants questioned or suggested improvement for was the experimental design. Often, participants would point out specific aspects of the experiment they thought were insufficient for measuring the phenomenon that they thought was being tested, such as the number of trials or the duration that visual stimuli were presented. In some comments, participants acknowledged that the researchers probably had already thought about a variable or possible confounding variable, but they still point them out intoning a hopeful attitude to be helpful:

> *"Pretty cool experiment! However, is that 5 trials per conditions enough to precisely calculate accuracy?"* P23358(D)

> *"Would be curious to know if you're tracking the quickness (or not) of the responses. While I didn't cheat, I kind of wonder the effect of knowing ahead of time that I was looking at websites and that more complex websites came up, in the study, as less appealing, and if that affected my choices. But you were probably testing for that as well, no?"* P41546(A)

> *"Might be interesting to try a shorter duration of exposure in subsequent studies as well (if that was 500ms, maybe 50ms?) - short enough that the participant can't read the words of the website as that might detract from them just rating on visceral appeal alone."* P41537(A)

Many of these performance feedback comments suggest that participants are willing to make altruistic contributions that can ultimately enhance the experiment design and experience for others. While such comments support the research process at the experiment-level, our next theme shows that comments referring to participants' own data can contribute to another phase of the scientific process, data analysis and interpretation.

Theme 2: Participants can help ensure data quality

Compared to in-lab experiments, online experiments can have more uncontrollable environmental factors that influence the data. Theme 2 revealed that participants comments are helpful during data analysis because they reveal distractions, alert for wrongfully inserted data, and provide additional information that can explain outliers.

For instance, P1210(C) pointed out possible oddities in her data entry due to distractions:

> *"I had to take a Skype call halfway during the test, that is the reason there was a large delay in answering one."*
>
> P1210(C)

As P41168(A) exemplifies below, participants convey a strong desire to tell about or exclude their random responses and meaningless data points. This kind of information from participants is particularly useful, and even necessary, for experiments that involve timed stimuli and are highly affected by ambient distractions.

> *"there is no way to indicate that i accidentally missed a few...my dog kept barking and then i would look up, and when i missed the [stimulus] entirely i couldn't invalidate the question, i just had to pick an answer out of nowhere."*
>
> P41168(A)

Other participants use the comment box to reveal that they did not provide truthful data about themselves:

> *"I shaved a few years from my actual age - still same decade."* P40989(A)
>
> *"I gave an incorrect response: I've lived outside the USA for 21 years (not just 17). [...]"* P1566(C)
>
> *"False info cause I don't want anyone knowing my stuff [...]"* P33164(C)

As the last comment conveys, volunteers are willing to provide data on their behavior but some participants prefer not to reveal their personal, identifiable data.

Participants' comments also portray their awareness of problems arising from incorrect responses or distractions and their willingness to disclose details if this information helps researchers. For example, one participant wrote the following in what appears to be an attempt to explain her results:

> *"I got distracted and missed one the screenshots. You might add a "skip" option to the test, because I had to pick a random number to proceed and if that happens a lot, it might contaminate the data."* P2846(A)

The comments show that participants readily reveal details about themselves and their situations. This additional context can support researchers' understanding of the data and ensure data quality.

Theme 3: Participants suggest new research directions

We found that a large number of participants, when taking a specific online experiment, draw on their experiences to formulate ideas about possible influences on experimental results. These comments can be translated into follow-up hypotheses either for conducting additional analyses on the same data or for designing completely new experiments.

For an experiment investigating cultural differences, participants suggested new possible independent variables, confounding factors, and possible covariates.

> *"[...] I wonder if there is a gender difference too"*
>
> P7594(C)
>
> *"does the test take the impact of good and bad looking people on the [stimuli] into account? i heard of an fmri study that prove the activity of joy and pain centers in the brain when visualizing respectively."*
>
> P182(A)

Another participant asked whether differences in people's visual preferences are due to prior experiences with computers:

> *" [Stimuli] that look cluttered, messy, unprofessional, or old are automatically unpleasant to me. I'm an Apple user, which might be relevant? Although mostly it makes me sound like a snob, but I have a point, I swear. Because Apple are very into making their designs look rounded and modern, so it's just sort of something I'm used to. I think if I'd grown up using Windows machines, I might like more angular designs, because Windows computers have a much more angular, old-fashioned look to them."*
>
> P65572(A)

Participants also frequently suggest to collect more data to test a different hypothesis, one that was not intended by the original experiment, as illustrated by P5468(B)'s comment:

> *"I think that this study could have also been used to find out if the cell phone usage of the other people one is having a meal with affects one's own cell phone use. [...]"*
>
> P5468(B)

The following comment and others like it do not explicitly suggest future hypotheses, but the expressed reflections and ideas can be coupled with researchers' expertise to formulate future research questions, which is one way citizen scientists can guide research.

> *"Great test! Visual appeal I believe has two humps of user response; 1) instant (like what you have done here), and then 2.) applied meaning if the content is within the context of what the user is expecting. For example, going to a car site and seeing a beautiful vehicle on the banner will rank high on the instant response, but if the secondary and tertiary content has ATVs and RVs only the applied response will be very low. Thanks, [email address]"* P41621(A)

The finding that participants share their expertise on a specific research subject could have major implications for turning volunteer-based online experiments into a more effective form of citizen science where participants and scientists contribute with their different experiences and knowledge.

Summary of Themes 1-3

The comments suggest multiple opportunities for involving participants in the research process: (1) Early on when experiments have just been launched, they contribute to debugging and improving experiments by suggesting technical and other issues. (2) Contributing to the data analysis, participants also provide comments on distractions, cheating strategies, and

personal information that might explain their individual responses. (3) During the conclusion and interpretation phase of an experiment's results, participants are eager to discuss the findings and share ideas for future follow-up experiments.

Altogether, our data showed that participants are interested in more than their own individual takeaways and search to engage with the research project more collaboratively. The newfound understanding that participants have a desire to engage with online experiments at deeper levels emphasizes the need to reconsider how we conceptualize and design volunteer-based online experiments. With consideration and functionality for innovative participant-researcher interaction, volunteer-based experiment platforms can become citizen science projects with meaningful learning experiences for participants, as we will see in the next section.

Opportunities for Participant Learning

The last three themes suggest participants' interest in learning about the experiment beyond their individual results. They are interested in how their data and results compare to others, contribute to the research project's goals, and even how their experience with the study fits in the experimental design.

Theme 4: Desire to learn more about themselves

Although each study on LabintheWild concludes with a summary of participants' results using basic, easy-to-understand graphs and brief explanations, Theme 4 highlighted that participants have an interest to learn more detailed aspects of their results. For instance, in an experiment that asked participants to rate the same stimuli twice, many participants expressed curiosity about their performance:

> *"Curious to know how consistent I was in scoring the same images."* P40942(A)

This comment was raised because the results page compared people's visual preferences to others but did not provide information on their internal rating congruity.

In a different experiment where participants learned about their thinking styles relative to parts of the world, participants frequently asked to receive more granular information on how they compared to others:

> *"It was very interesting, but a contrast of different countries results could have been added, so that we can compare countries results to see if our perception is affected by our location."* P23394(D)

> *"[...] please include how everyone else who took the test did so we can compare our results to others"* P23839(D)

Such comments can inform the experiment designer which personalized and comparative results would be most interesting to participants.

Theme 5: Desire to learn about the research project

Theme 5 underlines participants' curiosity to learn about the overall research goal and how their data fits in. Some are more explicit in asking about the hypothesis, such as P170(C):

> *"Interesting as always I wonder what the hypothesis is you are trying to proof."* P170(C)

Others are less specific but nonetheless inquisitive of the more general guiding research question:

> *"what is this all about???"* P41177(A)

> *"Wonder what you are testing"* P33409(C)

Many participants inquired how their individual data contribute to the overall research goal. Those comments often include participants' email addresses, suggesting their desire for interactions with the researchers:

> *"Thank you, this was some interesting minutes for me, and I am curious about what can you take out of my results. [Email address]"* P6244(B)

> *"I would like to know more about the findings of this research project, if possible. Thank you! My email address is: [email address]"* P366(A)

Some participants are interested in learning about the research project and its background to become involved, hoping that their suggestions will be of use to researchers:

> *"What should be the parameters upon which we look upon the site for appeal? I was looking forward to more of CSS and cool colors, over images. My email ID is [email address.] I would again be interested with helping with this project, so please do update me of any improvements and whenever suggestions are required. Thanks"* P603(A)

Comments where participants are proactive in leaving their email addresses, roughly 3% of all comments, especially show their eagerness to interact with the researchers. Leaving questions as comments, ranging from 2% to 12% of all comments depending on the project, additionally highlights that participants are curious about the research project and that some may hope to engage in discussion.

Theme 6: Desire to learn about experimental design

As we discovered in Theme 2, some participants pointed to potential flaws in the experimental design in their comments. These comments could be convicting in tone, suggesting that the researcher made a mistake or should look into other parameters. The same overall concern for the soundness of experimental design and the experiment's validity was shared among more participants whose comments were more inquisitive, such as:

> *"were some [visual stimuli] intentionally made to become black and white?"* P291(A)

Based on the email addresses participants left, it seemed that participants wanted follow-up also on the more theoretical side of online experiments:

> *"Is it possible to get some theoretical basis of this test, how has it been constructed and why in that way? Thanks: [email address]"* P627(A)

It is worth noting that participants' curiosity of the experiment design could be interpreted as a need for researchers to justify their decisions to participants. Taking care to provide participants with an opportunity to learn the main concepts of

experimental design (Theme 6) can then benefit researchers in giving participants a way to test and revise study designs (Theme 1). Therefore, investing in learning opportunities can inadvertently help both participants and researchers.

Summary of Themes 4-6

In this second part, we found that an additional opportunity for volunteer-based experiment platforms is to create learning experiences for participants, a practice currently not fully explored by these platforms. We found that comments include questions, inquiries for follow-ups, and thoughts that indicate participants' desires to learn about themselves and science. The requests for additional information show that participants value the learning experience provided by the experiment and more specifically by the personalized results page. From the perspective of researchers conducting volunteer-based experiments, answering these needs should be seen as a counterpart and deserved compensation for participants' time and efforts.

DISCUSSION AND DESIGN IMPLICATIONS

The six themes detailed above highlight several learning opportunities and the need for greater interaction between researchers and participants than what is currently supported on volunteer-based online experimentation platforms. These findings demonstrate how volunteers benefit from participation and how motivated they are to possibly contribute in unplanned ways. Identifying these areas of improvement is a major step to show how volunteer-based online experiments can adopt more citizen science characteristics and better serve participants and researchers.

In this section, we move one step beyond and discuss the design implications related to our findings. We organize our discussion around prominent design possibilities and address participants, researchers who design feedback-based online experiments, and the designers of feedback-based online experiment platforms. Although both the platform designers and researchers can benefit from an awareness of these design implications, we recognize that they have different responsibilities and priorities, so we call attention to a specific group when we believe the group is better positioned to address these opportunities. We actively try to keep at the forefront of our thoughts and ideas the needs of participants and the potential impact our design suggestions have on them. We strongly encourage researchers and designers to consider participants and their nuanced needs and desires when applying the following design suggestions to their efforts.

Allow for Participant-Researcher Interaction

Themes 1-3 of our analysis highlighted participants' contributions to the implementation of online experiments and revealed a great potential to involve participants in multiple stages of the experiment process. A key observation from this analysis is that participants contribute without being asked to do so, which underlines their desire to altruistically support and improve the research. However, the questions participants raise as well as the email addresses they leave suggest that current online experiment platforms insufficiently cater to participants' desires for bi-directional communication with the researchers. In fact, with the rise of online experiments, the communication between researchers and participants has been mostly reduced to pre-selected text in the form of instructions and debriefings. Instead of interpersonal exchanges between researchers and participants at the start and end of the experiment as common in in-lab studies, most online experiments solely offer a comment box to collect feedback that is helpful to the experimenters while less beneficial to participants.

The need for more possibilities for interaction between participants and researchers translates into multiple design opportunities requiring varying degrees of technical expertise:

A simple design intervention that could be incorporated in platforms would provide participants and researchers with options for requesting and giving follow-up. As it is, many participants add their email addresses in the comment box without being asked. Volunteer-based online experiment platforms usually do not require signing in, and one could argue that the resulting anonymity leads to more trust and perhaps even a higher likelihood that participants provide truthful responses [36]. To enable follow-ups with more participants without risking that their data becomes identifiable, we suggest that platforms ask participants if they want responses from the researchers about anything included in their comments. If participants indicate yes, the platform could prompt participants for their email addresses and then store the email addresses and a copy of the comments in a separate database.

For highly trafficked online experiment platforms though, numerous participants in a given study may want follow-up correspondence from researchers. Sustaining these conversations is unrealistic for researchers, but forums where participants can discuss issues and ideas among themselves is one possible solution. Galaxy Zoo supports a discussion forum, and the researchers involved have found that more experienced volunteers help newer volunteers and that the forum is crucial for providing a space for questions and topics researchers cannot or do not know how to address [5]. Considering the success of Galaxy Zoo's forum, a more comprehensive technology intervention would also refer participants to forums in which they can share technical bugs, perceived issues with the experimental design, and other observations. For instance, LabintheWild participants already make use of external forums for more general discussions of the research (e.g., multiple Reddit threads refer to LabintheWild's experiments [35]); however, external forums are generally part of another specific community (e.g., groups on Reddit) with its own goals and rules, creating an extra burden for online experiments' volunteers to join.

We propose instead that platform designers consider providing a forum-like environment for volunteers to discuss common interests around the experiments. This requires platform designers to make additional design decisions about what types of forums to offer based on what kinds of online communities researchers feel comfortable fostering. The forum could be moderated and/or anonymous, and it could even be specific to discussions about experiments' results pages for participants. An advantage of such forums is that they highlight participants' interests and could encourage their future engagement. For instance, the platform could take the interests expressed in a forum and intelligently suggest other experiments that

a specific volunteer might like to try, ask participants of a particular thread to help others in a related discussion, and/or acknowledge participant contributions to the forum discussion with a collectible badge system.

There are several differences between existing citizen science forums and those that would be suitable for discussion of volunteer-based online experiments. Zoouniverse has an active forum [50] with multiple threads where citizen scientists can discuss projects on the platform itself or exchange different views on current events and topics related to some of the experiments on Zooniverse. Each participant also has a summary profile that the public can view. However, in the case of volunteer-based online experiments, because not all information about the experiment design and information on the results page should be publicly available (so as to avoid influencing subsequent participants), we believe that forums should have the option to be closed (i.e., hiding discussions) until participants unlock them with a code given to them after their participation in a specific experiment. Finally, for volunteer-based online experiment platforms with a population as diverse as that on LabintheWild, the forum would also need to be inclusive of language and cultural behavioral differences, with question-and-answer settings so that participants from all countries could feel able to access, navigate, and contribute to the forum if they so desired. Constraints and features such as enabling people to join threads that are in specific languages or pertaining to specific national groups, or allowing participants to share identity information only with a chosen group of other forum members (rather than a public profile) are additional design decisions that must further consider the needs of and impact on participants.

A third possibility would be to allow citizen scientists and researchers to collaboratively change the experiment implementation, experimental design, or analysis. In this case, a main challenge is building effective communication and processes for bridging knowledge gaps and keeping track of the collaborative effort. A tool that supports the ability to propose research directions, discuss the proposed ideas between volunteers and researchers, and openly show how proposals are translated into changes could bridge these gaps. There are additional advantages to such a tool: (1) volunteers' proposals are openly available as evidence of their contributions and (2) discussions between researchers and volunteers as well as a description of the resultant changes made to the experimental design could teach interested participants about scientific experiments. As we will discuss below, this design approach also addresses some of the themes related to learning opportunities.

Provide Opportunities to Tailor Feedback

Although volunteer-based online experiment platforms commonly incentivize participants with personalized results pages [13, 36], our analysis revealed that participants often ask for additional information on these pages (Theme 4). Researchers themselves can try to improve the results pages by considering participants' feedback, but the range of requests may be difficult to understand, prioritize, and satisfy. In order to respect and try to meet participants' curiosities, we propose ways to involve participants in the design and redesign of feedback pages.

First, participants could suggest additional kinds of information they would like presented on the results pages. These suggestions could then be made visible for voting and open debate so the most popular and well defined ones to be included in the redesign of a results page. Co-designing an experiment's results page with the researchers in this way would involve participants in the research process and give them an active role in their learning about themselves and the science behind the experiment.

Second, platform designers could provide participants with interactive tools that support flexible analyses and visualizations, such as Voyager [46], to explore their data based on a predefined set of variables. This way, participants could personalize their results pages, explore analyses that interest them, and possibly share their visualizations with others to collectively make sense of results from the experiment. Providing support for semi-guided personal data exploration caters to the wide range of educational and skill backgrounds and interests that volunteer-based online experiments participants may represent.

There are tradeoffs between these strategies. Voting on specific feedback means that only very few participants' requests will be realized, but enabling participants to analyze the data themselves could satisfy more of these requests. At the same time, participants may not want to spend the extra time and effort to visualize their data no matter how intuitively built the provided visualization tool is. Despite these tensions, both strategies could enrich participants' interaction in online experiments.

Provide Information About Overall Research Project

In response to Themes 5 (research project) and 6 (experimental design) in our analysis, we suggest that researchers using volunteer-based online experiments also invest in outreach. Informing volunteers about the research project as a whole, including the background, goals, and final outcome, will ensure that participation in volunteer-based online experiments comes with additional benefits to participants. Researchers can disseminate this information via email newsletters, social media (e.g., a Facebook page), or online meet-the-scientist events for which participants can register.

Theme 6 highlighted the need for providing participants with the opportunity to learn about experimental design. Doing so could give reasonable concern for backlash as teaching participants too much about experimental design could influence their responses. However, we see this concern as being no different from other experiments where social scientists recruit participants mostly from a restrictive pool of undergraduate psychology students [16] or from the pool of Amazon MTurk workers [29, 28]. In fact, we would argue that because the participants coming to online platforms like LabintheWild are more diverse than those in laboratory studies [36], providing participants with the option to learn more about experimental design would not be a detriment to the quality of data collected. Moreover, as we discussed earlier, forums offering these learning opportunities could control the access to

threads pertaining to specific experiments until participants have finished the experiment and are able to unlock them.

In addition, our analysis showed that participants are interested in seeing how their data contribute to the overall research project. There are various ways to fulfill this need. For example, following Kraut et al.'s design claims [21] the results page could acknowledge participants' unique contributions personalized to their demographic background (e.g., "With the help of your participation, we will be able to compare people from Austria and Bangladesh!"). Similar to the suggestions of Rotman et al. [37], we also imagine a system that notifies participants if their data have been included in publications, visualizations, online repositories, etc.

LIMITATIONS AND FUTURE WORK

Our exploratory analysis contributed insights into the needs and desires of volunteers in online experiments and also raised the need for further research.

A limitation of this work is that our insights are based on comments that participants left on one specific volunteer-based experiment platform. We cannot generalize our findings to other volunteer-based platforms that might evoke more or less participant contribution (e.g., if the design promotes a different feeling of community). We also cannot conclude that participants in financially compensated online experiments, such as offered on Mechanical Turk, would benefit from the same suggestions.

From participants' comments, we also concluded that they desire to interact with researchers and contribute to research projects. While it is reasonable to assume that many participants would indeed engage in such activities if provided with the opportunity, we cannot be certain that a more time-consuming engagement than entering comments will be well-received. We are especially interested in evaluating long-term engagement in our future work in which we plan to implement some of the design opportunities discussed in this paper.

When talking about opportunities for participants to become citizen scientists, we referred to comments that were provided by only about 10% of LabintheWild's participants. Although this level of contribution is consistent with 'formal' citizen science projects [7] (a small fraction of users often contribute most of the content), it also means that many participants might not share the same desires and be interested in citizen science opportunities as those who provided comments. Our future work aims to evaluate the link between volunteers' demographics, levels of participation, and motivations in order to create appropriate ways to encourage contribution and engagement from diverse volunteers.

Finally, we are enthusiastic about exploring changes to the scientific processes that we believe are necessary to realize truly collaborative citizen science experiences. In particular, we believe that such scientific collaboration needs to be accompanied with conversations about types and relevance of contributions and how participants could choose from different levels of acknowledgment, from anonymity to authorship. For instance, citizen scientists have been listed as authors in publications before (e.g., [11]); however, not all contributions are large enough to warrant co-authorship. Instead, publications and digital libraries could have several ways of acknowledging contributions, such as by including a "citizen scientists" category. Although such acknowledgments may incentivize some participants, further research on what citizen scientists perceive as appropriate and meaningful incentives and forms of compensation is needed.

CONCLUSION

The primary take-away from our work is that volunteer-based online experiments should be considered as citizen science. Based on an analysis of 8,288 comments from LabintheWild participants, we were able to show for the first time that they are not just subjects; instead, participants already contribute to several parts of the research process and could be seen as collaborators.

We additionally identified opportunities for enhancing the collaboration between researchers and participants by involving participants in several stages of the research process (e.g., co-designing experiments and participant results pages) and providing learning opportunities (e.g., teaching participants about the research background and goals or about the experimental design).

Based on these findings, we derived design suggestions for a new generation of volunteer-based online experiment platforms which provide a more inclusive citizen science experience to researchers and participants alike.

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