Computational Modeling and Human Values: A Comparative Study of Corporate, Academic, and Government Research Labs

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Abstract

This paper investigates the relationship between human values and computational modeling through mixed-method field research at three organizations (corporate, academic, and government research labs). This research builds on research on the role of values in information technology design from science and technology studies, information ethics, and human-computer interaction. Surveys and interviews were used to identify statistically significant differences among modelers in the three organizations both in terms of their self-assessment of their values and in the frequency of value occurrences within specific organizational contexts. Interviews also provided qualitative data that explain the statistically significant differences. Results included a higher value placed on creativity and lower values placed on conformity-related values among researchers in the academic lab. This paper demonstrates that there are statistically significant differences among the values of the modelers employed within the three organizations. Future research involving more sites can generalize the relationship between values and organization type.

1. Introduction

Models shape science and society, and these same models, in turn, are shaped by the values of the modelers who develop them, as well potentially as other stakeholders [9]. Models, which are abstractions of reality, are developed to help summarize and make sense of the data collected and processed by information systems. These models may be used in domains such as the physical and natural sciences or the social, behavioral and cognitive sciences [2]. In order to exercise the models, they are embedded in software, utilize various visualization techniques, and are made accessible by a diverse set of technologies that can be located almost any where in the world. Often, computational models become components in decision technologies that support decision making for both the public and private sectors. Policies with wide-ranging and far-reaching effects for millions of people may be based on information derived from analysis by computational models. For example, a recent report for the U.S. National Science Foundation [19] stated that computer modeling and simulation "is more pervasive today – and having more impact – than at any other time in human history. Many critical technologies, including those to develop new energy sources and to shift the cost-benefit factors in healthcare, are on the horizon that cannot be understood, developed, or utilized" (p. ii) without models.

Models are constructed by people, and as such, the modelers who build models may intentionally or unintentionally imbed their values within models, or their values may shape the modeling process. As such, it is important to understand the contexts within which modeling occurs as well as the values of modelers.

This paper examines differences in values among three different organizations, including corporate, academic, and government research labs that develop computational models. The background section provides a brief overview of the role of human values in the development and use of information technologies in general and computational models in particular. The methods section describes the field research protocol employed in this study, including mixed-method data collection and analysis. The results section reports statistically significant findings from both the surveys and interviews, and then uses qualitative data from the interviews to explain these findings. The discussion section provides an overview of the implications of these findings as well as discussing the limitations of and potential future directions for this research. Finally, the conclusion section explains the significance of these findings for the study of human values and computational modeling.

2. Background

Values can be defined as, "guiding principles of what people consider important in life" [3]. While other studies have focused on modeling in different organizations [16], these studies tend to rely more on

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personal experience and anecdotes rather than on systematic social scientific approaches to data collection and analysis. Thus, there is a need for studies that systematically examine the differences in how values shape modeling in different organizations.

While the traditional technoscientific perspective has held that technologies are value-neutral, this argument has been opposed by researchers within the field of science and technology studies who argue that technologies do contain embedded values, and thus technologies are an important focus for ethical discussion. Winner [18] demonstrates that the design of technologies is a political process. Winner argues that values such as "power, authority, freedom, and social justice are embedded in technical structures" (p. 40). Sclove [15] extends this assertion by explaining that values can be explicitly or implicitly embedded in technologies. Sclove asserts that technologists should be aware of the social ramifications of their design work, and should use their positions to work toward equalizing power relations rather than reinforcing or further stratifying unequal power structures. Going even further, Martin, Huff, Gotterbarn, and Miller [13] argue that the ethical implications of embedded values are so significant that, "it is unethical to ignore the values embedded in technological artifacts" (p. 80). Johnson [12], based on Bijker [1], argues that values shape technologies and that, at the same time, technologies shape values. Johnson then builds on the work of Winner [18] and Sclove [15] to argue that technologies shape values through their embedded values. Thus, in order to understand the impacts of technologies, it is important to determine what values are embedded within the technologies.

At the same time, in the field of modeling, Crapo et al. [5] argue that to understand a model, it is also important to understand the context of the model. Uniting the insights of Johnson [12] with Crapo et al., it is possible to see that if technologies such as models shape values through embedded values, values shape models by way of the context, that is to say, through contextual values. Thus, study of contextual values alongside embedded values completes the mutually constitutive loop between models and values [7]. This paper builds on earlier work on transparency [6, 8], value conflicts [9], and professional codes of ethics [10] by focusing specifically on the relationship between values and organizations.

3. Methods

This paper seeks to answer the following question: Do values shape computational modeling differently in different organizations? The three field sites for this research included corporate, academic, and government research labs. The field sites were studied in that order. The field sites were selected because they are prominent sites for cutting-edge research in the field of computational modeling. The modelers at these research labs who participated in this study employ a wide range of different modeling techniques to solve problems in research and development.

3.1. Data collection

Data collection occurred in three stages at each lab. The first stage involved distributing an online survey as well as conducting an initial focus group meeting. A total of 76 modelers completed the survey, including 21 at the corporate lab, 22 modelers at the academic lab, and 33 at the government lab. The research protocol was approved by the participating organizations as well as by the researchers' institutions' Institutional Review Boards.

The survey included as a component the Schwartz Value Survey [14], which includes 56 values organized within ten universal value types found to varying degrees in national cultures around the world. Schwartz divides values into two dimensions: 1) openness to change versus conservation and 2) self-enhancement versus self-transcendence. Ten value types are positioned within the Cartesian coordinate system formed by these two dimensions: power, achievement, hedonism, stimulation, self-direction, universalism, benevolence, tradition, conformity, and security. He conducted a cross-cultural study demonstrating that all ten of these value types can be found in societies around the world. Schwartz's value dimensions, value types, and, even more specifically, the 56 distinct values that he used in constructing his survey form the foundation of the theoretical framework for this study. Further, the data analysis of this study is largely based on quantitative and qualitative analysis that applies the 56 values from the Schwartz Value Survey.

The Schwartz Value Survey [14] begins with the question: "How important are each of the following values as a guiding principle in your life?" Each of the 56 values is then listed, along with a definition of each value. Respondents are asked to rate each of these 56 values on a 9-point Likert-style scale, from 7 to -1, where 7 is defined as "of supreme importance," 6 is defined as "very important," 3 is defined as "important," 0 is defined as "not important," and -1 is defined as "opposed to my values." In the survey, we used the Schwartz Value Survey exactly as it was originally developed and has been widely used and cited within the social science research literature.

The second stage involved conducting structured interviews with modelers who had already completed the survey. A total of 40 of the 76 modelers (53%) participated in the interviews, including 14 at the corporate lab, 15 at the academic lab, and 11 at the government lab. These questions discussed issues such as the modelers' educational backgrounds, their perceptions of the role of values in modeling, their perspectives on codes of ethics, and their experiences with value conflicts among stakeholder groups. Each interview included a standard list of 17 questions developed in part based on the analysis of the answers to the survey questions. Each interview lasted approximately one hour. The first two authors participated in all interviews: one author asked the questions, while the other typed a transcript of the interview.

The third stage involved returning for a third time to the field site to report the findings to study participants as part of a confirmatory focus group. The first two authors returned to all three sites to report and obtain feedback about their findings after completing the data analysis. Each visit included two separate meetings, a focus group with study participants at that site and an individual meeting with the director or head of the laboratory. These meetings allowed participants to provide feedback on the findings of the study that further aided the analysis of the data. Thus, these final focus groups served a confirmatory role in the data collection and analysis, improving reliability.

3.2. Data analysis

Interview data was analyzed using content analysis. The first two authors analyzed the interview data independently at first, and then built consensus. First, both researchers separately coded for the presence of values by highlighting specific passages containing statements indicating specific values. Next, the researchers compared the highlighted passages and achieved consensus on where values appeared. Finally, the researchers separately coded for specific values using the 56 value categories included in the Schwartz Value Survey [14]. The parallel process by the two annotators supports the reliability of the analysis.

Quantitative data analysis of the data involved non-parametric statistical tests that compare independent distributions of data: Mann Whitney U and Kruskal-Wallis H. The Mann-Whitney test, also known as Mann-Whitney-Wilcoxon, compares the distributions of two independent groups of sampled data. It is the non-parametric equivalent of an unpaired t-test. Since it is a non-parametric test, this test makes no assumptions about the normality or the distribution of the data. Kruskal-Wallis test is another non-parametric test that is used to compare three or more independent groups of sampled data. The Kruskal-Wallis test does not assume normality or homoscedasticity and is a non-parametric alternative to one-way ANOVA.

Use of nonparametric tests was required for the survey analysis due to the use of a Likert-style scale, and was also an appropriately conservative approach for analyzing the interview data. These non-parametric tests are more robust than and carry fewer assumptions than their parametric equivalents, thus their results are highly reliable. Also, they were found to be consistent with and, if anything, less sensitive than parametric tests in analyzing the data (interpreted as less likely to produce false positives), since analysis of the same data using unpaired t-tests and one-way ANOVA confirmed each of the significance findings presented in the results section.

To analyze both the survey and interview data, Mann-Whitney U was used to compare differences between organizations in individual pairings, and Kruskal-Wallis H was used to compare differences among all three organizations. Analysis of survey data reveals differences in adherence to specific values, while analysis in interview data reveals differences in the frequency of occurrence of specific values within the organizational context.

4. Results

The following two subsections provide a detailed analysis of the statistically significant findings from the study. Specifically, six values (unity with nature, obedient, curious, loyal, honoring of parents and elders) demonstrated statistical significance on the surveys on both the Mann-Whitney U and the Kruskal-Wallis H, and ten values (responsible, national security, authority, equality, influential, wealth, healthy, a world at peace, accepting my portion in life, capable) demonstrated statistical significance on both of the same two non-parametric tests on the interviews.

4.1. Survey results

Six values were statistically significantly different among the three different organizations based on the survey results (see Figure 1). Specifically, unity with nature scored particularly high within the corporate lab, curious scored particularly high within the academic lab, and clean scored particularly high within the government lab. Further, obedient, loyal, and honoring of parents and elders scored particularly low within the academic lab. These survey results indicate differences in adherence to values with the three organizations.

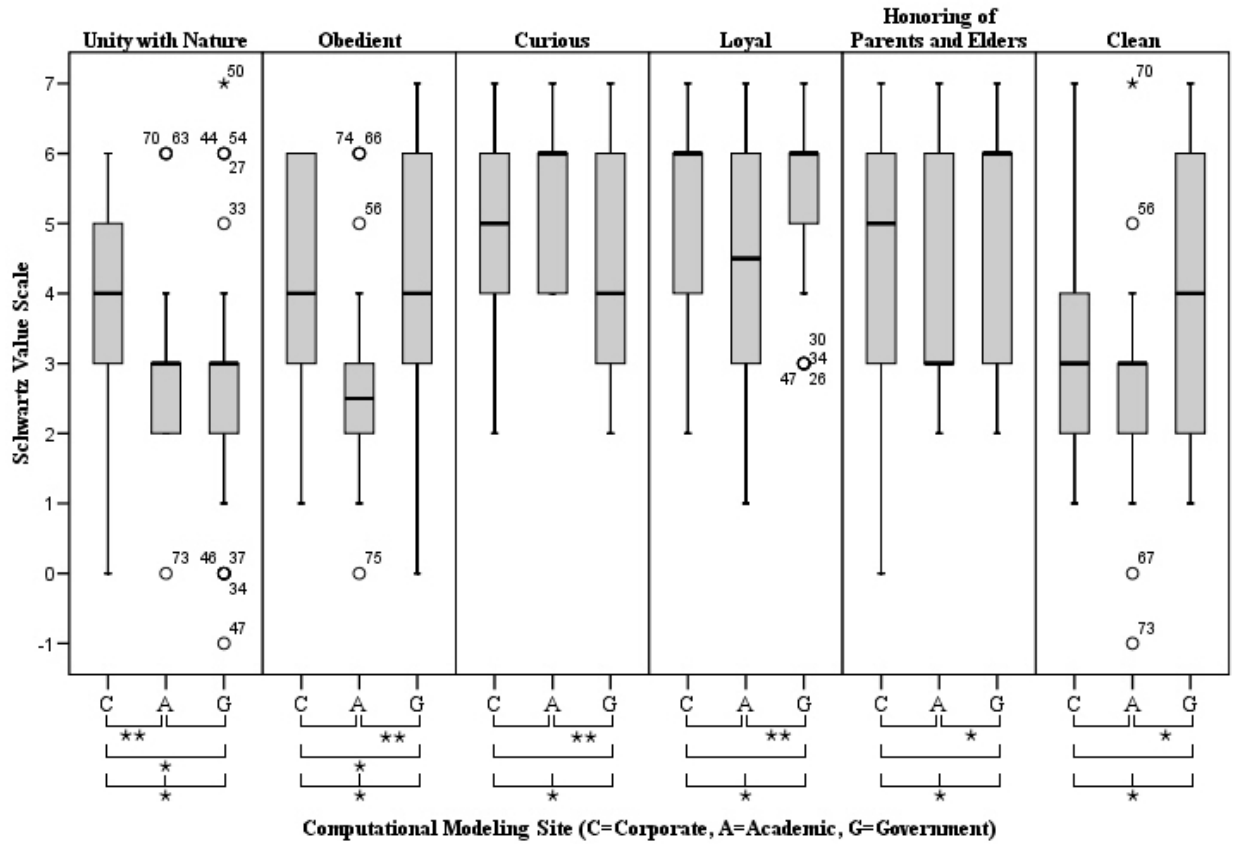

Figure 1. Survey results: Differences among the organizations in terms of adherence to values

Unity with nature was rated higher among individuals in the corporate lab than in the academic or government labs. Interestingly, although this relationship was highly statistically significant in the surveys, the interviews did not provide any data to directly explain this finding. While the surveys were comprehensive, listing each of the 56 values on the Schwartz Value Survey [14] and explicitly soliciting feedback on each of these values, the interviews did not solicit feedback on specific values in a one-by-one manner, but instead asked questions about the context of computational modeling within the organization. Thus, in some cases the interview data can help to explain the survey data, but in this case, there is no evidence that can help to explain this difference.

Obedient was rated higher in the corporate and government labs than in the academic lab. For example, in the corporate lab, one computational modeler explains, *"We have two masters. In the consulting world, you just want to make your customer happy. Here, you want to make your customer happy, but there's a tradeoff because you want to make your management happy too."* Another modeler explains, *"There's a tradeoff here between satisfying your customer and satisfying management."* Thus, in these cases, a major emphasis is placed on obedience, both to one's boss and to one's customer.

Similarly, obedient was also a major value in the interviews with modelers in the government lab. For example, one modeler explains, *"To please the customer, we have to get it done, to please our users, we have to make sure it works."* Another modeler states, *"If we didn't faithfully represent the values, we would have given the result they wanted but they might have failed otherwise."* These quotes emphasize the importance of obedience both to customers (individuals or organizations who are paying for the computational models to be built) and users (individuals or organizations who will use the computational models after they have been built) within the government research lab.

In the interviews at the academic research lab, obedient came up primarily in the context of describing prior jobs in government or industry. For example, one modeler explained about a previous job in a different organization, *"When I started there was a strong idea that if we do something for a client, if they ask us to do something, we try to do it the best even if it's not exactly what they want. When I left, it seemed that*

there was more willingness to put out garbage." Further, within the specific context of the academic research lab, there was an emphasis on doing research funded by contracts and grants that fund research more than development, and where the customer is a government funding agency that simply expects good work to be performed. Even the most compelling quote about obedience in the academic research lab included a caveat: *"We'll do whatever they ask as long as they don't want us to shoot people."* Thus, obedient was more valued in the corporate and government research labs than in the academic lab.

Curious was rated higher by modelers in the academic lab than by those in the corporate lab or especially in the government lab. For example, in the academic lab, one modeler explains, *"I do this for intellectual stimulation."* In the corporate lab, one modeler described that in one situation, *"The technical problem was very interesting."* However, curiosity did not come up in the government research lab. Thus, it appears that curious is a value which is more likely to be found among modelers in an academic lab than modelers in a government lab.

Loyal was rated higher by modelers in the corporate and government labs than the academic lab. For example, in the corporate lab, one modeler explains, *"I think that completing any project successfully, values and ethics play a role, and again it may be a very narrow definition of that, in terms of what I think I owe the project or the company to get something done."* Similarly, in the government lab, one modeler recounted the story, *"[A customer] had made some comments, [my organization] should take the blame because they were late. I went to management. I will not let my team take the blame. They backed me up one hundred percent. Their people personally apologized for the person who said that."* In this case, the story illustrates the loyalty both of the modeler to her or his team and the loyalty of the modeler's boss to the modeler. Thus, loyalty is a strong bond that travels in both directions across the complex hierarchy found within the government lab. However, in the academic lab, loyalty was much more about loyalty between an advisor and students rather than about an employee's loyalty to the organization. For example, one modeler explained about the advisor-student relationship, *"If you're working with someone, they take very good care of you."* Thus, overall, loyalty was a more significant value among modelers in the corporate and government labs than in the academic lab.

Honoring of parents and elders was also rated higher by modelers in the corporate and government labs than in the academic lab. Similarly to loyalty, honoring of parents and elders in the corporate and government labs referred to a wide range of relationships among employees, such a between a manager and a modeler and between a long-time modeler and a newcomer. However, in the academic lab, honoring of parents and elders was specifically and explicitly limited to the advisor-student relationship.

Clean was rated highest among modelers in the government lab. However, like unity with nature, the interviews did not provide any data to explain this finding. Thus, the rationale behind this difference is not entirely clear based on the results of this study.

For all six of these values, statistically significant differences were identified among at least two of the three different organizations. For four of these values, these differences can be explained through the interview data. The following subsection will discuss the quantitative results from the interview data and again link them to the qualitative results from the interviews.

4.2. Interview results

Ten values were statistically significantly different among the three different organizations on the interview (see Figure 2). Specifically, the corporate lab had high frequencies of occurrence for responsible, authority, equality, wealth, and accepting my portion in life, and low frequency of occurrence for influential. The academic lab had high frequencies of occurrence for national security and a world at peace. The government lab had high frequencies for healthy and capable.

Responsible was highly statistically significant, with the corporate lab as the highest and the academic lab as the lowest. One quote that characterizes the data from the corporate lab was, *"After I corrected my mistake, then the model was better, although it may not have been the best news, but it may have been a better model."* Similarly, at the government lab, another modeler comments, *"When you're presented with data, be responsible with it. In terms of analysis, certainly you want to be careful and honest about how you report your data."* Finally, at the academic lab, one contrasting quote is quite telling, *"We go to conferences and talk about these models, nobody stops and asks questions about whether it's a good thing or a bad thing."* At the corporate lab, the modeler goes out of her/his way to do the responsible thing, and stands by this decision regardless of the outcome. At the government lab, the modeler doesn't emphasize going quite as far, but still points out the need to be responsible. However, the academic modeler emphasizes the lack of emphasis on needing to act responsibly and consider the ethical implications of the modeling work found in academic modeling circles.

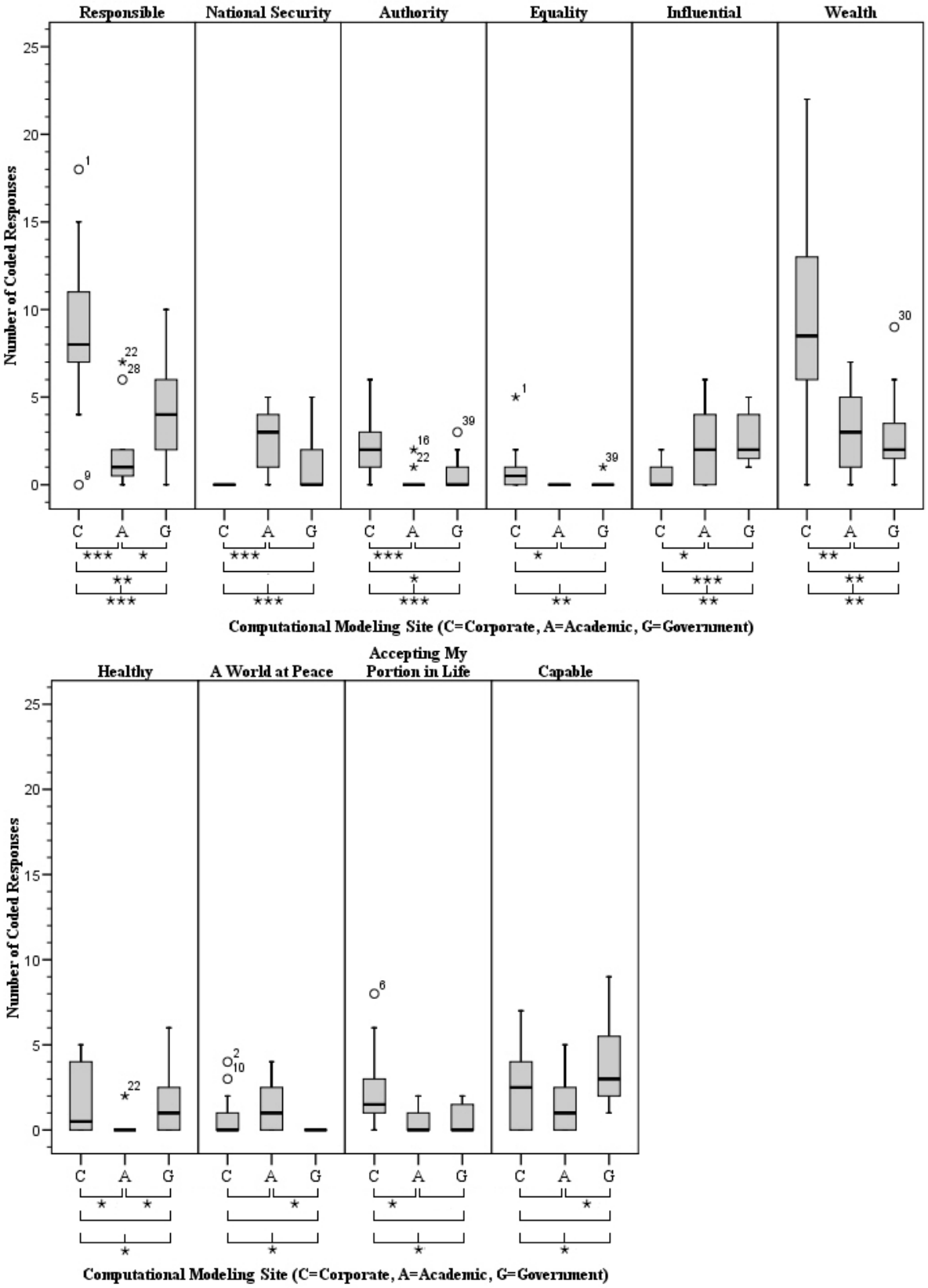

Figure 2. Interview results: Differences among the organizations in terms of occurrence of values

Thus, it is interesting that the value of responsible seems to be more present in the corporate and government labs than in the academic lab.

National security and a world at peace both occurred most frequently in the academic lab. These two values are paired, since these two issues most frequently occur in combination and more specifically in direct conflict. Quotes from the academic lab help to illustrate this point. For example, one modeler in the academic lab explains: *"The values that I bring to the project and the people that work on the project with me have in their everyday life is in changing the security posture of the US. The idea that the nation needs to be more secure and we need to have more security infrastructure is extremely important. There are some mixed feeling about working in defense departments and intelligence departments. I don't always feel comfortable about this. I have different feelings from the current administration. But mostly I feel strongly about improving our cyberinfrastructure."* Similarly, another modeler in the academic lab states, *"University campuses tend to be quite liberal, anti-war, yet much of the money is coming from the defense department."* Thus, the emphasis on both national security (largely as an activity that funds research at least in this specific academic lab, although this finding does seem at least somewhat generalizable to the broader academic research context) and a world at peace (apparently as a value held directly by the academic modelers themselves) presents an interesting value conflict and one that plays a significant role in the academic lab.

Authority occurred most frequently at the corporate lab. One modeler explained: *"Recognition of management authority [is very important]. Certainly there have been times when speaking out was not cool. Or when not being perceived as successful was not cool. There's a delicate balance in a research organization. On the one hand, you need direction from the top. Those decisions have to be made. On the other hand, you don't want some management meeting directing all of the technical work. It's a delicate balance that's been managed quite well here."* Here, the modeler makes a very interesting and highly nuanced point about the contrast between the management style of the organization and scientific research, and argues that the balance is managed well within that particular organization. The corporate lab was clearly the most hierarchical organization, and the academic lab, which had the lowest frequency of occurrence for the value of authority, was the least hierarchical of the three organizations. Thus, interestingly while there were different degrees of authority based on the three different organizations, this difference did not necessarily significantly affect the science performed in these three research labs.

Equality arose most frequently in the corporate lab. To some extent, this may be a reaction to the emphasis on authority, such that the need to seek equality for the sake of balance in certain situations is explicitly sought. Equality also directly impacted the design of the models. One modeler explains, *"If you take things like equity as a value, you're actually trying to build it into your model, trying to find a way to represent it in your model."* Thus, equality appeared to be most explicitly present in the corporate lab, although again this was likely largely a balance and overall value conflict with authority.

Influential was rated significantly higher in the academic and government labs than in the corporate lab. An academic modeler explains, *"I don't see how values get in here except through individual guys like me."* This quote illustrates the individual modelers that individuals can have in shaping the values of the models that they build and the organization in which they are situated. In the government lab, a modeler comments, *"[My organization's] models are more user-based and user-friendly. We've looked at it from the bottom-up instead of the top-down. I think there's been impact there."* Here, the modeler is expressing the influence that individuals can have through the bottom-up nature of the organization. Finally, in the corporate lab, one modeler states, *"I think it's kind of a function of corporate culture that one's values have very little impact on the corporation as a whole."* Thus, modelers in the academic and government labs were significantly more confident of their individual ability to influence the culture and values of their organization than modelers in the corporate lab.

Wealth, likely not surprisingly, was most emphasized within the corporate lab. The corporate lab was explicitly profit-driven, and much of the modeling work performed by the modelers in the corporate lab involved efforts designed to cut costs and boost profits. For example, one modeler in the corporate lab explains: *"In doing many of these tools, there's an understanding that in the real world, [the customer's] goal is to service these things as cheaply as possible. In service, the biggest cost is people. There certainly can be uncomfortableness in the users or those paying for it in that we're replacing them with a machine."* In this case, the modeler is expressing discomfort with the frequent emphasis on cost-cutting and efficiency which can lead to automation and workforce reductions that have a real human cost. In contrast, the academic and government labs are not-for-profit enterprises, but wealth is still important for them to be able to do their jobs. One academic modeler comments, *"We've gotten hungrier and we've started looking for [national security] work. The cynical thought is if [another university] won't lower itself to do that kind of work,*

it's one more opportunity for us." Here, although there isn't a profit motive per se, the lab still embraces the opportunity to get contracts to do research, which are necessary for funding expenses such as students and equipment, and are willing to take on national security work, which leads to the value conflict between national security and a world at peace described above. Finally, in the government lab, there is even less emphasis on acquiring wealth, and some degree of resentment toward the system of constantly needing to compete for contracts. One government modeler states, *"I'm pretty happy. The only thing is that you have to have a project in order to stay here. That's my biggest disappointment here."* The government modeler clearly would prefer a situation where there was not such a constant pressure to obtain funding. Thus, there are large disparities in the emphasis on wealth among the corporate, academic, and government labs.

Healthy arose most frequently in the government lab. Healthy appeared to be primarily a context-dependent value, since some research projects focus more on health and medicine than others, and some organizations have more such projects than others. In the government lab, this was a significant value. For example, one modeler in the government lab explains: *"We work in [a specific] area, which is a safety issue and high profile so if we do something wrong then everybody is going to know about it. I think one example in our work is the use of experimental data. We use that data. We have to make judgments about how we use it and if there's data that's clearly inappropriate for our use, I have to justify why I'm not using it. That to me is a moral issue."* Thus, in this case, the emphasis on healthy was due to the domain in which the modeling work occurred, which was a safety-related domain. Similarly, the corporate lab also had emphasis on healthy due to some medically-related projects. Specifically, one corporate modeler states, *"Ultimately you're always focused on a positive impact of how it's going to affect patients, you're always aligned with the values of patients. It's a general feeling that I get at the business here."* However, there was no real emphasis on healthy in the academic lab, largely due to the projects that the academic lab was pursuing at the time of the study. Thus, healthy appeared to be highly context-dependent, varying according to the projects pursued by the specific organizations.

Accepting my portion in life was a more frequently occurring value in the corporate lab than in the academic lab. Specifically, in the corporate lab, there were a number of instances where modelers clearly settled for less than optimal situations, which frequently conflicted with their own values. For example, one modeler in the corporate lab states, *"Because of the nature of the environment, even if you're working on a good model, sometimes the environment keeps you from doing it. The environment makes me feel I'm compromising my value system."* The same emphasis on accepting one's portion in life was not found to anywhere near the same degree in the government or especially the academic lab.

Capable occurred more frequently in the government lab than in the academic lab. In the government lab, modelers emphasized capable significantly more. For example, one modeler in the government lab explains, *"The way my values enter into [a project is that] I would try to do the best job that I could for them with the resources that I had."* In contrast, one of the academic modelers stated that the goal should be to, *"Get the contracts, satisfy the contracts to the extent to avoid getting sued, and get more contracts."* These two quotes as well as the overall quantitative results demonstrate a large gap between the academic and government labs in terms of the value of capable.

For all ten of these values, statistically significant differences were identified among at least two of the three organizations. Because the quantitative results were based on counts from the interview data itself, the qualitative interview data can explain these differences. Thus, both the survey and interview data revealed statistically significant results that can be explained through qualitative analysis of the interview data.

5. Discussion

Interestingly, the surveys and interviews identified distinct statistically significant differences among the three organizations, but this result is not surprising given that the surveys and interviews measure values in quite different ways. The measurement of values in the survey is an indication of an individual's conscious and acknowledged adherence to particular values, including the extent to which values are aligned with or opposed to their own values. Thus, the survey is an indication of self-reported adherence to particular values. In contrast, the interviews measure the frequency with which values arose in the interviews, which provides a sense of the extent to which particular values are salient within particular organizational contexts. Thus, the surveys measure the values of individuals as acknowledged by those individuals, while the interviews measure the organizational contexts within which those individuals are situated. While there is certainly interaction between the individual and the environment, it is not surprising that there are differences in these two different levels of values (personal and organizational).

In the survey results, while the findings about unity with nature and clean appear to be specific to the particular organizations studied, the other four values are consistent with stereotypes about scientific research within the three different types of organizations. Specifically, academic research tends to provide more freedom and opportunities for independently directed research, while corporate and government research tends to be more structured and top-down. Thus, it is not surprising that modelers working in the academic lab tended to value curiosity more than modelers working in government or corporate labs. Contrastingly, modelers in the corporate and government labs tended to value obedience, loyalty, and honoring parents and elders more than modelers in the academic lab. Curiosity tends to be a feature of unrestrained science, while obedience, loyalty, and honoring parents and elders are more likely to occur within a highly structured and more hierarchical context. Based on these results, it is not clear whether modelers with high degrees of curiosity and low degrees of obedience, loyalty, and honoring of parents and elders were more likely to choose to work in the academic lab, if the academic lab tended to show preference in hiring to individuals with those compatible values, or if the environment tended to shape the values of the individuals working within it, but it is possible that the results are a combination of all three factors, which is especially likely given the statistical significance of these findings.

The interview results also help to illustrate conflicts within and among different organizations. For example, the academic lab had a significant conflict between national security insofar as many of the research projects were funded by the military-industrial complex, and a world at peace, insofar as there tends to be strong anti-war sentiment on college campuses, including among many faculty and students involved in modeling research. There was also a conflict between authority and equality at the corporate lab, as the highly structured and hierarchical power structure within the corporation had to be balanced with the need for bottom-up emphasis on scientific research yielding findings that trump any corporate mandates and the need to consider all inputs. Finally, there also appeared to be a conflict in the corporate lab between the emphasis on wealth, which is related to the profit motive of the corporation, and accepting my portion in life, which appeared to be related to employees of the corporate lab feeling that they needed to make compromises relative to their own value system due at least in part to the profit motive of the corporation, especially in cases where they are required to work on projects that will lead to downsizing and workforce reductions. Thus, there are important conflicts within these different organizations, and there are also statistically significant differences in the incidence of these values among the three different organizations.

It is important to note that this study has significant limitations. Most importantly, due to the in-depth nature of the field research, it was only possible to study one site of each type. With multiple sites representing each type of organization, it would be easier to relate differences across sites as related to the type of organization rather than merely on specific features of the organizations themselves. Thus, hopefully this study can inspire additional research employing similar research designs, which can expand the number of organizations of each type studied. Another potential future direction would be to do a broad-scale survey of computational modelers based on the findings of this study, which could provide a much larger number of respondents from a larger number of organizations of each type, and could also compare the relationship among values, demographics, and modelers' specific design decisions. Such a survey would benefit from the development of an instrument that focuses on modeling-specific values, rather than the more generic Schwartz Value Survey.

6. Conclusion

The primary conclusion is that modelers in different organizations hold different values. These values can impact both the process and product of modeling. Thus, it is important to consider how the values of modelers in an organization might impact the models produced by that organization.

The danger is that models will reflect only the values of designers and not the values of users, which has negative implications not only for users but also ultimately for designers. While models that conflict with the values of users certainly may be problematic for users, users may choose not to use models that are opposed to their values, and thus failing to consider the values of users may ultimately hurt designers.

One possible way to counter this phenomenon is to though value sensitive design [11]. Value sensitive design can be used to promote equality, social justice, honesty, inclusiveness, or transparency [6, 8]. In order to make a model transparent, modelers need to ensure the following: (1) the model is thoroughly documented so individuals who did not directly participate in its construction can easily understand it, (2) the model's assumptions about reality and values are explicit and testable for validity, and (3) the individual elements of a model are explicitly available to the user. The semantic Web can be used to demonstrate the potential for a networked representation of information that

allows users to explore the meaning of content, giving them direct access to model content [4]. Documentation, explanation of assumptions, and inspection of components are all value sensitive design techniques that can make models more transparent.

The advent of very large, potentially rich data sets and streams, such as those enabled by the Internet, provide even greater opportunities for model building in an attempt to transform the data into information that people can use. However, vast amounts of data do not guaranteed that the model will be sensitive to the values of all stakeholders, so the 'Garbage In, Gospel Out' variant of 'Garbage In, Garbage Out' remains as relevant as ever [17]. Modelers need to be influenced not only by their own values and those of their organization but also by the values of their users and other stakeholders. Thus, the diversity of the values of modelers pose a threat in that customers may get different models depending on the values of modelers in different organizations, but it also represents an opportunity if sufficiently acknowledged and understood in that it may allow for increased alignment between the values of modelers and other stakeholders.

7. References

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