CITIZEN SCIENCE:
THEORY AND PRACTICE

How the General Public Appraises Contributory Citizen Science: Factors that Affect Participation

RESEARCH PAPER

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ABSTRACT

Understanding the factors that affect participation plays a crucial role in the success of any contributory citizen science project. We focus our study on the general public, who most likely have not participated in citizen science before, since they constitute a large part of society and their opinions have not been studied thoroughly. We first describe the survey, which was answered by 209 respondents in Germany who mostly had no prior experience in citizen science, that seeks to addressthe factors of personality traits, properties of citizen science projects, and general motivations. Our study focuses on two different levels of participation: in specific sample projects and in contributory citizen science in general, both of which are embedded in the survey. We use manual text clustering and linear regression models to study the different types of inputs from the respondents. We identify contribution to science, the fun element of the projects, personal interests, and new knowledge acquired from participation as the most significant motivators for the future intention of participating in the sample citizen science projects. On a higher level, the general motivations concerning "values" and "understanding" are the main drivers behind participants' future intention of participating in contributory citizen science. Meanwhile, no personality traits are found to be influence the intentions of the respondents. Based on these findings, several enhancements to the recruitment and communication strategies of citizen science projects can be made to maximize the participation of potential citizen scientists.

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INTRODUCTION

The term citizen science usually implies the participation of the general public in different stages of the scientific research processes, most notably the stages of data collection or data analysis (Bonney et al. 2009). A core feature of citizen science is the participation of a large number of people, or citizen scientists, which is the key to the success of a citizen science project (West, Dyke, and Pateman 2021). A successful recruitment process will bring a sufficiently large number of participants into a project (Kobori et al. 2016), who will actively join its various stages. There are a wide variety of factors that potentially affect an individual's decision to participate, such as a participant's expectations of other people (Grube and Piliavin 2000), their personal beliefs and values, their demographic background, personalities (West and Pateman 2016), and personal motivation (Kragh 2016). Among these factors, personality and especially motivation receives significant interest from the research community as they hold the key to one's decision to participate in volunteering activities (Rotman et al. 2012).

The motivation to volunteer depends on an individual's demographic background (Musick and Wilson 2007), and this motivation can change over time for the same individual (West and Pateman 2016). Furthermore, people often have more than one motivation to volunteer (Bell et al. 2008). Meanwhile, personality can be characterized as traits, which are stable over the years (Cobb-Clark and Schurer 2012) and have strong influence on an individual's behaviors (Barrick 2005). As citizen science can be considered a special form of volunteering (West and Pateman 2016) in which participants freely give their time and labor for scientific research rather than community service, it is worth studying how personalities and motivations influence an individual's decision to participate in this particular activity.

Based on these rationales, we first study how an individual's personality traits affect that person's intention to take part in citizen science. The majority of studies on motivation in citizen science focus on citizen scientists who already took part in a citizen science project (Land-Zandstra et al. 2016; Maund et al. 2020), and not on those who have not participated or declined to participate (Leao and Izadpahani 2016). We aim to understand the appraisal of citizen science by the general public irrespective of their previous contact with citizen science activities. In a best-case scenario, a recent estimate puts the number of actual citizen scientists at only one percent of the population (Haklay 2018), therefore the rest can be considered potential participants. Therefore, it is worth studying the factors that affect the decision to participate in citizen science from this massive community of potential citizen scientists. While previous studies inspected motivational factors during the stages of initial participation and sustained participation (West and Pateman 2016), there is currently little known of the motivations of prospective participants. We expect that the outcomes of this study will help citizen science project organizers to design projects appropriately and to effectively communicate them to the public, for example, matching certain properties of a project to individuals with relevant attributes and expectations. Ideally, this can help to improve recruitment strategies to attract the large yet harder-to-reach community of potential participants.

First, we review the related works on motivation in citizen science and – more generally – volunteering as the overarching concept that includes citizen science. We also discuss psychological factors that might affect participation in citizen science. We then describe our study on how motivations and psychological factors affect the intention of the general public to participate in citizen science, in which 481 individuals in Germany participated and 209 individuals provided complete answers through an online survey. We examine the relation among the respondents' personality traits, their evaluations of known motivations in citizen science, and their intention to participate in specific projects and contributory citizen science in general. Finally, we present the discussion and conclusions.

RELATED WORKS

In this section, we summarize the literature on motivation in volunteering and citizen science. We present an overview on the relation between personality traits and volunteering.

MOTIVATION IN VOLUNTEERING

Self-Determination Theory (SDT) is often used to explain participation in volunteerism (Oostlander, Güntert, and Wehner 2014). This theory identifies three core psychological needs, namely autonomy (control over one's behaviors and goals), competence (mastery of tasks and learning) and relatedness (sense of belonging and attachment to others), that enable the highest level of motivation (Ryan and Deci 2000). Another widely used categorization of motivations in volunteering comes from Batson, Ahmad, and Tsang (2002). In this categorization, there are four types of motivation for social participation, namely egoism (increasing one's own welfare), altruism (increasing the welfare of one or more other individuals), collectivism (increasing the welfare of a group or collective), and principlism (upholding some moral principle). Among these four types, egoism includes both intrinsic and extrinsic motives (Beza et al. 2017), while the other three lean more toward intrinsic motivation (West, Dyke, and Pateman 2021).

Currently, the Volunteer Functions Inventory (VFI) (Clary et al. 1998) is considered the most appropriate tool to access motivation among volunteers as it is built on well-established theoretical bases (Chacón et al. 2017). Using the functional approach, the authors identify the six motivation categories that span a wide variety of motives when individuals volunteer (Clary and Snyder 1999). These categories are value (to express the humanitarian and altruistic values), understanding (to get new knowledge and skills and/or to exercise one's own skills and abilities), social (to make friends with other people, to be with friends and/or to participate in socially desirable activities), career (to get skills, experience and professional contacts that are beneficial to one's future career), protective (protect one's ego from negative feelings and/or to address one's personal problems) and enhancement (to focus on self-development and make oneself feel good). Based on the intrinsic-extrinsic dichotomy, many of the six VFI motivation categories include both extrinsic and intrinsic components (West, Dyke, and Pateman 2021).

MOTIVATION IN CITIZEN SCIENCE

Previous studies base their approach mainly on well-established categorization systems to appraise motivation for citizen science. For instance, there are several works aligned with the four-pronged motivation model from Batson, Ahmad, and Tsang (2002); they find that motivations expressed by the participants can be mapped to the four groups of egoism, altruism, collectivism, and principlism (Rotman et al. 2012). Similarly, SDT is often used to explain why people participate in citizen science (Jones et al. 2018). Motivations of citizen scientists can also be projected through the lens of VFI (e.g., West and Pateman 2016; Maund et al. 2020). In some cases, the researchers adopt a modified version of the aforementioned motivation model to map citizen scientists' motivations (Wright et al. 2015).

Additionally, there are several works on motivation in citizen science that do not incorporate any general motivation models, and report several unique motivations that distinguish citizen science engagement from other forms of volunteering. Land-Zandstra et al. (2016) discuss contribution, interest in science, concern for the domain being investigated (i.e., health), fun, and education as motivation for citizen science. Dowthwaite et al. (2019) list six categories of motivation in online citizen science (i.e., enjoyment, helping, interest and curiosity, learning and teaching, social engagement, and status). Levontin (2018) proposes a motivation categorization that is tailored to citizen science, which includes 18 types of generic motivations that are present among citizen scientists across the whole spectrum of citizen science projects.

A common denominator among these works is the study object, i.e., participants already engaged in citizen science projects. Our study tries to close the relevant research gap in citizen science by exploring the motivations and viewpoints of the general public, who might not have been exposed to any citizen science activities yet. These inputs might extend the list of known motivations in citizen science and might improve the recruitment of new participants in citizen science projects.

RELATIONSHIP BETWEEN PERSONALITY TRAITS AND VOLUNTEERING

As personality is very important to understand human behavior, it might hold the key to one's decision to participate in volunteering and citizen science. Personality is known to be stable over several years, and the average personality change is minimal and does not vary significantly across age groups (Cobb-Clark and Schurer 2012). Recently there is a growing body of literature on the connection between personality and the quality and quantity of participants' contribution to volunteering and to citizen science. Ackermann (2019) studies the correlations between five personality traits and three types of volunteering (i.e., formal volunteering, informal volunteering, and online volunteering). This study concludes that extraversion is the main driving force behind volunteering activities, while the effects of other traits depend on the particular form of volunteering. This conclusion is in line with the results from Erez (2008), which indicate that extraversion has significant correlation to the understanding, social, and career motivations of VFI when people volunteer. In contrast, high neuroticism tends to discourage people from participating in formal volunteering activities (McCann 2017). Here, we try to gain further insights into the specific relationship between motivation and personality for the prospective intention to participate in citizen science.

METHODS

This study aimed to identify the most influential factors that affect the general public's participation in citizen science. We did this by inspecting self-reported likelihood of participation for a variety of citizen science tasks. A survey was prepared to capture the respondents' opinions on various characteristics of five sample citizen science projects, which represent the broad spectrum of contributory citizen science, as well as their personalities and general motivation for participating in citizen science. By analyzing the interdependences among the ways participants evaluated different aspects of the projects, the

personalities of participants, and their general motivations, we aimed to identify the most effective motivators for citizen science among the studied factors. The relationships among the building blocks of the study are presented in Figure 1.

THE DESIGN OF THE SURVEY

International Personality Item Pool personality test

The first part of the survey aimed to gauge the personality of the respondents, which served as the basis for studying their motivation for participating in citizen science. We chose a trait-based personality model rather than a type-based personality model, since the former is better suited to reliably measure correlations between personality traits and other characteristics. As a result, the Five-Factor model of personality from Digman (1990) was used to study the participants' five most typical personality categories, namely openness (i.e., intelligence, intellectual curiosity, creativity), conscientiousness (i.e., responsibility, seriousness), extraversion (i.e., happiness, confidence), agreeableness (i.e., friendliness, kindness) and neuroticism (i.e., the tendency towards sadness and emotional instability). As each personality trait is considered a spectrum rather than binary, these traits are estimated quantitatively. Among the available questionnaires designed for the Five-Factor model of personality, the International Personality Item Pool (IPIP) Big-Five Factor Markers was used to measure the respondents' personality traits as it offers an optimal balance between accuracy and speed of measurement. The IPIP personality test and other parts of the survey can be found in Supplemental Files 1 (English version) and 2 (German version).

Sample citizen science projects

Contributory citizen science is shown to be the most prevalent among the three types (i.e., contributory, collaborative, and co-created citizen science). In this type, participants contribute to the project's phase of data collection or data analysis, and the projects are designed exclusively by professional scientists (Bonney et al. 2009; Geoghegan et al. 2016). Therefore, it is worth examining the factors that encourage participants to take part in this type of citizen science. Given that most of the general public have not participated in citizen science before, it is mandatory to provide the respondents with a clear and comprehensive picture of the citizen science concept in general and of the contributory citizen science projects in particular, on the basis of which they can express their motivations and thoughts. Consequently, five contributory citizen science projects of different domains, participation modes, time requirements, and complexities were selected as examples, which jointly represent the broad spectrum of contributory citizen science at a suitable survey length and ensure an adequate level of background knowledge of citizen science among the respondents. Each sample project was described in detail using three different formats: textual description of each step of the project, images on the concrete action depicted in the text, and a video with subtitles showing how to follow the aforementioned steps.

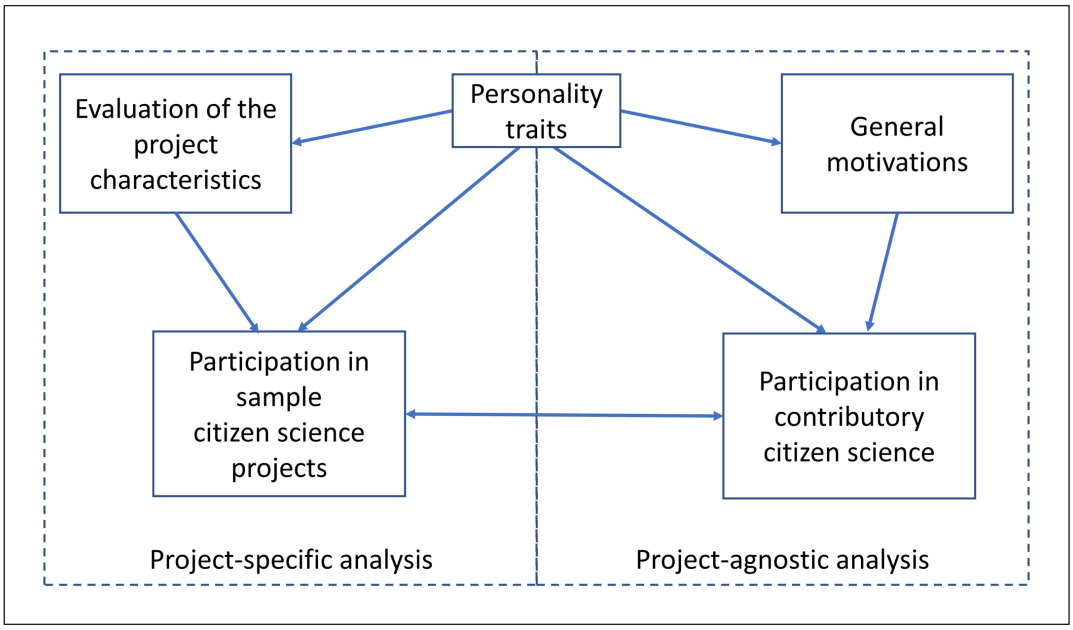

Figure 1 The conceptual model of the study.

Consequently, it is believed that respondents were able to understand the project adequately and estimate various characteristics of the project—which they were asked later in the survey (e.g., time requirement, complexity, degree of fun) (see Table 1). The full details of the five sample projects, as they appeared in the survey, can be found in Supplemental Files 1 (English version) and 2 (German version).

Following the standardized description of each sample project, which included the overview, aim, and detailed instructions on how to complete the project, we asked the respondents an identical set of questions, to generate common ground for comparison among the projects and for further analysis. The questions asked the respondents about the most important motivations for citizen science as addressed by relevant literature (Kragh 2016; Phillips et al. 2019), and began with a question on respondents' prior experience in citizen science, followed by questions on various characteristics of the project. Finally, respondents were asked to estimate the possibility of their future intention to participate in this project, later referred to as intention of participation (Table 1). In this study, all the questions except the first one featured a scale from 0 to 100 so that respondents could accurately answer.

The motivations in citizen science

This last part of the survey sought to collect the general motivations of the respondents for participating in contributory citizen science. This content was positioned last to ensure well-informed responses from the respondents as they are exposed to a diverse set of contributory citizen science examples in the second part. Respondents were asked to estimate the possibility of their intention to participate in contributory citizen science in general (represented by the variable Intention_CS). Then respondents were able to freely detail how they perceive the framework of citizen science in terms of motivations and barriers. Finally, a VFI questionnaire was used to measure the six main motivations (i.e., values, understanding, social, career, protective, and enhancement) of the general public should they intend to participate in citizen science later. We applied minor changes to the wording in the original VFI questionnaire while conserving its structure to adapt the questionnaire for studying the general motivation in citizen science.

Recruitment process

The survey was hosted in a surveying platform available for everyone without restrictions (e.g., login, participation code). Students were invited to participate through lectures, and invitations to the survey were sent among several mailing lists and groups on social media networks. In this process, special attention was paid to the geographic coverage of the survey. Invitations to the survey were circulated in social media groups of municipalities and cities across Germany. It took on average 30 minutes to complete the survey; pauses are allowed. No monetary reward was offered for completion.

In total, 209 individuals provided complete answers to the German version of the survey, which satisfied all our quality criteria (i.e., correct answers to the two attention-check questions, minimum completion time of at least 12 minutes). Table 2 details the demographics of these respondents, who come from 86 cities and municipalities in 15 out of 16 federal states in Germany. Table 2 shows

	QUESTION	CATEGORY	VARIABLE
1	Have you already participated in this project or a similar one in the same research area?	Prior experience	
2	The project is important to me personally and concerns me personally.	Project property	Importance_x
3	Participating in the project brings me fun and enjoyment.	Project property	Fun_x
4	Based on the task description, I believe that participating in this project is very time-consuming	Project property	Time_x
5	I am personally interested in the topic of this project.	Project property	Interest_x
6	By participating in this project, I can get in touch with other like-minded people.	Project property	Social_x
7	Based on the project description, I believe that it is difficult or stressful to provide accurate observations/measurements for this project.	Project property	Complexity_x
8	I would like to contribute to this area of research.	Project property	Contribution_x
9	I can acquire new knowledge by participating in this project.	Project property	Knowledge_x
10	How likely are you to participate in this project or projects of a similar nature in the future?	Future intention of participation	Intention_x

Table 1 The set of questions for each sample project and the associated variables. "x" represents a specific project (i.e., Project 1, 2, 3, 4 or 5).

		COUNT	PERCENTAGE
Gender	Male	75	35.88%
	Female	131	62.67%
	Others	3	1.43%
Age (mean = 31.68 ± 11.75 years, median = 28 years)	18–24	66	31.57%
	25–34	92	44.01%
	35–44	24	11.48%
	45–54	13	6.22%
	55–64	9	4.30%
	over 64	5	2.39%
Occupation	Students	115	55.02%
	Employee	79	37.79%
	Job seeker	3	1.43%
	Freelancer	4	1.91%
	Pensioner	8	3.82%
Experience in citizen science	Yes	16	7.65%
	No	193	92.34%

Table 2 Demographics of the 209 respondents who answered the German version of the survey.

that the vast majority of the respondents have not participated in citizen science, as they answered "No" to an earlier question on previous citizen science experience, located where a precise and understandable definition of citizen science was presented to aid in an accurate assessment of their involvement in such activities previously, including sample projects or similar citizen science projects.

DATA ANALYSIS

Participation in sample projects

The Cronbach's alpha of the five personality traits were computed, and they are all greater than .75. Therefore, the respondents' answers on personality traits were highly consistent, and the scores accurately represented their personality traits. Using multiple regression analysis, we sought to analyze the interdependence among the personality traits, the evaluation of project characteristics (i.e., variables in Table 1), and the intention of participating in each sample project. Specifically, we used the five personality trait scores as independent variables to predict the intention of participation. Similarly, we examined how the evaluation of project characteristics can predict the intention of participation. We then used the personality trait scores as predictors for the evaluation of the project characteristics. Based on these results, we sought to identify the common factors that significantly affect the intention of participation among all five projects. We also studied the differences in each project characteristic among the projects perceived by the respondents through the Friedman test and post-hoc analysis (i.e., Wilcoxon signed-rank tests with Bonferroni adjustment) to verify our selection of the sample projects. To study the role of gender in motivations to engage in citizen science, these analyses were repeated on the subgroups of female and male respondents. Additionally, Mann-Whitney U tests with Bonferroni adjustment were used to determine whether female and male respondents perceived the project characteristics differently.

Participation in contributory citizen science

At a more general level compared with a particular project, we examined the factors that encourage intention of participation in contributory citizen science (i.e., the variable Intention_CS). The factors in question are the five personality traits and the six general motivations discussed in the VFI questionnaire. The Cronbach's alpha for these general motivations are all greater than .72, suggesting a good internal consistency. We then studied the multiple regression equations that incorporate the aforementioned factors to understand their roles in affecting Intention_CS. The text typed by the respondents on the topic of motivations in and obstacles to citizen science were manually clustered into general motivations and general obstacles, respectively, with the former compared with the motivations addressed in our adapted VFI questionnaire. Specifically, we calculated the occurrence for each single word from the text input and focused on the single words with high occurrence. We then defined a few keywords for each text entry, and many keywords were based on the single words with high occurrence. These tags were then merged on the basis of their semantic relations and semantic similarities to form the final clusters.

RESULTS

In this section, we present the analyses of factors that affect the intention of participation in two different scopes: specific citizen science projects and contributory citizen science as a whole. This separation allows us to capture both minor details and general trends that are crucial to the participation of the general public in this type of citizen science. All statistical analyses were performed on the software IBM SPSS Statistics, Version 26.0.

MEASUREMENT OF RESPONDENTS' PERSONALITY TRAITS

Figure 2 shows the distribution of respondents' raw scores from each personality trait, which range from 10 to 50 based on the settings of the IPIP personality test. It is observed that the distribution of agreeableness, openness, and conscientiousness are left-skewed, which is in line with the observations reported in other studies with much larger sample sizes (Brown and Taylor 2015; Leonardi et al. 2020). Other details from the personality trait scores can be found in Supplemental File 3: Supplemental Table 1.

FACTORS THAT AFFECT INTENTION TO PARTICIPATE IN THE SAMPLE PROJECTS

Figure 3 shows the overview from 209 evaluations of the eight project characteristics across the five sample projects,

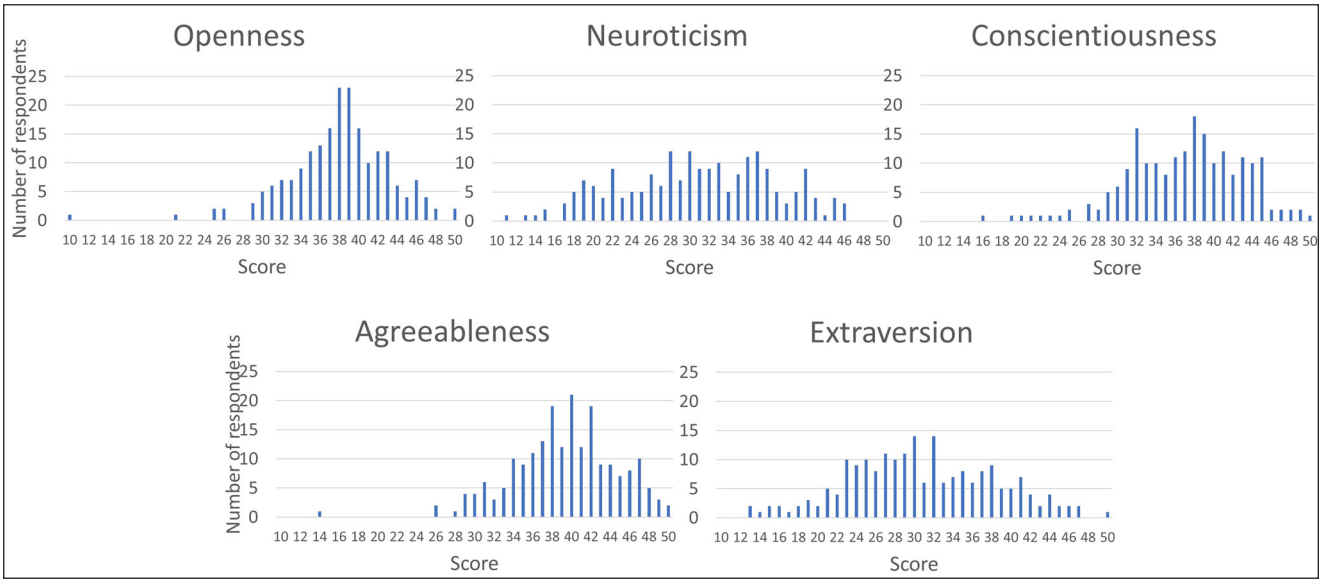

Figure 2 The score distribution of the five personality traits.

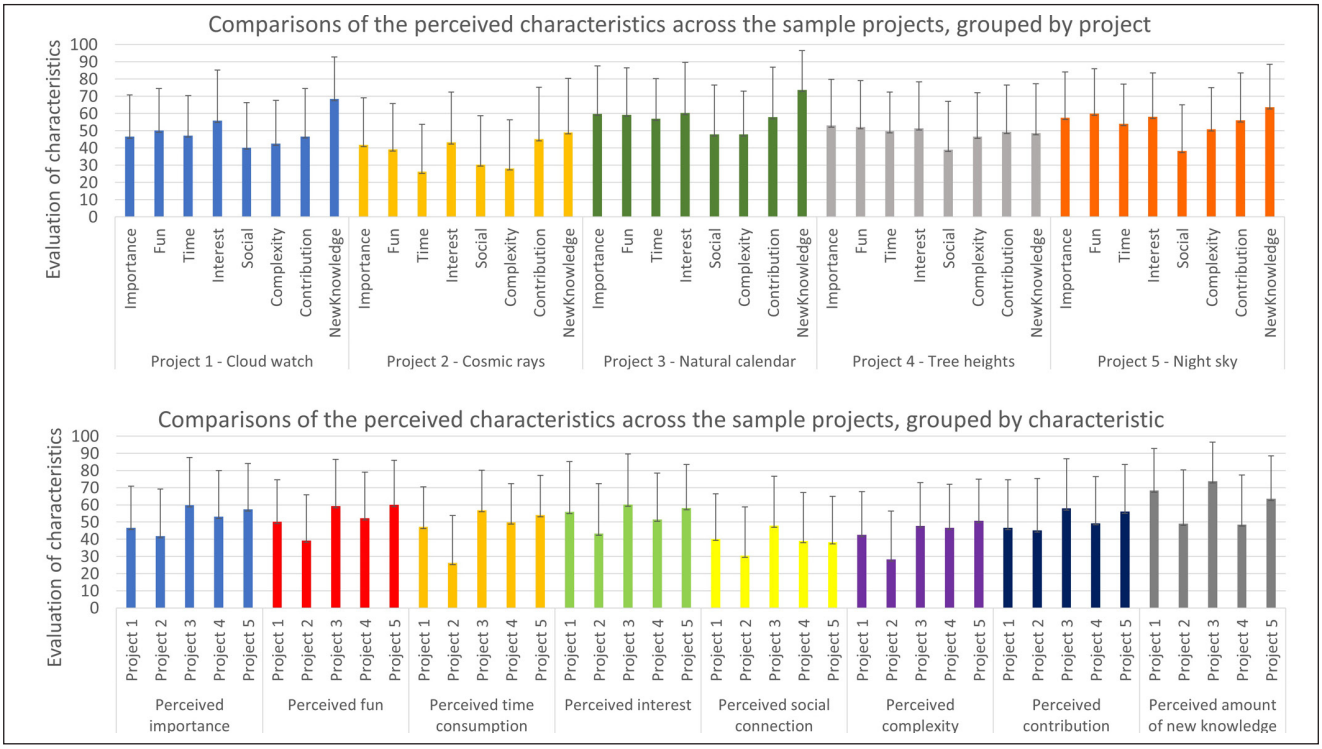

Figure 3 Comparison of the average evaluations of characteristics among the sample projects, grouped by project and by characteristic.

with each characteristic evaluated on a scale ranging from 0 to 100. For each characteristic, the five sample projects differed significantly from each other, which is confirmed by Friedman tests with significance level of 0.05 (Table 3). Given these significant differences, we performed post hoc analyses (i.e., Wilcoxon signed-rank tests with Bonferroni correction) for each characteristic to determine in which pairs of projects the differences occur. The post hoc analyses resulted in 53 pairs of projects (among 80 pairs of projects for 8 characteristics and 5 projects) in which there was a statistically significant difference concerning a characteristic under the strict requirement of the Bonferroni correction (i.e., significance level of .005 instead of the usual value of .05), which confirmed the diversity among the sample projects. The details of these post hoc analyses can be found in Supplemental File 3: Supplemental Table 2.

We then performed a multiple regression analysis using stepwise inclusion to study the predictive power of the independent variables (i.e., personality traits) on the dependent variable (i.e., intention of participation) for each sample project. The results show that there was no personality trait that could significantly predict the intention of participation in any of the projects. Only in Project 3, Natural calendar, was agreeableness the only moderately effective predictor, but the overall predictive power of this regression equation was very low ($R^2 = .075$).

Similarly, for each sample project, we studied the predictive power of the perceived project characteristics (i.e., the variables in Table 1) on the intention of participation. Table 4 indicates that some of these perceived characteristics of a project had significant effects on the intention of participation in that project. Specifically, the variable "Contribution_x" had a significant predictive power on the intention of participation in all five projects. Other variables such as Fun_1, Interest_2, Interest_3, Knowledge_4, and Fun_5 also effectively predicted the possibility an individual intends to subsequently participate in the corresponding projects. All these variables jointly explained a large proportion of the variability of the intention to participate in each project, with the minimum R^2 of .564 in Project 1 and all other R^2 greater than this value.

Finally, we examined how personality traits affect the evaluation of the project's eight characteristics, some of which (i.e., contribution, fun, knowledge, and interest) significantly predicted the intention of participation in the sample projects. The five personality trait scores were used to predict each project characteristic. In total, there are 40 regression equations covering eight characteristics of the five sample projects, which are detailed in Supplemental File 3: Supplemental Tables 3–10. Again, the personality traits had little predictive power on all the evaluation of the project characteristics, evident by the low value of R^2 in all regression results. Despite the low predictive power, it is worth noting that agreeableness stands out in all characteristics, except "Time" and "Complexity," across all five projects.

PROJECT CHARACTERISTICS	RESULTS OF THE FRIEDMAN TESTS
Interest	$\chi^2(4) = 53.54$, p-value < .001
Complexity	$\chi^2(4) = 121.91$, p-value < .001
Contribution	$\chi^2(4) = 52.30$, p-value < .001
Fun	$\chi^2(4) = 111.74$, p-value < .001
Importance	$\chi^2(4) = 127.65$, p-value < .001
Knowledge	$\chi^2(4) = 175.24$, p-value < .001
Social	$\chi^2(4) = 90.50$, p-value < .001
Time	$\chi^2(4) = 164.45$, p-value < .001

Table 3 The results of the Friedman tests for the differences among sample projects.

	PROJECT 1 CLOUD WATCH	PROJECT 2 COSMIC RAYS	PROJECT 3 NATURAL CALENDAR	PROJECT 4 TREE HEIGHTS	PROJECT 5 NIGHT SKY
Regression results	F(4,200) = 64.688 p-value < .001, $R^2 = .564$	F(2,202) = 178.761 p-value < .001, $R^2 = .639$	F(3,201) = 153.650 p-value < .001, $R^2 = .696$	F(3,201) = 166.578 p-value < .001, $R^2 = .713$	F(2,202) = 192.429 p-value < .001, $R^2 = .656$
Contribution	.460, p-value < .001	.647, p-value < .001	.350, p-value < .001	.583, p-value < .001	.610, p-value < .001
Social	.233, p-value < .001	/	/	/	/
Fun	.303, p-value < .001	/	.362, p-value < .001	.249, p-value < .001	.239, p-value < .001
Knowledge	–.114, p-value = .028	/	/	.098, p-value = .018	/
Interest	/	.194, p-value = .002	.190, p-value = .006	/	/
Time	/	/	/	/	/
Importance	/	/	/	/	/
Complexity	/	/	/	/	/

Table 4 The multiple regression analysis of the project characteristics on the intention of participation using stepwise inclusion (significance level .05). "/" means that the corresponding variable is not statistically significant.

FACTORS THAT AFFECT INTENTION TO PARTICIPATE IN CONTRIBUTORY CITIZEN SCIENCE

Through our adapted VFI questionnaire, the respondents gave different opinions on the general motivations in citizen science (Table 5), with highest average scores in the motivations values and understanding, followed by enhancement, career, social, and protective, respectively.

As the motivations for participating in the five sample projects were established earlier, we were interested in the prediction power of personalities and general motivations on the general possibility of the intention to participate in citizen science (i.e., Intention_CS). A multiple regression analysis with stepwise inclusion was performed to predict Intention_CS from the five personality traits. The result showed that agreeableness was the only significant predictor in this regression equation, which in overall has very weak predictive power on this probability ($F(1,203) = 5.041$, p-value = .026, $R^2 = .024$). Similarly, another regression analysis using the six VFI motivations as predictors for Intention_CS showed that *values* and *understanding* were the significant predictors, which overall have moderate predictive power on this dependent variable ($F(2,202) = 33.229$, p-value < .001, $R^2 = .248$). Finally, regression analyses indicated that personality traits have low predictive power on each of the six general motivations. The details of these regression equations can be found in Supplemental File 3: Supplemental Table 11.

We manually clustered the 577 text entries on "motivation for" and 443 text entries on "obstacle to" participation in contributory citizen science that were freely typed by the respondents; clusters were formed by carefully examining, comparing, and conceptualizing each of these entries. Table 6 details all the clusters formed at the end of this process.

As we differentiated two intentions (i.e., the future intention to participate in contributory citizen science in general and the future intention to participate in a sample project) in this study, it is crucial to examine the relationship between these probabilities. A correlation analysis indicated that the intention to participate in contributory citizen science (i.e., Intention_CS) highly correlates with the intention to

	VALUES	UNDERSTANDING	ENHANCEMENT	CAREER	SOCIAL	PROTECTIVE
Mean	3.56 ± 0.80	3.45 ± 0.72	2.95 ± 0.92	2.49 ± 0.96	2.12 ± 0.86	2.09 ± 0.87
Median	3.6	3.6	3.0	2.4	2.0	2.0
Cronbach's alpha	.81	.72	.83	.85	.81	.85

Table 5 Motivations of the respondents in a scale of 1 to 5, framed according to the modified VFI questionnaire. Cronbach's alpha is reported, along with the mean and median values, for each VFI motivation.

CLUSTER OF MOTIVATION	NUMBER OF ENTRIES	CLUSTER OF OBSTACLE	NUMBER OF ENTRIES
Support scientific research	140	High time consumption	128
New knowledge	104	Technical problem	65
Personal interest	65	Task complexity	48
Fun and enjoyment	50	(Lack of) motivation	44
Rewards	40	(Lack of) information or knowledge	43
Ease of participation	33	Other expenses	29
Social connection	30	Mobility, flexibility and weather	17
Environment and conservation	28	Data privacy	14
Curiosity	16	Lack of benefit or reward	13
Education	10	Forgetfulness	7
Hobby	7		
Importance	5		
Recognition and self-esteem	4		

Table 6 Major clusters of "motivation for" and "obstacle to" participation in citizen science, sorted by size of each cluster.

participate in the sample projects (i.e., Intention_x) among the 209 respondents, with the Kendall's tau-b correlation coefficients (τ_b) of .355, .277, .405, .364 and .329 for Project 1 to 5 (all p-values less than .001), respectively.

FURTHER ANALYSIS OF THE OBSTACLES TO PARTICIPATION

By analyzing the text inputs from the respondents, it was observed that the majority of them mentioned "High time consumption" as the foremost obstacle to their future participation in citizen science. Therefore, we sought to further examine the potential effects of the respondents' time estimation on their willingness to participate both in the sample projects and in contributory citizen science in general. However, in each sample project, the low values of the correlation coefficient τ_b between the variables Time_x and Intention_x (i.e., –.097, .068, –.159, –.001, and –.077 with p-value .044, .158, .009, .990 and .107 for Project 1 to 5, respectively) suggest that the respondents' estimation of completion time had little effect on their intention to participate in the project.

Based on the textual answers regarding the obstacles to participating in citizen science in general, the respondents were divided into two groups. Group 1 consisted of 119 respondents who cited time consumption as one of their perceived obstacles. Group 2 consisted of the other 90 respondents, who did not include time consumption as an obstacle. A Mann-Whitney U Test (with Bonferroni correction) was performed on the variables Intention_x and Intention_CS of the two groups (Table 7). These tests indicate that group 1 do not have a different intention of participation in citizen science from that of group 2, evident by the p-values larger than the Bonferroni-corrected significance level of .0083.

THE ROLE OF GENDER IN INFLUENCING THE RESPONDENTS' ENGAGEMENT IN CITIZEN SCIENCE

We repeated all our analyses on the female and male respondents to determine if gender plays any roles in the factors affecting the respondents' intention to participate in sample projects and in contributory citizen science in the future. Similar to the regression analysis on all respondents, it is observed that both female and male respondents considered the perceived contribution to science as the most important factor behind their intention to participate in the sample projects, followed by the perceived fun, perceived interest in the projects, and perceived social contacts, respectively (Supplemental File 3: Supplemental Tables 14 and 15). We used the Mann-Whitney U test with Bonferroni correction to look deeper into the comparison of these four important factors between two genders. Table 8 shows that in Projects 1, 2, 4, and 5, the male respondents' evaluations of the four factors do not differ significantly from those of the female respondents. In contrast, there are significant differences in the evaluation of perceived interest, fun, and contribution between female and male respondents in Project 3. Based on the mean ranks from Supplemental File 3: Supplemental Table 36, it can be concluded that female respondents rated the aforementioned factors higher than male respondents. Similarly, the intentions to participate in Projects 1, 2, 4, and 5 are not significantly different between the two genders, while in Project 3, female respondents showed a higher intention to participate in the future.

The intentions to participate in contributory citizen science between female and male respondents are broadly comparable, evident by the results of the Mann-Whitney U test with significance level .05 between their corresponding Intention_CS variables (Z = –.671, p-value = .502). Likewise, their evaluations of the six VFI motivations are not significantly different between the two genders (see Supplemental File 3: Supplemental Table 37). However, the female respondents' intention can be partially explained by the VFI motivations of *values* and *understanding* through a regression model with stepwise inclusion ($F(2,125) = 22.306$, p-value < .001, $R^2 = .263$), whereas no VFI motivations have significant predictive power on the male respondents' intention to engage in citizen science.

		INTENTION_1	INTENTION _2	INTENTION _3	INTENTION _4	INTENTION _5	INTENTION _CS
Group 1	Mean	44.10 ± 27.76	41.95 ± 30.43	49.83 ± 29.63	40.43 ± 27.58	51.61 ± 27.07	63.40 ± 24.98
	Median	50	50	51	42.5	53.5	70
Group 2	Mean	44.45 ± 27.22	42.91 ± 29.71	55.77 ± 28.79	48.23 ± 28.84	52.45 ± 26.91	61.2 ± 25.50
	Median	49.5	49.5	57	50	52.5	62.5
Mann-Whitney U test		z = –.118, p-value = .906	z = –.014, p-value = .989	z = –1.427, p-value = .154	z = –1.878, p-value = .060	z = –.026, p-value = .980	z = –1.130, p-value = .259

Table 7 Comparison of the intentions to participate between group 1 and group 2 using Mann-Whitney U tests with Bonferroni correction (significance level .0083). The intention indices range from 0 to 100.

Our analyses show that personality traits influence the evaluation of project properties and VFI motivations differently between female and male respondents. However, in general, the predictive power of personality traits on these factors is insignificant for each gender, which is evident by the absence of results or the low value of R^2 in the regression results (see Supplemental File 3: Supplemental Tables 18–35).

DISCUSSION

We targeted the general public, most of whom have no prior experience in citizen science, in this exploratory research. This was done to identify crucial factors that have the potential to motivate participants to eventually take part in citizen science projects. Ideally, this would be done by simultaneously organizing several citizen science projects that span various scientific domains, through which the general public's participation in these projects could be recorded and their most important motivations could be identified. As this, however, is unfeasible, we sought to measure the effectiveness of the potential factors for the possibility of the respondents' intention to participate in citizen science in the future. We acknowledge that this self-reported intention of future participation, given at present by the respondents, might not always lead to real participation in the future. However, it is assumed that there is a strong positive correlation between the respondents' future intention to participate in citizen science and their actual participation in the future. Furthermore, the former can be estimated through this study while the latter is difficult to observe and record in practice. Consequently, the respondents' self-reported intention to participate in the future was used in this study to identify the main factors that motivate their future participation.

Our statistical analyses confirmed that the sample projects differ significantly from each other regarding their characteristics. Despite these stark differences, it was observed that the perceived level of contribution to science (represented by the variables "Contribution_x") is the most essential factor for future participation among all projects, regardless of other factors such as the domain to which the projects belong and the participation mode (e.g., active and passive). The respondent's text inputs on perceived motivation in citizen science also confirmed this observation, as "support scientific research" was by far the most frequently mentioned motivation. Other characteristics, such as the perceived degree of fun and the perceived interest in the project, were also important as they together accounted for a significant proportion of the variability of the intention of participating in different projects (from 56.4% in Project 1 to 71.3% in Project 4, see Table 4). The respondents' text inputs also supported this observation as the most important clusters of motivation correspond to these characteristics. However, not all the characteristics were found to have direct impact on the participation, as importance did not appear in the regression equation. Gender usually does not influence the perception of project characteristics and the intention to join that project – with one notable exception for Project 3 (see Table 8). This exception might be explained by the domain and subjects of a project (e.g., flower buds, plants, shrubs, and bees in Project 3), which is considered more attractive by women (Szagun and Mesenholl 1993).

		PROJECT 1	PROJECT 2	PROJECT 3	PROJECT 4	PROJECT 5
Perceived interest	Z	–.492	–1.540	**–3.386**	–.600	–.284
	p-value	.623	.123	**.001***	.548	.777
Perceived fun	Z	–1.126	–.008	**–2.948**	–.434	–1.215
	p-value	.260	.994	**.003***	.664	.224
Perceived social contact	Z	–1.391	–1.243	–.773	–.048	–.472
	p-value	.164	.214	.439	.962	.637
Perceived contribution	Z	–.473	–.182	**–4.016**	–.683	–1.651
	p-value	.636	.856	**< .001***	.494	.099
Intention to participate	Z	–.568	-1.117	**–2.975**	–.672	–.253
	p-value	.570	.264	**.003***	.501	.800

Table 8 Comparison of the evaluation of important project characteristics and the intention to participate in the sample projects in the future between female and male respondents using Mann-Whitney U tests with Bonferroni correction (significance level .01). The significant differences are in bold and flagged with *.

Our findings are important as they shed light on the reasons why members of the general public with little experience in citizen science would consider participating in the sample projects. Irrespective of gender, they report to be most strongly motivated by their desire to contribute to science and by the prospect of fun and knowledge gained through their participation. Therefore, project organizers might incorporate this finding into their communication and recruitment strategy aimed at the public – and emphasize the dual gain for all parties involved: 1) Science can benefit 1) from the data support from the public and 2) from the enjoyment that the project might bring to the participants. We argue that examining the possible obstacles to participation is crucial in promoting citizen science to a wider audience. Interestingly, this study suggested that the respondents' perceived time consumption was not a significant barrier to their intention to participate in the sample projects as well as in citizen science in general, although time consumption is a well-known factor in the related literature (Geoghegan et al. 2016; Frensley et al. 2017; Cox et al. 2018). This observation contradicts with the respondents' answers on possible obstacles to participation in citizen science, in which time consumption is the first and most frequently mentioned obstacle. We believe that the respondents, especially those who cited time as an obstacle, usually thought that high time consumption would prevent their participation, but this perceived barrier was alleviated once the details of the sample projects were provided. At this moment, it might happen that the respondents could estimate the overall amount of time needed to complete a project through the given instructions; or the benefits of participating in the project (e.g., contribution to science, fun and enjoyment, new knowledge) outweigh their worry of time consumption. Either way, this contradiction suggests that communication is a crucial step in recruiting potential citizen scientists and lowering the hindrances for their participation. Apart from time consumption, other clusters of obstacles offer several directions in which citizen science can be improved and introduced to its audience. For instance, the cluster of "technical problems" (see Table 6) includes several complaints about the large number of stand-alone citizen science apps, which altogether occupy an excessive amount of storage on a smartphone. Therefore, a configurable citizen science app that can be reused across various projects could be well received by prospective participants. The clusters of "other expense" and "lack of benefit or reward" suggest that monetary incentives should be considered in the deployment of citizen science projects to compensate directly the claimed expenses from the participants and sustain their involvement.

Finally, personality traits were used as predictors for the intention to participate in sample projects and contributory citizen science in the future, but the results of the corresponding regression equations indicated that they had little effect. They also had weak predictive power on the general motivation to participate in citizen science. These findings contradict other studies that find that certain personality traits (e.g., extraversion, neuroticism) have significant effects on volunteer motivation and participation (Erez 2008; McCann 2017; Ackermann 2019). At the same time, our findings also suggest that citizen science is not reserved for those who have certain personality traits or certain gender. In other words, everyone can be a potential participant in citizen science provided that a project properly addresses their concerns. Contrary to personality traits, general motivations such as values and understanding were also effective, although to a lesser extent, in predicting intention to participate in citizen science. These two general motivations were also reported by actual citizen scientists as their most important motivations (Cox et al. 2018). In this study, there exists a noticeable accordance between these general motivations and the particular factors that positively affect future participation in the sample projects. Specifically, values includes the desire to contribute to scientific research, which is the most frequently cited motivation among the respondents. Similarly, understanding generally means the desire to get new knowledge and skills and to exercise one's own skills and abilities, which is exactly the variables "Knowledge_x" that were found to be significant in predicting the respondents' participation in the sample projects. Meanwhile, the general motivation of social and the variables "Social_x" were classified as insignificant motivators of the respondents in this study, which is also a conclusion from the work of Maund et al. (2020). We argue that the settings of the sample projects (e.g., individual tasks, online reporting) and the limited contacts with the project managers might be the reason for social's low rank among the general motivations.

LIMITATIONS OF THE STUDY

Because of the setting of this study, respondents did not participate in the sample projects while they answered our survey. Therefore, the lack of real exposure to sample projects might affect their evaluation of the projects' characteristics, although all details of the projects were given in three different formats. Additionally, our current wording of the VFI questionnaire, combined with the lack of prior participation in citizen science, might lead to inaccuracies in analyzing the respondents' general

motivations. For example, the current wording of the question "Participating in the project brings me fun and enjoyments" should be improved as follows: "I think that participating in the project would bring me fun and enjoyments." In this way, the latter might avoid a situation in which respondents who strictly follow the wording of the former might find this question irrelevant, as they have not participated in citizen science projects. Consequently, we hereby note that our results of the VFI questionnaire should be interpreted with caution. Although it is believed that the respondents' future participation in sample projects can be approximated by their self-reported intention to participate in sample projects, certain distinctions remain. These potential limitations should be considered when interpreting the results and conclusions of this study. Furthermore, we obtained a sample that has an uneven proportion of profession and age. Therefore, there might exist biases in the evaluation of the project characteristics and the general motivations in the VFI questionnaire. To solve this issue, a larger sample of respondents that conforms to the general profession and age proportion of Germany would be required so that the sample properly represents the general public.

CONCLUSION

It is vital to understand the factors that strongly affect the general public's decision to participate in contributory citizen science, as the general public is a massive group of people who likely have not taken part previously. Based on a sample of the general public in Germany, we conclude that the desire to contribute to science, the fun and new knowledge gained, and the personal interest in the projects, respectively, are the most influential drivers for an individual's intent to participate in sample projects, which serves as an indicator of the actual participation in the future. In general, values and understandings are the main motivations for intent to participate in contributory citizen science. Meanwhile, gender and especially personality traits have negligible effects on these intentions. While time consumption is often thought of as a major obstacle to participation among the respondents, this factor did not significantly reduce their intention to participate in the five sample projects. These findings might help the project organizers to design their projects and to plan communication and recruitment strategies to maximize participation of the general public. Further extension and replication of this study might be needed to confirm these findings in other types of citizen science and in other countries with different cultural and socioeconomic backgrounds.

SUPPLEMENTARY FILES

The Supplementary files for this article can be found as follows:

- **Supplemental File 1.** The English version of the survey. DOI: https://doi.org/10.5334/cstp.502.s1
- **Supplemental File 2.** The German version of the survey. DOI: https://doi.org/10.5334/cstp.502.s2
- **Supplemental File 3.** The detailed statistical and text analyses. DOI: https://doi.org/10.5334/cstp.502.s3

ETHICS AND CONSENT

This study was approved by German Aerospace Center with reference number 2020-037.

COMPETING INTERESTS

The authors have no competing interests to declare.

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