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Public grid computing participation: An exploratory study of determinants

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Abstract

Using the Internet, "public" computing grids can be assembled using "volunteered" PCs. To achieve this, volunteers download and install a software application capable of sensing periods of low local processor activity. During such times, this program on the local PC downloads and processes a subset of the project's data. At the completion of processing, the results are uploaded to the project and the cycle repeats.

Public grids are being used for a wide range of endeavors, from searching for signals suggesting extraterrestrial life to finding a cure for cancer. Despite the potential benefits, however, participation has been relatively low. The work reported here, drawing from technology acceptance and volunteer literature, suggests that the grid operator's reputation, the project's perceived need, and level of volunteering activity of the PC owner are significant determinants of participation in grid projects. Attitude, in addition to personal innovativeness and level of volunteering activity, predicted intentions to join the project. Thus, methods traditionally used for motivating volunteer behavior may be effective in promoting the use of grid computing.

Keywords:

Grid computing, Internet, technology acceptance, volunteering, theory of trying

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Public grid computing participation: An exploratory study of determinants

1. Introduction

Many computational problems being solved today require supercomputer performance in order to solve them in a reasonable amount of time. Due to increases in PC performance, millions of which are connected to the Internet but idle, there is an opportunity to accelerate this research. A number of organizations have launched grid computing projects to capture "lost" cycles via specialized software that aggregates the power of these idle systems into a virtual computer. In the past 10 years, "public" grids have been formed to provide this capability. They assist in solving problems ranging from discovering new prime numbers to searching for treatments for HIV/AIDS. Many of these grids have become very large: SETI@home, the largest and probably the most popular of these grids with nearly 4 million registered participants, uses a grid to analyze radio telescope data for patterns indicative of intelligent origins [6].

A number of other public grid projects focus on drug evaluation; they involve screening millions of chemical compounds to identify candidates for use in drug design. The entire process of bringing a new drug to market can take as many as 15 years [37]. One of the largest of these projects, the United Devices Grid MP Global, boasts over 1.3 million members contributing CPU time for projects including cancer and small pox research [23]. In the U.S., cancer deaths are estimated to exceed ½ million annually, with an estimated overall cost of nearly $210B [5]. Recently, bioterrorism simulations have emphasized the need to develop counteragents to highly infectious diseases such as small pox [14]. Thus, for every year the drug development process can be shortened, the result will yield savings both in cost and in lives.

Success of grids depends on attracting sufficient participation levels to warrant the infrastructure development. While an individual's decision to participate is clearly one of technology adoption, it is also a volunteering action in that a person is consenting to join a specific effort. In this paper, I examine the factors affecting volunteering to help in a health science activity (drug evaluation) on a public grid.

2. Philanthropic Grid Computing

Grid computing has been defined as the hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities [21]. While many organizations use multiple computing resources to tackle single problems, public grids differ in that the computing resources are provided by several independent sources, including individual home PC owners on the Internet.

Along with the enabling technology, public grids consist of three major parties: clients, operators, and participants. Clients are the individuals or organizations with the computational task(s) and data. The participants consist of individuals or organizations willing to accept a portion of the overall computational task on their machines. The grid operator is responsible for the overall operation of the grid. The operator incurs a number of expenses related to the linking of participants and clients: development of the client and server software; allocating tasks among the various providers; collecting, aggregating; and storing results as well as addressing technical issues of clients and providers. In recent years, these projects have evolved in both number and diversity (Table 1). In many cases, the same grid infrastructure is used to process data for multiple projects.

Insert Table 1 about here

Grid computing software is fundamentally different from most other types of software: the benefits (i.e., usefulness) from its use accrue to someone other than the person adopting it. In recent years, a growing number of "philanthropic" PC applications have been initiated to provide benefit to external individuals or organizations. Within this group of software, applications vary in the amount of human interaction required to help the projects. At the highest end of interaction, volunteers use their own cognitive skills to complete the project. For example, Distributed Proofreaders (http://www.pgdp.net) was founded to support the digitization of public domain books; each proofreader checks one or more pages which are then sent to another reader to provide verification. The lowest end is populated by the various distributed computing or "grid" projects. In grid projects, an application is installed which performs processing on a small subset of the total processing task without human input.

In summary, grid computing differs from traditional applications in three important ways. First, the *perceived usefulness* of the operation differs from that of traditional applications because these applications are "others-focused". Second, once installed, these applications require little or no interaction from the user. Thus, its *ease of use* is not a significant factor except during the installation process. Finally, the *behavioral intention* of the user is to perform volunteer work with the software being an intermediate step.

3. Grid Participation Determinants

Participation in a grid project may be viewed as both technology adoption and volunteering. To address this duality, this study used a multiple-perspectives approach: individual differences were considered, because they were posited to be related to intentions for both technology adoption [1, 61] and volunteering intentions [39, 48]. As noted in the Technology Acceptance Model (TAM), some but not all variables influence behavior intentions directly [16, 31, 33, 56, 59]. Consistent with this research, attitudes about the specific grid project were also considered yielding a research model that includes motivators for both attitude and intentions (Figure 1).

Insert Figure 1 about here

3.1. Individual Differences

Two factors, personal innovativeness and past volunteering experience, were examined.

3.1.1. Personal Innovativeness

In information systems research, personal innovativeness represents the degree to which an individual is willing to try out any new technology [1]. Prior conceptualizations in marketing characterized innovativeness as an individual's propensity to adopt a technology earlier than his or her peers [46]. Similarly, management literature denoted innovativeness as the receptivity to change [32, 62].

In either case, individuals with higher levels of personal innovativeness were more likely to be users of new technology than users with lower levels [58]. Past research has noted both direct and indirect effects (mediated by attitude) on behavioral intentions [34]. Thus,

H1a *Personal innovativeness will be positively related to grid computing attitudes.*

H1b *Personal innovativeness will be positively related to grid computing behavioral intentions.*

3.1.2. Volunteering Behaviors

Those who have volunteered in the past should be more likely to do so in the future. The assumption "the past predicts the future" is pervasive and an enduring trait of human behavior.

Research has shown that prior experience is an important determinant of behavior [3]. Habits are difficult to break and thus serve as predictors of intention [51]. Research suggests prior experience with products leads individuals to early adoption [22] and successful completion of a task is important to future decisions to engage in similar type tasks [8]. Past behavior has both direct and mediated influence on intention [7, 35]. Therefore,

H2a *Volunteering behavior will be positively related to grid computing attitudes.*

H2b *Volunteering behavior will be positively related to grid computing behavioral intentions.*

3.2. Volunteering Motives in Using Grid Technology

Because of the altruistic nature of grid computing, self-focused motives alone would probably not completely explain intentions. Volunteering research has suggested three motives that should also apply: solidary, purposive, and material rewards [13, 15].

- *Solidary* rewards are derived from group membership. As a member of a community, a person receives the benefit of being associated with a certain type of group and of shaping one's image among peers within the group.
- *Purposive* rewards are based on a person's ability to help an organization meet its goals. For example, a person may contribute to an organization because he or she believes the purpose of the organization is noble.
- *Material* motives include personal benefits. In a grid context, material rewards include performance points (e.g., a person may receive a certain amount of credit for the amount of data processed), sweepstakes eligibility, or other incentives.

Three factors, operator reputation, perceived need and cause importance, were examined.

3.2.1. Grid Operator Reputation

It is likely that a person who is motivated to volunteer will be even more motivated if he or she believes that the organization is worthy of assistance. Signaling theory suggests that customers search for strategies, actions, or other aspects that seem costly to bad businesses and profitable for good ones [10]; these will be used to derive information about unobservable product or service attributes that customers deem to be important. When a firm fails to fulfill its signals, its reputation and credibility decrease [25]. Therefore, a good reputation is a trust that an organization will meet its promises. Assuming an individual evaluates these promises favorably, an organization with a good reputation should lead customers to have a more positive attitude towards the service that is offered [11, 12, 17, 41]. Furthermore, solidary rewards accrue from association with a group supporting a worthy organization. Thus,

H3a *Grid operator reputation will be positively related to grid computing attitudes.*

H3b *Grid operator reputation will be positively related to grid computing behavioral intentions.*

3.2.2. Perceived Need of the Organization

An important purposive motive for volunteering is gaining a sense of contribution. One factor that affects this sense of contribution is the perceived need of the organization [29, 30]. Implicit in the decision to become a donor is a belief the actions can make a difference. Because of this, charitable organizations try to motivate volunteering by emphasizing the significance of their needs. Relief organizations often assign one or more foster children to donors, so they can see the magnitude of the need in human rather than monetary terms.

Given two projects with equal importance (ceteris paribus), a person will likely help the project with the greatest need. For example, a person wishing to help children in living in poverty might select an organization that focuses on regions with lower per capital incomes perceiving that organization to have the greater need. Thus, an organization supporting children in might be perceived as having a greater need than one in North America or Western Europe where the per capita income is higher.

Therefore,

H4a *Perceived need of the organization will be positively related to grid computing attitudes.*

H4b *Perceived need of the organization will be positively related to grid computing behavioral intentions.*

3.2.3. Cause Importance to the Individual

Like other forms of participation, the focus of a particular grid project will probably influence participation [28]. Public grid computing projects have a wide range of goals. These project goals are essentially independent of the actual technology but still may be important in shaping attitudes and intentions about the technology used to address them. There are material rewards in supporting a cause that has personal importance. The level of involvement with an issue is influenced by the perceived importance [60]. Higher involvement is thought to have more influence on attitudes and beliefs, because more attention is paid to the subject [38]. Thus, grid computing projects having higher cause importance to the individual are more likely to gain support.

H5a *Cause importance to the individual will be positively related to grid computing attitudes.*

H5b *Cause importance to the individual will be positively related to grid computing behavioral intentions.*

3.2.4. ***Attitude***

Attitude represents the feelings toward performing a behavior [42]. Attitude has a direct relationship to behavioral intention which in turn predicts behavior [18]. This relationship has been verified in a technology context in a number of studies [26, 50] as well as other settings [49]. Based on the strong and consistent link between attitude and behavioral intentions, it was hypothesized that attitude will be related to behavior intention for grid computing. Thus,

H6 *Overall grid computing attitudes will be positively related to grid computing behavioral intentions.*

4. Method

A laboratory experiment was conducted to test the hypotheses. A total of 249 individuals participated; of these, 11 (4%) were current or previous participants in the grid program presented here and were excluded from further analysis. The majority of the remaining 238 respondents were business and psychology students at two large Midwestern U.S. universities. Student participants received extra credit for survey completion. Descriptive statistics are given in Table 2.

Insert Table 2 about here

4.1. Stimuli and Procedures

Web pages were used to present the information and collect the data. Each participant worked individually to evaluate the grid project. Afterwards, respondents used the same Web pages to provide demographic data.

In order to match practices commonly employed by operators of public grid projects, the participant grid software used a single program to process data for multiple projects. This configuration was based on one previously used by the grid operator **United Devices**. The Web pages described this computational grid and two grid projects based on actual work previously conducted by the company. The descriptions were taken from information on the United Devices Web site – one philanthropic and the other commercial. The philanthropic project was the United Devices Cancer Research Program, which was developed to aid in the search for new drugs to treat leukemia and other cancers. The commercial project was the United Devices Web Performance Testing Program, which used each grid computer to simulate a Web browser session with pauses to mimic reading time or interactive input (such as searches and adding items to a shopping cart).

4.2. Independent Variables

The independent measures were individual differences (personal innovativeness and volunteering behavior) and volunteering motives (grid operator reputation, perceived grid operator need, and cause importance). Personal innovativeness was taken from Agarwal and Prasad [1]. Volunteer behavior consisted of four categories based on self-reported volunteer hours per week: none (0), 1 hour (1), 2 hours (2), three or more hours (3). Grid operator reputation was based on items taken from previously used measures [27, 44]. Perceived need items were adapted from Fisher and Ackerman [19]. Project importance included two items based on product importance measures from marketing literature [9] that assessed respondent's opinion of the importance of cancer research. Participants responded on 7-point scales with endpoints strongly disagree (1) to strongly agree (7) for all measures, with the exception of volunteer behavior. Specific item wording can be found in the appendix.

4.3. Dependent Variables

The dependent measures were attitude and intention to try the grid program. The three items for attitude were adapted from Ajzen [2] and included. "I think the idea of integrated grid computing software for this project is…bad/good, unfavorable/favorable, negative/positive.” Based on items adapted from Venkatesh et al [53], the ***goal*** of using grid software was measured by the three items “I plan to try this program”, “I predict that I will try this program” and “I intend to try this program” measured on seven-point scales varying from strongly disagree (1) to strongly agree (7). The mean (standard deviation) of intentions score was 3.54 (1.46) and thus this group may be considered mildly reluctant (neutral being 4).

4.4. Measurement Model

A confirmatory factor analysis (CFA) using AMOS 5 was conducted to test the model. The overall fit was assessed using multiple sample size independent indices. These indices and their recommended threshold values are provided in Table 3. The obtained indices exceeded the recommended values for all reported indices, suggesting that the model provided a good fit for the data.

Insert Table 3 about here

Reliability and convergent validity of the constructs were assessed by Cronbach’s alpha and composite reliability (Table 4). Cronbach’s α for all five constructs exceeded the recommended 0.70 threshold [40]. Composite reliabilities exceeded the recommended 0.70 level [20] in all but one case (cause importance) implying acceptable levels of reliability for each of the constructs.

Insert Table 4 about here

To evaluate discriminant validity, the average variance extracted (AVE) for each construct was compared with the shared variance between constructs. Table 5 indicates that the AVE statistics (diagonal values) for each construct exceeded the shared variance in the corresponding row and column in each case [24]. Variance extracted estimates were also in excess of the 0.50 recommended level with the exception of cause importance. Thus, the model exhibited acceptable discriminant validity.

Insert Table 5 about here

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5. Structural Model

The structural model was also assessed using the same set of fit indices used for the measurement model. Results were analyzed by assessing the structural model with attitude toward the grid software and intentions toward the grid software as the dependent variables (Figure 2). For the structural model, R^2 values were calculated for the endogenous (dependent) constructs.

Two variables, perceived need and operator reputation, were significant predictors of attitude toward participating in the grid projects, explaining 14% of the variance. Attitude, along with personal innovativeness and volunteer behavior determined behavior intentions, accounted for 45% of the variance in the intentions. Thus hypotheses H2a, H3a, H4a, H1b, H2b, and H6 were supported. The relationship between personal innovativeness and intentions (H1a) and between cause importance and attitude (H5) were not statistically significant.

Insert Figure 2 about here

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6. Conclusion

The results obtained suggest the importance of both technology acceptance and volunteer participation factors in predicting public grid computing project participation. The tested variables (operator reputation, perceived need, and volunteer behavior) explained a relatively small proportion of explained variance in attitude but nevertheless, when both direct and indirect effects were taken into consideration, resulted in considerable relationships (0.11, 0.12, and 0.19 for operator reputation, perceived need, and volunteer behavior respectively)[2]. Furthermore, this percentage was explained solely by non-technology factors, indicating that a perceptual duality (i.e., technology and volunteering) does indeed exist. Surprisingly, the cause importance was not a predictor of attitude or intentions.

6.1. Implications

The results have several implications. The relatively small proportion of variance in attitude explained by the tested variables suggested that other important determinants (both technology and volunteering) were not tested.

From a technology perspective, diffusion of innovations research suggests that innovations that are perceived as having greater advantage, compatibility, trialability, and observability and less complexity will be adopted more rapidly than others [45]. Viewing grid participants as members of an online community, practices in use, such as name recognition for participants

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[2] Total effects calculations:
Operator Reputation = 0.54 * 0.20 = 0.11
Perceived Need = 0.54 * 0.23 = 0.12
Volunteer behavior = 0.54*.012 + 0.13 = 0.19

(e.g., SETI@Home), posting past achievements of the group (e.g., distributed.net), and providing statistics on community size (e.g., United Devices) may affect potential participants' decisions.

From a volunteering perspective, material motives may be important determinants of participation. Material rewards previously or currently employed by grid operators include "points" for participation (e.g., United Devices), cash for participation (e.g., Entropia), and entry in a regularly scheduled lottery (e.g., Parabon). Research on increasing participation across a wide variety of voluntary activities has suggested additional incentives such as discount coupons for future purchases, donations to charities, and "prepayments" - rewards given prior to any commitment of the participant [57].

Finally, viewing participation as a consumption act, a consumer behavior/risk reliever perspective offers additional insights: rather than looking at motives, the focus is on mitigating the influence of inhibitors [47]. Among the most obvious inhibitors are security and privacy concerns [36, 54]. Common risk relievers include celebrity endorsements, free sample/trial offers, and choosing a product or service based on familiarity (i.e., bundling a low familiarity product/service with high familiarity product/service) [4].

The results also suggest that the types of people who most likely support such projects are computer owners who are more innovative and have volunteered in the past. A reputable download site of public domain software such as Ziff-Davis' ZD Net (www.zdnet.com) might serve as an avenue for increasing participation rates given that downloading suggests higher levels of personal innovativeness.

Similarly, requests from a known volunteer organization or charitable organization might appeal to donors and volunteers looking for ways to increase their level of participation. Because reputation is important, a partnering relationship may be effective in improving the operator's reputation by association. Finally, grid operators would do well to emphasize the savings in terms of both lives and dollars resulting from accelerated drug evaluation.

7. Limitations

In this study, there is a possibility that the relative youth of the participants may have created a bias. The nature of this bias however, is unclear. Some research has suggested a negative relationship between age and computer attitudes [55] and Web usage [43], while others have found no such relationship [52]. Also two very specific projects were examined. The results may have depended on the specific project choices (cancer research and Web testing).

Finally, post survey discussion with participants suggested the importance of a number of factors that were not specifically stated in the project descriptions but may have impacted project perception. These included such uncertainties as the duration of the project ("How long will I have to let this program run on my computer?"), the proportion of processing for each project ("How much of my computer's processing actually goes towards cancer research?"), and the nature of the volunteer commitment ("What happens if I change my mind?"). While such questions are frequently available via frequently asked questions (FAQs) sections of Web sites, these sources may go ignored by less sophisticated users. Inclusion of this information in the project description page or download page may help alleviate uncertainty and thus positively affect intention.

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Appendix - Operationalization of variables

Personal Innovativeness

- I like to experiment with new personal computer software.
- Among my peers, I am usually the first to try out new personal computer software.
- If I heard about a new personal computer software package, I would look for ways to experiment with it.

Operator Reputation

Based on what I know about the grid service operator (United Devices), I think United Devices...

- has a good reputation.
- has a good overall image.
- has good products/services.

Perceived Need

- The Cancer Research Grid project really needs my help.
- Every person who volunteers will make a difference.
- My help is important to the success of the Cancer Research Grid project

Cause Importance

- Cancer research is important to me.
- Cancer research should be a top national priority.

Volunteer Behavior

On average, how many hours of volunteer work do you perform per week?

Attitude toward Grid

I think the idea of integrated grid computing software for this project is...

- 1) Bad 7) Good
- 1) Unfavorable 7) Favorable
- 1) Negative 7) Positive

Behavioral Intentions

During the next six months...

- I plan try the integrated grid program.
- I predict that I will try the integrated program.
- I intend to try the integrated program.

Table 1 Sample list of public grid computing projects

Project	Year of Inception
GIMPS (Great Internet Mersenne Prime Search) computes for prime numbers given that if 2^P-1 is a prime number, then P must also be a prime number.	1996
This non-profit organization serves as a gathering point for topics related to distributed computing as well as the process of linking these computers to solve particular problems. Most projects to date have focused on cryptographic key deciphering.	1997
The largest Search for ExtraTerrestrial Intelligence (SETI) in terms of number of participants. SETI@home examines radio telescope data for patterns indicative of extra-terrestrial origins	1999
This project seeks to help predict the Earth's climate over the next 50 years.	1999
The FightAIDS@Home project hopes to assist fundamental research to discover new drugs using the growing knowledge of the structural biology of AIDS.	2000
Parbon operates a number of projects including ComputeAgainstCancer which is trying to understand and reduce the side effects of chemotherapy and create better ways to screen new cancer drugs.	2000 (Compute Against Cancer)
United Devices operates a number of projects including the United Devices Cancer Research Project which is focused on uncovering new cancer treatments and the Small Pox Research Grid which is attempting to identify drug candidates that would combat post-infection by small pox.	2001 (Cancer Research Project) 2003 (Small Pox Research Grid)
World Community Grid's mission is to create the largest public computing grid benefiting humanity. It currently includes the FightAIDS@Home Project (see above) and the Human Proteome Folding Project.	2005 (Human Proteome Folding Project)

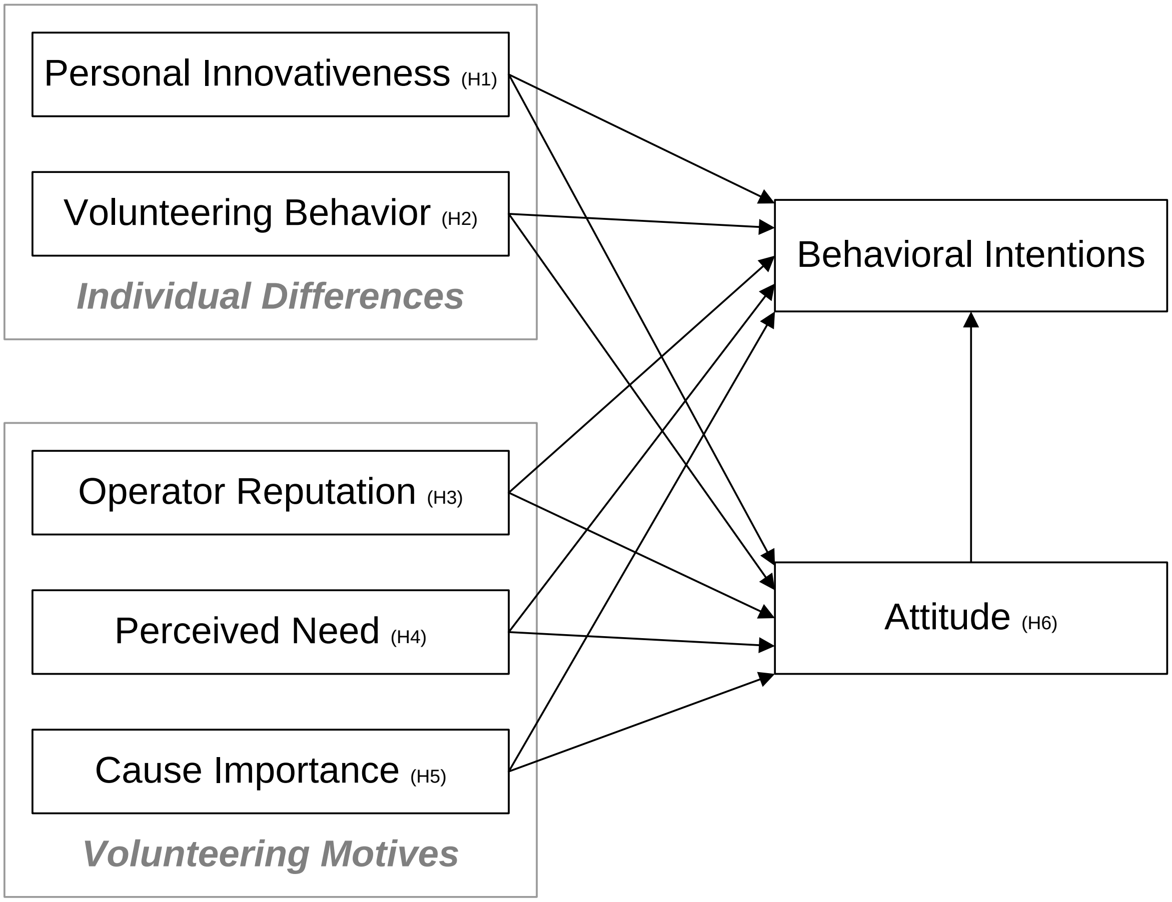

Figure 1 Research model

Table 2 Sample characteristics (N=238)

		Count	Percentage
Gender			
	Male	156	66%
	Female	82	34%
Age			
	18-24	225	95%
	25 and above	13	5%
Average volunteer hours per week	0	120	50%
	1	48	20%
	2	40	17%
	3 or more	30	13%
Frequency of Web use			
	A few times a week	1	1%
	About once a day	8	3%
	More than once a day	229	96%
Home Computer *			
	Computer with high-speed access	200	84%
	Computer with modem Internet access	26	11%
	Computer without Internet access	6	3%
	No computer	6	3%

* Percentages do not add up to 100% due to rounding errors

Table 3 Fit indices for the measurement model.

Fit Index	Recommended Value	Measurement Model	Structural Model
χ^2/df	≤ 3.00	1.49	1.32
Goodness of Fit (GFI)	≥ 0.90	0.93	0.94
Adjusted Goodness of Fit (AGFI)	≥ 0.90	0.90	0.91
Normalized Fit Index (NFI)	≥ 0.90	0.95	0.96
Non-Normed Fit Index (NNFI)/Tucker-Lewis Index (TLI)	≥ 0.90	0.98	0.99
Comparative Fit Index (CFI)	≥ 0.90	0.98	0.99
Root Mean Square Residual (RMSR)	≤ 0.10	0.09	0.06
Root Mean Square Error of Approximation (RMSEA)	≤ 0.10	0.05	0.04

Measurement Model: χ^2=174.2.1, df=117, p =.000;
Structural Model: χ^2=131.1, df=99, p =.017

Table 4 Internal consistency of the constructs

Construct	Number of Items	Cronbach's Alpha	Composite Reliability
Perceived Need	3	0.85	0.84
Perceived Reputation	3	0.92	0.92
Personal Innovativeness	3	0.87	0.87
Cause Importance	2	0.71	0.62
Volunteering Behavior	1	-------	-------
Attitude	3	0.95	0.95
Behavioral Intentions	3	0.96	0.96

Table 5 Construct means, standard deviations, correlations, and average variance extracted

Construct	Mean	S.D.	1	2	3	4	5	6	7
(1) Volunteer Behavior	0.92	1.08	**----**						
(2) Personal Innovativeness	3.90	1.44	0.10	**0.84**					
(3) Operator Reputation	4.96	1.04	-0.03	0.06	**0.89**				
(4) Perceived Need	4.88	1.14	0.07	0.17 **	0.29 **	**0.83**			
(5) Cause Importance	5.66	1.07	0.04	-0.06	0.20 **	0.40 **	**0.67**		
(6) Attitude	4.96	1.56	0.13 *	0.15 *	0.24 **	0.29 **	0.07	**0.93**	
(7) Behavior Intentions	3.54	1.46	0.22 **	0.31 **	0.10	0.28 **	0.07	0.59 **	**0.94**

Notes: Values on the diagonal are the square root of the average variance extracted (AVE). Off diagonal entries are the correlations between constructs (i.e., shared variance).

* $p < 0.05$ level; **$p < 0.01$ level (2-tailed).

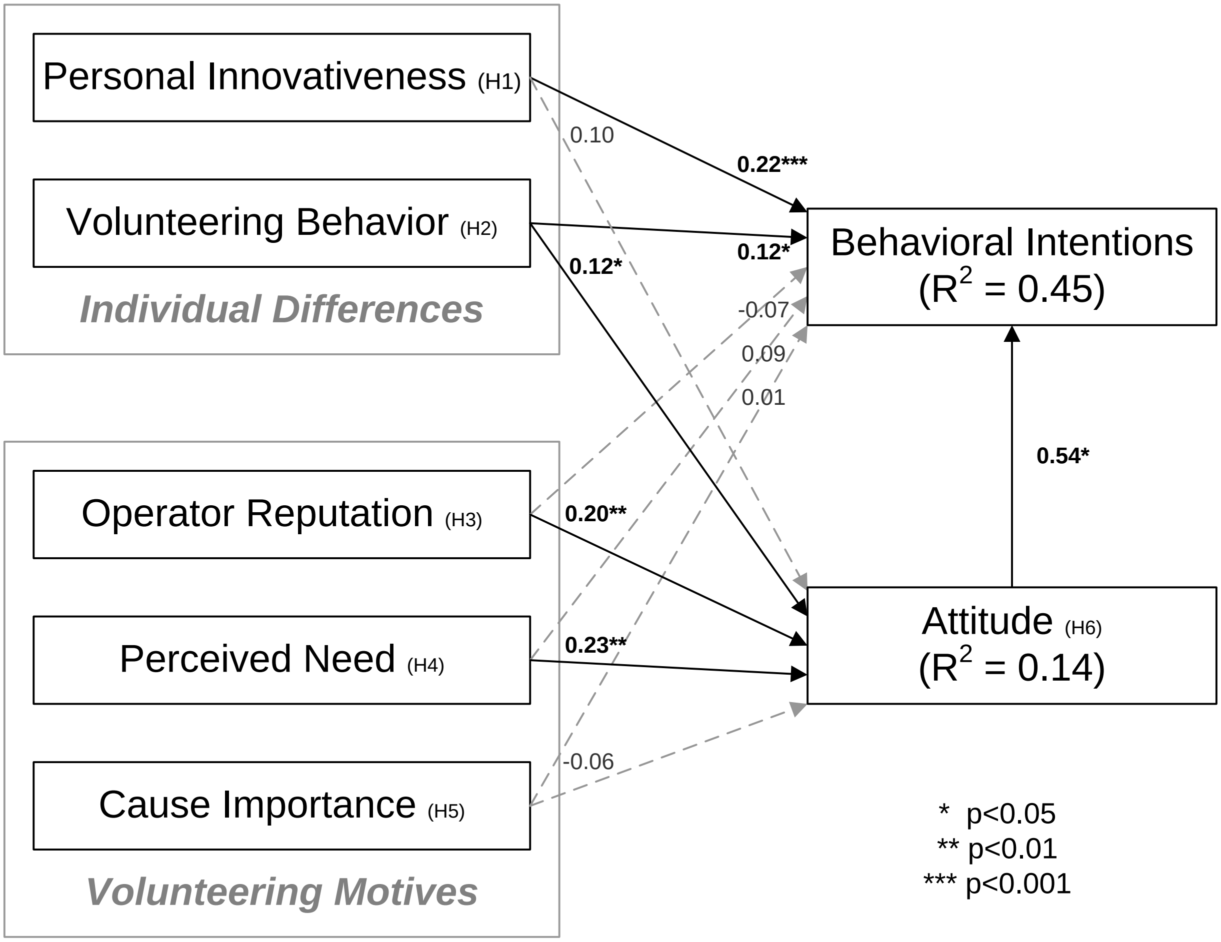

Figure 2 Structural model results