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Abstract

With rapid advances in hardware speed and data communication bandwidth, one might not expect to have to deal with issues such as response time and system performance. But these issues remain a very real concern today. Lengthy system response times may cause lower satisfaction and poor productivity among users. Lowered user satisfaction may lead to discontinued use of an application, especially in discretionary applications such as those found on the Internet.

The intent of this experimental research is to (1) substantiate that slow system response time leads to dissatisfaction; (2) assess the point at which users may become dissatisfied with system response time; (3) determine a threshold at which dissatisfaction may lead to discontinued use of the application, and (4) determine if experience influences response time tolerance.

The results showed that indeed satisfaction does decrease as response time increases. However, instant response was not perceived as making the system easier to use or learn. It also showed that for discretionary applications, there appears to be a level of intolerance in the 12-second response range.

Background and Introduction

With rapid advances in hardware speed and data communication bandwidth, one might not expect to have to deal with issues such as response time and system performance. But these issues remain a very real concern today. As systems become more powerful, their applications become more complex as users expect more functionality and richer information. While response time is recognized as a component in some application usability and human factors studies (Goodwin, 1987; Nielsen, 1994; Shneiderman, 1991; Shneiderman, 1998) users today face similar system response time issues that faced users a decade ago. As web developers experience slow response times due to lengthy downloads of graphic intensive material, they are redesigning the sites to minimize this overhead. This will not be an acceptable long-term solution to accommodating electronic commerce. The network may have pockets of high-speed access and adequate bandwidth, but overall high-speed access is unavailable and many of the sites may not have been designed to handle the traffic and data volume (Berst, 1997).

This investigation will focus on the discretionary application user. A discretionary user has choices of other information sources, including not using the computer, to complete a desired objective. A person looking up the latest movie releases, stock market information, or sports scores on a website is an example of this type of user. The user can opt to use a different web site or consult other sources for this information.

This study is important for developers of browser-based discretionary-use applications. We are now learning more about providing applications in a competitive environment. There has been a surge of internet and intranet browser-based applications that fit into this category. Internet service and information content providers may be underestimating user tolerance levels for poor system performance. In addition, violation of response time warranties in system specifications has led to litigation in this area and vendors should be aware of this risk ("Inability to provide…" 1990).

Prior Research

Lengthy system response times may cause lower satisfaction and poor productivity among users (Kuhnmann, 1989; Nielsen, 1997; Shneiderman, 1998). Lowered user satisfaction is significant because it may lead to discontinued use of an application or force the user to find alternative sources of information, especially in discretionary applications such as those found on the Internet.

Response Time

Geist, Allen, and Nowaczyk studied user perception of computer system response time and suggested that a model of user perception is central to the design effort (1987). Computer system response time is generally defined as the number of seconds it takes from the moment a user initiates an activity until the computer begins to present results on the display or printer (Shneiderman, 1998; Geist, et al., 1987).

Research has assumed that system delay has an effect on user performance and that this effect can be evidenced through increased user productivity at decreased system response times (Butler, 1983; Dannenbring, 1984; Nielsen, 1994, 1995; Shneiderman, 1998; Smith, 1983). Most of the productivity studies were performed during the 80's with mainframes as the basis of organizational computing. These results support the hypothesis that an inverse relationship exists between system delay and user productivity, and are consistent with the findings of several other studies (Dannenbring, 1983; Lambert, 1984, Thadani, 1981). Much of the research today stems from the early work of Robert B. Miller. In a classic paper analyzing the performance issue, Miller proposed the ideal response time to be around two seconds (1968). Shneiderman agrees with Miller's findings that a two-second limit is appropriate for many tasks, as long as the monetary cost is not excessive (1998). But there is a wide discrepancy between what is appropriate and what is acceptable. According to Shneiderman, response times longer than 15 seconds are disruptive (1998, p. 367). However, very rapid responses can be unsettling and lead to higher error rates (Goodman and Spence, 1981; Kosmatka, 1984; Shneiderman, 1998).

In the past 25 years, research in the area of system response time has pointed to a very short (1-2 second) response time being satisfying to the user. But how long will a user wait for a system to respond before becoming dissatisfied and frustrated? System response time doesn't draw as much attention in the research spectrum for all the controversy it raises.

Research Model and Methodology

The intent of this research is to (1) substantiate that slow system response time leads to dissatisfaction; (2) assess the point at which users may become dissatisfied with system response time; (3) determine a threshold at which dissatisfaction may lead to discontinued use of the application, and (4) determine if experience influences response time tolerance.

This investigation studies the impact of system response time on discretionary-use applications and attempts to identify levels of satisfaction and determine a threshold for discontinuance. The study focuses on four dependent constructs used in prior response time and satisfaction studies: ease of use and ease of learning, satisfaction, system power, and reuse. The research model is shown in figure 1.

Hypotheses

If other factors influencing system response time satisfaction such as previous experience, expectations, user interface, and data are held constant or controlled for, it would be possible to measure satisfaction based on system response time only. If the system responds within acceptable limits, dissatisfaction will be minimal. This leads to:

H1. *User satisfaction will decrease as system response time increases.*

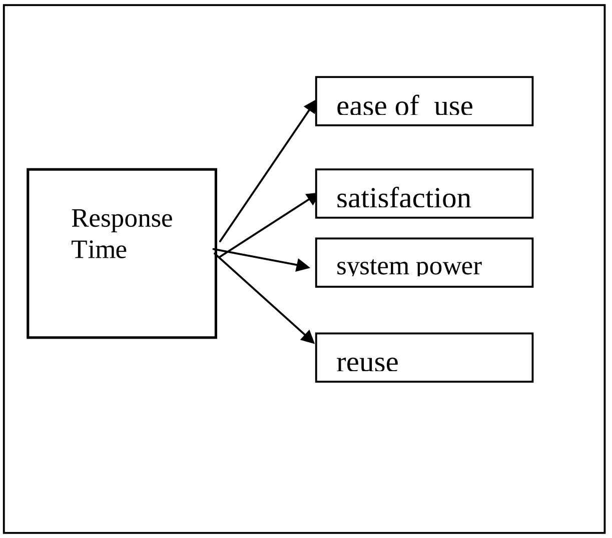

Figure 1. Research model.

In a discretionary application, the user has the option of choosing an alternate way for filling their needs. A user's attitude toward the system can be assessed to determine at what point they would discontinue using the system. This leads to:

H2. *In discretionary applications, response time dissatisfaction may lead to discontinued use.*

How "easy" an application is to use may be a factor that can determine the user's satisfaction level. System response time alone may influence the user's perception of ease-of-use. If other factors influencing ease-of-use, such as screen flow, expectations, the instructional user interface script, and the data itself - are held constant or controlled for, it would be possible to assess satisfaction based on ease-of-use while manipulating response time. This leads to:

H3. *Perceived ease-of-use of an application will decrease as user satisfaction decreases*

Previous research into novice-expert differences has strongly implied that user interface changes that aid novices tend to impair experts and vice versa (Burns, et al., 1986). Research into experience has shown that the expectations and responses of experienced users are different than that of novice users. Burns et. al. reported that NASA Space Station missions experiments found large improvements in speed and accuracy for nonexperts on certain types of displays. Experts had fewer errors but showed no response time difference on alphanumeric displays. While this study is not comparing different display types, it could be that response time tolerance levels are also different between the two groups. Experienced users may have a better understanding of the process and be more willing to accept longer response times. If other factors are held constant, it would be possible to compare the tolerance levels of the two groups. This leads to:

> H4. *Experienced users will be more tolerant of slower response times than inexperienced users.*

Research Setting

The application processed a user selection and proceeded through a series of windows to reach the desired result (Figure 2). This is consistent with the Objects/Actions Interface (OAI) Model (Shneiderman, 1997) that follows a hierarchical decomposition of objects and actions in the task and interface domains. It is a common and helpful way to decompose a complex information problem and fashioning a comprehensible and effective website. Each subject located restaurants by various scenarios: atmosphere, price, cuisine, location, and smoking preference.

This study utilized an experimental research technique. The sample group consisted of 100 subjects chosen from the Computer Information Systems (CIS) Department at Colorado State University. To measure user satisfaction based on system response time, a browser-based software application was presented to each subject individually. Each subject was put into one of five different groups, where each group was exposed to a different response time rate. Each group (numbered 1 to 5) had at least 20 subjects. Group 1 was the control group with an instant response rate (0 seconds).

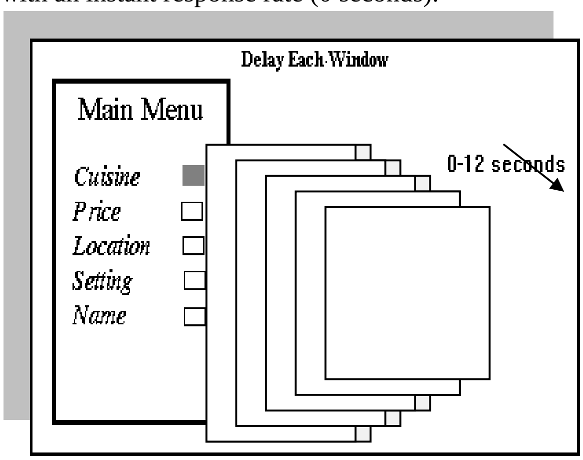

Figure 2. Restaurant Locator Frame Hierarchy.

Experimental pre-testing was done to assess the response time interval between each group. Testing was done at two- and three-second intervals, and pretests showed that a three-second interval provided better results.

As subsequent windows were displayed, a built-in timing mechanism controlled the amount of delay between the user-initiated action and the display of the next screen. The delay was consistent within each group, but varied from group to group. The delay segmentation was instant (control), three, six, nine, and twelve seconds respectively. At the conclusion of the session, each user completed the "Questionnaire for User Interaction Satisfaction" (QUIS). The questionnaire captured approximately 15 variables that were then combined into the categorical variables shown above.

Survey Instrument

The QUIS, version 5.5 short form, is a tool developed by a multi-disciplinary team of researchers in the human-computer interaction lab at the University of Maryland (Chin et al., 1988). The QUIS was designed to assess a user's subjective satisfaction with specific aspects of the human-computer interface. The QUIS team successfully addressed the reliability and validity problems found in other satisfaction measures, creating a measure that is highly reliable across many types of interfaces (UMD Webmaster, 1999). The QUIS is used for commercial and educational purposes. Because of its proven effectiveness, it was used for this experiment.

Results

Factor Analysis

Principal Components Factor Extraction was followed by VARIMAX rotation of factor loadings. This factor analysis showed significant correlation among certain groups of questions on the survey. Factor loadings were used to identify constructs or "constructs", which were averages of groups of questions. The three factor constructs were labeled according to the subject grouping they fell under. While factor analysis was done with differing amounts of initial factors, the most significant results showed a "three-factor" grouping.

Findings

User satisfaction will decrease as system response time increases.

The "satisfaction" construct was compared to each response time group using ANOVA. A linear relationship was shown to exist between response time and the satisfaction construct. The null hypothesis of "no relationship between satisfaction and response time" was rejected ($p=.0177$). Regression analysis showed a significant slope ($b=-.22$). For every unit (three second) increase in response time, there is an average of .22 drop in average satisfaction.

Several questions on the QUIS based survey addressed the question of satisfaction (Figure 3). The results clearly show a drop in user satisfaction as the response time increases. When the users were asked, "What was your overall reaction to the system (frustrating...satisfying)?" - the control group had a mean score of 8 (on a 9 point Likert scale), while the 12 second response group had a mean score of 6.5.

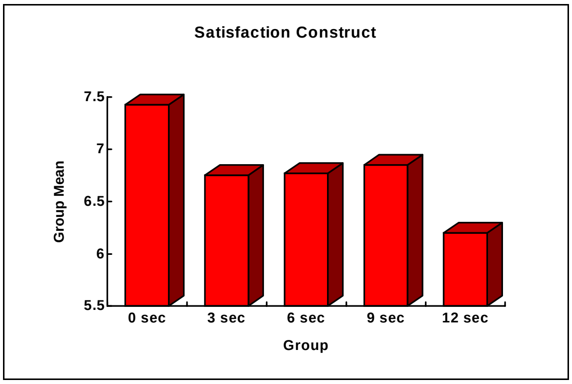

Figure 3. Satisfaction Construct Histogram

Previous research has shown that a 1-2 second response time is the most pleasing to the user (Shneiderman, 1998). This study showed that, for browser-based applications, the highest level of satisfaction existed in the sub-3 second category. However, satisfaction stayed high and fairly steady through the nine-second category, with a noticeable drop in the twelve-second category. It appears that users are willing to tolerate an approximate ten second delay. Because of the three-second intervals for each response group, it is impossible to make conclusions about differences using a one or two-second interval between screens.

In discretionary applications, response time dissatisfaction may lead to discontinued use.

Chi Square analysis and logistic regression analysis were both used to test this hypothesis. Since counts in each group (with response "No" for q14) were so low, a Fisher's Exact Test was run on the data. Results of this test suggest that response time dissatisfaction would lead to discontinued use (p=.024).

The logistic regression analysis was done using q14 as the dependent variable and "response time group" as the independent variable. Results showed that the highest response time group (12 seconds) had a higher probability of people choosing not to use the computer application. A threshold at the 12-second response time group existed, versus a smooth trend through each response time group. The statistical results of tests on this hypothesis were supported. Question 14 on the survey, "Would you use this application again?" was an open-ended yes/no question. This was the most important question in testing this hypothesis. As shown in the histogram above in Figure 7, the first four groups (0,3,6,9 second response time) all the answers to question 14 were "yes". It is only in the last group (12-second response time) where five subjects answered "no".

Analyses of the qualitative open-ended responses of question 14 provide additional insights. Several participants in the 6, 9, and 12-second response time groups that answered "yes," also qualified their answer with "the system was slow." Participants suggested that they would use the system again, but recognized that it was slow. Other answers suggested that participants had adapted to long (12 seconds or more) wait times when using the Internet. Only a couple of participants in the 12 second group qualified their "no" answers with "I could use a phone book," suggesting total application disuse.

"Ease of use" of an application will decrease as user satisfaction decreases.

The "ease-of-use" and "satisfaction" constructs, suggested by the factor analysis, and were used in the t-test and regression analysis. A t-test for the slope (p<.0001) rejects the null hypothesis that the slope is flat. Regression analysis, using the "ease of use" construct as the dependent variable and the "satisfaction" construct as the independent variable, show an upward slope (slope=.347). Regression analysis suggests that for every one-unit increase in "satisfaction", there is corresponding .347 units increase in perceived "ease of use".

"Ease of use" was also measured by several questions in the QUIS based survey. Results clearly show a trend that as perceived "ease of use" decreases so does satisfaction. The trend is not as sharp and steep as the slope for satisfaction. This suggests that response time does influence satisfaction to a higher degree than perceived "ease of use".

Results also show that "system learning" actually got easier as response time increased. When participants were asked in question 10, "Learning to operate the system was (difficult...easy)?", the means for each group rose steadily from a 7.9 (0 response group) to an 8.4 (12 second response group). This suggests that the additional response time may have given the participant more time to learn the system, or that a more immediate response time forced a participant to "rush" their way through the system.

Experienced users will be more tolerant of slower response times than inexperienced users.

Results of ANOVA between experience groups and the "satisfaction" construct show no evidence of tolerance of slower response times between the experienced and inexperienced users. The null hypothesis of "no effect between experienced and inexperienced users" is supported (p=.948). The other null hypothesis of "no effect between response time and experience level" is also supported (p=.535). Hypothesis four is therefore not supported.

The results do not support this hypothesis. Although increasing system response time was shown to decrease satisfaction, there was no significance between experience level of the participant. Previous studies show support both for and against this hypothesis (Shneiderman, 1988). More subjects and possibly a more careful differentiation in the sample population are needed to further test this hypothesis.

Discussion of Results

The research indicates that system response time does affect user satisfaction. Analysis of the histograms in Figures 2 and 3 reveals some interesting results. As response time increased, the users did not feel that the system was any less easy to use or learn (looking at the composite variable means). As the response time increased between each group, so did the "ease of reading characters on the screen", "clearness in sequence of screens", and "learning to operate the system". The composite variable of satisfaction and all individual questions relating to satisfaction showed a general decline as system response time increased.

User's perceptions of system power and speed paralleled their level of satisfaction. As shown in the histogram in Figure 4, user's reported that the system was fast enough for the application and sufficient power through the six-second category. These perceptions dropped off noticeably after nine seconds. Many users feel that their client system is at fault or under-powered. As was discussed earlier, response time delays in browser applications can be the result of many different factors.

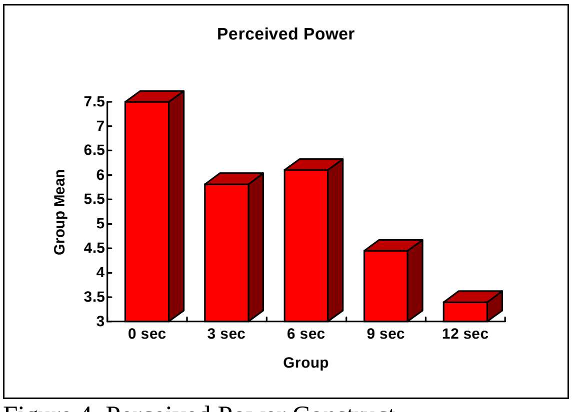

Figure 4. Perceived Power Construct

This study showed that indeed satisfaction does decrease as response time increases. It also showed that for discretionary browser-based applications, there appears to be a level of intolerance in the 12-second response range. Some response time delays actually contributed to perceived ease-of-use. Further research and usability studies may lead to a new understanding of response time guidelines for browser-based applications.

REFERENCES

Barber, R. and H. Lucas, "System Response Time, Operator Productivity, and Job Satisfaction," *Communications of the ACM*, 26, 1 (Nov 1983), 972-986.

Berst, J., "Bandwidth Progress Report," ZDNet, 1997, <url> http://www.zdnet.com/anchordesk/story/story_1384.html, accessed 9/99.

Burns, M., D. Warren and M. Rudisill, "Formatting Space-Related Displays to Optimize Expert and Nonexpert User Performance," *Design Methods II / Proceedings of ACM CHI'86 Conference on Human Factors in Computing Systems* (1986), 274-280.

Butler, T. W., "Computer Response Time and Use Performance," *Proceedings of ACM SIGCHI '83 Conference on Human Factors in Computer Systems* (1983), 58-62.

Chin, J., V. Diehl and K. Norman, "Development of an Instrument Measuring User Satisfaction of the Human-Computer Interface," *ACM Proceedings to the Human interface SIG* (Sep 1988), 213-218.

Dannenbring, G. L., "The Effect of Computer Response Time on User Performance and Satisfaction: A Preliminary Investigation," *Behavior Research Methods & Instrumentation*, 15, 2 (1983), 213-216.

Dannenbring, G. L., "System Response Time and User Performance," *IEEE Transactions on Systems, Man, and Cybernetics*, 14, 3 (1984), 473-478.

Geist, R., R. Allen and R. Nowaczyk, "Towards a Model of User Perception of Computer System," *Response Time User System Interaction* / *Proceedings of ACM CHI+GI'87 Conference on Human Factors in Computing Systems and Graphics Interface* (1987), 249-253.

Goodman, T.J. and R. Spence, "The Effect of Computer System Response Time Variability on Interactive Graphical Problem Solving," *AIEEE Transactions on Systems, Man, and Cybernetics*, 11, 3 (1981), 207-216.

Goodwin, C. J., *Research in Psychology Methods and Design*, John Wiley and Sons, New York, 1995.

Goodwin, N. C., "Functionality and Usability," *Communications of the ACM*, 30, 3 (Mar 1987), 229 – 233.

Inability To Provide Computer Response Time As Promised Results In Liability For A.D.Little, 1990, Lucash, Gesmer & Updegrove, LLP, <url> http://www.lgu.com/con43.htm, accessed 12/12/98.

Kosmatka, L. J., "A User Challenges the Value of Subsecond Response Time," *Computerworld*, 18, 24 (1984), ID 1-8.

Kuhmann, W., "Experimental Investigation of Stress-Inducing Properties of System Response Times," *Ergonomics*, 32, 3 (1989), 271-280.

Martin, G. and K. Corl, “System Response Time Effects on User Productivity,” *Behaviour and Information Technology,* 5, 1 (1986), 3-13.

Miller, R. B., “Response Time in Man-Computer Conversational Transactions,” *Proceedings Spring Joint Computer Conference*, Montvale, NJ, AFIPS Press, 1968, 267-277.

Nielsen, J., *Usability Engineering,* AP Professional, Boston, MA, 1994.

Nielsen, J., *Usability Laboratories: A 1994 Survey*, 1994, <url> http://www.useit.com/papers/uselabs.html, accessed 9/99.

Nielsen, J., *Multimedia and Hypertext: The Internet and Beyond,* AP Professional, Boston, MA, 1995.

Nielsen, J., *The Need for Speed,* 1997, <url> http://www.useit.com/alertbox/9703a.html, accessed 9/99.

Rushinek, A. and S. Rushinek, “What Makes Users Happy?,” *Communications of the ACM,* 29, 7 (July 1986), 594-598.

Shneiderman, B., “Human Values and the Future of Technology: A Declaration of Responsibility,” *ACM SIGCHI Bulletin,* 23, 1 (1991), 6-10.

Shneiderman, B., *Designing the User Interface: Strategies for Effective Human-Computer Interaction*, 3rd ed., Addison-Wesley, Reading, MA, 1998.

Smith, D., “A Business Case for Subsecond Response Time: Faster Is Better,” *Computerworld,* 17, 16 (1983), ID 1-11.

Thadani, A. J., “Interactive User Productivity,” *IBM Systems Journal*, 20, 4 (1981), 407-423.

Webmaster UMD, <url> http://www.lap.umd.edu/QUIS/index.html, accessed 9/99.

Westerman S., D. Davies, A. Glendon, R. Stammers and G. Matthews, “Age and Cognitive Ability as Predictors of Computerized Information Retrieval,” *Behaviour and Information Technology,* 14, 5 (1995), 313-326.