CITIZEN SCIENCE:
THEORY AND PRACTICE

Standardizing the Assessment of Citizen Scientists' Motivations: A Motivational Goal-Based Approach

RESEARCH PAPER

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ABSTRACT

Understanding volunteers' motivations to participate in Citizen Science (CS) projects is essential for these projects' effective management and success. Many studies have investigated citizen scientists' motivations, but only a few have used a theory-based approach to provide a standardized methodology to measure CS motivations. The current research aims to take the literature a step further by developing and applying a general, standardized, theory-based framework of CS motivation and a CS motivation scale (CSMS) that can be used to assess volunteers' motivations across diverse CS projects. The CSMS comprises 58 items corresponding to 15 motivational categories. It is grounded in Schwartz's theory of basic human values, while incorporating the wealth of empirical knowledge on citizen scientists' motivations. We administered the scale to three separate samples of either Dutch or Hebrew-speaking participants who volunteered for three CS projects. Analysis of participants' ratings of their motivations supported our theoretical framework, showing that 13 of the scale's 15 motivational categories fell into 4 higher-order motivations, which correspond to Schwartz's theory of values: openness to change, self-enhancement, continuity (conservation), and self-transcendence. Results further provide concrete insights into CS participation behavior, showing that certain motivations (including help with research, benevolence, and self-direction) were consistently among the most important motivators for participation across CS projects. Finally, we found that prioritizing certain motivations can also predict participation behavior (e.g., duration of participation and willingness to participate in additional volunteering activities). The CSMS is a new tool that can be applied across projects spanning diverse domains and populations, advancing and standardizing the growing literature on CS motivations.

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INTRODUCTION

The success of citizen science (CS) projects is contingent on the willing participation of citizen volunteers. In general, it is well established that citizen scientists may derive benefits from their participation in CS projects (e.g., new knowledge, the opportunity to reconnect with nature, or the sense that one is impacting policy; Guiney and Oberhauser 2009; Devictor, Whittaker, and Beltrame 2010; Schuttler et al. 2018; Davis, Ramirez-Andreotta, and Buxner 2020). However, for researchers to effectively attract and retain participants, knowledge of these benefits is not sufficient; rather, CS researchers need to understand the motivational goals that drive volunteers to choose to contribute their time and energy to CS projects in the first place (Clary and Snyder 1999; Rotman et al. 2012; Reed et al. 2013; Wright et al. 2015). Indeed, an extensive stream of research has sought to shed light on the motivations of CS volunteers (e.g., Bonney et al. 2009, Bonney et al. 2014; Nov, Arazy, and Anderson 2011; Rotman et al. 2012; Maund et al. 2020; West et al. 2021). For instance, a recent study that surveyed environmental citizen scientists in Great Britain has identified six different types of participants groups based on motivations to participate (West et al. 2021). However, currently, there is no standardized tool to measure motivations to participate in various CS projects (Robinson et al. 2021). The current research aims to further the literature by proposing a general, theory-based, top-down framework of volunteers' motivations to participate in citizen science. We integrate this framework with a bottom-up review of empirical research to develop a comprehensive scale of CS motivation (the CSMS) that can be used across different types of CS projects.

To date, studies have revealed diverse motivations for CS participation, which vary across individuals and different types of projects. In some cases, volunteers are motivated primarily by an interest in or concern for the environment and wildlife (Alender 2016; Frensley et al. 2017; Ganzevoort et al. 2017; Maund et al. 2020; West et al. 2021) or by the opportunity to spend time in nature (Ganzevoort et al. 2017; Koss et al. 2009; Johnson et al. 2014). In other cases, volunteers are motivated more generally by the desire to contribute to research (Land-Zandstra, Devilee, et al. 2016; Maund et al. 2020, West et al. 2021) or by interest in the topic of a specific project or science in general (Land-Zandstra, van Beusekom, et al. 2016; Domroese and Johnson 2017) (see Supplemental File 1: Supplemental Table 1 and Supplemental File 1: Supplemental Table 2 for a list of papers measuring motivations for CS and representation of items).

Many of the items currently in use to measure participants' motivations tend to be grounded in the features of the specific projects at hand. For example, in an extensive study of the motivations of participants in the Galaxy Zoo project (a CS project for morphologically classifying large numbers of galaxies; Raddick et al. 2010; Raddick et al. 2013), researchers created a list of potential motivations based on participants' responses to an open question on the project's forum ("What makes Galaxy Zoo interesting?") coupled with in-depth interviews. The researchers then developed a survey based on these motivations. Approaches such as this one can generate exhaustive lists of motivations for a specific project. Still, these motivations are not necessarily applicable to other projects and do not lead to a broad understanding of volunteers' motivations to participate in citizen science.

Theory-driven approaches can produce more general models of citizen scientists' motivations. Several studies have adopted such approaches, relying on different frameworks. Some used Batson, Ahmad, and Tsang's (2002) framework of motivations for community involvement (Rotman et al. 2012; Beza et al. 2017), whereas others used Ryan and Deci's (2000) framework of intrinsic and extrinsic motivations (Nov, Arazy, and Anderson 2014; Curtis 2015; West et al. 2021), or Ajzen's theory of planned behavior (Wehn and Almomani 2019). The most widely used model of motivations is the Volunteer Functions Inventory (VFI; Clary and Snyder 1999), which identifies six motivations categories (Rutherford et al. 2019). Nevertheless, in those studies, the process of model development and the corresponding motivational questionnaires were based mainly on existing CS motivations; that is, on bottom-up model development. As such, some top-down theory-driven motivational goals may have been unintentionally excluded. Furthermore, measured categories in those studies are neither exhaustive nor exclusive, and it is unclear how they interrelate (Shye 2010).

Our study addresses the shortcomings of current research on citizen scientists' motivations by proposing a general and comprehensive motivation scale that integrates both a universal motivation theory and the extensive domain knowledge that has accumulated over the years. Our scale is based on Schwartz's theory of basic human values (Schwartz 1992; Schwartz et al. 2012). Next, we present an overview of this theory.

THEORETICAL FRAMEWORK: SCHWARTZ'S THEORY OF BASIC HUMAN VALUES

Schwartz's theory of basic human values (Schwartz 1992) identifies a set of 10 broad values that all individuals share (Schwartz et al. 2012 further refined the classification into 19 values). A value is a guiding principle in people's lives

or a broad life goal that people consider important, such as security or self-direction. The set of values is ordered according to their importance for each individual, and the order can differ across individuals. In Schwartz's model, each value is underpinned by a set of motivations, and the values are arranged in a circle according to the relationships between their corresponding motivations (Figure 1). Specifically, values with conflicting motivations are located opposite each other, and values with compatible motivations are located alongside each other (Schwartz 1992). Schwartz (1992) further suggested that the ten values can be classified into four higher-order groups, constituting two bipolar dimensions (Figure 1). The first dimension comprises the opposing higher-order values of self-transcendence versus self-enhancement. The motivations to transcend selfish interests to benefit others' well-being (self-transcendence: universalism and benevolence) are contrasted with motivations to enhance selfish interests (self-enhancement: power, achievement, and sometimes hedonism). The second dimension comprises openness to change versus conservation. The motivation for change (openness to change: self-direction and stimulation, and sometimes hedonism) is contrasted with the motivation to keep things as they are (conservation: security, tradition, and conformity). Importantly, this circular structure of values (Schwartz 1992) was found to be universal and has been supported in more than 200 samples in more than 80 countries (Sagiv et al. 2017) and can be used to develop other motivational concepts (e.g., goal orientations, Levontin and Bardi 2018). As such, developing a scale to measure CS motivations based on values theory should lead to a scale applicable to most CS projects across the world.

Next, we describe the construction of the CS motivation scale (CSMS). Our objective was to develop a novel scale to measure CS motivations based on values theory and the items already in use in the CS literature. We then illustrate the use of the CSMS to assess citizen scientists' motivations and to test the CSMS validity in three CS projects in different domains and countries. In doing so, we show CSMS's compatibility with the underlying theoretical framework, and we also illustrate its practical benefits—showing how the CSMS can be used to derive concrete and general insights about citizen scientists' motivations, to compare these motivations across projects from different CS domains, and to predict participation behavior.

MATERIALS AND METHODS

DEVELOPMENT OF THE CS MOTIVATION SCALE

In developing our CSMS, we sought to create categories of motivations for CS participation that would be derived from the theoretical framework of basic human values (Schwartz 1992; Schwartz et al. 2012) while simultaneously capturing as many items as possible from scales used in previous studies of CS motivation. We carried out a three-step process to meet this objective.

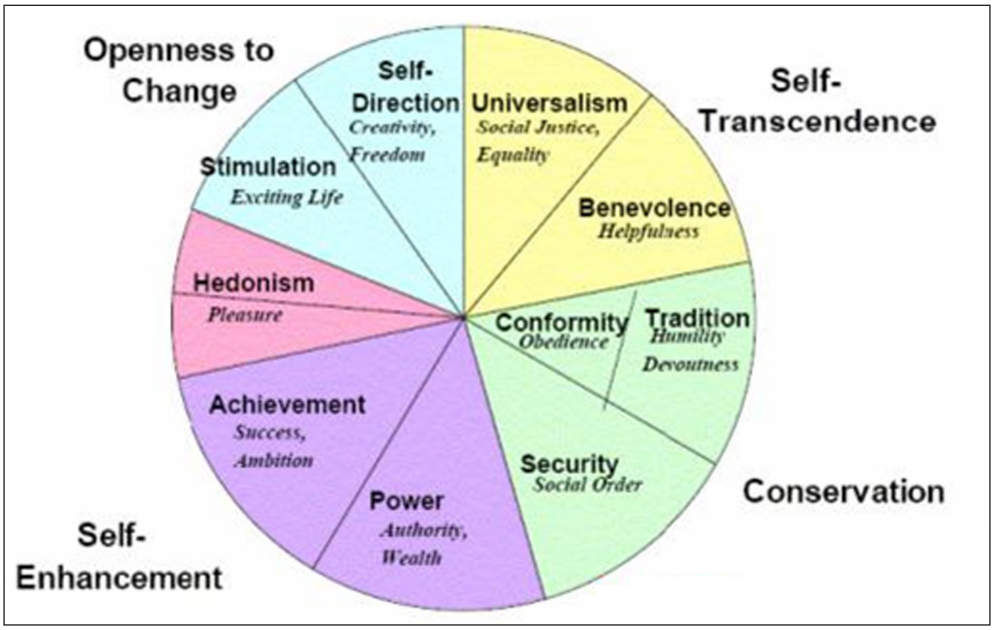

Figure 1 The set of ten values all individuals share according to the theory of basic human values (Schwartz, 1992) and their corresponding four higher-order values, which constitute two bipolar dimensions.

Step 1: Identifying relevant studies

Our first step was to conduct a comprehensive scientific literature review for papers that explored volunteers' motivations to participate in CS projects. To this end, we relied on a previous systematic review of CS theory and methods undertaken by Follett and Strezov (2015). Follett and Strezov's (2015) review covered 888 peer-reviewed papers published until 2014. They classified these papers into ten categories, including a Motivation/Effects category that included 53 papers; we considered these papers candidates for relevant research on citizen scientists' motivations. Next, following Follet and Strezov's (2015) methodology, we identified 72 additional papers from 2015 and 2016 that discussed motivations to participate in CS. We carefully read all 125 papers, searching for relevant empirical quantitative and qualitative information on CS motivations. We identified 32 papers that contained such information. Finally, we used Google Scholar (2019) to identify papers or reports citing these 32 papers. This search yielded a list of 1,636 sources, which we then reviewed following the same procedure described above. This step yielded 10 additional papers. Given our careful review process, we believe that these 42 papers adequately represent the CS motivation types and may serve as a sound basis for developing our scale.

Step 2: Harvesting and classifying motivation items

At the second stage, three researchers served as judges and read the 42 papers that included relevant data about motivations for CS, and they harvested motivation items (e.g., "I want to learn," "I strive to challenge myself") from quantitative surveys (copying the items verbatim) or from interviews (extracting items and revising them). All three judges read all 42 papers, and when they had disagreements, they discussed them. Overall, the judges harvested 280 unique items from 32 papers for which quantitative surveys or interviews were available; 10 of the 42 papers did not include any motivational items (Supplemental Tables 1 and 2).

Next, we grouped the harvested items into 15 motivational categories (Table 1). To define these motivational categories, we first turned to Schwartz's

MOTIVATIONAL CATEGORY	DEFINITION IN TERMS OF MOTIVATIONAL GOALS	EXAMPLE OF A CS ITEM
Self-direction	Independent thought and action—choosing, creating, exploring	"I am interested in the topic of this project."
Stimulation	Excitement, novelty, and change	"I strive to challenge myself."
Hedonism	Pleasure and sensuous gratification	"I want to have fun."
Achievement	Personal success through demonstrating competence according to social standards	"It's an opportunity to perform better than others."
Power	Power through exercising control over people, material, and social resources	"I want to gain recognition and status."
Face	Security and power through maintaining one's public image and avoiding humiliation	"I want to enhance my reputation."
Security	Safety, harmony, and stability of society, of relationships, and of self	"I want to live in secure surroundings".
Conformity and tradition	Restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms	"Other people I know are participating."
Benevolence	Preservation and enhancement of the welfare of people with whom one is in frequent personal contact	"I want to contribute to my community."
Universalism-social	Commitment to equality, justice, and protection for all people	"I want to make the world a better place."
Universalism-nature	Preservation of the natural environment	"I want to protect the environment."
Routine*	Everyday, ordinary, and regular	"I was doing this activity anyway."
Social expansion*	Expand social groups, create and belong to a new community, meet new people	"I want to be part of this volunteers' community."
Help with research*	Contribution to science	"I want to contribute to science."
Teaching*	Providing an educational opportunity to others	"I want to provide learning opportunities to others."

Table 1 Definition of the 15 motivational categories measured in the citizen science motivation scale (CSMS) and examples of CS items. The first 11 categories are theory driven and represent basic values based on Schwartz (1992) and Schwartz et al. (2012), whereas the last four (marked with *) are data-driven categories based on previous CS research.

framework (Schwartz 1992; Schwartz et al. 2012) and defined 11 categories, each corresponding to a basic value (Table 1). For each motivational item, we then identified the motivational category to which it corresponds (see Table 1 for examples). Notably, each of these 11 motivational categories was represented by at least one item; some were represented by many items (suggesting that these categories may be particularly relevant to CS research and many CS projects). Some of the motivation items did not correspond to any of the values proposed by Schwartz (1992; 2012). We classified these motivations into four additional categories (Table 1): participation as part of a routine; the goal of social expansion (that is, expanding one's social groups, creating and belonging to new communities, and meeting new people); the goal to help with research and contribute to science; and the motivation to teach (provide an educational opportunity to others).

Step 3: Formulation of the scale

Finally, we developed the CSMS from the harvested items in each of the 15 categories (Supplemental File 1: Supplemental Table 3). Each scale item was formulated to represent as many harvested items as possible while closely reflecting the broader motivational goals associated with its category. The final version of the CSMS consisted of 58 items corresponding to 15 motivational categories, with 2 to 7 items in each category (Supplemental Table 3). Our analysis suggests that 13 of the 15 categories can be further classified into four higher-order motivations that are compatible with the higher-order dimensions identified by Schwartz and colleagues (2012): openness to change; conservation, which we hereafter call continuity to differentiate from nature conservation, self-enhancement, and self-transcendence (Supplemental Table 3).

The CSMS scale was translated into different languages to enable comparison across countries. We used the scale's English, Dutch, and Hebrew versions in this study. Three judges with proficient English and either Hebrew or Dutch separately translated the items from English into Hebrew or Dutch. Next, three judges with the same proficiency used the back-translating process to back-translate the items from Hebrew or Dutch into English (Brislin 1970). The CSMS scale is available for public use (Levontin, Gilad, and Chako 2018). Researchers are encouraged to use the complete list of 58 items. If a shorter scale is preferred, researchers may choose the items most relevant to their project from the 58 items. We recommend, however, that each category be represented with at least two items. In the three-part empirical study reported in what follows, we used both the complete and shortened versions of the CSMS.

APPLICATION AND VALIDATION OF THE CSMS: EMPIRICAL STUDY

PARTICIPANTS AND PROCEDURE

To demonstrate and validate the CSMS and, more broadly, to provide new insights into citizen scientists' motivational goals, we administered different versions of the CSMS (complete or shortened) to volunteers in three different continuous, long-term CS projects, elaborated below. Collectively, the samples consisted of 754 citizen scientists from two countries. In each case, participants responded to each item by indicating, on a 5-point Likert scale (1 = "not at all"; 5 = "very much"), the extent to which that item was an important reason for their participation in the CS project (Supplemental Table 3).

Sample 1: Backyard nature observation project

The first sample included 372 citizen scientists participating in a backyard nature-observation project in the Netherlands (68.3% female; M_{age} = 60.29, *SD* = 10.54). In this project, citizen scientists monitored different kinds of plants, animals, and insects in their backyards year-round. Participants were free to select one or more species of interest, and they were asked to enter counts of these species each week throughout the year. A link to the Dutch version of the CSMS (including all 58 items) was sent in an email newsletter in February 2019 to all the project's volunteers. Of the project's 14,000 volunteers, 40% usually opened the newsletter, and around 500 responded to a yearly survey of the project; our sample of 372 was in line with the latter number. In addition to responding to our survey, participants were asked to report the year of their initial participation.

Sample 2: Bird counting project

The second sample included 160 volunteers of a backyard bird-counting project aimed at monitoring trends in common bird populations in Israel (40.8% female; M_{age}= 49.15, *SD* = 5.98). As part of the project, volunteers were asked to select a place near their home and spend about ten minutes outdoors, identifying and counting birds (Colléony and Shwartz 2020). Using a bird-guide page, volunteers wrote the names and the numbers of each species they saw. A link to the Hebrew version of the CSMS, which included 40 of the 58 items (covering all 15 categories; see Supplemental File 1: Supplemental Table 4, for the chosen items from the English version), was sent by email in May 2018 to approximately 1,200 volunteers. As in sample 1, participants were also asked to report the year of their initial participation to the best of their recollection.

Sample 3: Quality-of-life improvement project

The third sample included 222 volunteers in a quality-of-life improvement project intended to create change in public sectors in Israel (59.9% female; M_{age} = 37.11, *SD* = 10.84). In this project, volunteers used their smartphones to respond to surveys on topics such as education, healthcare, and transportation, to help improve the quality of life for fellow citizens. Answering the surveys was possible at any location and time. A link to the Hebrew version of the CSMS that included 36 out of the 58 items, corresponding to 13 out of the 15 categories (excluding face and universalism-nature; see Supplemental Table 4 for chosen items) was sent by email in April 2019 to about 1,000 volunteers. In addition to responding to the survey, participants were also asked to report how they would like to continue to be active in this citizen science volunteers' community by choosing as many activities as they wished out of five possible activity types (i.e., answering questionnaires, participating in in-person experiments or online experiments, receiving resources about behavioral economics, and attending community events). We summed up the number of chosen activities for each volunteer to create an index of future participation.

ANALYSIS STRATEGY

We first present the average rating for each motivational category for each sample, highlighting the most and least important motivations in the project (Table 2). Next, we carried out a confirmatory procedure of the structure of relations among motivational categories and its correspondence to Schwartz's (1992) circular motivational continuum (Schwartz et al. 2012) using multidimensional scaling (MDS) analysis (Borg and Lingoes 2012; Levontin and Bardi 2019). We used MDS Proxscal analysis with Euclidean distance measures and the inter-correlations among the centered variables as the data. We specified an ordinal MDS, with the primary approach to ties and a Torgerson initial configuration. Results are counted as a good representation of the data the closer the stress measures are to 0, and the closer the DAF (dispersion accounted for) and Tucker's coefficient of congruence are to 1.

Finally, we used stepwise regressions (with a p = .05 entrance criterion and a p = .10 exit criterion) to determine the categories of motivations that best predict various measures of participation behavior. In samples 1 (backyard nature-observation project) and 2 (bird-counting project), the dependent variable was the longevity of participation,

MOTIVATIONAL CATEGORY	MEAN (SD)		
	SAMPLE 1	SAMPLE 2	SAMPLE 3
Self-direction	**3.71 (.77)**	**4.07 (.91)**	**4.16 (.59)**
Stimulation	3.15 (1.04)	3.56 (1.07)	3.81 (.94)
Social expansion	2.65 (1.08)	2.76 (1.31)	3.64 (1.14)
Hedonism	**3.90 (.73)**	3.91 (.88)	3.42 (.67)
Achievement	*1.28 (.54)*	*1.79 (1.27)*	*2.49 (1.50)*
Power	*1.51 (.65)*	*1.83 (.93)*	*1.92 (.88)*
Face	*1.66 (.86)*	*2.09 (1.17)*	--
Routine	3.30 (1.01)	3.16 (1.07)	*2.46 (.98)*
Conformity	*1.51 (.77)*	*1.88 (.94)*	*1.32 (.58)*
Benevolence	**4.02 (.81)**	**4.24 (.75)**	**4.07 (.78)**
Universalism-social	3.67 (.85)	**4.19 (.86)**	**4.19 (.70)**
Universalism-nature	**4.61 (.54)**	**4.69 (.62)**	--
Help with research	**4.25 (.82)**	**4.30 (.87)**	**4.11 (.78)**
Security	3.64 (1.41)	3.52 (1.37)	**3.84 (1.08)**
Teaching	3.48 (1.10)	3.77 (1.16)	3.63 (1.20)

Table 2 Mean scores (SD) of motivational categories for participation in the three CS projects: backyard nature observation (sample 1), bird counting (sample 2), and quality-of-life improvement (sample 3). Each sample's five **top-rated** motivational categories are **in bold**; the *bottom* four are in grey *italic*.

calculated according to participants' indications of the dates on which they began volunteering. In sample three (the quality-of-life improvement project), the dependent variable was the willingness to participate in additional volunteering activities (measured as the number of activities participants indicated they would like to participate in). All motivations were simultaneously entered into the regression, which returned the combination of motivations that best predict the dependent variable, such that other motivations are redundant to the prediction of the dependent variable.

RESULTS

AVERAGE MOTIVATION RATINGS FOR EACH CATEGORY

Table 2 presents, for each sample and each motivational category, participants' mean ratings of the extent to which that category was important in motivating their participation in the specific CS project. Overall, we observe that the wish to help with research, benevolence, and self-direction appears among the top five most important motivators across all three projects. In contrast, power, achievement, and conformity are consistently among the lowest-ranked motivations. The only motivation that was ranked differently between the three projects was hedonism.

Sample 1: Backyard nature observation project

The results of the MDS analysis for sample 1 are presented in Figure 2a. The results are a good representation of the data (Normalized raw stress = 0.0162). These results are generally aligned with our theoretical framework such that, in most cases, motivational categories corresponding to a particular higher-order motivation (Schwartz 1992; Schwartz et al. 2012) emerged in proximity to one another. Specifically, motivational categories of openness to change—self-direction, stimulation, and hedonism (Schwartz 1992)—emerged near one another (in the middle of the space). Notably, social expansion, a category we identified based on our data, also emerged as belonging to openness to change. Similarly, the motivational categories corresponding to self-enhancement—achievement, power, and face—emerged close to one another on the left side of the space.

The motivational category of conformity, corresponding to continuity, emerged at the bottom of the space. Moreover, the category of routine identified in this research emerged in proximity to conformity, suggesting that it also corresponds to continuity. Security, which according to Schwartz (1992) is related to the higher-order motivation of continuity (i.e., conservation), emerged separately, at the top of the space. The self-transcendence motivations of benevolence, universalism-social, and universalism-nature emerged close to each other on the right side of the space, together with the data-driven category of help with research. Finally, the data-driven motivational category of teaching emerged as a separate category at the bottom of the space.

The spatial relationships across higher-order motivations were also generally aligned with our theoretical expectations. Specifically, as expected, openness-to-change motivations emerged opposite continuity motivations, and self-enhancement motivations emerged opposite self-transcendence motivations. The motivational category of teaching emerged between continuity and self-transcendence motivations. The motivational category of security emerged close to openness-to-change motivations, suggesting that the meaning of the security motivation for the volunteers in this project may differ from Schwartz's conceptualization. Correlations between motivational categories for sample 1 (alongside their reliability scores) are presented in Supplemental File 1, Supplemental Table 5.

Sample 2: Bird-counting project

The results of the MDS analysis for sample 2 are presented in Figure 2b. As for sample 1, these results are a good representation of the data (Normalized raw stress = 0.027). In general, the results of this analysis were similar to those of sample 1 and were aligned with our theoretical framework, such that motivational categories belonging to the same higher-order motivation emerged in proximity to one another. The openness-to-change motivations of self-direction, stimulation, and hedonism—as well as social expansion—emerged close to each other in the middle of the space. The self-enhancement motivations of achievement, power, and face emerged on the left side of the space. The continuity motivation of conformity emerged at the bottom-left part of the space, together with routine. The self-transcendence motivations of benevolence, universalism-social, and universalism-nature—as well as help with research—emerged close to one another in the top right part of the space. Security emerged at the bottom of the space, and teaching emerged in the middle of the space.

As with sample 1, the spatial relationships across motivational categories were generally aligned with our theoretical expectations. Specifically, as expected, openness-to-change motivations emerged opposite continuity motivations, and self-enhancement motivations emerged opposite self-transcendence motivations. In this analysis, unlike in sample 1, security emerged between continuity and self-transcendence motivations,

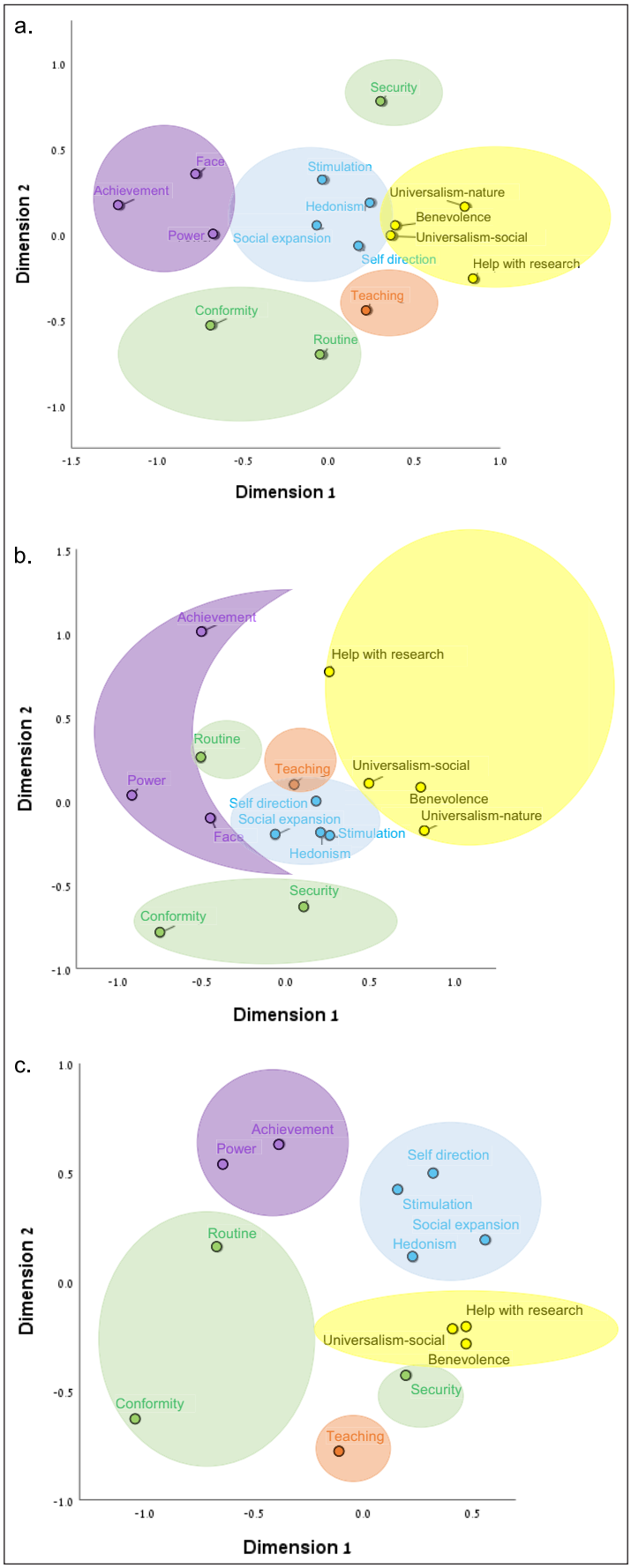

Figure 2 Results of multidimensional scaling (MDS) analyses of citizen science motivations in a two-dimensional space for sample 1, (**a**) backyard nature observation; for sample 2, (**b**) bird counting; and for sample 3, (**c**) quality-of-life improvement.

and teaching emerged close to the openness-to-change motivations. Correlations between motivational categories for sample 2 and reliability scores are presented in Supplemental File 1: Supplemental Table 6.

Sample 3: Quality-of-life improvement project

The results of the MDS analysis for sample 3 are presented in Figure 2c. As in samples 1 and 2, the results were a good representation of the data (Normalized raw stress = 0.0285), and the spatial relationships observed among motivational categories were generally aligned with our theoretical expectations. Specifically, the openness-to-change motivations of self-direction, stimulation, and hedonism—as well as social expansion—emerged close to one another at the top right side of the space. The self-enhancement motivations of achievement and power emerged close to each other at the top of the space. The continuity motivation of conformity, in addition to routine, emerged on the left side of the space. The self-transcendence motivations of benevolence and universalism-social—as well as help with research—emerged near one another at the bottom right side of the space. The motivation for security emerged at the bottom right side of the space, and the motivation for teaching emerged relatively at the bottom of the space.

Likewise, as expected, openness-to-change motivations emerged opposite to continuity motivations, and self-enhancement motivations emerged opposite to self-transcendence motivations. Security and teaching motivations emerged between continuity and self-transcendence motivations. Correlations between motivational categories and reliability scores are presented in Supplemental File 1: Supplemental Table 7.

PREDICTING PARTICIPATION BEHAVIOR

For samples 1 and 2, we used stepwise regressions to evaluate the associations between participants' ratings of motivational categories and their duration of participation. The results for sample 1 (mean duration of participation: 3.02 years, *SD* = 1.59) suggest that routine and benevolence best predict the duration of participation (Table 3a). The results for sample 2 (mean duration of participation: 4.95 years, *SD* = 4.93) suggest that routine and universalism-nature as positive predictors and stimulation as a negative predictor best predict duration of participation (see Table 3b). For sample 3, we used stepwise regression to evaluate participants' willingness to participate in additional volunteering activities (mean number of activities: 3.82, *SD* = 1.06). Results suggest that self-direction and social expansion best predict the willingness to participate (Table 3c).

GENERAL DISCUSSION

Engagement in CS projects is evergrowing, helping to answer real-world scientific questions and emerging as a powerful practice that can inform policy (Turbé et al. 2019). Participants are at the heart of these projects, and therefore understanding their motivations is key to the success of any CS project (Lotfian et al. 2020). A growing body of literature examining motivations has highlighted a set of intrinsic and extrinsic motivations, but also the dynamic nature of volunteers' motivations (i.e., motivations shift with time, and vary between projects and among socio-demographic groups of volunteers; Larson et al. 2020; Lotfian et al. 2020; West et al. 2021). The fact that most research, to date, has focused on features of a specific CS project (but see West et al. 2020; Richter et al. 2021) limits the possibility to understand the dynamic nature of CS motivations. Therefore, it is important to develop theory-based tools that allow profound exploration of motivations across projects and contexts. Here we have developed and applied such a tool, the CSMS. This scale overcomes the shortcomings of prior approaches to measuring CS motivations in two ways: First, it is grounded in a well-established theoretical framework—namely, Schwartz's theory of basic human values (Schwartz 1992; Schwartz et al. 2012); second, it incorporates the extensive empirical knowledge obtained on CS motivation studies. CSMS can thus serve as a general, standardized tool for measuring citizen scientists' motivations across diverse CS projects.

We demonstrated and validated the CSMS by administering it to three samples of actual citizen scientists, participating in three different long-term CS projects. Our research joins a few recent studies aiming to explore and compare citizen scientists' motivations across projects and contexts (West et al. 2020; Richter et al. 2021). For instance, Richter et al. (2021) demonstrated that some intrinsic (e.g., "to have fun") and extrinsic motivations (e.g., "contribute to science") were equally important across countries and projects, while the type of project was more strongly related to motivations than demographic variables. Similarly, our results have shown that the more self-focused motivation of self-direction and more other-focused motivations of benevolence and help with research were equally important across countries and projects. The analysis also revealed that structural relations among the motivational categories captured in our scale were generally aligned with those of the underlying theoretical framework—lending support to the validity of our approach. Our analysis further enabled us to derive concrete insights regarding citizen scientists' motivations.

MOTIVATIONAL CATEGORY	B	*SE*	ß	*t*	*p*	LLCI	ULCI
Routine	.38	.11	.24	3.60	< .001	.17	.60
Benevolence	.29	.12	.16	2.39	.018	.05	.53

Table 3a Stepwise regression predicting participation duration in sample 1.

R^2 = .117; $F(2, 238) = 15.71$, $p < .001$.

SE: Standard Error, LLCI: Lower-level confidence interval, ULCI: Upper-level confidence interval.

MOTIVATIONAL CATEGORY	B	*SE*	ß	*t*	*p*	LLCI	ULCI
Routine	1.76	.46	.41	3.84	< .001	.85	2.68
Stimulation	–1.97	.51	–.47	–3.89	< .001	–2.98	–.96
Universalism-Nature	2.65	.82	.37	3.22	.002	1.01	4.29

Table 3b Stepwise regression predicting participation duration in sample 2.

R^2 = .279; $F(3, 73) = 9.417$, $p < .001$.

SE: Standard Error, LLCI: Lower-level confidence interval, ULCI: Upper-level confidence interval.

MOTIVATIONAL CATEGORY	B	*SE*	ß	*t*	*p*	LLCI	ULCI
Self-direction	.34	.13	.19	2.71	.007	.09	.58
Social expansion	.16	.07	.18	2.54	.012	.04	.29

Table 3c Stepwise regression predicting willingness to participate in additional volunteering activities, sample 3.

R^2 = .092; $F(2, 219) = 11.08$, $p < .001$.

SE: Standard Error, LLCI: Lower-level confidence interval, ULCI: Upper-level confidence interval.

THE RELATIVE IMPORTANCE OF SPECIFIC MOTIVATIONS IN CS PROJECTS

In general, findings across all three samples point to similarities in participants' ratings of the various motivations (Table 2). Specifically, in all cases, the wish to help with research, benevolence (wanting to help people within one's circle), and self-direction (creating, exploring) were among the top five most important motivators. These results are in line with those of many other studies, which also show that citizen scientists attribute high importance to these categories of motivations (e.g., Alender 2016; Ganzevoort et al. 2017; Koss et al. 2009; Raddick et al. 2013; Richter et al. 2021; West, Pateman, and Dyke 2016; West et al. 2020).

Motivational categories that consistently ranked in the bottom five across all three samples were the self-enhancement motivations of power (gaining recognition and status) and achievement (personal success), as well as conformity (adhering to social expectations). We further note that face (concerns regarding one's image or reputation), another self-enhancement motivator, was among the five lowest-ranked motivators in samples 1 and 2 (this category was not included in sample 3). These results align with previous studies showing that receiving certificates, gaining recognition and respect from others, or enhancing individual development, were the least important motivation for participating in CS projects (Larson et al. 2020; Richter et al. 2021; West et al. 2020). Altogether, these results suggest that self-enhancement does not strongly motivate participation in CS projects. Likewise, the desire to conform to social expectations does not seem to be a powerful motivator.

Our results also reveal certain differences across samples. The idea that motivations somewhat differ across projects makes intuitive sense, given that different projects take place in different settings and are likely to provide participants with different benefits. In our case, two of the projects (samples 1 and 2) involved an outdoor activity of observing or counting organisms in nature. In these samples, universalism-nature was rated as one of the top three most important motivations to participate (alongside help with research and benevolence). These findings are consistent with several nature-related CS motivation studies that found that some of the top motivators for participating in a wildlife conservation project were helping with research and a concern for wildlife (Larson et al. 2020; Maund et al. 2020; Richter et al. 2021). In sample 3, however, the project involved an indoor activity of answering surveys, suggesting that universalism-nature was not likely to be a relevant motivation—and indeed, based on this assumption, the project managers did not include it in the survey. Rather,

in sample 3, universalism-social, self-direction, and help with research were the top three motivating factors (with benevolence close behind in fourth place).

Notably, one of the top-rated motivations across all three samples—help with research—was not a top-down, theoretically based category but rather was derived from our review of previous empirical research on CS motivations (e.g., Koss et al. 2009; Land-Zandstra et al. 2016; Larson et al. 2020; Richter et al. 2021; Tinati et al. 2016). This type of motivation is likely to be unique to CS, as opposed to other forms of volunteering that are unrelated to science. The inclusion of such motivations makes the CSMS unique. Indeed, although the CSMS motivations map to some of the Volunteer Functions Inventory (VFI) motivations, a scale which has been widely applied to measure citizen scientist motivations (e.g., Alender 2016; Maund et al. 2020; Wright et al. 2015), some of the unique and important CS motivations, such as help with research and teaching, are not explicitly measured in the more general VFI measure.

A recent conceptualization of CS motivations (West et al. 2021) compared different theories and categorizations within environmental citizen science and showed how they relate to each other. Their analysis shows how all CS motivation categories map onto the framework of extrinsic and intrinsic motivations. In their subsequent survey, the authors combine the different categories from different theoretical approaches based on the motivations they found in the existing literature. The CSMS, which focuses on four rather than two higher-order motivations (Supplemental Tables 3 and 4), maps well to the extrinsic-intrinsic conceptualization (E-I model) and adds to it. As an example for the overlap between the two conceptualizations, the CSMS higher-order motivation of openness to change includes: self-direction motivation, which maps to the E-I model understanding motivation (West et al. 2021; Clary and Snyder 1999); social expansion and hedonism motivations, which map to and expand the E-I model social motivation (West et al. 2021; West et al. 2021; Clary and Snyder 1999); and stimulation motivation which maps to and expands the E-I model protective motivation (West et al. 2021; Clary and Snyder 1999). Other CSMS motivations such as routine and security are absent from the extrinsic versus intrinsic conceptualization but were proven worth measuring (Tables 3a,b) as they may be related to participation duration.

STRUCTURAL RELATIONSHIPS AMONG MOTIVATIONAL CATEGORIES

Across all three samples, our correlation and MDS analyses revealed structural relations among motivational categories that lent support to the theory-based structure of the scale. The MDS and correlations analyses identified four distinct higher-order motivations aligned with Schwartz's theory (openness to change; self-enhancement; continuity; self-transcendence; Schwartz 1992; Schwartz et al. 2012), and two separate motivational categories (teaching and security). In the MDS analyses, the relative spatial positioning of the four higher-order motivations was also aligned with our theoretical expectations, such that the openness-to-change higher-order motivations were opposite to the continuity higher-order motivations, and the self-enhancement higher-order motivations were opposed to the self-transcendence higher-order motivations. This structure is important since any behavior, such as participation in CS projects, is a tradeoff between conflicting motivations (Schwartz et al. 2017). When one higher-order group of motivations encourages specific behavior, its opposite will inhibit it (Schwartz et al. 2017).

IMPLICATIONS: USING MOTIVATIONS TO PREDICT PARTICIPATION BEHAVIOR

Our regression analyses provided an additional perspective on the practical value of the CSMS, revealing that specific motivations are associated with stronger (or weaker) tendencies to participate in CS projects and that these motivations differ across project types. In sample 1 (backyard nature observation), the motivations of routine and benevolence predicted participation duration. In sample 2 (bird counting), routine positively predicted participation duration as in sample 1, but also universalism-nature. Notably, for this sample, stimulation was a negative predictor, meaning that the higher participants rated stimulation in terms of importance, the shorter was their duration in the project. In sample 3 (quality-of-life improvement project), self-direction and social expansion positively predicted participants' willingness to participate in future volunteering activities. Both of these motivations correspond to the openness-to-change higher-order motivation.

Our findings regarding the motivations associated with the duration of participation in nature-based projects (samples 1 and 2) differ from those of Rotman et al. (2014), who used interviews to identify factors impacting long-term engagement in nature-related CS projects across three different cultural samples. They found that the motivational categories of self-direction, power, and social expansion were most predictive of participation. This difference may be attributed to the methods used to evaluate the motivations, interviews versus surveys. Future studies might examine these discrepancies further using a mixed approach, including a survey with the CMSC and interviews. More broadly, our findings highlight the importance of avoiding generalizations and considering, on the project level, the unique factors that might encourage or discourage participation. Thus, one size may not fit

all, and CS projects can now use the CMSC to identify the specific set of motivations that may drive their participants.

CONCLUSIONS

Understanding citizen scientists' motivation is important for a project's success to ensure wide recruitment, ensuring that participants have a fulfilling experience and that potential benefits are achieved. This research developed a general, standardized, and theory-based scale for assessing citizen scientists' motivations, the CSMS, and showed its usefulness in measuring and understanding motivations across projects spanning diverse domains and populations, advancing and standardizing the growing literature on citizen science motivations. We found that although volunteers' motivations differ to some extent across projects, there are many common threads—such that, in general, participants tend to value help with research, benevolence, and self-direction while attributing minimal importance to self-enhancement motivations. These results are consistent with a few recent studies, which developed frameworks and used a theory-based approach to explore the motivation for participation in CS projects (e.g., Larson et al. 2020; Lotfian et al. 2020; Richter et al. 2021; West et al. 2020). Importantly, we found that the motivations that ultimately predict people's participation behavior in a specific project may differ from the motivations they most value. Researchers may leverage such knowledge to attract and retain CS volunteers, thereby enhancing CS projects' likelihood of answering scientific questions and promoting informed decisions in the long term.

DATA ACCESSIBILITY STATEMENT

By request from the first author.

SUPPLEMENTARY FILE

The supplementary file for this article can be found as follows:

- **Supplemental File 1.** Supplemental Tables 1 to 7. DOI: https://doi.org/10.5334/cstp.459.s1
  - **Supplemental Table 1.** List of the 32 papers that measured motivations for CS participation and that were used to develop the CSMS.
  - **Supplemental Table 2.** Representation of items in categories.
  - **Supplemental Table 3.** The 58 items of the Citizen Science Motivation Scale (CSMS) and their classification into categories and higher-order motivations.
  - **Supplemental Table 4.** Citizen Science Motivation Scale (CSMS) items as administered to the different samples.
  - **Supplemental Table 5.** Correlations between motivational categories in sample 1.
  - **Supplemental Table 6.** Correlations between motivational categories in sample 2.
  - **Supplemental Table 7.** Correlations between motivational categories in sample 3.

ETHICS AND CONSENT

This project was reviewed and approved by the Behavioral Sciences Research Ethics Committee of the Technion – Israel Institute of Technology, Approval number 2018–044.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Liat Levontin contributed to the conception, design, and analysis of data and the writing. Zohar Gilad contributed to the conception, design, data collection and analysis, and writing. Baillie Shuster contributed to data analysis and writing. Shiraz Chako contributed to the conception,

design, data analysis, and writing. Anne Land-Zandstra contributed to the conception, data collection, and writing. Nirit Lavie-Alon contributed to the data collection and writing. Assaf Shwartz contributed to the conception, design, and writing.

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