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Edward Mahindra
New Jersey Institute of Technology, egm3@njit.edu

Brian Whitworth
New Jersey Institute of Technology, bwhitworth@acm.org

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The Web of System Performance: Extending the TAM Model

Edward Mahinda
New Jersey Institute of Technology
egm3@njit.edu

Brian Whitworth
New Jersey Institute of Technology
bwhitworth@acm.org

ABSTRACT

Information technology can substantially enhance a wide variety of work performances, but such gains are lost if people cannot use the applications. Hence the Technology Acceptance Model (TAM) model successfully made usability a key application quality requirement, alongside functionality. However the field of quality systems requirements includes factors distinct from usability. The Web of System Performance (WOSP) model extends the TAM approach, adding requirements like security, connectivity, flexibility, extendibility, privacy, and reliability as possible factors. This paper reports a conjoint analysis of the contribution of these factors in a proposed corporate software purchase of browser. It finds security, privacy, usability, functionality, reliability and connectivity are the main factors users would consider in such a software purchase.

Keywords

TAM, WOSP, usability, functionality, connectivity, flexibility, extendibility, privacy, reliability, security, conjoint analysis, system requirements.

INTRODUCTION

The use of information technology (IT) in today's organizations has increased dramatically in recent years. By some estimates, over the last two decades, approximately 50% of all new capital investments in organizations have been in information technology (Westland and Clark, 2000). The total worldwide expenditure on IT had exceeded one trillion US dollars per annum in 2001, with a 10% annual compounded growth rate (Seddon, Graeser and Willcocks, 2002). This notwithstanding, organizations today have less financial resources available for information technology than they previously did (Rivard, Poirier, Raymond and Bergeron, 1997). The result has been an increasing desire by organizations to control their IT related spending, including end-user computing. One way to achieve this is by better information system evaluation, i.e. "buying smarter". Evaluating information technology helps firms enhance overall performance (Taylor and Todd, 1995), and provides the information senior executives need to justify huge IT investments (Brynjolfsson, 1993).

This paper investigates the criteria by which such evaluation decisions are made, and in particular, whether the functionality/usability TAM dimensions are sufficient. We first review both TAM and WOSP concepts, then briefly explain conjoint analysis, and finally report a study of how various evaluation criteria affected subjects asked to select a common browser for an international company.

The TAM Approach

The Technology Acceptance Model (TAM) explains the determinants of technology acceptance over a wide range of end-user computing technologies and user populations. In this model, perceived ease of use and perceived usefulness influence attitudes towards an application, which in turn influence the intention to use it. TAM has accumulated considerable empirical support for its overall explanatory power over a wide range of technologies, users and organizational contexts. In comparison with the other models and frameworks, TAM is parsimonious, has a strong theoretical basis, has significant empirical support, and most important, is IT specific. It seems the current dominant model for investigating technology acceptance by users (Hu, Chau, Sheng and Tam, 1999).

However, while TAM has successful explanatory power, it seems deficient compared to current system design requirements literature that mentions criteria like flexibility (Knoll & Jarvenpaa, 1994, p6), security (OECD, 1996), reliability (Jonsson, 1998), extendibility (McCarty & Cassady-Dorion, 1999) and privacy (Benassi, 1999). Berners-Lee considers scalability important for the World Wide Web (Berners-Lee, 2000). Alter adds conformance to standards to the list (Alter, 1999). A recent software engineering text mentions usability, but also considers security and reliability as critical to software design (Sommerville, 2004, p24). The TAM model was used to investigate the acceptance by physicians of telemedicine, an IT-based innovation that aims to support and improve the provision of care to patients (Hu et al., 1999). The investigations found perceived ease of use and perceived usefulness explained only 37% of the variances in attitude towards the technology, while perceived usefulness and attitude together only explained 44% of the variances in the intention to use the technology. These considerations suggest that the TAM approach is valid but incomplete.

The WOSP Model

The Web of System Performance (WOSP) model derives its criteria from a systems theory approach, one that could equally be applied to biological systems (Whitworth and Zaic, 2003). In this model information systems are like other systems found in nature (David, McCarthy, & Sommer, 2003). They can be represented on four levels (hardware, software, cognitive and social), and the performance at each level is *how successfully it interacts with its environment*.

This performance is analyzed according to four basic system elements: boundary, internal structure, effectors, and receptors. A system's boundary determines what enters the system, and can be designed to repel external threats or to use external opportunities. Internal structure manages and supports the system, and can be designed to maintain operations despite internal changes, or changing them to suit external changes. Effectors have the purpose of changing the external environment, and can be designed for maximum effect or minimum cost. Finally, receptors enable the ability to communicate, and can be designed to enhance or limit information exchange. Each of these elements has a dual role in system performance, and can be designed to maximize opportunity, or minimize risk. This gives rise to eight system performance sub-goals, fundamental to any system, namely:

- **Effectors:**
  - Functionality – to act on the environment
  - Usability – to reduce action costs
- **Boundary:**
  - Security – to prevent entry
  - Extendibility – to use outside objects
- **Structure:**
  - Reliability – to perform the same despite internal change
  - Flexibility – to perform differently given external change
- **Receptors:**
  - Connectivity – to exchange social meaning
  - Privacy – to limit social meaning exchange

The sum total of these eight criteria is proposed to be system performance. The ability to reproduce itself, critical to biological performance, has been left out of the model, because most information systems do not reproduce. It is represented in the cost of system creation, and it is assumed that IT purchasers automatically factor cost against performance.

The WOSP system performance criteria definitions are as follows:

- *Functionality:* a system's ability to change its environment relative to itself.
- *Usability:* a system's ability to minimize the resource cost of actions.
- *Security*: a system's ability to protect against unauthorized entry, misuse or takeover.
- *Extendibility:* a system's ability to use outside elements in its performance.
- *Flexibility:* a system's ability to perform in new environments.
- *Reliability:* a system's ability to continue operating despite internal changes like part failure.
- *Connectivity*: a system's ability to exchange information with other same type systems.
- *Privacy:* a system's ability to control the release of information about itself.

All the above criteria are known to systems requirements literature, but their combination in a single system model is new. The WOSP model further proposes that each of these dimensions of system performance is in a natural state of tension with the others. They can be visualized as the corners of a *web of performance*, where pulling one corner can give "bite back effects (Tenner, 1997) where there are tensions (see Figure 1). The WOSP model actually extends the TAM functionality/usability model to include other aspects of system performance. The WOSP model adds software qualities that affect user acceptance. This article presents an investigation of the WOSP model as an improved means of explaining the determinants of user acceptance of technology.

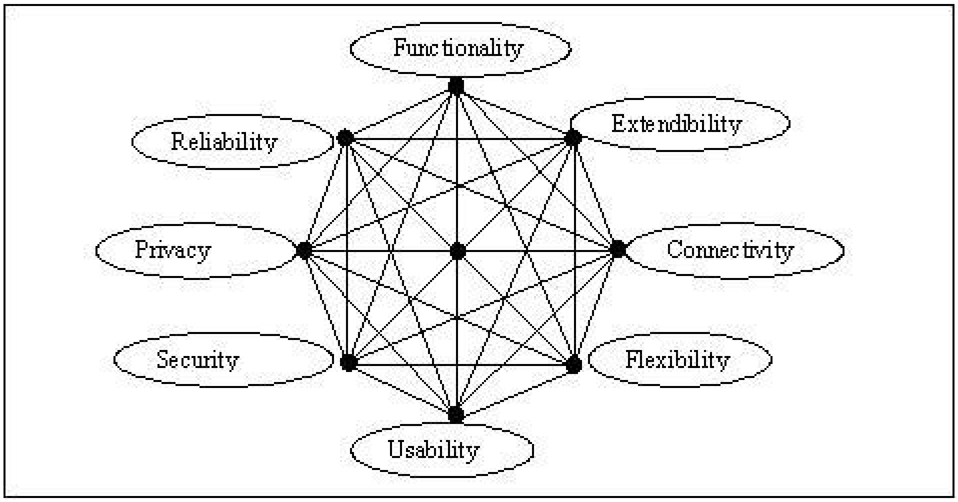

Figure 1. The WOSP Model

CONJOINT ANALYSIS

Research into how application users evaluate information system performance by the eight WOSP system criteria involves multivariate analysis. The experimental dependent variable is perceived system performance, and the given ratings on the eight WOSP criteria are the independent variables. The most appropriate analysis technique is therefore a dependence multivariate technique (Hair, Anderson, Tatham and Black, 1995). For a single metric dependent variable, possible analysis techniques are multiple correlation analysis, regression and conjoint analysis. Conjoint analysis is a dependence technique that can be used whether the dependent variable is metric or nonmetric.

With regression analysis, the number of predictor variables to be included has to be decided. On the other hand, the conjoint analysis method is used to analyze the effects of predictor variables when they are already known. It is widely used in the marketing and agricultural disciplines to gauge the importance to consumers of the various attributes of a product or service, but is very new to the field of information systems.

Conjoint analysis is based on the idea that people evaluate the value of a product or service by adding up the separate amounts of utility provided by each of the attributes of the product or service. It is unique among multivariate analysis methods in that a set of hypothetical products or services is first constructed by combining the attributes that make up the product or service at various levels. The hypothetical products or services are then presented to the subject, who is required to indicate his preference of the various alternatives in the set as he practically would in real life. Conjoint analysis decomposes these preferences to determine how much is due to each factor. A product or service with a particular set of levels or values of the various factors is referred to as a treatment or a stimulus.

If the overall preference for a particular combination is regarded as the total worth of that product, the factors are considered part-worths of the product, as follows:

Total Product Worth = Part-worth of $level_i$ for $factor_1$ +

Part-worth of $level_j$ for $factor_2$ + …+

Part-worth of $level_n$ for $factor_m$

where the product has m factors, each with two or more levels. The treatments stimuli consist of $level_i$ of $factor_1$, levelj of $factor_2$, and so on up to $level_n$ for $factor_m$

Conjoint analysis is unique in that it allows for the generation of a preference model for each subject, which can then be aggregated for a group. Thus analysis can be either at the individual or at the group level. Conjoint analysis was selected as the method for investigating the WOSP model.

Conjoint analysis shows the relative importance of each factor by part worth estimates. To provide a consistent basis for comparison across different individuals, the range of values for each model is standardized. It calculates relative importance values for each factor from their part worths such that the total for all factors comes to 100%, making it possible to compare the significance of the various factors.

EVALUATING THE WOSP MODEL

The research question was whether the TAM approach sufficiently describes the technology acceptance process, or whether users also factor in WOSP criteria. The WOSP model proposes that the factors relevant to system performance vary with the environment. However, *it particularly applies to social-technical systems* (Whitworth & Whitworth, 2004), which add a social level to system performance, e.g. email, browsers, bulletin boards and chat rooms. Hence the experimental software used in this investigation of user software evaluation was a browser. Browsers are increasingly important, and are rapidly becoming the universal platform on which end users launch information searches, email, multimedia file transfer, discussion groups, and many other Internet, intranet, and extranet applications. Their online use seems likely to increase, as such transactions become even more commonplace. Companies may choose common or recommended browsers to increase compatibility, and to help their employees choose a better online interaction platform. Also there are many browsers available, and even within browsers (like Netscape), there can be many variants. An Internet browser seemed a good example of the sort of social-technical software that requires a user evaluation and choice.

Experimental Design

The eight WOSP factors are assumed to represent aspects that affect the total worth of the performance of the software. The subjects needed to be given this information to make their assessment. The values of these factors differentiate the various alternatives presented to the subjects. To avoid distorting the relative significance of the factors, they were given the same number of levels, namely high, medium, or low. These were only three, as since there were eight factors in total, the levels needed to be limited so that the possible combinations for evaluation did not become too many.

The additive model was used for this analysis. It is the most basic and common model, and accounts for 80-90% of the variation in preference in almost all cases (Hair et al., 1995). It is usually sufficient for most situations, and assumes only that the individual simply adds up the part worths for each factor in a stimulus to get a total value for the stimulus being evaluated. The interactive model, which takes into account the interaction of factors as well, would have required many more alternatives to be evaluated, cognitively taxing subjects without a corresponding increase in explanation power. For investigating how the different levels of a given factor relate to each other, the part worth model alternative of the analysis method was chosen, as it is the most general, and gives the most information on how a user's preference of a given factor varies with its values of high, medium, or low.

The fractional factorial design is used where the number of factors and levels increases to the point that it is impractical for a subject to evaluate all the possible combinations of factors and levels and give consistent answers that are meaningful. This was the case with this experiment, since there were 8 factors, each with 3 possible levels. We used the conjoint module of the SPSS statistical software package to create an orthogonal fractional factorial design, with 27 stimuli, keeping 6 stimuli as "holdouts" for checking subject evaluation consistency. This design meant that subjects had to evaluate a total of 33 stimuli, i.e. 33 different browsers.

The full-profile method was used, where each stimulus in the set has all the eight factors that a user must consider, each having a level defined, and is presented separately. The design also had to control for the effects of the order in which the stimuli in a set were presented to the various subjects. This was randomized, so no two subjects received the stimuli in the in the same order. Also, for each subject, the order in which the factors appeared in the stimuli set was also randomized. Again, no two subjects had the performance factors in the stimuli set arranged in the same order.

For the experiment dependent variable (the browser selected for the company), ranking, rather than rating, was used as a measure of user preference, because ranking is generally more reliable, as subjects are forced to be more discriminative. The dependent variable was the subject's browser selection, and the independent variables were the eight WOSP parameters. The order in which the 33 stimuli were evaluated, and the order in which the WOSP factors appeared in each of the stimuli, were control variables.

Subjects

The subjects were 28 graduate students at the New Jersey Institute of Technology (NJIT), with 43% female and 57% male. The cultural background of these participants was diverse. On average, they had been using a browser for over 8 years, and in the 6 months prior to the experiment, they had, on average, used a browser for 23 hours each week. They used the browser for a variety of reasons, such as doing general information searches, online financial transactions, online purchases, emailing, and taking courses online. In general, they were very familiar with browser software.

Method

The participants were asked to take on the role of a senior IT manager who had to evaluate 33 different web browser types and versions to make a recommendation for their organization. The treatment was to present to each subject the results of a previous technical analysis. This gave each browser a different set of WOSP performance factor ratings. Given these ratings, the participants then had to rank the browses according to preference.

As a preliminary "priming" phase, subjects were presented with illustrative statements for each factor, and asked to rate them on a scale of 1-5 for:

- *Clarity* of statement meaning
- *Validity* of the statement, relative to the factor definition.
- *Importance* of the statement in assessing browser software

The order in which factors were presented to subjects was randomized, so no two subjects received the statements in the same order. This controlled for order effects. For each factor, the statements were then sorted in descending order of the total of the individual scores, first by importance, then by clarity, then by validity. It was assumed that those statements that ranked highest were those that the subjects were most in agreement with. The six statements that ranked highest for each factor were taken as the most descriptive for the factor, and used to anchor the factor in the second phase of the experiment.

In the second phase, subjects were asked to evaluate each browser as follows:

- *Grade the browsers* as Strong, Good, Adequate, Limited or Weak, based on the given performance factor ratings
- *Score the browsers 1 – 100. Score the worst browser as 1, and the best browser as 100, and then grade the other browsers scores in between 1 and 100.*
- *Rank the browsers from 1 to 33, with 1 the best and 33 the worst. No two browsers can have the same rank.*
- *Explain* the reasoning behind your decisions.

The entire experimental procedure was carried out via email. This standardized the subject procedure, reduced researcher variability, and cut down on administration time (compared to a face-to-face experiment).

Results

The results were assessed for the accuracy of the estimated models at both the individual and the aggregate levels. The objective in assessing reliability was to ascertain how consistently the model predicts across the set of preference evaluations given by each individual. For the rank-order data, Spearman's rho and Kendall's tau correlations were calculated and tested for statistical significance. The lowest Spearman's rho correlation in the data was 0.85, with a corresponding Kendall's tau of 0.65, which was also the lowest. The significance for all correlations was less than 0.01.

The parameters estimated for the model from the experimental stimuli set were used to predict the preference for the hold-out stimuli, and the predicted preference was then statistically compared with the actual responses to assess model reliability. The hold-out stimuli were not used for calculating the model parameters. This tested for internal consistency on the part of the subject, and showed whether the subject's decision was consistently logical or not (Bajaj, 2000). The holdout sample also served as measure of model accuracy, to check against over-fitting of data (Hair et al., 1995). A set of 6 stimuli were used as hold-outs in the experiment, and to ensure that extreme values by any individual subject did not bias the aggregate results, a boxplot analysis was done on the part worths of each of the eight factors generated by the 28 subjects to check for any extreme outliers. Three data sets were identified as having inconsistent internal validity, taken for the purposes of this experiment as a Kendall's tau for the holdouts of less than 0.4. In addition, one data set was identified as having an extreme outlier for the performance factor usability. These four data sets were excluded from any further analysis.

Ideally, if the performance factors are equally important to users, they should each have a relative importance of 12.5%, since there are 8 of them. It was assumed for this experiment that all the eight performance factors had an equivalent effect on software performance. This assumption amounts to a null hypothesis, that all eight factors are considered to be equally important by users (Bajaj, 2000). However, the mean is just a point estimate of the true value, whereas the confidence interval of the means is given as a better estimate of the true value of the parameter (Vining, 1998). The 99% confidence interval is given for the average relative importance. In terms of the confidence interval, the null hypothesis would be that all the 8 performance factors contain 12.5% in their confidence interval. Alternative null hypothesis for each factor is that the expected relative importance of 12.5% is within or less than the confidence interval of the mean.

The second metric by which the results are given takes account of the possibility that the relative importance values could be biased by the extreme values of some subjects in the sample (Bajaj, 2000).This is the percentage of subjects in the sample that gave a relative importance equal to or greater than the expected 12.5% to a given factor.. The results of the experiment are summarized in Table 1 below. A graph of the average importance values for the factors, and the lower and upper confidence limits, is given in Figure 2.

Performance Factor	**Avg. Importance.**	**Std Dev.**	**99% Confidence**	**above12.5%**
Security	22.78	12.78	16.07-29.50	70.83
Privacy	15.47	9.19	20.30-10.64	58.33
Usability	14.16	9.88	19.36-8.97	50.00
Functionality	12.02	8.21	16.33-7.70	29.17
Reliability	11.64	8.15	15.93-7.36	33.33
Connectivity	9.24	6.54	12.68-5.80	33.33
Extendibility	7.69	4.56	10.09-5.30	16.67
Flexibility	6.99	6.46	10.39-3.59	16.67
Correlation with Avg. Importance				0.95

Table 1. Summary of Results

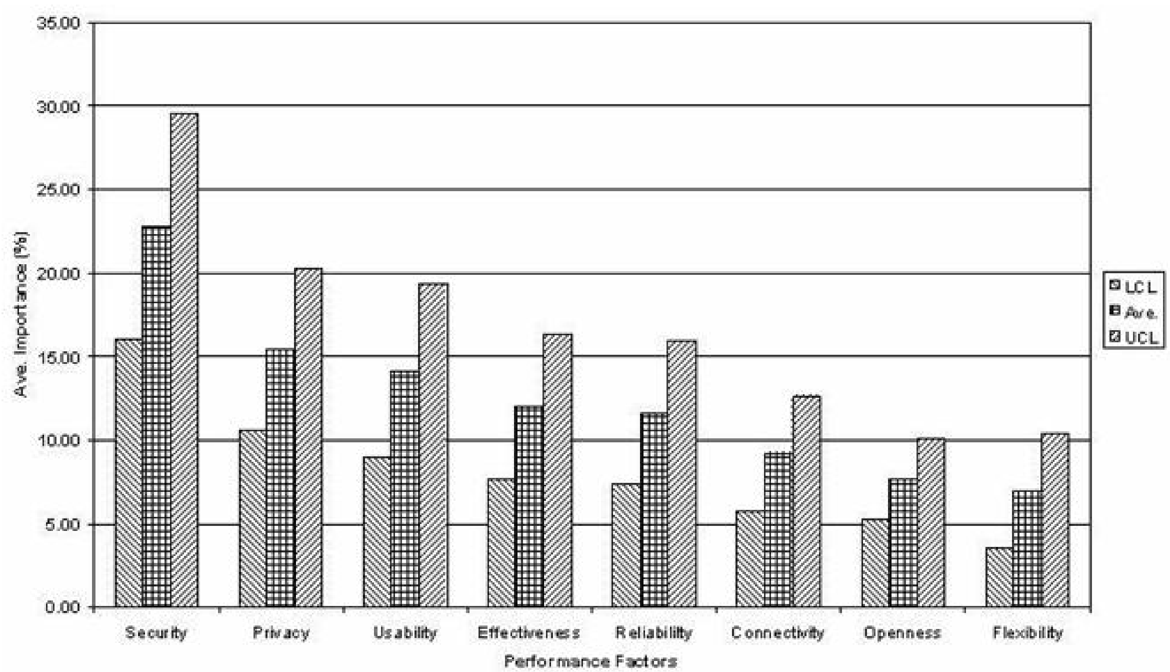

Figure 2. Graph of Lower Confidence Limit, Average Factor Importance, and Upper Confidence Limit

CONCLUSION

For the purposes of evaluating the results, it will be assumed that if the expected average importance value of 12.5% is at least contained within the confidence interval of a factor, that factor is significant in the subject's performance evaluation model. As can be seen from Table 1, the null hypothesis that all performance factors are of equal significance is rejected. Security, usability, privacy, functionality, reliability and connectivity play a significant role in the decision model of subjects when assessing the performance of web browsers. Extendibility and flexibility have some effect on the evaluative process, but not a major one. The close correlation between the average importance of a factor and the percentage of individuals who gave a part worth greater than 12.5% for that factor is very high. Therefore the relative importance of a factor was also reflected by the number of individuals who gave it a high part worth. This study suggests that factors other than those suggested in the TAM theory, such as security and reliability, affect technology acceptance. The results support the WOSP model, although it would be necessary to study types of software other than browsers to get a full picture of the factors affecting software selection.

Limitations of experiment

One limitation of this experiment is that there were no evaluations of interactions among the factors. This would be interesting from a research point of view. Another limitation is the use of students as subjects, though most of the student subjects in this experiment were either working or had working experience. Finally the software target of this study was a browser. Although browsers are surprisingly complex organizational level applications, they are not the only example, and not necessarily the most complex applications that are also organizational in scope. It would be useful to repeat this experiment with other software of comparable complexity (Venkatesh, Morris, Davis and Davis, 2003).

DISCUSSION

It is surprising that functionality and usability, which TAM predicts as primary user selection criteria, rank third and fourth, respectively, in this study. While the TAM approach may be the primary user acceptance theory, it seems not to represent the primary user acceptance factors. Its validity does not necessarily imply its priority.

It is also theoretically relevant that reliability has a distinctly different weight from security, suggesting that software users distinguish these concepts from each other. While some technology acceptance models make reliability an aspect of security (Laprie, 1992), others see it as *"the ability of a system to resist attack"* (Littlewood et al., 1993). This approach explains why mechanisms that increase fault-tolerance (reliability) can reduce system security (which is illogical if reliability is an aspect of security). Recent models reclaim the reliability/security distinction, as the first is based on provision of service, while the second is based on denial of service (Jonsson, 1998).

Similarly, while security has been described in the literature as including confidentiality as an attribute (Defence, 1985; European Commission, 1993), our research suggests security and privacy are distinct in the minds of users. Likewise, while flexibility has been suggested to include scalability (an aspect of extendibility) and connectivity (Knoll and Jarvenpaa, 1994), our results suggest flexibility, extendibility and connectivity are recognized as distinct concepts by users.

Some literature describes software requirements in terms of functional and non-functional requirements (NFR) (Chung, Nixon, Yu and Mylopoulos, 1999). In this scheme, requirements like security, privacy and reliability are NFRs, and while they appear as secondary requirements, remain a frequent cause of software failure (Cysneiros and Leita, 2002). The WOSP model sees factors that affect the risk of software failure as affecting performance, as much as those that contribute to software success. It does not distinguish between functional and non-functional criteria, nor between functional and qualitive factors. It presents the eight sub-goals as distinct modular constructs, each modifying other with the unifying concept of system performance (Whitworth and Zaic, 2003).

Despite the recent IS interest in flexibility, under terms like mobility and agility, this study found flexibility had the lowest relative importance. This may have been because flexibility is not very relevant to browser software, or because many users do not fully understand or appreciate its value. Or it may be because although flexibility is very important to system designers and programmers, it is not so important to users.

Of the eight factors the WOSP model presents, extendibility, flexibility and connectivity are the least known. More familiar factors like security, usability and reliability may be rated as more important, following the availability heuristic (Kahneman, Slovic and Tversky, 1982). As users become more educated, their rating of software acceptance factors may change.

The main finding of this paper is that the specialties of current system design and evaluation may need to integrate. As a 1997 security review notes:

"The face of security is changing. In the past, systems *were often grouped into two broad categories: those that placed security above all other requirements, and those for which security was not a significant concern."* (Kienzle & Wulf, 1997).

Just as security specialists need to recognize that system performance is more than security, so may other disciplines like usability, flexibility, reliability and privacy. System performance is not a one-dimensional concept, and this study suggests that users recognize this in their evaluations. Hence it is time that information theory did likewise.

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