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Developing a Semantic Differential Scale for Measuring Users' Attitudes toward Sensor based Decision Support Technologies for the Environment

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Abstract

The purpose of this paper is to describe the development and testing of an Emerging Technologies Semantic Differential Scale (ETSDS) designed to measure the attitudes of potential users toward an emerging technology. The strategy consisted of identifying initial items and descriptors that may help to understand respondents' attitudes about one emerging technology; test bi-polar adjectives to construct the scale; determine representativeness of items on a particular construct domain for content validity; and finally, to test the reliability and construct validity of the instrument. The instrument development process resulted in a reliable and valid parsimonious 10-item scale for quantitatively measuring attitudes toward the deployment of global sensor networks that is easily adaptable to other emerging technologies with similar attributes. The instrument is likely to be useful to both academics and practitioners with interests in attitudes about innovations, technology adoption, and users' behavioral intention toward emerging technologies.

Keywords: Semantic differential scale (SDS), public health, attitudes, emerging technologies, scale development, environment.

1. INTRODUCTION

Emerging sensor technologies hold promise for creatively addressing modern day threats to public health and other environmental systems, however, promises are hard to deliver when such emerging technologies are poorly or not understood, and by extension, not embraced. The reasons for non-acceptance are complex and include technical and human factors that are critical to advancing selling new technologies to a variety of users. Technical factors include but are not limited to unknown manufacturing costs, form factors, means and timing for deployment, managing data communication, and issues of energy efficiency (Lau et al., 2006). Human factors include perceived usefulness of the technology and behavioral intentions toward it, in addition to knowledge of the technology, the problems it is intended to resolve, and the perceptions of the seriousness of threats. The threat of rejection of new innovations can be mitigated if, at the earliest stages, the attitudes of potential users and decision-makers are understood and addressed (Davis & Venkatesh 2004; Jain, 2006; Venkatesh, Morris, Davis, & Davis, 2003). According to Fishbein (1975) attitude as a concept is important in understanding and predicting both the reaction of people to an entity or a change and how reactions can be influenced. Instruments measuring attitudes can enable developers of emerging technologies gauge user and potential user perceptions and intentions to use the technologies and judgments about trusting them.

However, developing instruments for predicting reactions to various emerging technologies can be time consuming and cost prohibitive. Time is often of the essence when determining the prospects of a new technology as well as how much to invest to educate and promote it before too many resources are expended on research and development. This paper reports on the development of a simple and effective survey instrument to quantify potential user attitudes about one emerging technology.

2. LITERATURE REVIEW

Drake (2002) while quoting the Center for Devices and Radiological Health's Division of Device User Programs and Systems Analysis wrote: the study of human factors is a science devoted to understanding the interaction of people (users) and equipment (p. 8). Attitudes and perceptions are significant human factors in the acceptance of new tools for information systems and communication.

Models exist for examining users' acceptance of technology and explaining the various dynamics and factors that contribute to a successful or otherwise adoption of innovations (Venkatesh, Morris, Davis, & Davis, 2003). The Technology Acceptance Model (TAM) specifies that the usage of information technology is determined by beliefs a user holds about the perceived usefulness (PU) and perceived ease-of-use of the technology (PEU) (Davis, 1989). According to Lanseng and Andreassen (2007), TAM posits that the actual use of information technology is determined by a user's intentions and attitudes more than beliefs. Jarrett (2003) said the Theory of Reasoned Action can be used to predict intent regarding adoption of innovations based on attitudes and subjective norms.

The research literature documents many instruments that have been used to measure attitudes toward technology (Bandalos & Benson, 1990; Francis & Katz, 1996; Loyd & Gressard, 1984; Masoud, 1990; Sexton & King, 1999). The Semantic Differential Scale (SDS) is a tool used frequently for measuring social attitudes (Osgood, Suci & Tannenbaum, 1957). Attitudes are evaluations--dispositions toward or away from things, people, or concepts; beliefs, on the other hand are thoughts people have about the object or construct (Intrieri, von Eye, & Kelly, 1995). Judgments must be focused on a single construct. The SDS is a seven-point bipolar rating scale that uses opposing adjective pairs from which respondents select a point corresponding to their disposition about the object or concept in question (Christensen &Knezek, 1998; Osgood, Suci & Tannenbaum, 1957). It has many advantages including its relative ease to construct, ease of use for research participants, and reliability of the quantitative data it provides. Researchers can create a scale using carefully selected opposing adjectives pairs for effectively quantifying attitudes on a wide range of constructs. Osgood et al. (1957) observed in their own studies testing this scale that the correlation scores across 100 college students surveyed on 40 items yielded a reliability coefficient of 0.85.

3. METHODS

Developing the Emerging Technologies Semantic Differential Scale

The SDS for this study was developed by providing a description of sensor devices and sensor network systems to four graduate interns in a university technology transfer organization. Each participant received a mocked-up description of the devices as well as the global deployment of sensor systems (see Appendix A) and was asked to list adjectives each would use to describe his or her impression of the object and concept. The lists were pooled then sent back to each participant for a second review. Participants were asked to identify more adjectives they preferred from their peers' suggestions or stick to their own choices. Twelve adjectives in total were agreed to by at least 75% of the participants. Two of the 12 adjectives were eliminated because of participants' perceptions that the adjectives conveyed similar meanings to other adjectives on the list. For instance, during a discussion convened after participants had made their lists, two of the participants indicated that it was difficult for them to distinguish the difference between *not complicated* and *not complex*. Likewise, the participants indicated that *novel* and *innovative* could be construed as having the same meaning. As a result, *not complex* and *novel* were dropped from the list, and the remaining ten adjectives were used to devise an Emerging Technologies Semantic Differential Scale (ETSDS).

The online Encarta World English dictionary was used to select the best antonyms for the ten adjectives; the bi-polar adjective pairs comprised the scale to measure attitudes. Adjective pairs were alternated so that positive adjectives and negative did not align on opposite sides of the scale. This step helped to prevent acquiescent responses on either side of the scale.

For example, participants were asked to rate "global deployment of sensor systems" in terms of an attribute. A feature such as value, for example, would be represented on the numeric semantic differential scale in the following form:

Unsafe 1 2 3 4 5 6 7 Safe

Participants indicated whether they judged the concept of "global deployment of sensor networks" to be extremely safe or not by marking the extremes (7 or 1 respectively) or if they have not formed a judgment, by selecting the neutral position 4, which is half-way between the two extremes.

The Emerging Technologies Semantic Differential Scale is a 10-item scale where the higher score is equal to a positive attitude.

Data Collection Procedures

The pilot testing of the ETSDS was undertaken with 85 doctoral students and doctoral graduates of an Information Systems program in a Mid-western university. Survey Monkey was used to administer the web-based survey that included demographic questions and the 10-item scale. Instructions were provided; anonymity was assured, and the study was IRB approved. Seventy-five completed and usable surveys were returned. The data were uploaded to SPSS for analysis.

4. DATA ANALYSIS

Scores for each of the items on the ETSDS were summed and divided by number of items (10) to determine each participant's score. Score interpretation included: 0.0-1.99 = very negative; 2.0-2.99 = negative; 3.0-3.99 = moderately negative; 4.0–4.99 = undecided/neutral; 5.0- 5.99 = moderately positive; 6.0– 6.99 = positive; 7 = very positive. Pearson product-moment correlation (2-tailed) was calculated to note the significance of relationships between items on the ETSDS. The assumption for using correlation technique is that mean scores are normally distributed; and all observations remain independent of each other. To determine the reliability of the Emerging Technologies Semantic Differential Scale., a factor analysis was performed.

5. RESULTS

Table 1. Factor Analysis of the ETSDS

Component Matrix

	Bipolar Adjectives	Component 1	Component 2
B1	Unsafe – Safe	.645	.313
B2	Meaningful – Meaningless	.818	-.017
B3	Uninspiring – Motivating	.704	-.050
B4	Interesting – Tedious	.617	-.302
B5	Outdated – Innovative	.616	-.453
B6	Good – Bad	.806	.251
B7	Complicated – Simple	***.164***	***.847***
B8	Useful – Useless	.812	.012
B9	Unreliable – Reliable	.663	.286
B10	Time Saving - Time Consuming	.597	.082

Confirmatory factor analysis (CFA) demonstrated the existence of two factors in the ETSDS based on the pilot test; the 10 items created two scales; the bipolar adjective *complicated-simple* loads by itself on the second component while all the other items load on the first component, given that the criterion for factor item retention was a loading of at least .50 (Nunnally, 1978). Because it is not advisable to have a single item in a scale (Nunnally, 1978), a reliability check was performed to determine if the scale is unidimensional and reliable with the *complicated-simple* bipolar adjective included. The alpha for all items was 0.83, therefore a unidimensional scale works. Also the alpha increased slightly without the bipolar adjective *complicated-simple* to 0.87.

Except in associations where *complicated-simple* is one of the items, this result shows that as respondents scored higher on an item, higher scores are also observed in an associated item. The three strongest include *useless-useful* and *bad-good* (r=0.76); *useless-useful* and *meaningless-meaningful* (r=0.69) and; *bad-good* and *unsafe-safe* (r=0.67). Negative associations were observed between *complicated-simple* and each of the other items on the scale**.** (Table 2, Appendix B)

6. DISCUSSION AND CONCLUSION

This study makes several important contributions to the technology management field, and to the attitudes and technology acceptance literature. Typical studies focus on investigating attitudes using scales based on fear, anxiety, and other emotions, however, the Emerging Technologies Semantic Differential Scale was developed and demonstrated to be a simple measure that was also proven to be reliable to quantify attitudes as evaluative judgments about objects and concepts concerning information and communication technologies. Analysis centered on bipolar adjectives that have relevance to the constructs used in traditional TAM investigations (e.g. usefulness). This investigation indicates that by adopting this technique, credible results can be obtained swiftly for studies focused on technology users and stakeholders. This transcends traditional techniques and boundaries, and can be valuable for understanding attitudes. This study may inspire new research on a more global scale to investigate relationships between knowledge and attitudes to emerging technologies.

Future investigations could expand to potential users and users of emerging technologies, thereby providing further insights into evaluative judgments about little known technologies. The context of the study is relatively new in Information Systems, and thus the instruments used are not well established in this area. The use of Semantic Differential Scales seems to be an advantage for similar studies. For instance, a limitation that has been observed with semantic differential tools is the situation where responses appear to be linear on the extremes of the bipolar adjective scale, a situation that has been ascribed to the education level of respondents (Lenno, 2006). According to Sommer and Sommer (1997), people with lower levels of education often will abandon the middle points of the scale and focus on the fringes. This limitation was not observed in this study since respondents were highly educated. The terms used might have slightly different interpretations although this was minimized by using iterative process with people who have experience in assessing or evaluating new technologies. Social desirability is a limitation of this tool, especially where participants are highly invested in the study or concept being researched.

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Appendix A: Description of Sensor network devices

Projects are in the pipeline which involve the deployment of a Global Sensor system that will have implication for Global Health and Security. According to Chino (2010) "the project involves distributing these sensors throughout the world and using them to gather data that could be used to detect everything from infrastructure collapse to environmental pollutants to climate change and impending earthquakes. From there, the "Internet of Things" and smarter cities are right around the corner."

After reviewing the description above, please suggest 10-15 adjective pairs that you believe could best be used to describe your feelings about 'deployment' of sensor systems.
What were the factors you considered in your suggetion?

Examples:
Pleasant - Unpleasant
Non intrusive - Intrusive

1. 'Deployment'

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Appendix B: Table 2

Table 2 Inter-item Correlations (N=75)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	1									
B2	.487***	1								
B3	.495***	.588***	1							
B4	.347***	.627***	.482***	1						
B5	.337***	.628***	.489***	.533***	1					
B6	.673***	.605***	.605***	.515***	.535***	1				
B7	-.104	-.276***	-.133	-.333***	-.438***	-.258***	1			
B8	.475***	.687***	.567***	.514***	.555***	.759***	-.308***	1		
B9	.443***	.412***	.340***	.296***	.260***	.447***	.080	.493***	1	
B10	.367***	.443***	.430***	.452***	.430***	.605***	-.035	.575***	.378***	1

***Significant at the 0.001 level (2-tailed), $p \leq 0.001$.
B1=Unsafe-safe; B2=Meaningless-Meaningful; B3=Uninspiring-Motivating; B4=Tedious-Interesting; B5=Outdated-Innovative; B6=Bad-Good; B7=Complicated-Simple; B8=Useless-Useful; B9=Unreliable-Reliable; B10=Time consuming-Time saving.