PARTICIPATION IN CITIZEN SCIENCE: DRIVERS AND BARRIERS FOR SHARING PERSONALLY-COLLECTED WEATHER DATA VIA WEB-PLATFORMS

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ABSTRACT

The importance and potential of involving citizens in gathering data about the environment and also higher levels of participation in environmental governance and decision making are on the increase. In parallel, the diffusion of Information Communication Technologies (ICTs) that are interactive and easy to use have provided new horizons for facing extreme weather events and the threatening hazards resulted from those. Nevertheless, the success of citizen observatories hinges on the continued involvement of citizens as central actors of these initiatives. Developing strategies to (further) engage citizens requires an in-depth understanding of the behavioral determinants that encourage or impede individuals to collect and share environment-related data. In this paper, the behavioral determinants of sharing personally-collected weather data via web-platforms are analyzed by using the Theory of Planned Behavior from the behavioral sciences. The findings and analysis are based on a qualitative empirical research carried out in the Netherlands, United Kingdom and Italy. These results were complemented by a review of secondary literature. Consequently, a model was developed that identifies the main drivers and barriers for participation in citizen weather observatories. This model can be utilized as a tool to develop strategies for further enhancing ICT-enabled citizen participation in climate change adaptation.

KEYWORDS

ICT-enabled Citizen Participation, Citizen Science, Citizen Observatories, Theory of Planned Behavior, data sharing

1. INTRODUCTION

In the face of diverse climate change implications such as floods and droughts, continuous and widespread observations of the weather are of crucial importance to equip authorities and citizens in at-risk locations with essential information as they have to deal with more frequent and/or more intense flood risk hazards. Yet there are two major flaws in the traditional means of observing the weather such as Remote Sensing (RS) using satellites and in-situ observations of hydrological and meteorological variables. The first one is the low resolution and density of the data acquired using these methods and the second one is the passive role that they perceive for citizens in terms of understanding their environment (Ciravegna, Lanfranchi et al. 2013). Increasing understanding of the potentials of involving 'citizen science' (or citizen observations) in gathering data and the rapid diffusion of Information Communication Technologies (ICTs) that are interactive and easy to use have provided a bright horizon ahead in facing extreme weather events and threatening hazards resulted from that. The combination of these trends has gained popularity in many disciplines, including the water management domain, and is often referred to as citizen observatories through e-Participation (Wehn et al. 2015).

An example of these ICT-mediated citizen observatories are online amateur weather networks. Amateur weather observation is not by any means a new practice and actually the meteorological science was initiated thanks to the enthusiasm and interest of amateurs (Eden, 2009). During the past two decades, a shift in the ideology of some groups within society about the competence of citizens to participate in weather data collection and sharing coupled with the recent advancements in ICTs and the increasing availability of user-friendly and affordable weather stations (Bell, Cornford, & Bastin, 2013). This resulted in the formation of what nowadays are called online amateur weather networks. Currently, several online amateur weather networks exist and these are evolving rapidly both in terms of the number of users and data visualization and reporting features. The so-called citizen contributed data that is collected using Personal Weather Stations (PWSs) and shared through these platforms can have various applications; there have already been instances of using these data to improve severe-weather warnings (Blum, 2013) and to verify the surface precipitation (Apps, Elmore, & Grams, 2013). However, the increase and success of these applications are dependent on the strong, continuous and widespread involvement of citizens and their active role as the main actors of these initiatives - which in many instances are yet to be achieved. The main objective of this paper is to investigate what drives citizen participation in gathering and sharing data in order to help to maximize their active and continued involvement in citizen observatories. We therefore draw on a well-established theory from the behavioral sciences to investigate the influential factors that may affect citizens' willingness to participate in these initiatives.

2. THEORETICAL CONTEXT

Collecting and sharing weather data using Personal Weather Stations is a citizen-centered and voluntary activity. The first step in describing any behavior that is under the performer's direct management is to understand the decision making process behind it. Several decision making theories exist in the domain of behavioral sciences that try to conceptualize and describe such behaviors, such as the Theory of Reasoned Action (TRA) (Fishbein and Ajzen 1975), Theory of Planned Behavior (TPB) (Ajzen, 1985), Prospect Theory on decision making (Kahneman and Tversky, 1979), diffusion of innovation theory (Rogers 1968), Technology Acceptance Model (TAM) (Davis, Bagozzi et al. 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris et al. 2003).

In line with the higher research objective of this study, that was to investigate the conditions that enable the citizens to choose using the ICTs as a mean to participate in water management under severe weather conditions, the Theory of Planned Behavior (TPB) was chosen as the framework for studying the behavioral determinants of sharing personally-collected weather data via web-platforms. This theory is well grounded and has been implemented previously and tested in numerous studies in diverse areas of research such as health related studies (Nguyen, Potvin et al. 1997, Conner, Kirk et al. 2003), environmental psychology (Stern 2000, Koger and Winter 2010), entrepreneurship (Kautonen, Van Gelderen et al. 2013), data sharing (Wehn de Montalvo 2003), etc. According to this theory, the behavioral intention of an individual to perform a behavior is based on three main constructs; 'attitude' toward the behavior that is linked with expectations about the outcomes resulting from performing that behavior; perceived 'social pressure' or beliefs about the expectations of others and their (dis)approval and, finally, the 'perceived behavioral control' or perceptions of the absence or presence of specific factors that impede or facilitate performing that behavior (Ajzen, 1991).

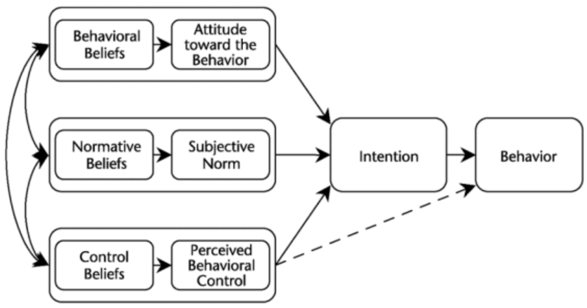

Figure 1. The Theory of Planned Behavior diagram, Source: (Ajzen 1991)

Aside from the wide range of previous applications, the strength of this theory is the inclusion of the 'perceived behavioral control' factor that helps explaining behaviors that are not fully under volitional control and require skills or resources (Wehn de Montalvo, 2003). This is the case for the behavior of interest here, i.e. sharing PWS data via online platforms (or citizen observatories).

3. METHODOLOGY

Empirical research was conducted in the Netherlands, UK and Italy with regards to the influential factors on citizens' willingness to participate in a specific case of ICT-mediated citizen observatories, i.e. citizens sharing their personally collected-weather data using web-platforms. This behavior was studied within two major groups of citizens: (1) Personal Weather Station data-sharers and (2) the general public (other members of society who either do not have a PWS or have the equipment but do not share the data it generates via web-platforms). Based on our theoretical framework, we aimed to identify the range of beliefs that may facilitate or impede sharing personally-collected weather data via web-platforms. To achieve this, we needed to acquire an in-depth understanding of citizens' beliefs about this activity and therefore chose a qualitative empirical research approach. The results and findings from this empirical research were further complemented by a review of secondary literature (for the full literature review see Gharesifard, 2015).

An online semi-structured survey with open ended questions was used to collect data about the PWS data sharers for practical reasons (their geographically diverse locations) and potential privacy issues (since the PWSs are usually located at their home). The second group (non-PWS data sharers) could be reached more easily and therefore was interviewed either face-to-face (for the Netherlands and UK cases) or via phone/Skype (Italy case) using the same questions. Furthermore, in each of these countries, one location with low concentration of PWSs (Delfland in the Netherlands, Doncaster in UK and Ascoli Piceno in Italy) and another one with high concentration of these stations (Hoofddorp in the Netherlands, London in UK and Vicenza in Italy) were selected for conducting the interviews with the general public (See Figure 2). This strategy was adopted to be able to include the dominant facilitating or impeding beliefs that this group might have towards sharing PWS data via online-platforms.

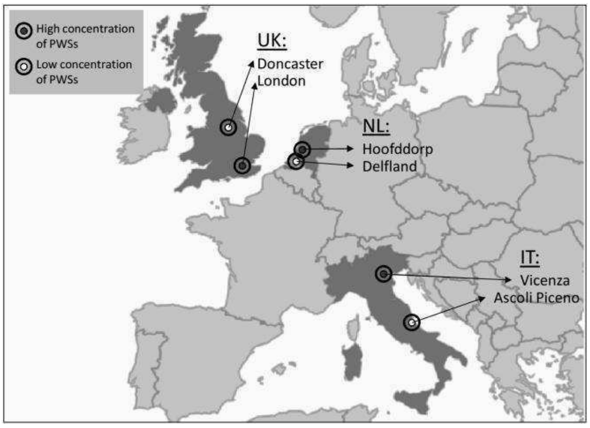

Figure 2. Locations of the case study areas in the Netherlands, UK and Italy

While conducting the interviews among the general public, in all case study areas, general factors such as the interviewees' age groups and gender were taken into account. Moreover, 100 email invitations to participate in the online survey were sent per case study to the potential respondents from the PWS data-sharer group (the total number of identified PWSs that could be contacted at the time of conducting the research were 149 in the Netherlands, 539 in the UK and 292 in Italy). The main criteria that were considered while selecting these potential respondents were: (1) inclusion of at least some stations from the six previously mentioned interview locations, (2) a balanced inclusion of possible respondents from regions with different station frequency categories, (3) spatial coverage of the rest of the stations across the country. Table 1 presents the number of interviews with the general public and online survey response from PWS-data sharers in all three case studies.

Table 1. Overview of interviews and responses to online surveys

Case study	Interviews with the general public	Valid responses to online surveys (PWS data sharers)
NL	11	13
UK	10	14
IT	9	16
Sum:	**30**	**43**
All three cases	**73**	

4. RESULTS AND DISCUSSION

4.1 Attitude towards Sharing Personally-Collected Weather Data via Web-Platforms

'Attitude' is one of the main components argued to affect the intention of performing a specific behavior and in our case is based on the perceived (positive and/or negative) outcomes or consequences of sharing personally collected weather data via web-platforms. Based on the collected data during empirical research, beliefs about the outcomes of sharing in all three cases can be clustered into four domains: 'tangible personal outcomes', 'intangible personal outcomes', 'social outcomes' and 'interpersonal trust'. Table 2 summarizes the elicited beliefs based on the views of both engaged (i.e. data sharing) and non-engaged citizens.

Table 2. Summary of the beliefs about the outcomes of getting engaged in sharing personally-collected weather data

Perceived Outcomes	Positive	Negative
Tangible personal outcomes	• Usefulness of the collected data for personal purposes (GP8, PWS8)	• Uselessness of the collected data for personal purposes (GP7) • Privacy and security issues (GP5, PWS6)
Intangible personal outcomes	• Sense of belonging to a community of friends with shared interests/visions (GP6, PWS5) • learning from each other (GP3, PWS2) • Interest in the weather (PWS10)	• Not being recognized (PWS6) • Not having Interest in the weather (GP7)
Social outcomes	• Risk prevention applications (GP4, PWS9) • Benefit the society at large through creating knowledge about the weather (GP15, PWS25)	
Interpersonal trust	• Trust in citizens' competence and data reliability (GP15, PWS22) • Trust in citizens' intentions (GP9, PWS4)	• Mistrust in citizens' competence and/or data reliability (GP11, PWS12) • Perceiving doubtful intentions (GP3, PWS1)

Notes: GP …=The frequency (occurrence) of similar responses received from interviewees from the general public
PWS… = The frequency (occurrence) of similar responses received from PWS data sharers during the online surveys

Regarding tangible personal outcomes, the usefulness of the collected data for personal purposes like business, education, etc was mentioned by both PWS data sharers and the general public as a motivator for citizen's engagement in sharing the data. Not being able to find any personal application for the data however was elicited as a deterring factor by the general public. Furthermore privacy and security issues such as the fear of theft (as some of the equipment must be installed outdoor), the possibility of being located by unwanted visitors like marketers, vendors and researchers and also cyber security were among the mentioned concerns by both groups. Positive personal outcomes such as a sense of belonging to a community of friends with shared interests/visions, learning from each other and the inner enjoyment (resulted from having a keen interest in the weather) were perceived as intangible outcomes of citizens' involvement. On the other hand, a sense of boredom (because of having no interest in this activity) was identified by some respondents from the general public as a form of intangible negative outcome. For the PWS data sharers, however, the only negative outcome of this domain was not being recognized and acknowledged for the free service that they provide. At the societal level, both groups of respondents could only perceive positive outcomes as these data sharing initiatives may serve risk prevention and may also benefit society at large by creating knowledge and professionalism regarding the weather (the latter was frequently mentioned by both groups of respondents). The interpersonal trust domain relates to the expectations regarding the sharers' competence and the objectives of sharing promoters. . Views on the weather-related competence of citizens and the reliability of the data that they produce as well as the reasons (agenda) of data sharing promoters were highly diverse both among the PWS data sharers and the general public respondents.

4.2 Social Pressure to Share Personally-Collected Weather Data via Web-Platforms

'Social Pressure' is the second main component of the TPB and in this study refers to the (dis)approval by key referents (individuals, groups or institutions) about sharing personally collected weather data via web-platforms. Based on the data collected, the normative beliefs about the referents' views in the three cases can be represented by five different domains: '(Non-) governmental organizations', 'Scientific community', 'Weather enthusiast community', 'Other society members' and 'Moral norms and altruism' (see Table 3).

Table 3. Summary of the source and nature of perceived pressure to share personally-collected weather data

Social pressure Key referents	Perceived pressure	
	To share	Not to share
(Non-) governmental organizations	• New weather related commercial actors (GP2, PWS2) • Traditional weather related commercial actors (GP5, PWS3) • Weather-related (inter)governmental organizations (GP9, PWS8) • Other industrial sectors (GP8, PWS6)	• Traditional weather related commercial actors (GP2, PWS6) • Weather related (inter)governmental organizations (GP3, PWS2) • Other industrial sectors (GP6, PWS2)
Scientific community	• Scientists (GP5, PWS3) • Educational institutes (GP2, PWS5)	• Scientists (GP5)
Community of weather enthusiasts	• Weather enthusiast individuals (GP5, PWS5) • Weather networks (PWS10) • Weather-related hobby clubs (PWS5)	
Other members of society	• Environmentalist community (GP1) • Family members and peers (GP1, PWS1)	• Critics of Citizen Science/ Big Data (GP9, PWS8) • Anti-environmentalist community (GP1, PWS1) • Family members and peers (GP1)
Moral norms and altruism	• Risk prevention (GP4, PWS9) • Benefit for society at large (GP15, PWS25)	

With respect to the domain of (non-) governmental organizations, new weather-related commercial actors such as PWS manufacturers and application developers who are the emerging providers of weather-related products and services were perceived to approve of sharing the data because of the direct benefits that they obtain from the diffusion of the technology that is required for this activity. On the other hand, there were opposing perceptions of the (dis)approval by the traditional weather-related commercial actors (long-established organizations such as news agencies/channels and private weather forecast organizations), weather-related (inter)governmental organizations and other industrial sectors such as agriculture, energy, tourism and transport sectors. In the scientific community domain, scientists were elicited as supporters of sharing such data by both groups; however the general public also perceived the scientists as opponents of data sharing. In case of educational institutes, a consensus existed among both groups in favor of sharing since they may use the data for educational purposes. As their label suggests, communities of weather

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enthusiasts were perceived to support sharing personally-collected weather data. There were also a few respondents who mentioned beliefs about the (dis)approval of other members of society such as the (anti-)environmentalist community, family members and peers. Critics of Citizen Science/ Big Data were frequently mentioned to impose negative pressure on those who engage in data sharing. Moral norms and altruism relate to moral obligations to perform or not perform a behavior and therefore may be categorized as a 'Social Pressure' antecedent. Moral and inner approval due to the perceived usefulness of sharing PWS data for risk prevention and the benefits of this activity for society at large were reasons why respondents perceived positive pressure to share PWS data.

4.3 Perceived Control over Sharing Personally-Collected Weather Data via Web-Platforms

Perceived Behavioral Control is the third main component of the TPB and also a function of beliefs, in our case about the perception of an individual about the absence or presence of factors that may impede or facilitate PWS data sharing via online-platforms. According to the theory, these factors can be further divided into two groups based on their relation to the individual who performs the behavior; internal factors or external ones (Ajzen & Madden, 1986; Wehn de Montalvo, 2003). During our study, four different control domains were identified, namely 'technical skills', 'knowledge self-efficacy', 'resource control' and 'opportunities'. The first two categories are internal factors while the last two are external ones (see Table 4).

Table 4. Summary of the perceived control over getting engaged in sharing personally-collected weather data

Social pressure		Perceived Control	
		Easy/present	Difficult/absent
Internal factors	Technical skills	• Having technical skills to set up and maintain the PWS (GP2, PWS8) • Having relevant IT skills (GP4, PWS7)	• Lack of technical skills to set up and maintain the PWS (GP3, PWS8) • Lack of relevant IT skills (GP7, PWS8)
	Knowledge Self-efficacy		• Lack of knowledge about meteorology science (GP1, PWS2) • Unfamiliarity with data collection methods (GP10, PWS10)
External factors	Resource control	• Presence of weather observation equipments (type, accuracy, quality and price matters) (GP13, PWS6) • Reliable Internet connection (GP5, PWS5) • Availability of financial means (GP5, PWS9) • Availability of time (GP6) • Presence of easy to use web-platforms and Apps (GP7, PWS10) • Availability of appropriate PWS installation location (GP1, PWS2)	• Unavailability of equipment that is accurate, high quality and/or at a reasonable price (GP3, PWS2) • Unreliable Internet connection (GP3, PWS9) • Unavailability of financial means (GP9, PWS15) • Lack of time (GP6) • Sophisticated web-platforms and Apps (GP5, PWS7) • Unavailability of appropriate PWS installation location (PWS3)
	Opportunities	• Incentives provided by web-platforms (PWS10) • Opportunities to gain and exchange knowledge (PWS4)	

Having technical skills for setting up and maintaining their PWSs and also having general (hardware and software) IT skills were mentioned as factors that - if present - may facilitate sharing personally-collected weather data and - if absent - will make it difficult. With regards to knowledge self-efficiency, perceptions about the required level of meteorology science appeared as an inhibiting factor for a few respondents; however, unfamiliarity with data collection methods was more frequently elicited by both groups of respondents (PWS sharers and interviewees from the general public). Having control over resources such as the following were mentioned as facilitating factors: accurate, high quality and reasonably priced weather observation equipment, a reliable internet connection, the initial as well as long-term availability of financial resources, having enough time, the ease-of-use of the web-platforms and apps and, last but not least, the availability of an appropriate location to install the PWS station outdoors. On the contrary, the absence of any of these resources was perceived as a barrier for citizen participation. Opportunities are the last series of 'circumstantial factors' whose absence is not expected to affect the behavior (Wehn de Montalvo, 2003) but their presence may serve to facilitate sharing personally-collected weather data. PWS-data sharers identified several incentives that may be provided by web-platforms (such as a certificate for data provision, group excursions to visit official weather station, etc.) to enhance the chance of their long-term participation, including the opportunity to gain and exchange knowledge.

4.4 Summary - Key Barriers and Drivers for Citizens to Share PWS Data via Online-Platforms

The model presented in Figure 3 summarizes the full range of drivers and barriers that may influence the willingness of citizens to become (and remain) engaged in sharing their personally-collected weather data. The highlighted beliefs and domains in this model represent the key drivers and barriers for citizen participation to share PWS data via web-platforms identified from all the three case study areas.

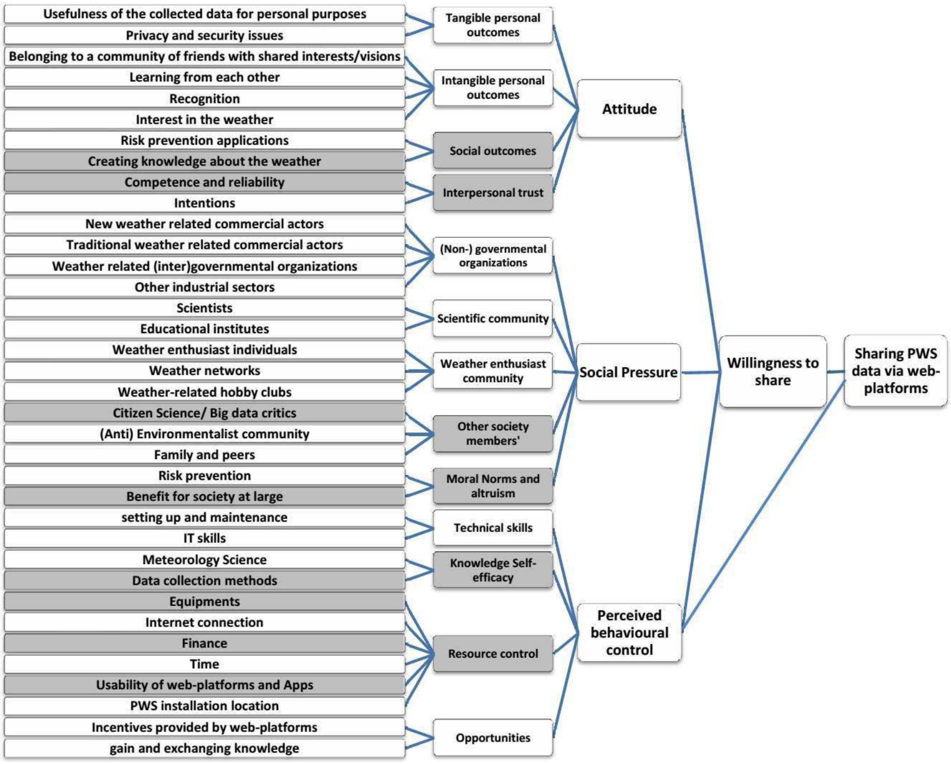

Figure 3. The model of sharing personally-collected weather data via web-platforms (NL, UK and IT)

With regards to the identified outcome-oriented beliefs, social outcomes and trust-related factors appeared as the most salient factors. Social outcomes, especially benefiting society at large by creating knowledge about the weather, were frequently mentioned as drivers for sharing PWS data. Trust-related issues were also highly elicited by the respondents. Furthermore, one of the most contested beliefs was the competence and reliability of the citizens to participate in this activity. Considering the social pressure component, the most frequent negative pressures were perceived from the critics of Citizen Science/Big Data, while moral obligations to share data were mentioned by many respondents from both groups as a driving force. Finally, to summarize the control factors, the existence of resources such as equipment, short/long term financial means and easy to use web-platforms and apps were widely believed to facilitate citizen participation in PWS data sharing. Furthermore, acquaintance with data collection methods was also perceived as a major facilitator of sharing personally-collected weather data.

5. CONCLUSION

ICT-enabled citizen observatories are providing new modes for citizen participation in many environmental-related domains. These innovative approaches can play a crucial role for facing worsening natural hazards resulting from severe weather conditions. This study contributed to investigating these initiatives and describing the dynamics behind them by performing a systematic analysis of the beliefs that citizen (both engaged and non-engaged) hold regarding sharing PWS data. These beliefs portrait the drivers and barriers that may influence the citizens' willingness to become (and to remain) engaged in sharing personally-collected weather data via online platform. The results of this study (both in terms of the range of influential factors and their frequency) can be utilized as a tool for decision makers to develop strategies for further enhancing citizen participation in weather-related observatories. This can be done by addressing the identified inputs and preconditions for citizen participation which may well result in a boost in the current level of citizen engagement in sharing PWS data.

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