

## CASE STUDIES

# Drivers of Participation in Digital Citizen Science: Case Studies on Järviwiki and Safecast

Victoria Palacin<sup>\*,†</sup>, Sarah Gilbert<sup>‡</sup>, Shane Orchard<sup>§</sup>, Angela Eaton<sup>||</sup>, Maria Angela Ferrario<sup>¶</sup> and Ari Happonen<sup>\*</sup>

Digital citizen science platforms are prominent examples of modern volunteerism that provide people with opportunities to observe natural phenomena and to engage in scientific processes. In this study, we explore the values and motivations underlying sustained participation in digital citizen science projects through the lenses of two social psychology theories (Schwartz's Human Values Theory and Self-Determination Theory). We present in-depth analyses of interviews with 15 long-term volunteers in two digital citizen science initiatives (Järviwiki and Safecast) that have been collecting environmental data for a decade in Finland and Japan. Our results advance the understanding of the values underpinning motivations. Our analyses show that openness-to-change values, such as self-direction, are important for initial participation, yet a diverse range of values, except for power, play a role in sustaining participation. Our study also shows that the values related to sustained participation are linked with extrinsic motivations, suggesting that when extrinsic motivators are self-directed, people will not only perform tasks willingly and enthusiastically but also in a sustained manner. Conceptualizing the behavioral continuum that drives volunteering actions provides practical insights that can assist the design, development, and evaluation of digital citizen science platforms.

**Keywords:** digital citizen science; human values; motivation; incentive mechanisms; Safecast; Järviwiki

## Introduction

Technology enables public participation (Rotman et al. 2014a; Ruge 2015), by helping people to engage in projects that serve a breadth of purposes, in contexts such as open governance, community action, and participatory science. Participatory science has enjoyed considerable success through a wide variety of projects, from classifying galaxies in Galaxy Zoo, to protein folding in the game FoldIt, and the Audubon Society's Christmas bird count, which has been running for a century. Digital citizen science projects such as these are playing an increasingly important role in scientific progress by raising public awareness, helping foster informed decision-making, and supporting communal data literacy projects (Balestrini et al. 2015).

In this work, we focus on digital citizen science platforms for environmental monitoring. These platforms are designed to support people-driven data collection of meaningful, geospatial data via mobile devices (Burke et

al. 2006; Goldman et al. 2009; Ganti et al. 2011; Guo et al. 2014). These technologies have become widely popular in the last decade across the world (Ruge 2015), with digital citizen science platforms like Safecast and eBird engaging millions of people in observing environmental phenomena. Digital citizen science, however, faces numerous challenges including privacy and security concerns (Christin et al. 2011; Krontiris et al. 2014), data quality and interoperability issues (Loss et al. 2015; Foody et al. 2017), lack of reusable development methods and frameworks (Heggen 2013; Zaman and De Meuter 2015), and a need for sustained participation (Foody et al. 2017; Jennett and Cox 2018; Orchard 2018). This last challenge is pivotal because without participation, these projects cannot exist.

This has motivated numerous studies in digital citizen science to identify and report the motivations of participants from interviews and surveys (Rotman et al. 2012; Iacovides et al. 2013; Reed et al. 2013; Curtis 2015; Jennett and Cox 2018; Orchard 2018). Also, scholars in the participatory sensing field have approached the study of participation by designing reward-centric incentive mechanisms aimed at enhancing volunteers' engagement (Jaimes et al. 2015; Restuccia et al. 2016). Despite these efforts, we still have little knowledge about how social and psychological factors can affect participatory behaviors that are fundamental to the success of digital citizen science platforms (Foody et al. 2017; Jennett and Cox 2018).

\* LUT University, FI

† MIT Center for Civic Media, US

‡ University of Maryland, US

§ University of Canterbury, NZ

|| Safecast, US

¶ Lancaster University, GB

Corresponding author: Victoria Palacin ([victoria.palacin@lut.fi](mailto:victoria.palacin@lut.fi))

Currently, there is a need to understand a) how volunteering behaviors (actions) in digital citizen science relate to behavioral drivers (Jennett and Cox 2018; Palacin-Silva et al. 2018) and b) the effect of temporal factors on these volunteering behaviors (Rotman et al. 2012; Rotman et al. 2014b). It is not possible to study volunteering behaviors (actions) or motivations alone without understanding the values that drive them (Knowles 2013). To learn more about what drives initial and sustained participation we used two meta-theories from social psychology, Schwartz's Human Values Theory (Schwartz 2012) and Self-Determination Theory (SDT) (Ryan and Deci 2000b), to explore volunteering dynamics in two digital citizen science cases. Schwartz's Human Values Theory is an established theory in social psychology that seeks to measure universal values (Schwartz 2006), which are understood to be one of the drivers of individual action through their effect on people's attitudes, emotions, and behaviors across time and situations (Maio 2016, pp. 51–126). This theory has been shown to be predictive of participation decisions in online contexts (Hsieh et al. 2013) and has been validated in several domains and dozens of different countries (Maio 2016, pp. 53–59) SDT (Ryan and Deci 2000b) is a theory of motivation that addresses the source of underlying needs that give rise to activity, such as autonomy (control over one's goals and actions), competence (sense of mastery at tasks and/or new learning), and relatedness (experiencing a sense of social belonging). An advantage of SDT is that these needs are reported to be innate and universal, making the theory useful for understanding motivations in a wide variety of contexts. In this study, we acknowledge the feedback relationship between actions, motivations, and values (Knowles 2013, p. 103; Maio 2016; Hanel et al. 2017; Palacin-Silva, 2018, p. 4).

Our study helps to advance understanding of the values and motivations that drive participation in digital citizen science. Conceptualizing the behavioral continuum that drives volunteering actions can provide practical insights to inform digital citizen science design, guide the design of incentive mechanisms, map volunteer experiences, and evaluate and test technological platforms. We build on existing work on participation in digital citizen science platforms (Balestrini et al. 2015; Jennett and Cox 2018) by presenting in-depth analyses of two case studies that have successfully engaged volunteers in Finland and Japan: Järviwiki, which is an environmental observatory maintained by the Finnish government in which volunteers log information about the state of lakes and water bodies across Finland; and Safecast, which is a Japanese volunteer-run initiative, started in response to the Fukushima power plant disaster, in which participants collect data about radiation by carrying Geiger devices. These cases are particularly interesting for two reasons: first, they have engaged volunteers for more than a decade in environmental monitoring; and second, they have collected the largest environmental datasets about the phenomena they monitor in the countries where they were launched. To better understand the success of these projects, we interviewed 15 long-term volunteers from Safecast and

Järviwiki and conducted thematic analyses to map values and motivations that relate to participation.

This paper begins with an overview of the two digital citizen science projects. We then review related work in the field and the two theoretical constructs that guide our analysis. The results are organized by each of the three research questions, identifying the underlying motivations, values, and associations between them in the two case studies. Finally, in the discussion, we reflect on the relevance of these findings to the future of digital citizen science in the era of online participation, and we highlight potential engagement pitfalls.

## Case Studies

### *Safecast*

Safecast was developed in response to a natural disaster. In March 2011, a 9.0 Mw earthquake hit Japan's coast and caused a nuclear energy accident in the Fukushima power plant. This accident was the second major event of its kind in the world and its effects will stand for decades to come. During massive disasters such as this, people rely on traditional mass media, such as television, radio, and newspapers, to get information. In the weeks that followed the accident, activity on social media showed a growing mistrust of the government and mainstream media due to a delayed release of radiation records (Hajikhani et al. 2018). In response, people started buying Geiger counters. Commercially available supplies ran out quickly, which led to people become increasingly interested in building their own devices. This discussion was taken to the Tokyo Hackerspace by a multidisciplinary group of people, and a week later "bGeigie" was built. This was the beginning of the Safecast initiative.

Safecast ([blog.safecast.org](http://blog.safecast.org)) provided people with the opportunity to build their own Geiger devices and to collect radiation measures by providing instructions and hardware. This enables people to monitor their own environments rather than depend on governmental bodies for that information. Once participants collect the data, they upload it to an open site so anyone can use it. As of 2019, Safecast has supported the collection of more radiation data than all citizen science projects in history (more than 40 million data points), and is the largest monitoring project in the field.

Safecast is entirely volunteer run. In exchange for their participation, volunteers get 1) real-time information about the radiation levels of places of interest to them (e.g., their home or their children's school), and 2) learning experiences from interactions with a community of people who share their knowledge on how to build and operate Geiger devices and how to make sense of open data.

### *Järviwiki*

In Finland, data describing the condition of Finnish lakes were only narrowly available until 2009, in that access was limited by government protocols. While some data had been moved to electronic databases, it was not freely and openly accessible over the Internet. In 2009, however,

this changed with the introduction of national-level open data movements such as the Helsinki Region Infoshare—a service that aims to make all public regional information quickly and easily accessible through the Internet. The trend of opening public data continued, and as of April 2020, the Finnish open data registry listed 1718 openly shared datasets and 791 organizations participating in open data movements.

In 2011, Järviwiki (Lakewiki in English) was launched in response to increasing interest in making public the observations that the Finnish Environment Institute (SYKE) had been receiving (via post) for decades from local people. Its monitoring schema relies fully on public participation: People write and maintain their observations on the wiki. Järviwiki supports the collection of data such as water temperature, surface status, sunlight penetration measurement (Secchi depth) and algae blooms. Järviwiki provides an information-sharing platform and generates a centralized visualization based on collected data, thus building additional knowledge on top of individuals' personally collected data. Through participation, people in Finland have become stewards of their lakes and are more actively joining and starting restoration initiatives across the country.

Järviwiki is an observatory maintained by the Finnish government but is run by volunteers. In exchange for their participation volunteers get 1) information about the state of water bodies in places of interest to them (e.g., the lake near their cottage) that has been processed by the platform and is plotted in usable charts, and 2) digital social rewards by having their names publicly listed as contributors to the lake's wiki.

## Related Work

### *Public participation and participatory science*

Work by the United Nations suggests that environmental issues are best handled with the participation of all concerned people (United Nations 1992; United Nations Economic Commission for Europe 1998). Public participation has become a norm in policy and decision-making in most countries, (Mapuva 2015; Quick and Bryson, 2016) and an irreplaceable part of the sustainable development agenda (Brundtland et al., 1987; United Nations 1992). This is particularly true for environmental decision-making, where public participation has been sought and embedded into environmental policy on local and international scales in an attempt to improve the quality, acceptance, and durability of decisions (Reed 2008).

Participatory science is a practice in which members of the public collaborate with professional scientists to conduct scientific research (Bonney et al. 2009; Hand 2010; Dickinson et al. 2012). Often people conduct activities such as collecting, categorizing, transcribing, or analyzing scientific data about a phenomenon of interest (Bonney et al. 2014). This practice has become extremely popular across many scientific disciplines in the past decade (Rotman et al. 2014a), assisted by the rapid spread of mobile technologies. Digital citizen science has evolved to support people-driven data collection of meaningful,

geospatial data via mobile devices (Burke et al. 2006; Heggen 2013).

### *Participatory environmental sensing*

Digital citizen science includes a subset of projects known collectively as participatory environmental sensing, citizen sensing, crowdsensing, or community monitoring (Burke et al. 2006; Goldman et al. 2009; Ganti et al. 2011; Guo et al. 2014), which have been used for a variety of purposes including scientific research and crisis communication (Goldman et al. 2009; Estrin et al. 2010). They also serve as an effective means for inclusive engagement, education, and civic outreach (Bonney et al. 2009; Hand 2010; Dickinson et al. 2012). The data submitted via digital citizen science platforms represents a deliberative act of modern public participation (Palacin-Silva et al. 2018).

Participatory environmental sensing presents an opportunity to monitor social and environmental phenomena at large scales through technology (Newman et al., 2012; Guo et al. 2014; Balestrini et al. 2015). Some sensing projects have already achieved outstanding results, such as the creation of the largest radiation records in history by Safecast (Safecast 2019), large records of bird populations by eBird (eBird 2019), identifying new galaxy elements by Zooniverse (Zooniverse project 2019), and discoveries of different protein types by FoldIt (University of Washington Center for Game Science 2019).

### *Motivations to volunteer in digital citizen science*

People join and participate in community projects for several reasons. Understanding the motivational aspect of volunteering in digital citizen science is still a developing field of knowledge (Jennett and Cox 2018). Field projects such as iSPEX (Land-Zandstra et al. 2016), Zooniverse (Reed et al. 2013), Stardust@home (Nov et al. 2011), Happy Match (Crowston and Prestopnik 2013), and the Great Pollinator (Domroese and Johnson 2017) have reported that their participants are driven by a deep interest in contributing to science, followed by curiosity (e.g., to try new devices or experiences), learning interests, enjoyment of the activities and social engagements (e.g., a sense of community). In addition, some research studies of FoldIt (Iacovides et al. 2013), Eyewire (Curtis 2015), and small-scale citizen science projects (Rotman et al. 2012; Rotman et al. 2014b), have highlighted that recognition is also a driver of participation. Still, the knowledge we have regarding the temporality of these motivations and how they change/evolve/strengthen/disappear during a project is still quite limited (Rotman et al. 2014a; Rotman et al. 2014b).

### *Incentive mechanisms*

To meet the motivational needs of volunteers and nurture sustained participation behaviors, citizen science projects may use incentive mechanisms. These mechanisms provide incentives that range from remuneration (e.g., through micropayments, gamification, and reputation mechanisms) to non-monetary incentives (e.g., social rewards and hedonism-enhancing features) often

aligned with auction theories and/or resource or privacy awareness principles (Khan et al. 2012; Jaimes et al. 2015; Restuccia et al. 2016). **Table 1** summarizes 25 metatypes of incentive mechanisms from two taxonomies (Jaimes et al. 2015; Restuccia et al. 2016). Most of these incentive mechanisms appeal to self-enhancement values, which means that these mechanisms are based on providing what is classified as wealth or reputation, online or offline, to increase participation. This may have unintended consequences, such as driving people to become more self-interested and less likely to support pro-social or pro-environmental activities in the longer term, as evidenced in the self-enhancement pitfall by the Common Cause Report (Crompton 2010, p. 37). Thus, it is important to study incentive mechanisms beyond those that focus on self-enhancement.

**Human values, motivations, and actions**

Research on digital citizen science has focused on understanding concrete actions (i.e., volunteering behaviors) to nurture participation (Nov et al. 2011; Rotman et al. 2012; Crowston and Prestopnik 2013; Iacovides et al. 2013; Reed et al. 2013; Curtis 2015; Land-Zandstra et al. 2016; Domroese and Johnson 2017; Jennett and Cox 2018; Orchard 2018). Yet, sustaining participation in citizen science projects remains a major challenge (See et al. 2016; Jennett and Cox 2018; Palacin-Silva et al. 2018). As Knowles highlights in her work (Knowles 2013, p. 103): “trying to affect behavior without affecting the underlying motivations for this behavior (e.g., values, frames, worldview) is a Sisyphean task: no matter how much progress is made,

there will continue to be powerful forces working against success.” Scholarly work in social psychology argues that behavior is the result of the trade-off between values and motivations alongside other individual differences, including traits, habits, ideologies, attitudes, and life circumstances (Kasser and Ryan 1996; Kasser 2002; Grouzet et al. 2005; Maio 2016, pp. 51–126). Therefore, we explore participation through two theoretical lenses: the human values that underlie actions and the motivations that drive them.

**Human Values Theory**

As Rokeach noted, “Every human has a set of values.” (Rokeach 1973, p. 5). Rokeach described human values as “beliefs that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence” (Rokeach 1973, p. 5). These guiding principles of life organize people’s attitudes, emotions, and behaviors, and typically endure across time and situations (Schwartz 2006). Human values have been conceptualized by many theorists and researchers since the 1950s as a) beliefs linked with emotion that are not objective; b) motivational constructs that reflect desirable goals; c) transcendent actions and situations (that differ from norms or attitudes); d) standards or criteria that guide one’s decision making; and e) an interlinked system with values affecting one another (Schwartz 1994).

Schwartz developed an empirically grounded theoretical model considering 67 countries that identified 10 basic human values derived from three universal requirements

**Table 1:** Taxonomies of incentive mechanisms in digital citizen science/participatory sensing.

Source	Type	Mechanism
<b>Taxonomy of incentive mechanisms for citizen science (Jaimes et al. 2015)</b>	Monetary	<ul style="list-style-type: none"> <li>– Uniform micropayments</li> <li>– Macro micropayments</li> <li>– RADP-VP-RC</li> <li>– Credit satisfaction index</li> <li>– Multi-interaction</li> <li>– Regret minimization</li> <li>– Steered crowd sensing</li> <li>– Platform-centric</li> <li>– User centric</li> <li>– VGC reverse</li> </ul>
	Collective motivations	<ul style="list-style-type: none"> <li>– Noise spy</li> <li>– P-Sense</li> </ul>
	Social reward: interaction	<ul style="list-style-type: none"> <li>– Noisetube</li> <li>– Cenceme</li> </ul>
	Social reward: self interest	<ul style="list-style-type: none"> <li>– Livecompare</li> <li>– Mobishop</li> </ul>
	Intrinsic motivations and fun	<ul style="list-style-type: none"> <li>– Ebirding</li> <li>– Floracaching</li> </ul>
<b>Taxonomy of incentive mechanisms in participatory sensing (Restuccia et al. 2016)</b>	General purpose	<ul style="list-style-type: none"> <li>– Non-game theoretical</li> <li>– Auction based theory</li> <li>– Non-auction based theory</li> </ul>
	Application specific	<ul style="list-style-type: none"> <li>– Quid pro quo</li> <li>– Information trade</li> <li>– Gamification</li> </ul>

of a human being: social interaction, biological needs of individuals, and survival needs of groups. These basic human values are distributed along four higher-level dimensions: 1) self-enhancement (concern for oneself); 2) self-transcendence (concern for others' well being); 3) openness to change (readiness for change); and 4) conservationist (preservation of the current status and resistance to change) (Schwartz 2003, 2006).

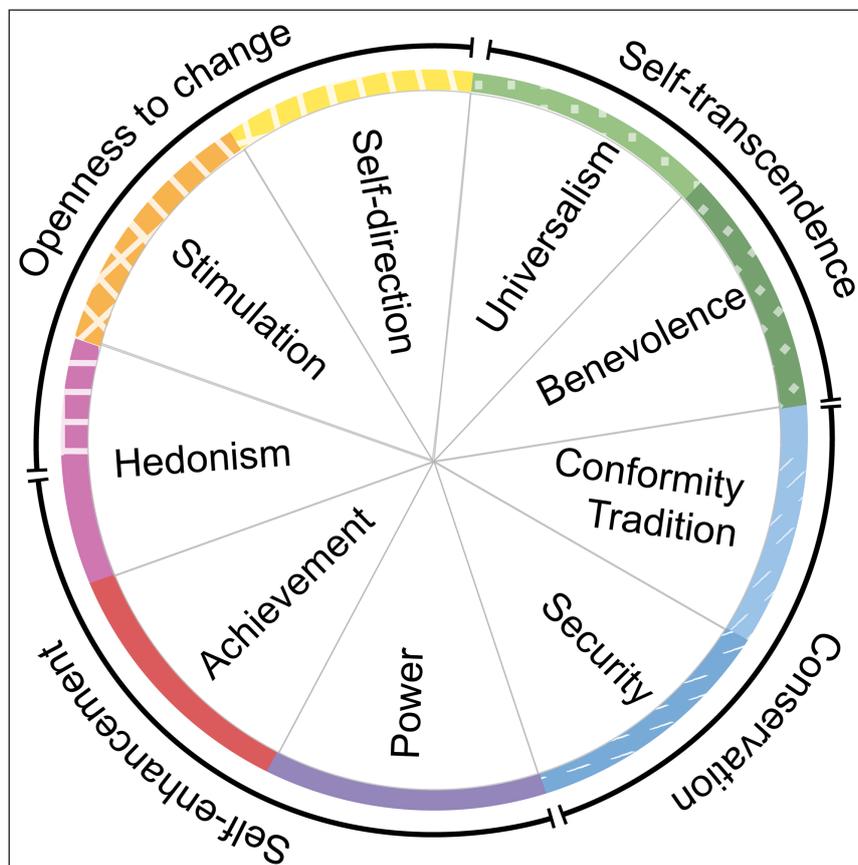
As depicted in **Figure 1**, the circumplex structure in Schwartz's Values Theory indicates strengthening and suppressing dynamics between values such as the bleed-over effect and the seesaw effect. In the bleed-over effect, values that appear next to each other are more likely to be equally important to a person. Moreover, the activation of a value has a strengthening effect on neighboring values. In the seesaw effect, values on opposing sides of the circumplex are rarely held strongly by the same person. When a value is activated, its opposing values tend to be suppressed (Crompton 2010). We introduce the ten basic human values along with quotation examples from this study in **Table 2**.

Schwartz's Human Values Theory has been studied in domains like psychology (Maio 2016) and social (Bilsky et al. 2011) and political sciences (Feldman 2003). More recently, however, computing-related research areas such as human-computer interaction (HCI) (Preece 2016; Preece and Shneiderman 2009), value-sensitive design (Friedman and Hendry 2019), values-first software engineering (Ferrario et al. 2016), and social computing (Chen et al. 2014) have used this theory in their studies.

Prior research has shown correlations between people's values and their corresponding actions and behaviors (see, for example, Bardi and Schwartz 2003; Crompton 2010; Kingston 2016; Seddig and Davidov 2018). It is argued that people feel a sense of achievement when their actions are aligned with their most important values (Rokeach 1973). This causes a conscious and/or unconscious pursuit of consistency between values and behavioral choices (Bardi and Schwartz 2003; Crompton 2010). Often, values are grouped as intrinsic and extrinsic (Crompton 2010, p. 77). Intrinsic values represent values related to caring about issues bigger than the self (e.g., benevolence), and extrinsic values are those related to individual self-enhancement (e.g., power). However, it is debatable whether this grouping is an oversimplification of values (Common Cause Foundation 2014) because some values may be seen as neither intrinsic nor extrinsic (such as security), and the binary grouping gives the mistaken impression of one side being better than the other. SDT can offer some insights to inform this debate.

**Self-Determination Theory**

SDT is macro-theory of human motivation with a number of empirically testable aspects that have been widely validated across varied contexts, such as learning (Ryan and Deci 2000a), gaming and game design (Tyack and Mekler 2020), and peer production (Benkler 2011). The theory addresses the source of underlying needs that give rise to activity, such as autonomy (control over one's goals and actions), competence (sense of mastery at tasks and/or



**Figure 1:** Schwartz's Human Values circumplex (adapted from Schwartz 2003).

**Table 2:** Basic human values defined by Schwartz (Schwartz 2003), with examples extracted from the interviews.

Value	Definition	Example from the interviews
<b>Universalism</b>	To pursue understanding, appreciation, tolerance, and protection for the wellbeing of everyone and for nature.	<i>“As a old scout, nature is important.” (Participant 3)</i>
<b>Benevolence</b>	To pursue the preservation and enhancement of the welfare of the people we know.	<i>“I thought this might be beneficial for someone.” (Participant 3)</i>
<b>Conformity/Tradition</b>	To pursue respect, commitment and acceptance of traditional practices aligned with culture or religion.	<i>“I started already [monitoring lakes] as a child, I was 15 years old when it clicked. I think it’s the regularity.” (Participant 6)</i> <i>“Because the place itself was a like a community, like a part of Japan’s history and I thought it was important to preserve them.” (Participant 15)</i>
<b>Security</b>	To pursue safety, harmony, and stability of society, of relations and of self.	<i>“We knew the real problems in the lake and let’s say that we have now dug into the problem and I was happy to start updating.” (Participant 7)</i>
<b>Power</b>	To pursue social status and prestige, control or dominance over people and resources.	<i>“When you do radiation monitoring in partnership with universities, you don’t get interruptions by government nor by researchers.” (Participant 9)</i>
<b>Achievement</b>	To pursue personal success through demonstrating competence according to social standards.	<i>“I got to get high level knowledge of radiation which master’s degree students might learn.” (Participant 11)</i>
<b>Hedonism</b>	To pursue pleasure and sensuous gratification for oneself.	<i>“I would do this as a side activity while warming up my sauna, I would upload data on the platform.” (Participant 8)</i>
<b>Stimulation</b>	To pursue excitement, novelty, and challenge in life.	<i>“I’ve noticed that the system has been developed and there has been more features. Of course, it becomes more interesting the more there are different types of observations and data related to waters.” (Participant 5)</i>
<b>Self-Direction</b>	To pursue independent thought and action, choosing, creating, exploring.	<i>“I had a notebook where I started putting them, every day. Then I started doing charts to a notebook.” (Participant 6)</i>

new learning), and relatedness (experiencing a sense of social belonging), while acknowledging that support and nutriment from the social context of the environment are sought to satisfy growth development (Ryan and Deci 2000a,b; 2017).

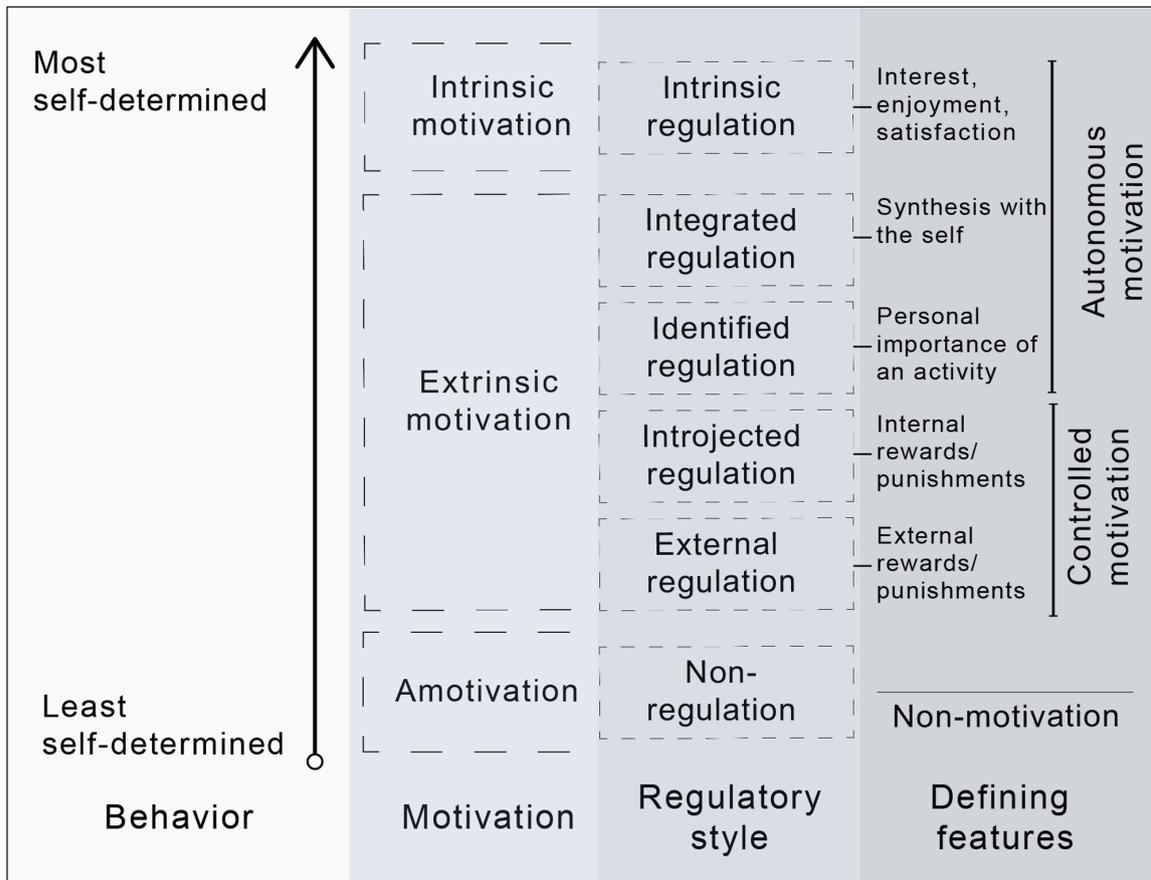
A benefit of SDT is that it untangles prior binary understandings of motivation by postulating the existence of six types of motivations that fall along a spectrum from intrinsic to extrinsic (see **Figure 2**). Intrinsic motivations have often been emphasized as key to sustaining engagement, whilst extrinsic motivations have often been disregarded owing to the assumption that they lead to resentment or disinterest (Ryan and Deci 2000b). However, SDT has evidenced that not all extrinsic motivators are the same; rather, they have varying degrees of internalization and integration, where internalization refers to the process of taking a value as one’s own, and integration refers to the process by which individuals come to think of an externally motivated task as self-enforced. As extrinsic motivations are internalized, they move upwards in the continuum towards intrinsic motivation.

Ryan and Deci (2000a) suggest two ways that internalization may be facilitated: first, by enhancing self-efficacy and autonomy, and second, by harnessing the social components of extrinsic motivations, such as sense of belonging and relatedness. Thus, while some extrinsic motivations could lead to resentment, others are

positively motivating and can drive people to perform tasks willingly and enthusiastically. **Table 3** presents the scale of motivations as defined by Ryan and Deci (2000a) with examples from the interviews. Studying motivations provides key insights into why people freely devote their time and energy to volunteer projects. However, Benkler (2011) argues that participation in user-driven enterprises, such as digital citizen science, occurs because humans are largely selfless. While self-interest is a factor, people are driven to social and collaborative production. This argument makes SDT particularly compelling as an approach to help investigate these potential explanations.

**Connecting Values and Motivations**

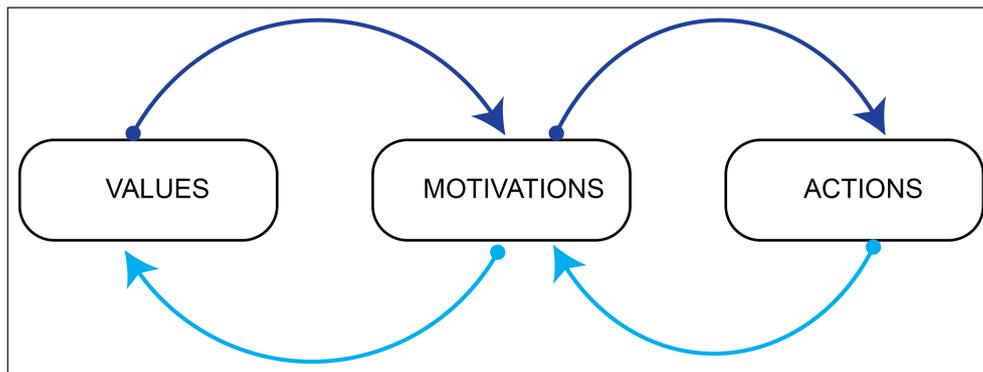
In 2017, new findings in values research noted that “value instantiations” were the bridge between abstract values and specific actions (Hanel et al. 2017). Researchers observed that even if the same level of importance is attributed to a specific value, different people might produce different actions in response to it. This was attributed to differences in contexts and personal experiences across the world (Hanel et al. 2017). Motivations, as such, are value instantiations that drive actions and have a highly contextual and temporal nature (Maio 2016). In this study, we acknowledge the feedback relationship between actions, motivations, and values (see **Figure 3**) (Knowles 2013, p. 103; Maio 2016; Hanel et al. 2017; Palacin-Silva 2018, p. 4).



**Figure 2:** The spectrum of motivation according to the Self-Determination Theory (adapted from Ryan and Deci 2000b).

**Table 3:** Motivations defined by Ryan and Deci (2000a) with examples extracted from the interviews.

Motivation	Definition	Example
<b>Amotivation</b>	Lacking intention to act, not feeling competent, and believing that acting will not yield the desired outcome.	<i>“Japan is a busy country; Japanese volunteers were trying to find time to monitor data when they were also busy with work and family. So, we did not have much time.” (Participant 11)</i>
<b>External</b>	Actions performed to satisfy a demand or externally imposed reward	<i>“At that time what made us anxious was that media was saying it was dangerous and other many things.” (Participant 13)</i>
<b>Introjected</b>	Actions performed due to pressure, to avoid guilt, or to enhance ego, self-esteem, and/or self-worth	<i>“Compared to other users on the same lake [I am] most active, but [I do] envy some people on lake Saimaa that have automatic monitoring.” (Participant 3)</i>
<b>Identification</b>	Actions on behalf of a goal that is of personal importance, so activities conducted are accepted as one’s own	<i>“After the earthquake everyone wanted to know the information about radiation, and I bought the device after two or three months. I started to measure radiation around my house and places inside my town including the streets my children use to go school.” (Participant 14)</i>
<b>Integrated</b>	Activities are fully assimilated to the self. These motivations share qualities with intrinsic motivation but are extrinsic because they are still conducted for an outcome that is separate from the behavior, even though it is valued by the self	<i>“Lakes are part of Finnish nature. They are important to Finnish people.” (Participant 2)</i>
<b>Intrinsic</b>	Behavior that is completely self-determined and, in contrast to extrinsic motivation, not a means to an end but rather pursued for its own sake. Intrinsically motivated behavior is sustained by the experience of interest and enjoyment.	<i>“Well this is only a hobby, some sort of thing to be proud as there are lot of my pictures there.” (Participant 1) “It is still fun now. It is community, community is fun.” (Participant 3)</i>



**Figure 3:** Feedback relationship between values, motivations, and actions (adapted from Palacin-Silva 2018, p. 4 and Knowles 2013, p. 103).

### Summary

Participation in digital citizen science projects has been the focus of numerous studies that identify the motivations of participants from interviews and surveys. Yet there is a lack of research on the role of psychological constructs in digital citizen science settings. Given that studies from social computing and HCI have shown that human values (Chen et al. 2014; Boyd et al. 2015; Mukta et al. 2016; Esau 2018) and self-determined motivations (Ryan and Deci 2000a; Benkler 2011; Tyack and Mekler 2020) are important influences on digital behaviors, and that values and motivations are phenomena that exist together; understanding both is important to the concept of long-term participation. Thus, we explore sustained participation in two such initiatives and asked:

- RQ 1: What motivates participation in a digital citizen science initiative?
- RQ 2: What are the values underpinning participation in a digital citizen science initiative?
- RQ 3: How do motivations align with values in the studied cases?

### Methodology

#### Case study design

The main goal of this study was to learn more about why people join and participate actively for years in digital citizen science projects. Because these questions required an in-depth explanation of an ongoing social phenomenon, we opted to take a case study approach (Yin 2018). The two case studies, Safecast and Järviwiki, were analyzed using semi-structured interviews. The cases share common features; both have at least a national reach, use some type of technology for data collection, and have achieved continuous and sustained volunteer participation for more than five years. However, they differ in their cultural background and level of governmental support. Therefore, this was an exploratory multiple-case study with multiple embedded units of analysis (Yin 2018).

#### Data collection

With the support of Safecast and Järviwiki, recruitment calls for this study were distributed via their official mailing lists. Recruitment continued until we exhausted the population of willing participants. A total of 15 exemplary

volunteers (Järviwiki: 8, Safecast: 7) signed up for this study<sup>1</sup>. Interviews were conducted between January and April 2018. All communications, including emails, surveys, and interviews with the participants, were held in their native languages (Japanese, Finnish, or English) and translated after data collection.

The nature of the interview was semi-structured, the protocol was designed so that each interview would last 45 minutes, and the questions<sup>2</sup> and probes were organized in five major sections (see **Table 4**).

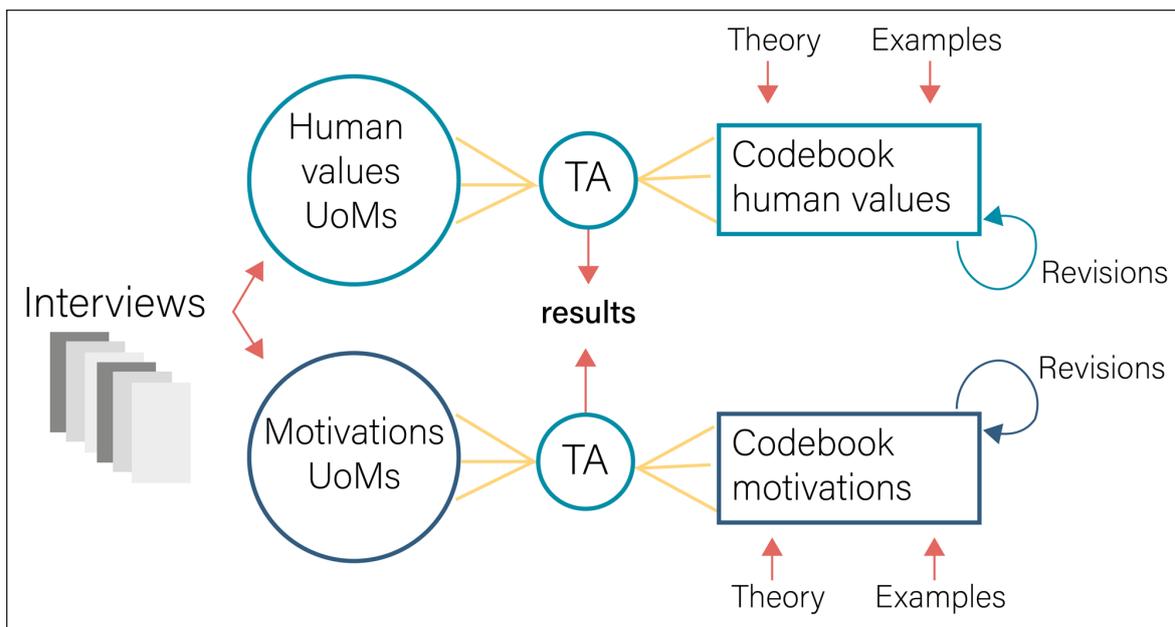
#### Data analysis

Our approach to data analysis (see **Figure 4**) followed a coding process that was based on the identification of units of meaning (UoM) in relation to the Schwartz Human Values and Termination theories, guided by a codebook (Boyatzis 1998; Campbell et al. 2013). To improve data capture and consistency, we utilized two rounds of coding, with two independent coders each, to allow for the contextualization and refinement of codebook definitions as recommended by (Campbell et al. 2013). Finally, inter-rater scores (Krippendorff's alpha) were calculated to ensure reliability (Krippendorff 2011).

- 1) *Thematic Analyses:* The data analysis followed the semi-qualitative thematic analysis approach by Boyatzis (Boyatzis 1998), where the units of analysis were units of meaning, described in detail below, and the themes were the Human Values and Self-Determination Theories.
- 2) *Units of Meaning:* A unit of meaning is a unit of analysis that represents a portion of sentences or single paragraphs that capture the full meaning and context of what a respondent says (Garrison et al. 2006; Campbell et al. 2013). An example of a UoM would be: "I talked with my neighbors and worker in my company and offered to use the devices. So, I lent devices and they were also monitoring radiation." This procedure reduces coder subjectivity and to improves the discriminant capability of the coding scheme by ensuring that text would be unitized in a standard way (Campbell et al. 2013). A total of 1517 UoM were identified across the 15 interviews: 789 were related to human values and 728 to self-determination.

**Table 4:** Interview design: sections and goals.

Interview section	Goal
<b>Section 1: Participant portrait</b>	Understand participant's profile and reporting practices
<b>Section 2: Initial motivations</b>	Explore the past interactions with the monitoring platform and volunteering experiences
<b>Section 3: Motivations to stay</b>	Understand current experiences, motivations, and emotions when using the monitoring platform
<b>Section 4: Motivations to leave</b>	Identify key tensions and pain points that may have driven dropout from the initiative
<b>Section 5: Dreams</b>	Explore future goals and emotions related to their participation in environmental monitoring



**Figure 4:** Data analysis overview (UoMs: units of meaning; TA: thematic analysis).

3) *Codebook Development and Coding:* Codebook development started with the first author creating initial versions of the two codebooks—the human values codebook, which was based on Schwartz’s Human Values Theory (Schwartz 2012), values descriptions by the Common Cause Report (Crompton 2010), and an example study that used the Schwartz Human Values Theory to perform a thematic analysis (Knowles 2013); and the motivation codebook, which was based on the definitions of human motivation by Ryan and Deci’s SDT (Ryan and Deci 2000a), and an example study that used SDT to perform a thematic analysis (Gilbert 2018). A one-interview sample was coded by the three researchers using the initial codebooks. This coding cycle served to improve the codebooks, which were subsequently updated with more examples as the coding cycles continued.

**Intercoder reliability and agreement**

Intercoder reliability refers to the extent to which two or more independent coders, using the same coding schema, agree on the coding of the content (SAGE Research Methods Encyclopedia 2008). Each interview was coded by two coders. One author coded interviews for the motivations, another for the values, and the first author coded

**Table 5:** Krippendorff’s alpha scores.

	N coders	alpha	N cases	N decisions
Human values TA	2	0,71	789	1,578
Motivations TA	2	0,98	728	1,456

TA: thematic analysis.

interviews for both values and motivations. After the interviews were coded, Krippendorff’s alpha was used to test agreement between the coders for each set of codes. The alpha score for the motivations codes was 0.98, and for the values, it was 0.71 (see **Table 5**). As the minimum acceptable reliability score for the Krippendorff coefficient is 0.67 (Krippendorff 2018), the scores confirmed a high degree of consistency between the respective coders for both code sets.

**Results**

The results are organized by each of the research questions, which identify the underlying motivations, values, and associations between values and motivations in the two case studies. Quotations from the interviews are included in this section and its supplemental files. The format P(number) denotes the participant from whose interview the quotation was extracted.

**RQ 1: What motivates participation in a digital citizen science initiative?**

Below we report on the motivations for participating in each case, including initial participation and sustained participation.

**Safecast**

The most described initial motivations of Safecast interviewees were identified and integrated motivations. Similarly, these were also the two types of motivations that participants described when discussing their reasons for staying in Safecast. However, amotivation was also commonly described by participants when discussing their continued participation in Safecast (see **Figure 5**). Each of the motivations are discussed in further detail in the Supplemental File 1, Appendix A.

**Järviwiki**

Unlike Safecast, in which intrinsic motivators were described by few participants as an initial motivation, Järviwiki participants described intrinsic motivations most frequently when discussing their initial motivations, followed by identified motivations and integrated motivations. These three motivations also played an important role in sustained participation. However, as with Safecast, Järviwiki participants also described challenges to participation, reflected as amotivation, when discussing sustained participation (see **Figure 6**). Each of the motivations are discussed in further detail in the Supplemental File 2, Appendix B.

**RQ 2: What are the values underpinning participation in a digital citizen science initiative?**

We report on the values underlying participation (initial participation and sustained participation) in each of the two cases.

**Safecast**

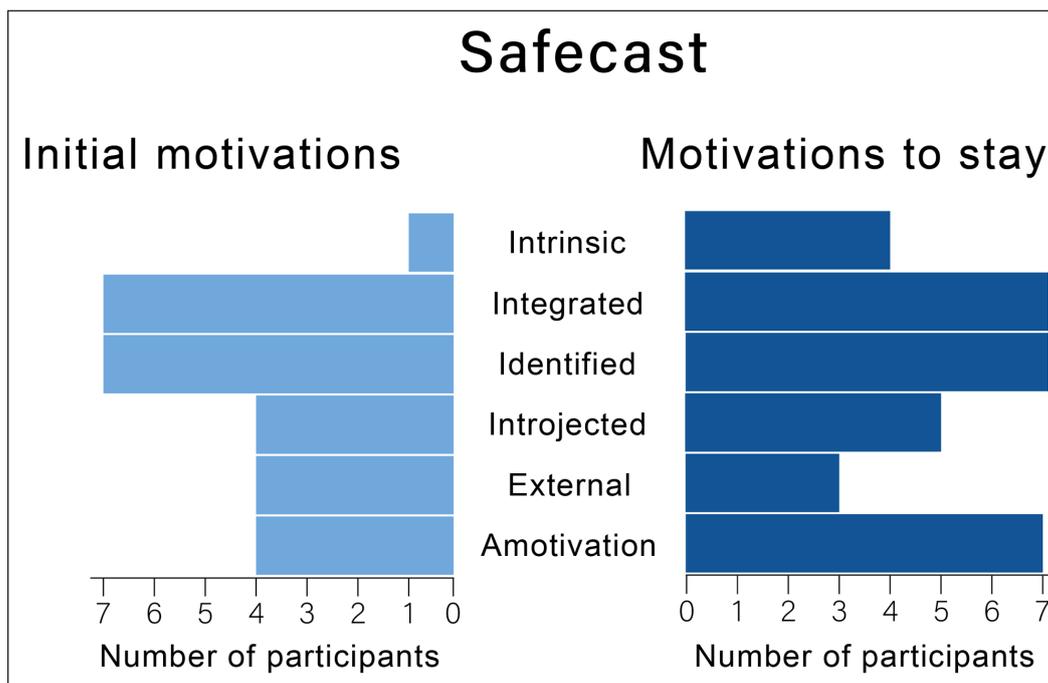
Self-direction, stimulation, and achievement were important values to participants when joining Safecast. These were enhanced by a strong need for security and sense of benevolence, whilst conformity/tradition, universalism, and power were the least influential values to drive participation. However, the value of hedonism (doing something because it is enjoyable) was not important at all at the time of joining Safecast (see **Figure 7**).

Self-direction, universalism, conformity/tradition, and achievement were the most important values for staying in Safecast. These are enhanced by a strong need for security, stimulation, and benevolence, while hedonism and power were the least influential values among the interviewed Safecast participants (see **Figure 8**). Each of the values are discussed in further detail in the Supplemental File 3, Appendix C.

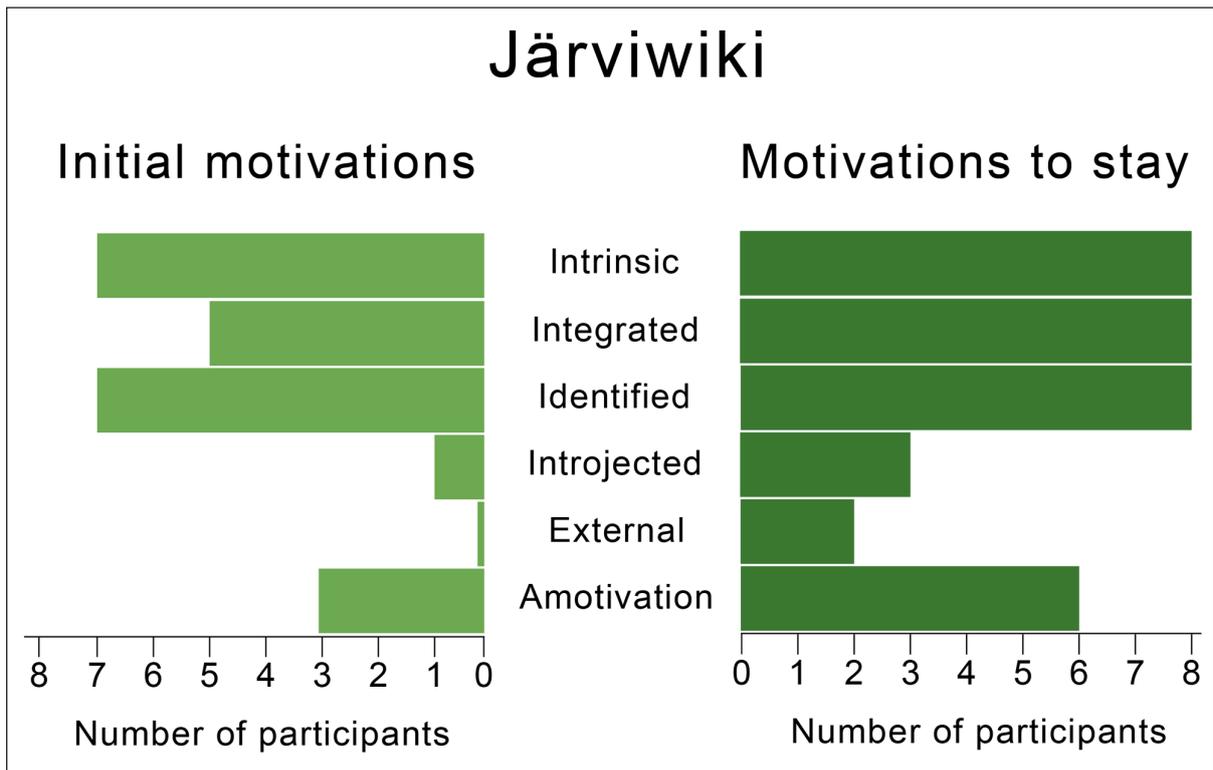
**Järviwiki**

Self-direction, stimulation, conformity/tradition, and universalism were found to be important values at the time of joining Järviwiki. These were enhanced by a strong sense of benevolence, hedonism, achievement, and security. Power was the least influential value driving participation in the case study sample (see **Figure 7**).

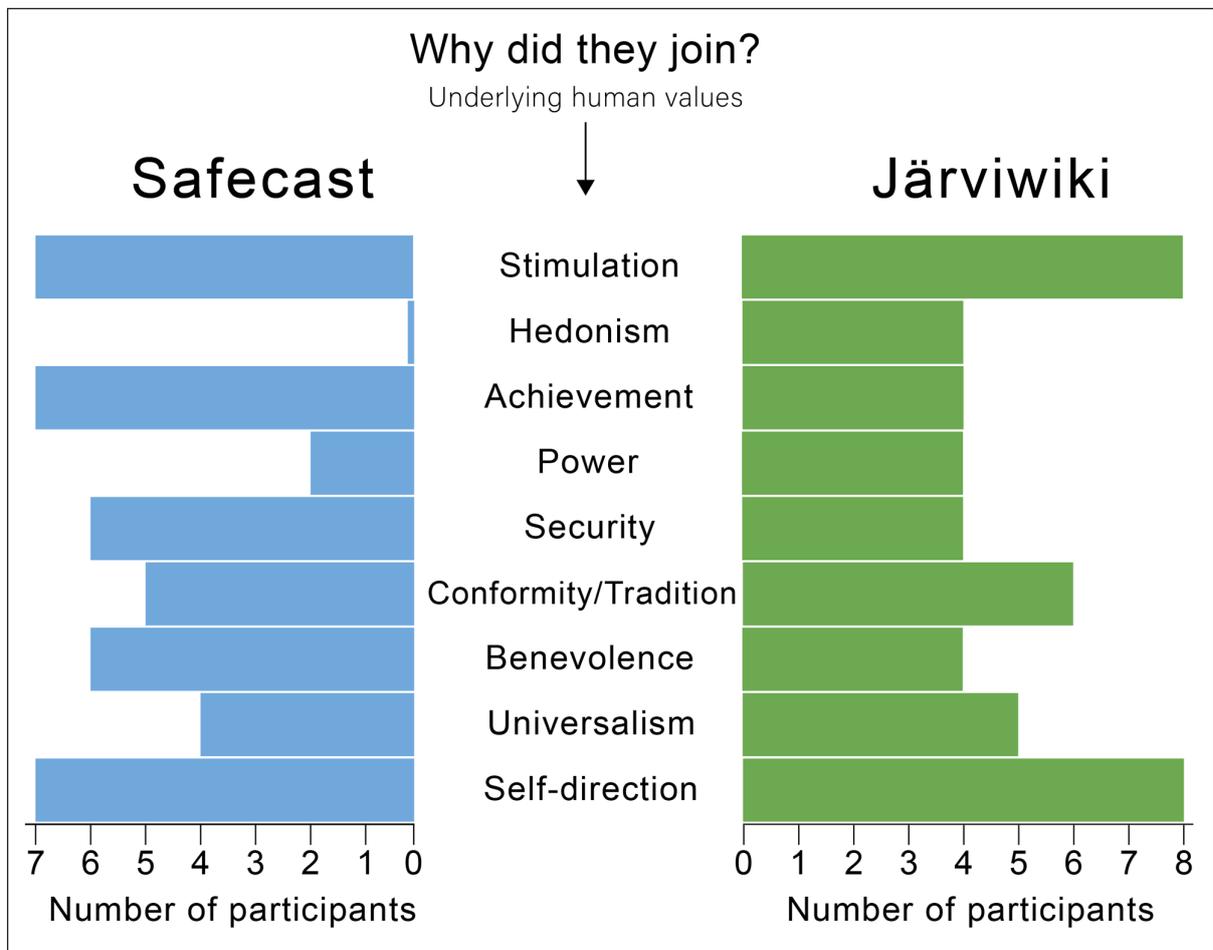
Self-direction, universalism, conformity/tradition were reported to be the most important values for staying in Järviwiki; these values are enhanced by a strong feeling of benevolence, stimulation, achievement, hedonism, and security. Power was the least influential value driving sustained participation among the interviewed participants (see **Figure 8**). Each of the values are discussed in further detail in the Supplemental File 4, Appendix D.



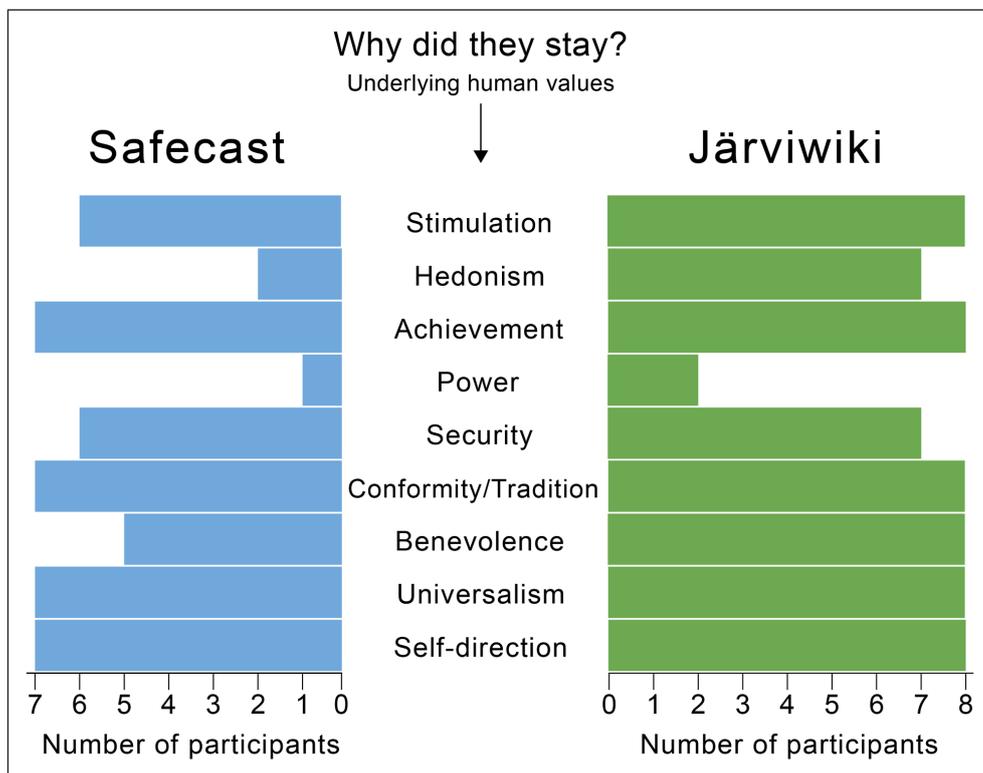
**Figure 5:** Motivations underlying participation among Safecast participants.



**Figure 6:** Values underlying participation among Järviwiki participants.



**Figure 7:** Values underlying initial participation among Safecast and Järviwiki participants.



**Figure 8:** Values underlying sustained participation among Safecast and Järviwiki participants.

**RQ 3: How do motivations align with values in the studied cases?**

The most frequent co-occurrences between values and motivations are shown in **Figure 9**. To map these co-occurrences, all the UoMs were cross-analyzed using the codes for the values and motivations. Finally, we counted the unique co-occurrences per participant (i.e., if a co-occurrence was mentioned by the same participant several times, it counted as one. For instance, achievement and integrated motivations were determined to be related because all 15 volunteers had a UoM where integrated regulation and achievement co-occurred compared with one volunteer for whom achievement and external regulation co-occurred.

Our analysis identified areas of overlap between the motivations and values that drive participation in Safecast and Järviwiki. These overlaps provide a starting point for understanding which values can be leveraged to drive more self-directed and autonomous actions. The co-occurrences are shown in **Figure 9**.

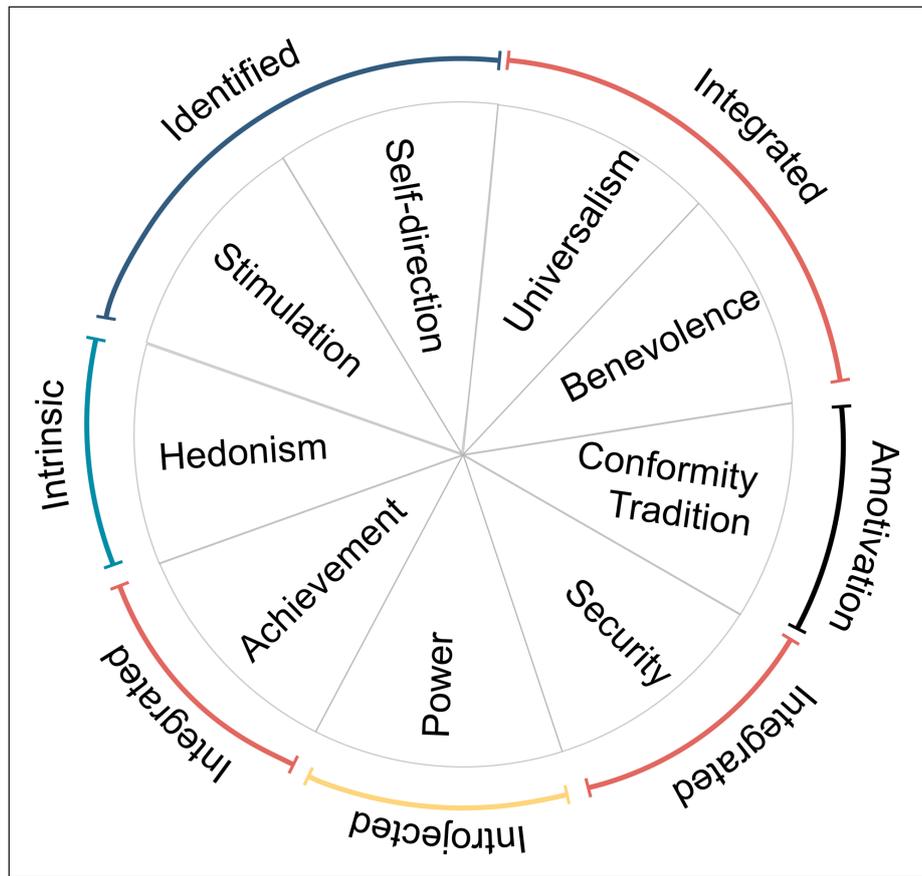
**Figure 9** builds on the Schwartz Human Values circumplex (Schwartz 2003) by adding an additional layer that showcases where motivations and values overlap in these two digital citizen science initiatives. The following section highlights these overlaps through illustrative quotes from the text, organized by motivation.

*Amotivation* occurs when participants struggle with or lack intention to act. We found that this most often co-occurred with the combined values of conformity/tradition. This example from P7 highlights one such overlap, where we can see how hesitance to adopt a new technology results in a reluctance to participate: “I wouldn’t like to play with IT, it’s kind of against my principles.”

*Introjected* motivations describe actions that are performed to enhance ego or in response to external pressure or guilt. We found that this motivation often overlapped with the value “power.” This quotation from P9 highlights the important role leaders can play in collaborative online initiatives [69]: “So I can say those core members have attraction as a human.”

*Identified* motivations describe those in which a person begins to associate some personal importance with the action. We found that identified motivations often co-occurred with the values stimulation and self-direction. In our data, we observed co-occurrences between identified motivations and stimulation when participants described the technology they were using as a contributing factor in their participation: “Yeah it nicely visualizes statistical data with help of a machine” (P8). We also observed overlaps between self-direction and identified motivations. This connection is unsurprising, given that identified motivations are the first motivations in the spectrum that are self-directed. The following quotation from P11 highlights one example of this overlap as they move away from relying on information provided by others to collecting it for themselves: “I want to find the truth and I want to find out by myself to know if the media shows correct data or if the data is changed by government on purpose.”

*Integrated* motivation results when an activity is congruent with personally endorsed goals and needs that are already part of the self. We found that integrated motivations co-occurred with values that are also personally important, such as universalism, benevolence, security, and achievement. First, this quotation from P11 provides an example of overlap between integrated motivations and universalism, as their love of nature is fully



**Figure 9:** Interaction between values and motivations underlying participation among Järviwiki and Safecast participants.

assimilated as part of themselves and is a core reason for contributing to Safecast: “When I was small my parents raised up me and taught me to appreciate and be close to and commune with nature. And I have been loving nature.” Similarly, the value benevolence was also associated with integrated motivations as participants described helping others as a value that was highly integrated. For example, P5 discusses how participation in Järviwiki creates an archive of nature observations that anyone can contribute to: “It is a good tool to save observations to kind of common memory.” We also observed overlaps between security and integrated motivations, such as in this quote from P14: “It is still said our fundamental power resource is nuclear power plant, we don’t know when the next accident will happen. So, I think what we need is to do something to prepare ourselves.” Because Japan continues to rely on nuclear power, Safecast allows participants to collect information that provides them with a greater degree of certainty regarding air quality. Finally, in this quotation from P9, we see how achievement and integrated motivation overlap as P9 describes their ultimately successful learning process through participation in Safecast: “by hearing and talking those conversations about radiation and I started to understand more and more.”

*Intrinsic* motivations, where activities are conducted for their inherent satisfaction, were predictably associated with the value hedonism, which is also associated with pleasure. For participants of Järviwiki, this was commonly found in descriptions of use of the system

as a hobby, such as P6: “It’s a hobby, I get to make the measurements,” whereas in Safecast, this was commonly found in descriptions of participation as fun, such as in this statement by P12: “It is still fun now. It is community, community is fun.”

Overall, we found that extrinsic motivators that are self-directed and autonomous can drive people to perform tasks willingly and enthusiastically in a sustained manner, particularly when they are associated with pro-social and pro-environmental values such as universalism and benevolence.

**Discussion**

We have described the values and motivations that drive long-term participation in two digital citizen science cases, Järviwiki in Finland and Safecast in Japan. In this section, we reflect on the implications of these findings.

***Integrated and identified motivations are important for sustained participation***

Our first research question focused on exploring what motivates participation in the two cases. For Safecast participants, identified and integrated motivations drove volunteering, whereas Järviwiki participants were driven by intrinsic, identified, and integrated motivations. These three types of motivations are the most self-determined, which means that their corresponding actions (e.g., to submit an observation) are perceived as important activities for the self.

Although citizen science activities are a hobby for some, for most of these volunteers, monitoring is perceived as important because there is a direct benefit to their own interests. Both of these initiatives have demonstrated an understanding that support of the participants' personal goals is key to sustaining participation. For instance, both Järviwiki and Safecast provide simple and readable visualizations based on the collected data. People can access, read, and understand the collected data in an open manner. Most importantly, they can understand what the data means for their own local contexts because they can find information about their area in few steps.

Safecast and Järviwiki also have a long history of collecting ideas and feedback from volunteers about their platforms. In this process, they have created services and visualizations that provide both volunteers and scientists with what they need for their everyday decision-making. Although some researchers argue that to popularize citizen science activities, they must become volunteers' hobbies (Haklay 2013), these cases show that creating digital services (based on citizen science data) focused on providing volunteers with what they need to pursue their personal goals, is also important to sustain long-term participation. Despite this, we also observed some differences between the two cases, such as the more important role of intrinsic motivators among Järviwiki participants. Thus, it is important for designers of such initiatives to understand the specific goals of their volunteers through research methods such as user journeys, card sorts, or affinity maps (IDEO 2015).

#### ***Appealing to power to sustain participation and the shortcomings of incentive mechanisms***

For research question 2, we explored the values that underpin participation in the two initiatives. We found that values such as self-direction and stimulation were important for both Safecast and Järviwiki volunteers when they decided to begin their volunteering activities. Sustaining participation, however, was associated with a larger number of values, including stimulation, hedonism, achievement, security, conformity/tradition, benevolence, universalism, and self-direction. These observations are in line with previous studies by Rotman et al. (2014a,b), which show that a self-directed personal interest is key to initial participation. But broader motivations are needed for sustaining long-term participation.

Across both cases, power seems to be the least influential value. Power refers to the pursuit of social status, prestige, control, or dominance over people or resources (Schwartz 2003) and is a self-enhancement type of value. Surprisingly, current incentive mechanisms are often focused on rewards that provide wealth or reputation online or offline to increase participation (see, for example, the reward mechanisms listed in **Table 1**). These types of rewards rely on values centered on self-enhancement, such as power. Focusing on values that appeal to personal gain can cause people to become more self-interested and less likely to support pro-social or pro-environmental activities in the long term (Crompton 2010, p. 37). The use of mechanisms that appeal to self-transcendence by

embracing universalist and benevolent values, for example, by centering their core project recruitment campaigns with the well-being of the community, appear to be rarer. However, in the case of Järviwiki and Safecast, focusing on values that appeal to universalism and benevolence are key elements of long-term sustained participation.

These results suggest that as projects strive to engage more people in their activities, careful thought should be put into understanding the role of values on the temporality and quality of engagement. Similarly, Knowles (2013, p. 68) highlights that *"While appealing to Self-Enhancement values will likely generate more donations (at least in the short term), they will be generated from people who are as a result less inclined to take further action on behalf of the cause (i.e., negative spillover). Self-Enhancement appeal is, therefore, a case of one step forward, two steps back. To consistently make progress in a positive direction, the campaign needs to communicate a consistent, issues-based, Self-Transcendence focused message."* A way to avoid this pitfall is to use self-enhancement mechanisms (e.g., rewards) as part of a larger engagement strategy that fosters values like self-direction, stimulation, universalism, benevolence, security, and achievement. As our results show, when extrinsically motivated values, such as universalism and benevolence, are self-directed, they can drive people to perform tasks willingly and enthusiastically in a sustained manner.

#### ***Moving beyond intrinsic/extrinsic values***

In research question 3, we explored how motivations align with values in the studied cases. The goal of this question was to explore the interactions between values and motivations.

We know that values and motivations exist together and operate alongside other individual differences, such as culture, personality, and context (Maio 2016). However, a common integration between these two theories has been the grouping of values under an intrinsic/extrinsic binary (Kasser and Ryan 1996, p. 280; Common Cause Foundation 2014). Here we untangle the different types of motivations in relation to human values, arguing that this can provide valuable insights for understanding the drivers of sustained participation at different stages in a digital citizen science project. For example, project designers could understand that some of their participants value stimulation (new experiences); however, without knowing if that value is related to an introjected or integrated motivation, the engagement strategies they design could fail by not addressing participants' needs and personal goals. Furthermore, exploring the dynamics of participation from the lenses of different theories can be beneficial to enhance the understanding of links between human experience and behavior and to explain enduring behaviors like sustained engagement (Kasser 2002, 2004; Grouzet et al. 2005).

#### ***Exploratory design reflections***

In this section, we reflect on the implications of this study for the design of digital citizen science platforms. Our insights are derived from interviews, further observations,

and conversations with the stakeholders running the studied projects.

#### Fostering trust through digital citizen science

In digital citizen science platforms, the volunteer has total control over the information they are giving and can see how it is being used for a common cause. People may develop trust in these platforms, because when you are part of a process it is easier to trust it.

However, to build and sustain trust, these platforms must aim to have neutral and fact-based information. This can be achieved by designing mechanisms that enhance transparency, accountability, openness, and shared ownership. For example, Safecast is largely trusted by the population in Japan, which in turn has led to its use by the Japanese government as an official source for radiation measures (Brown et al. 2016). This level of trust was achieved by opening the entire process of radiation monitoring to everyone, from the recording of measures and data verification, to knowledge-sharing and the release of open data.

#### Design for a diversity of values and motivations

Digital citizen science platforms should be designed for diversity across all ages, genders, skillsets, values, and motivations. For example, although our findings showed patterns between motivations and values that were more common than others, we nonetheless observed a multitude of motivations and values that were important to individual participants. Although demographic statistical sampling is a well-accepted procedure for sub-sampling a larger population, sampling for different values/motivations is not a common practice. Hence, it is possible that a narrative or frame used to promote an initiative could attract only people with a similar value background. Organizers should be aware of the values and motivations linked with their initiative and its impacts on recruitment campaigns and participation. Approaches like value-sensitive design (Friedman and Hendry 2019) and values-first software engineering (Ferrario et al. 2016) have developed tools like envisioning cards (Friedman et al. 2019), values q-sort, starmaps, and others (Values in Computing 2019) to support the creation of digital technology that accounts for the values of designers and participants.

#### The critical role of incentive mechanisms

The use of incentive mechanisms for engagement has to be aligned with long-term strategies for building sustained public engagement. As discussed above, current incentive mechanisms in the field are focused mainly on rewards; they are centered on self-enhancement values that can cause that people to become more self-interested and less likely to participate in a sustained manner. Incentive mechanisms should be used in moderation, and as part of a larger engagement strategy.

#### Limitations

This study used rigorous and systematic procedures for data collection and analysis, which included different rounds of validations and inter-rater agreement calcula-

tions. However, different types of research methods serve different needs. While we were able to investigate these two cases in depth, generalization is limited to theoretical prepositions and not to populations or universes (Yin 2018).

In the present study, the values of tradition and conformity were studied in a bundle, due to the close meanings the coders assigned to both values.

This study interviewed exemplary volunteers from Japan and Finland. However, we did not collect socio-demographic information (i.e., gender, education, or income) as this was not seen as necessary for this study in the research-planning stage. Thus, this is a limitation of our data analysis.

Lastly, this work interviewed only 15 long-term volunteers. Hence, our observations and consequent results are limited by that number of participants. However, the nature of this work is exploratory and qualitative. The procedures for data collection and analysis were designed to be deep and strict to counterbalance this limitation.

#### Conclusions and Future Work

Digital citizen science has the capacity to drive scientific breakthroughs, foster community trust, and support decision-making processes. We've explored the values and motivations that underlie initial and sustained participation in digital citizen science projects from the lenses of Schwartz's Human Values Theory and SDT. We present in-depth analyses of two case studies of digital citizen science initiatives (Järviwiki and Safecast) that have been collecting environmental data for a decade in Japan and Finland. Our analyses show that openness-to-change values such as self-direction and stimulation are important for initial participation. Yet, self-transcendence values such as universalism play a large role in sustaining participation. These values are related to identified and integrated motivations across the participation spectrum described by SDT. These types of motivations are the most self-determined forms of motivation, suggesting that when extrinsic motivators are self-directed, people will not only perform tasks willingly and enthusiastically but also in a sustained manner.

The current incentive mechanisms in the field are focused mainly on rewards; they are centered on self-enhancement values such as power and achievement, which can cause people to become more self-interested and less likely to support pro-social or pro-environmental activities in the long term. Our findings suggest that these pitfalls can be avoided by appealing to self-direction, universalist, and hedonist values, especially as projects progress beyond the initiation stage. In Järviwiki and Safecast, this was done by creating transparent processes, led, and controlled by the people, which provided opportunities to nurture and support these values in both the short and longer term.

Finally, this study provides three suggestions for organizers/designers of participatory digital citizen science initiatives: 1) Foster trust through digital citizen science by designing mechanisms that enhance transparency, accountability, openness, and shared ownership of the commons (e.g., data and technology artifacts); 2) design

for a diversity of values to assist the recruitment and ongoing engagement of volunteers, and; 3) integrate and vary the use of incentive mechanisms within a holistic engagement strategy that aims at co-constructing the future we want to live in.

## Notes

<sup>1</sup> This study was evaluated and approved by the LUT University ethics board in November 2017.

<sup>2</sup> The interview questions are available at: <http://bit.ly/2vvK2Yh>.

## Supplementary Files

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

- **Supplemental File 1: Appendix A.** Safecast interviewees' motivations, ordered along the spectrum from amotivation to intrinsic motivation. DOI: <https://doi.org/10.5334/cstp.290.s1>
- **Supplemental File 2: Appendix B.** Järviwiki interviewees' motivations, ordered along the spectrum from amotivation to intrinsic motivation. DOI: <https://doi.org/10.5334/cstp.290.s2>
- **Supplemental File 3: Appendix C.** Safecast interviewees' values, ordered by importance for participation. DOI: <https://doi.org/10.5334/cstp.290.s3>
- **Supplemental File 4: Appendix D.** Järviwiki interviewees' values, ordered by importance for participation. DOI: <https://doi.org/10.5334/cstp.290.s4>

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## Competing Interests

The authors have no competing interests to declare.

## Author Contributions

- Victoria Palacin conceived of the presented idea, designed the study, coordinated and carried out the interviews, analyzed the data, and led the synthesis and writing of this manuscript.
- Sarah Gilbert supported the framing of the data analysis, analyzed the data, investigated specific details related to the Self-Determination Theory, and co-lead the writing of this manuscript.
- Shane Orchard supported the framing of the data analysis, analyzed the data, and contributed to the writing of this manuscript.
- Angela Eaton contributed to the data synthesis of this study and investigated specific details related to the Safecast case study.

- Maria Angela Ferrario contributed to the conception of the idea and the study framing, and supervised the findings of this work.
- Ari Happonen contributed to the data collection of this study and investigated specific details related to the Järviwiki case study.

All authors contributed intellectually to the final manuscript.

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