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TECHNOLOGY MEDIATED INTERRUPTIONS: THE EFFECTS OF TASK AND INTERRUPTION CHARACTERISTICS ON DECISION-MAKING

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Abstract

Interruptions are uncontrollable attention breakers that create stress in the work environment. Past literature has shown that interruptions impair performance. This study examines two common interruption characteristics; frequency and complexity, and investigates their effect on decision-making performance by employing cognitive fit theory (Vessey, 1991), distraction conflict theory (Baron, 1986), and research on cognitive capacity. We propose that complex interruptions will impair performance less than frequent interruptions for simple tasks. On the other and, we hypothesize that complex interruptions will deteriorate performance more than frequent interruptions when the task is complex. This research has implications on the design and appropriation of information systems to reduce potential negative effects.

Keywords

Interruption, performance, task, cognitive state, decision-making, frequency, complexity

Introduction

Technologically enhanced work environments create a trade-off between eliminating delays and increasing performance. Tools such as electronic mail systems, automated task lists, chat tools, Internet-enabled phone systems, and PC-based video teleconferencing systems all provide an opportunity for enhancing productivity in the workplace. Paradoxically, these tools also create the opportunity for interruptions, in the form of email notifications, task reminders, or incoming instant messages, which break concentration and possibly impair performance. Depending on the task and interruption characteristics, the impairment of the performance may vary.

Interruptions can vary on dimensions such as frequency, duration, complexity, timing, and content (Speier, Vessey, & Valacich, 1999) and have been shown in some cases to deteriorate performance (e.g., Kahneman, Laird, & Fruehling, 1983; Woodhead, 1965; Speier et al., 1999). Possible consequences of interruptions include unsustainable mental attention and effort (Baecker, Grudin, Buxton, & Greenberg, 1995), rationed resources (Baron, 1986), broken task flow (Bederson, 2004), impaired task processing (March, 1994), task accuracy (Cellier & Eyrolle, 1992; Schuh, 1978), and time spent (Schiffman & Griest-Bousquet, 1992).

Knowledge workers employ a number of strategies to counteract such effects, such as changing software settings, shutting applications down entirely, disconnecting from the Internet, working from other locations, or simply attempting to ignore the interruptions themselves (Jackson, Dawson, & Wilson, 2003; Minassian, Muller, & Gruen, 2004). Despite efforts to minimize interruptions and their effects, our knowledge about how systematically to evaluate both the causes and consequences of interruptions is still limited. To address this gap in the literature, this paper analyzes the effects of interruption frequency and complexity on decision outcomes. The organization of the paper is as follows. First we discuss the prior research on interruptions, introducing a comprehensive interruptions framework building on past work by Speier, Vessey, and Valacich (2003). We follow this with our research model, the development of our hypotheses, and our proposed research methodology.

Theory Development and Hypotheses

In this section, we distinguish between interruptions and distractions, and provide a motivation for our comprehensive interruptions framework. We then introduce our research model and, based on existing literature, hypothesize how the complexity and frequency of interruptions impact performance.

Background on Interruptions

This research differentiates between interruptions and distractions. Interruptions are defined as uncontrollable, unpredictable stressors that produce information overload, requiring additional decision-maker effort (Cohen, 1980), which typically results in the recipient discontinuing his or her current activity (O’Conaill & Frohlich, 1995). Information overload occurs when the amount of input to a system exceeds its processing capacity (Milford & Perry, 1977) and the person cannot accurately process information. Previous literature describes various causes of information overload resulting from information technology, such as information push technologies, speed of access, and flow of emails (Bawden, 2001; Schultze & Vandenbosch, 1998). While interruptions may not be critical to completing the task at hand, they typically require “immediate attention” and are activities that “insist on action” (Covey, 1990). For example, a decision maker involved in analyzing an online financial report may get an email pop-up from a co-worker that requires immediate feedback. Distractions, in contrast, are stimuli such as a background music or extra light coming from the hallway that direct attention away from the ongoing activity. Unlike interruptions, distractions may intrude on different sensory channels and may be ignored until the primary task is over (Cohen, 1980; Groff, Baron, & Moore, 1983).

The Interruptions Model

A framework for analyzing the impact of interruptions on performance is presented in Figure 1. The impact of interruptions on task performance is examined through the effect of interruption antecedents and moderating factors on downstream cognitive mediators and outcomes. Antecedents include (1) task characteristics: factors that has a direct impact on performance such as complexity, importance, and novelty; (2) interruption characteristics: factors that impact cognitive processing such as frequency, complexity, timing, and content of interruption (Speier et al., 1999; Czerwinski, Cutrell, & Horvitz, 2000); and (3) decision-maker characteristics: gender, ability to multitask, domain expertise, motivation, and so forth (Silverman, 1970; Mackay & Elam, 1992; Loy, 1991). Moderating factors include (4) environmental/social factors:

social expectations in the organization regarding response to interruptions, or the social affinity one has with the interrupter (Rennecker & Godwin, 2005); and (5) information presentation format: the way that task information is presented to the decision maker. These antecedents and moderating factors interact to influence cognitive mediators (cognitive load, cognitive state, and processing mechanisms) and downstream task and interruption outcomes (Kahneman, 1973; Meyer, 1998).

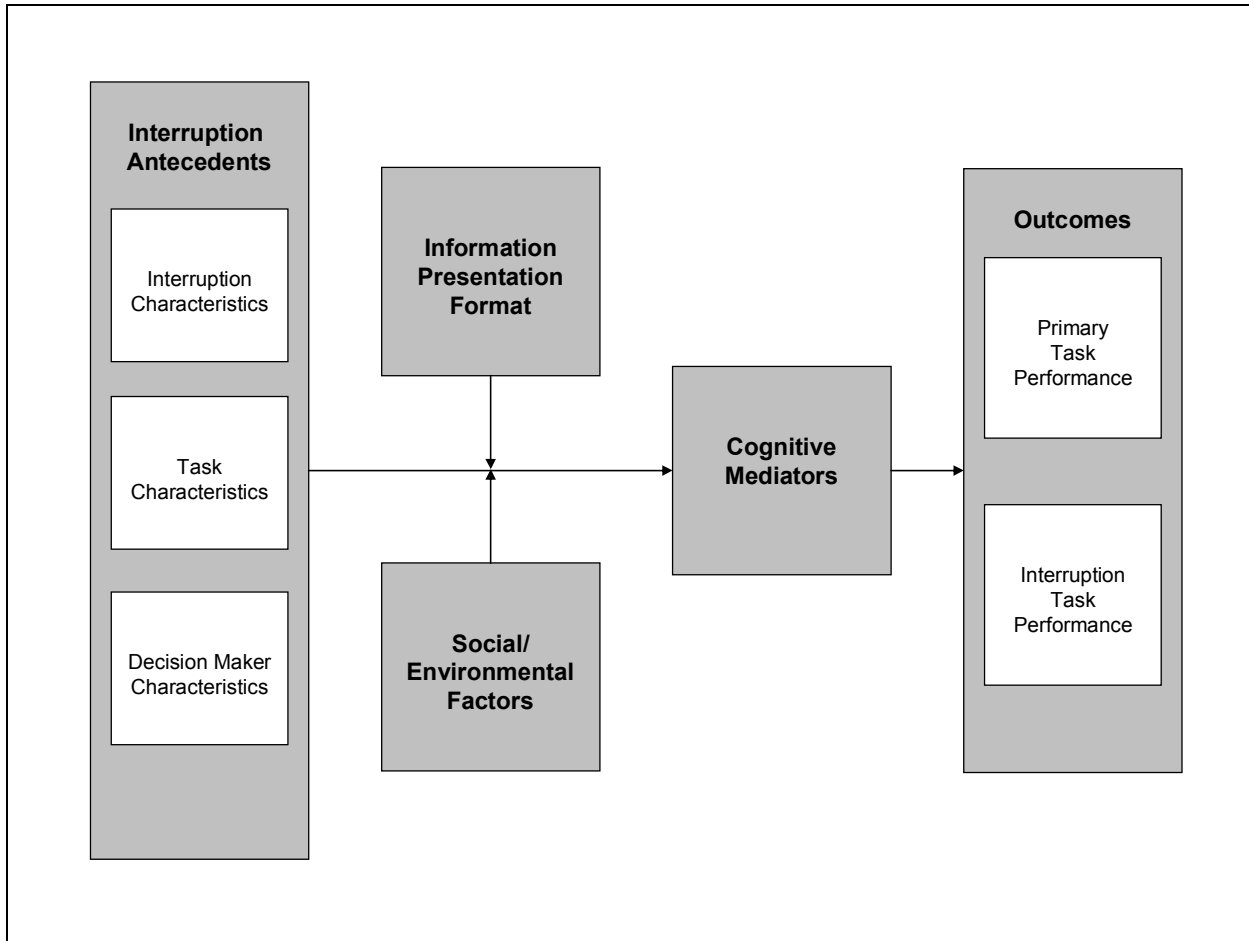


Figure 1: Interruptions Framework

For the purposes of this paper, we specifically explore the effects of task complexity, interruption complexity and frequency, and information presentation format on cognitive mediators and outcomes. Our research model is illustrated in Figure 2. Background on the each of the factors explored in our model, and our associated hypotheses, are explored next.

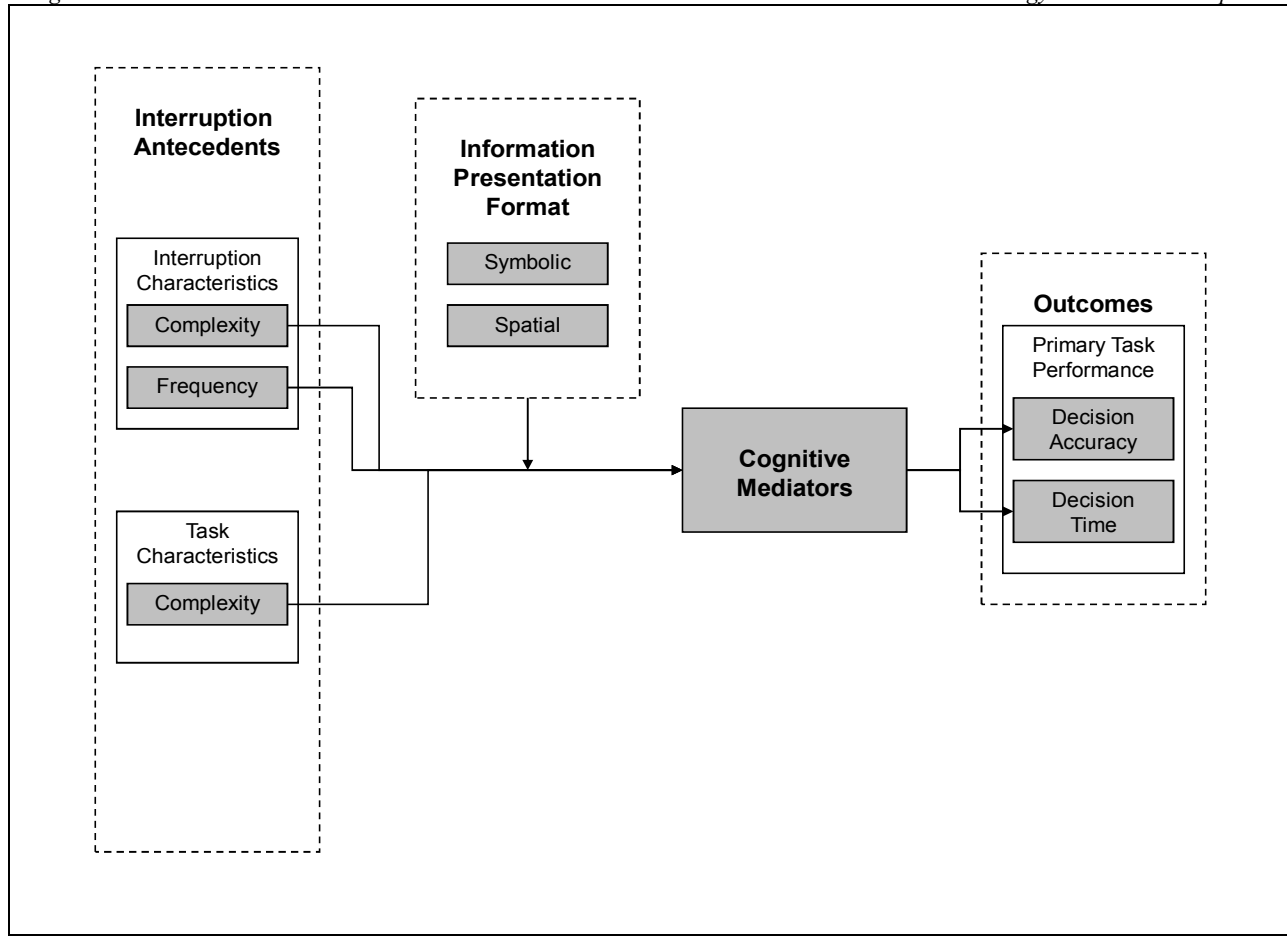


Figure 2: Research Model

Task Complexity

Complex tasks are characterized by having multiple paths, multiple end states, conflicting interdependence, and probabilistic linkages (Campbell, 1988). Furthermore, they consist of multiple subtasks (Vessey, 1994) and require high cognitive effort (Vessey, 1994). Compared to simple tasks with a single subtask, complex tasks require processing more information cues (Payne, 1982), leaving little or no excess cognitive capacity for processing new information. For the purposes of this research, complex tasks are operationalized as tasks with multiple subtasks, such as making a decision with multiple decision rules or a comparison analysis of multiple conditions to satisfy.

Interruption Complexity

Complex interruptions, which are characterized by multiple subtasks, high cognitive effort, and a large number of information cues, overload the cognitive capacity. Thus, they not only break the workflow but also cause primary task cues to exit the working memory, which erodes the ability to recall the former position in the primary task. For the purposes of this research, complex interruptions are operationalized as tasks that interfere with the primary task by requesting a decision with multiple subtasks, such as an image analysis where the answer is a condition which satisfies three different decision rules.

Interruption Frequency

Frequent interruptions increase the number of information cues to be processed, which also overloads the cognitive capacity. Furthermore, continuous work activity gets fragmented, and the person is frequently forced to switch between tasks (Mark, Gonzalez, & Harris, 2005), which will require a recovery period to return to the primary task (Kahneman, 1973). Infrequent interruptions also fragment the primary task, but they do not increase the cognitive load as much as frequent interruptions do. For the purposes of this research, interruption frequency is operationalized as high frequency and low frequency and is based on the number of times that interruptions occur, breaking the flow of work and fragmenting the primary task.

Information Presentation Format

Tan and Benbasat (1990), in their taxonomy for matching information presentation and cognitive fit theory (CFT) (Vessey, 1991), assert that if there is a match between the information presentation format and the process needed to process the information, then cognitive fit occurs. In other words, symbolic formats are optimal for presenting a discrete set of symbols (e.g., a table presenting a time schedule), and spatial formats are optimal for initiating a relationship among discrete set of graphs (e.g., a graph showing fluctuations in the exchange rate over time). Cognitive fit facilitates decision making by minimizing the cognitive effort needed to interpret the information. If cognitive fit does not occur, then the decision maker exerts cognitive effort to transform the information into the appropriate format (Vessey, 1994), which reduces accuracy, increases decision time, or both.

The Theoretical Basis for Interruption Effects

The four major theoretical bases for explaining the impact of interruptions on decision-maker performance are the Yerkes-Dodson Law, Distraction Conflict Theory (DCT), the flow channel schema, and the Cognitive Model. The Yerkes-Dodson law states that increasing arousal (e.g., stress, anxiety) improves performance up to the point (different for simple and complex tasks) at which arousal-creating events become intense enough to deteriorate performance (Yerkes & Dodson, 1908). Based on the Yerkes-Dodson Law, Distraction Conflict Theory indicates that distractions facilitate the performance of simple tasks and inhibit the performance of complex tasks (Baron, 1986; Sanders & Keele, 1986). Interruptions increase arousal (Baron, 1986), narrow attention, and cause some primary task cues to exit the working memory (Norman & Bobrow, 1975). But if the arousal level is low, the task will be completed with no loss in accuracy (Baron, 1986; Janis & Mann, 1977).

Csikszentmihalyi (1991) argues that all activities have a flow channel (defined as the balance between one's skills and challenge level to sustain control over an activity) which allows "optimal experience" in a task. By challenging the person at his/her skill level to process more information than one actually can, interruptions may break the flow and impair performance. Interruptions create anxiety and impair performance. Finally, Kahneman's (1973) Cognitive Resources Allocation Theory (capacity model) argues that interruptions result in capacity and structural interferences. Capacity interferences occur when the number of incoming cues is greater than a decision maker can process. Structural interferences occur when a decision maker has to attend to two inputs that require the same physiological mechanisms, such as attending to two different auditory signals. These interferences increase the demand on cognitive load (amount of incoming information), which narrows a person's attention to one task at the cost of another (Speier et al., 1999), the work flow gets broken (Csikszentmihalyi, 1991), and performance falls.

Effect of frequent interruptions and presentation format on simple tasks

Based on DCT, decision makers working on simple tasks may benefit from frequent interruptions. On the other hand, if information requests are highly frequent, then the workflow will be interrupted. Therefore, we propose that performance will be higher for simple tasks interrupted with low frequency. Therefore, we propose the following:

- H1a: For simple symbolic tasks with symbolic representation, decision accuracy will be higher during high-frequency interruptions than low frequency.
- H1b: For simple symbolic tasks with symbolic representation, decision time will be longer during high-frequency interruptions than low frequency.
- H1c: For simple spatial tasks with spatial representation, decision accuracy will be lower during high-frequency interruptions than low frequency.
- H1d: For simple spatial tasks, with spatial representation, decision time will be longer during high-frequency interruptions than low frequency.

Effect of frequent interruptions and presentation format on complex tasks

Performance in complex tasks is likely to deteriorate during frequent interruptions, especially during high-frequency interruptions. Complex tasks and limiting tasks will allow little or no excess capacity for new incoming cues. Thus, frequent incoming cues will pressure the decision maker to switch between tasks without performing any of them completely (Kahneman, 1973). The increase in the number of incomplete pending operations may result in demotivation (Jones & McLeod, 1997) or frustration about further "investing" in the primary task or to reliance on shortcut perceptual processing. Thus performance is impaired. Accordingly, we propose that complex tasks under high frequency of interruptions should be in spatial format representation to ease comprehension and perceptual processing. Therefore, we propose the following:

- H2a: For complex-symbolic tasks interrupted in high frequency, decision accuracy will be higher under spatial format than symbolic format.
- H2b: For complex-symbolic tasks interrupted in low frequency, decision accuracy will be higher under symbolic format than spatial format.
- H2c: For complex-symbolic tasks with spatial format, highly frequent interruptions will impair decision accuracy more than interruptions of low frequency.

H2d: For complex-symbolic tasks with spatial format, decision time will be longer for high-frequency interruptions than interruptions of low frequency.

Effect of complex interruptions and presentation format on simple tasks

As the complexity level of interruptions increases, the effort required to understand and solve the task will increase. The excess cognitive capacity in cognitively fit simple tasks will help in cognitive processing (Vessey, 1991), but time pressure, even with prioritization, will impair performance. Therefore, we propose the following:

H3a: For simple symbolic tasks with symbolic representation, decision accuracy will be lower when the interruption complexity level is high rather than low.

H3b: For simple symbolic tasks with symbolic representation, decision time will be longer when the interruption complexity level is high rather than low.

H3c: For simple spatial tasks with spatial representation, decision accuracy will be lower when the interruption complexity level is high rather than low.

H3d: For simple spatial tasks with spatial representation, decision time will be longer when the interruption complexity level is high rather than low.

Effect of complex interruptions and presentation format on complex tasks

Complex tasks are demanding tasks that leave little or zero excess cognitive capacity (Kahneman, 1973; Baron, 1986). Thus any shift from one complex task to another complex task (interruption) breaks the flow, overloads available capacity, and increases anxiety. Increased arousal narrows attention, cues get lost, the decision maker fails to position back, and performance falls. Therefore, spatial representation may facilitate comprehension, help position back, and decrease the deterioration of performance. Therefore, we propose the following:

H4a: For complex symbolic tasks with symbolic representation, decision accuracy will be lower when the interruption complexity level is high rather than low.

H4b: For complex symbolic tasks with symbolic representation, decision time will be longer when the interruption complexity level is high rather than low.

H4c: For complex spatial tasks with spatial representation, decision accuracy will be lower when the interruption complexity level is high rather than low.

H4d: For complex spatial tasks, with spatial representation, decision time will be longer when the interruption complexity level is high rather than low.

H4e: For complex symbolic tasks, decision accuracy will be higher with a spatial representation than with a symbolic representation when the interruption complexity is high.

Interruption Frequency vs. Interruption Complexity

The impact of interruption characteristics on simple and complex task performance will differ. Decision makers involved in simple tasks may get overwhelmed by both the complexity and the frequency of interruptions. But the person attending a high-complexity interruption is exposed to more cues than (s)he can process and therefore loses control over the primary task. In contrast, highly frequent interruptions, if ignored, may not impair performance as severely. Thus, we propose that for simple tasks, complex interruptions impair performance more. For complex tasks, we propose that high frequency interruptions will generate incomplete and pending tasks. This will in turn result in failure to invest in the primary task which will erode performance more than highly complex interruptions (which only generate capacity interference). In this regard, we propose the following:

H5a: For simple symbolic tasks with a symbolic representation format, task accuracy will be lower during interruptions of high complexity than interruptions of high frequency.

H5b: For simple symbolic tasks with a symbolic representation format, decision time will be longer during interruptions of high complexity than interruptions of high frequency.

H5c: For simple spatial tasks with a spatial representation format, task accuracy will be lower during interruptions of high complexity than interruptions of high frequency.

H5d: For simple spatial tasks with a spatial representation format, decision time will be longer during interruptions of high complexity than interruptions of high frequency.

H5e: For complex spatial tasks with a spatial representation format, task accuracy will be lower during interruptions of high frequency than interruptions of high complexity.

H5f: For complex spatial tasks with a spatial representation format, decision time will be longer during interruptions of high frequency than interruptions of high complexity.

H5g: For complex-symbolic tasks with a spatial representation format, decision accuracy will be lower during interruptions of high complexity than interruptions of high frequency.

H5h: For complex-symbolic tasks with a spatial representation format, decision time will be longer during interruptions of high complexity than interruptions of high frequency.

Research Methodology

Design

Two experiments using a 2 x 2 experimental design will be used to test our hypotheses (see Figure 3). In the first experiment, the information presentation format (symbolic, spatial) and interruption frequency (high, low) will be manipulated. The within-subjects factors will be task complexity (simple, complex). In the second experiment, frequency will be replaced with complexity of interruption (high, low).

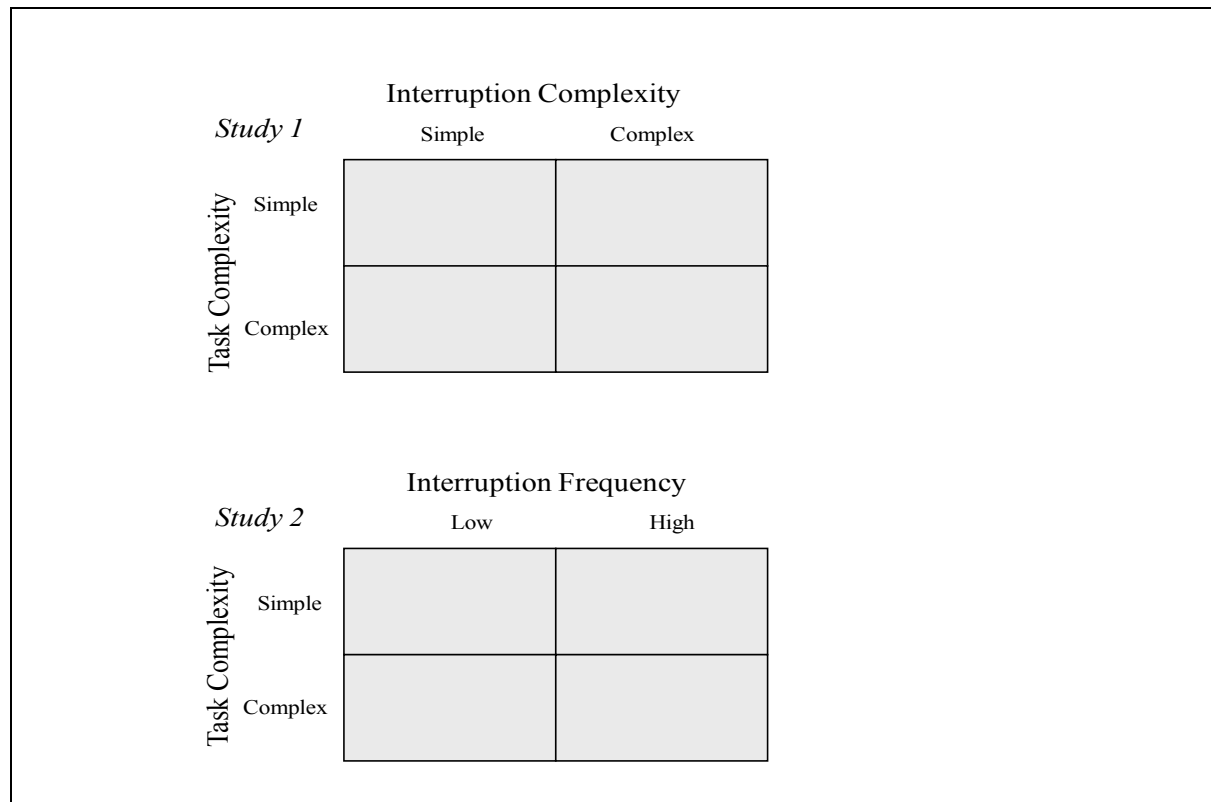


Figure 3: Experimental Designs

Subjects

The sample consists of 250 undergraduate students taking an introductory course in management information systems at a large northwestern university. Subjects were given extra credit for participating in the study. The demographic properties of the sample will be evaluated. A reward of \$10 is promised to the top 1% of performers. The top performers are sorted with respect to minimal task completion time and maximal test score.

Treatment Conditions

In each experiment, two groups serve as the treatment groups and one as the control group. The two treatment groups are given a total of 12 tasks, 6 for each presentation format. The control group in each experiment is not disturbed by any interruptions. Instead, they randomly perform the interruption tasks after or before the primary tasks. Subjects were told that they were responsible for all the questions.

In the first experiment, each participant is assigned to both simple and complex primary tasks with either symbolic or spatial task presentation, and with a low or high frequency interruption rate. The complexity level of the primary task is counterbalanced within each group. Task complexity is manipulated (two levels—simple and complex) as a within-subjects factor. Simple primary tasks consist of easy addition, subtraction, and graphical analysis questions, while complex tasks require the individual to perform multiple subtasks simultaneously or sequentially as defined by Buffa (1980) and Campbell (1988), such as making a decision with three different decision rules (see Appendix). The information format is manipulated

(two levels—symbolic and spatial) as a between-subjects factor in both the experiments. Symbolic format take the form of table representation where information is presented in cells and the row and column identify the cell, and symbolic format takes the form of graphical representation where data is presented in bars and axes identify the bars. Interruption frequency is manipulated (two levels—high and low) as a between-subjects factor for the first experiment only. The high level consists of 12 interruption tasks, while the low level consists of 4 interruption tasks during the 12 primary tasks period.

In the second experiment, task complexity and the information presentation format are varied in the same manner as in experiment 1. The complexity level of the primary task is counterbalanced within each group, as in experiment 1. Further, in the second experiment, interruption complexity is manipulated (two levels—simple and complex) as a between-subjects factor. Complex interruptions are operationalized as tasks with multiple subtasks, while simple ones are operationalized as having a single subtask (see Appendix.). The participants are interrupted in the middle of the primary task by means of pop-ups tasks, which appear in a large window covering the screen, and participants are instructed to respond to the interruption tasks.

Factors Investigated

The primary dependent variables for both the experiments are decision accuracy and decision time. We also measure perceptions about the task.

Decision accuracy is measured by giving 1 point to correct and 0 points to incorrect answers.

Decision time is measured in seconds. It is calculated by subtracting the total time spent on the interruption (TSI) task from the time spent on primary task (TSP) divided by the average time spent.

Controlled Variables

There are four control variables: average number of hours spent on the computer per day, computer anxiety, cognitive ability, and gender.

Findings

Data collection will be completed in spring 2007, and findings will be available prior to AMCIS 2007.

Predicted Limitations

Limitations of the research includes the use of student subjects and generalizability of the tasks.

Future Research

There is lack of research regarding the systematic evaluation of the effects of interruptions on work productivity. More specifically, work interruptions can vary by a variety of characteristics only two of which (frequency and complexity) are explored in the current research. Other interruption characteristics might include factors such as the timing or duration of interruptions. Further, this research also explores limited task characteristics, however task characteristics can also vary widely, including dimensions such as task complexity, importance or novelty. Again, future research should propose more comprehensive taxonomies of both interruption in task characteristics, and examine the effects of such interruptions in systematic ways. In addition, future research should also explore the effects of interruptions in different settings. For example, the current research explores the influence of interruptions on decision-making, however, interruptions are also commonplace in electronic commerce environments.

References

- Baecker, R.M., Grudin, J., Buxton, W.A., & Greenberg, S. *Readings in human-computer interaction: Toward the year 2000*. San Francisco: Morgan Kauffman, 1995.
- Baron, R.S. "Distraction-conflict theory: Progress and problems," *Advances in Experimental Social Psychology* (19), pp. 1-39, 1986.
- Benbasat, I., & Dexter, A.S. "An investigation of color and graphical information presentation under varying time constraints," *MIS Quarterly* (19:1), pp. 59-83, 1985.
- Buffa, E.S. *Modern production/operations management*. New York: Wiley, 1980.
- Campbell, D.J. "Task complexity: A review and analysis," *Academy of Management Review* (13:1), pp. 40-52, 1988.
- Cellier, J., & Eyrolle, H. "Interference between switched tasks," *Ergonomics* (35:1), pp. 25-36, 1992.

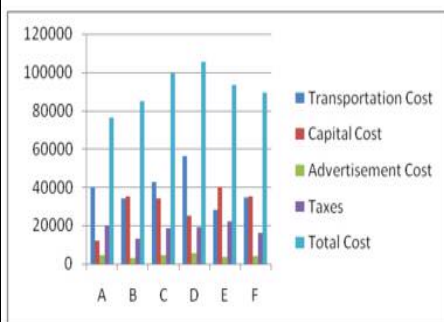
- Cohen, S. "Aftereffects of stress on human performance and social behavior: A review of research and theory," *Psychological Bulletin* (88), pp. 82-108, 1980.
- Cohen, S. *Statistical Power analysis for behavioral sciences* (2nd. ed). New York: Academic Press, 1988.
- Corragio, L. *Deleterious effects of intermittent interruptions on the task performance of knowledge workers: a laboratory investigation*. Unpublished dissertation, University of Arizona, 1990.
- Covey, S. R. *The Seven Habits of Highly Effective People*. New York: Simon and Schuster, 1989.
- Csikszentmihalyi, M. *Flow: The Psychology of Optimal Experience*. New York: HarperCollins, 1991.
- Czerwinski, M., Cutrell, E., & Horvitz, E. Instant messaging: Effects of relevance and time. In S. Turner & P. Turner (Eds.), *People and computers XIV: Proceedings of HCI 2000*, 2, British Computer Society, pp. 71-76, 2000.
- Janis, I.L., & Mann, L. *Decision making: A psychological analysis of conflict, choice, and commitment*. New York: Free Press, 1977.
- Jackson, T., Dawson R., & Wilson D. "Reducing the effect of email interruptions on employees," *International Journal of Information Management* (23:1), pp. 55-65, 2003.
- Jones, J.W., & McLeod, R. "The structure of executive information systems: An exploratory analysis," *Decision Sciences* (17), pp. 220-249, 1986.
- Kahneman, D. *Attention and effort*. Englewood Cliffs, NJ: Prentice Hall, 1973.
- Laird, D.A., Laird, E.C., & Fruehling, R.T. *Psychology and human relations and work adjustment*. New York: McGraw Hill, 1983.
- Mackay, J.M., & Elam, J.J. "A comparative study of how experts and novices use a decision aid to solve problems in complex knowledge domains," *Information Systems Research* (3:2), pp. 150-172, 1992.
- Meyer, J. "Information overload in marketing management," *Marketing Intelligence & Planning* (16), pp. 200-209, 1998.
- Milford, J.T., & Perry, R.P. "A methodological study of overload," *Journal of General Psychology* (97), pp. 131-137, 1977.
- Minassian, S.O., Muller, M.J., & Gruen, D. "Diverse Strategies for Interruption Management in Complex Office Activities," *IBM Research*, 2004.
- Norman, D.A., & Bobrow, D.G. "On data-limited and resource-limited processes," *Cognitive Psychology* (7), pp. 44-64, 1975.
- O_Connail, B., & Frohlich, D. (1995). *Timespace in the workplace: Dealing with interruptions*. Paper presented at the CHI proceedings, short papers. Available from http://www.acm.org/sigchi/chi95/proceedings/shortppr/boc_bdy.htm.
- Payne, J.W. "Task complexity and contingent processing in decision processing: An information search and protocol analysis," *Organizational Behavior and Human Decision Processes* (16), pp. 366-387, 1976.
- Payne, J.W. "Contingent decision behavior," *Psychology Bulletin*, pp. 382-402, 1992.
- Rennecker, J., & Godwin, L. "Delays and interruptions: A self-perpetuation paradox of communication technology use," *Information and Organization* (15), pp. 247-266, 2005.
- Schiffman, N., & Griest-Bousquet, S. "Optimal shopping performance under graphic and numeric CRT formatting," *Human Factors* (27:4), pp. 433-444, 1992.
- Schuh, J. "Effects of an early interruption and note taking on listening accuracy and decision making in the interview," *Bulletin of the Psychonomic Society* (12:3), pp. 242-244, 1978.
- Silverman, J. Attentional styles and the study of sex differences. In D.I. Mostofsky (Ed.), *Attention: Contemporary theory and analysis*. New York: Appleton-Century-Crofts, pp. 61-68, 1970.
- Schultze, U., & B. Vandenbosch. "Information Overload in a Groupware Environment: Now you see it, now you don't," *Journal of Organizational Computing and Electronic Commerce* (8:2), pp. 127-148, 1998.
- Speir, S. *The effects of task interruption and information presentation on individual decision making*. Unpublished doctoral dissertation, Indiana University, Bloomington, 1996.
- Speier, S., Valacich, J.S., & Vessey, I. "Information overload through interruptions: An empirical examination of decision making," *Decision Sciences* (30:2), pp. 337-360, 1999.
- Speier, S., Vessey, I., & Valacich, J.S. "The effects of interruptions, task complexity, and information presentation on computer-supported decision-making performance," *Decision Sciences* (34:4), pp. 771-797, 2003.
- Tan, J.K.H., & Benbasat, I. "Processing of graphical information: A decomposition taxonomy to match data extraction tasks and graphical representations," *Information Systems Research* (1:4), pp. 416-439, 1990.
- Vessey, I. "Cognitive fit: A theory-based analysis of the graphs versus tables literature," *Decision Sciences* (22), pp. 219-240, 1991.
- Vessey, I. "The effects of information presentation on decision making: A cost-benefit analysis," *Information and Management* (27), pp. 103-119, 1994.
- Vessey, I., & Galletta, D. "Cognitive fit: an empirical study of information acquisition," *Information Systems Research* (2:1), pp. 63-84, 1991.
- Woodhead, M.M. "The effects of bursts of noise on an arithmetic task," *American Journal of Psychology* (77), pp. 627-633, 1965.

Complex Symbolic

Period	1	2	3	4	5	6
Capital Cost	3000	4500	4000	4300	2500	3400
Labor Cost	45000	38000	45000	34000	45000	55000
Taxes	25000	1700	2200	3500	1000	1100

Question: What is the total number of periods where capital cost was no more than 10% of the labor cost but was at least twice the taxes?

Complex Spatial



Question: 1. Total cost less than 100,000 2. Capital cost at most is 50% of the total cost 3. Taxes can be no more than 10% of the total cost. Which location(s) meet your manager's criteria?

Simple Symbolic

	June	July	August	September	October	November
Red Parking Lot						
Capacity (cars)	200	200	200	200	200	200
Load (per hour)	230	150	200	140	75	95
Purple Parking Lot						
Capacity (cars)	350	350	350	350	350	350
Load (per hour)	200	250	140	175	250	150
Green Parking Lot						
Capacity (cars)	360	360	360	360	360	360
Load (per hour)	380	210	300	380	240	310

Question: Which parking lot had the least amount of empty spots per hour during the month of August?