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The Influence of Task Interruption on Individual Decision Making: An Information Overload Perspective

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ABSTRACT

Interruptions are a common aspect of the work environment of most organizations. Yet little is known about how interruptions and their characteristics, such as frequency of occurrence, influence decision-making performance of individuals. Consequently, this paper reports the results of two experiments investigating the influence of interruptions on individual decision making. Interruptions were found to improve decision-making performance on simple tasks and to lower performance on complex tasks. For complex tasks, the frequency of interruptions and the dissimilarity of content between the primary and interruption tasks was found to exacerbate this effect. The implications of these results for future research and practice are discussed.

Subject Areas: Decision Making, Information Overload, and Interruptions.

INTRODUCTION

In recent years, the term "information overload" has evolved into phrases such as "information glut" and "data smog" (Shenk, 1997). What was once a term grounded in cognitive psychology has evolved into a rich metaphor used outside the world of academia. In many ways, the advent of information technology has increased the focus on information overload: information technology may be a primary reason for information overload due to its ability to produce more information more quickly and to disseminate this information to a wider audience than ever before (Evaristo, Adams, & Curley, 1995; Hiltz & Turoff, 1985).

Decision makers' day-to-day activities increasingly involve the use of computers (Panko, 1992) and many of the recent developments in information technology have also exacerbated the number of interruptions that occur in the work environment. For example, electronic mail systems are often configured to notify the user immediately of new messages. In a similar way, web-based push technologies send information directly to a worker's PC at specific times of the day or when the computer has been inactive for brief periods. Computer-based tasks often involve high cognitive loads that might be susceptible to interference from interruptions (Baecker, Grudin, Buxton, & Greenberg, 1995). A recent survey found that 50% of management at Fortune 1000 companies "were interrupted more than six or more times an hour, leaving them overwhelmed by the number of messages they receive" (Reuters, 1997, p. 12).

It is somewhat intuitive that interruptions should have a deleterious effect on decision maker performance because they force cognitive resources to be rationed across more than one task. Rationing of resources can change the way tasks are processed (March, 1994) and the manner in which information is used (Baron, 1986). These changes may ultimately result in decreased task accuracy (Cellier & Eyrolle, 1992; Schuh, 1978) and increased time required to solve problems (Shiffman & Griest-Bousquet, 1992).

Despite the prevalence of interruptions in the workplace and the possibility that performance may deteriorate as a result, very little research has been conducted into the effects of interruptions. This research has two objectives. First, it examines the influence of interruptions on the decision-making performance of individuals performing simple and complex tasks. Second, this research examines the influence of the content and the frequency of interruptions on decision-making performance of individuals addressing complex tasks. The paper proceeds as follows. We review the relevant prior research and develop research propositions, after which we present the research methodology. Finally, we present the results of the two laboratory experiments, followed by a discussion of the empirical findings, limitations, and future research opportunities.

THEORY DEVELOPMENT AND PROPOSITIONS

This section first describes information overload. It then examines interruptions as a contributor to information overload in a decision-making context, leading to the propositions tested in this research.

Information Overload

Information overload occurs when the amount of input to a system exceeds its processing capacity (Milford & Perry, 1977). Decision makers have fairly limited cognitive processing capacity (Miller, 1956; Simon, 1979). Consequently, when information overload occurs, it is likely that a reduction in decision quality will occur. Research from a number of disciplines (e.g., accounting, finance, consumer behavior) has found, for example, that information overload decreases decision quality (Abdel-Khalik, 1973; Chewning & Harrell, 1990; Shields, 1980; Snowball, 1980), increases the time required to make a decision, and increases confusion regarding the decision (Cohen, 1980; Jacoby, Speller, & Kohn, 1974a, 1974b; Malhotra, Jain, & Lagakos, 1982).

In studies to date, information overload has been conceived primarily as "information load," which has been operationalized in different ways: the amount of information (e.g., number of cues: Casey, 1980; O'Reilly, 1980); number of alternative outcomes (Shields, 1980; Stewart, 1988); and overall diversity of the information (Iselin, 1988). The number of information cues is the most commonly cited determinant of information overload (Evaristo et al., 1995). Hart (1986) indicated that an increase in task demands (i.e., task complexity) directly influences mental workload and can lead to information overload. More recent research has articulated the importance of time in understanding information overload (Schick, Gordon, & Haka, 1990), suggesting that information overload occurs when the time required to meet a decision maker's processing requirements exceeds the amount of time available for such processing, resulting in degradation of decision quality (Hahn, Lawson, & Lee, 1992; Peters, O'Connor, Pooyan, & Quick, 1984).

Interruptions

An interruption is "[a]n externally generated, randomly occurring, discrete event that breaks continuity of cognitive focus on a primary task" (Corragio, 1990, p. 19) and typically "requires immediate attention" and "insists on action" (Covey, 1989; pp. 150-152). This definition implies that another person or event creates an interruption and that the timing of an interruption is beyond the control of the individual.

Interruptions can exacerbate information overload in two ways. First, they take time away from working on ongoing work activity, potentially resulting in a feeling of time pressure and, ultimately, information overload. An interruption breaks a decision maker's attention on a primary task and forces the decision maker to turn his or her attention towards the interruption, if only temporarily. A decision maker's attention is broken and refocused because the interruption cues may use the same sensory channel as those used in processing another activity and demand much, if not all, of his or her attention. Interruptions, therefore, create both capacity and structural interference (Kahneman, 1973). Capacity interference occurs when the number of incoming cues is too numerous for a decision maker to process. Structural interference occurs when a decision maker must attend to two inputs that require the same physiological mechanisms (e.g., attending to two different visual signals, one from a computer screen and one from a colleague entering an office). Thus, interruptions create interference which increases the overall cognitive processing load and forces an individual to focus or narrow his or her attention on one task at the expense of another.

Second, the interruptions themselves can place greater demands on cognitive processing and result in an increase in information load and task processing demands (Norman & Bobrow, 1975). When this occurs it may result in a decision maker forgetting some of the information needed for processing the primary task and, therefore, some cues are lost or never enter working memory. As the decision maker completes the interruption task and returns to the primary task, a recovery period is needed to reprocess information that was forgotten while attending to the interruption or lost from working memory due to capacity interference (Kahneman, 1973). In such cases, decision accuracy may be decreased and/or decision time increased (Kahneman; Laird, Laird, & Fruehling, 1983).

Very little prior research has examined the influence of interruptions on decision performance. As a result, there is sparse empirical guidance on how interruptions influence the processes and performance of individual decision makers. There is, however, a significant theoretical and empirical examination of distractions. Although we believe interruptions and distractions are different (e.g., interruptions are more intrusive than distractions) it is likely that the cognitive processing and resulting effects of distractions and interruptions on decision performance will be similar as both disrupt, and potentially overload, the finite cognitive capabilities of the decision maker. Therefore, we examine the prior theoretical underpinnings behind the influence of distractions on performance to guide our development of the theory associated with interruptions.

To further our understanding of interruptions on decision-making performance, we examine task and interruption factors that are likely to induce information overload: task complexity, interruption frequency, and interruption content. First, we examine task complexity because prior research has linked task complexity directly to information overload (Evaristo et al., 1995). Second, we examine two characteristics of interruptions that have been investigated in the information overload literature. Interruption frequency results in a decision maker having to process a greater number of information cues, which have been found to induce information overload (Casey, 1980; O'Reilly, 1980). The diversity (or similarity) of information content influences information overload (Iselin, 1988). We therefore examine the relationship between information content of the primary and interruption task on decision performance.

Interruptions and task complexity

Distraction/Conflict Theory (see Baron, 1986, for a review of this literature; Goff, Baron, & Moore, 1983; Sanders & Baron, 1975) provides a theoretical grounding to explain the influence of distractions (e.g., industrial noise or background music) on decision performance. The theory has been used to explain the influence of distracting noise on performance in a broad range of settings (Boggs & Simon, 1968; Hockey, 1970). In general, the tenets of Distraction/Conflict Theory state that distractions facilitate performance on simple tasks and inhibit performance on complex tasks.

The different effects of distractions/interruptions on simple and complex tasks may result from the number of cues that must be processed and the number and complexity of individual processes needed to perform each type of task (Wood, 1986). Simple tasks require processing fewer cues than complex tasks and are less likely to challenge the cognitive capacity of the decision maker (Baron, 1986). When distractions/interruptions occur, arousal or stress elevates, attention narrows and irrelevant cues are more likely to be dismissed or ignored (Sanders & Baron, 1975). The increased arousal results in a decision maker completing the task more quickly (e.g., faster decision time) with little or no loss of task-relevant cues (e.g., equivalent decision accuracy). Prior research demonstrates that distractions help decision makers focus on the relatively few information cues of their simple primary task, resulting in faster completion times and little or no loss in decision-making performance (Baron).

Decision makers performing complex tasks have little if any excess cognitive capacity. Narrowing one's attention as a result of the interruption is likely to result in the loss of information cues, some of which may be relevant to completing the task. Under these circumstances, performance is likely to deteriorate. As the number or intensity of the distractions/interruptions increases, the decision maker's cognitive capacity is exceeded, and performance deteriorates more severely. In addition to reducing the number of possible cues attended to, more severe distractions/interruptions may encourage decision makers to use heuristics, take shortcuts, or opt for a satisficing decision, resulting in lower decision accuracy (Baron, 1986). This implies the following propositions:

> **Proposition 1:** Interruptions facilitate decision-making performance on simple tasks.

> **Proposition 2:** Interruptions degrade decision-making performance on complex tasks.

Characterization of interruptions

It is likely that different types of interruptions will have different effects on decision maker performance (Kahneman, 1973). Little research has been conducted into the effects of interruption characteristics on performance. Moray (1993), for example, stated that there is "no systematic body of research on what physical or psychological characteristics make an interrupt" (p. 120). Prior literature does suggest, however, broad categories of interruptions: (1) those that affect cognitive processing (Kahneman); and (2) social characteristics that influence the manner in which decision makers respond to the interruption (Kirmeyer, 1988). Characteristics that primarily influence cognitive processing include frequency, duration, content, complexity, and timing of the interruption. Social characteristics include the form of the interruption, the person or object generating the interruption, and social expectations that exist regarding responsiveness to the interruption.

Of the possible interruption characteristics, two that appear to be particularly relevant to information processing capacity and information overload are interruption frequency and interruption content. More frequent interruptions are likely to place a greater processing load on the decision maker. Each interruption requires a recovery period (Kahneman, 1973) where reprocessing of some primary task information occurs. Consequently, the number of recovery periods, the recovery time, and the likelihood of errors all increase as the frequency of interruption increases.

Woodhead (1965) and Eschenbrenner (1971) discovered that decision accuracy decreased as the frequency of distractions increased. However, Corragio (1990) found that interruption frequency had no effect on performance. It is possible that Corragio's manipulation was not strong enough to have an effect. To clarify our understanding of frequency as a characteristic of interruptions, we state the following proposition:

> **Proposition 3:** Decision-making performance on complex tasks degrades when the frequency of interruptions increases.

There are two schools of thought regarding the effect of information content on decision performance. On the one hand, research in cognitive psychology suggests that task accuracy is reduced when short-term memory tasks using the same or similar information are processed simultaneously (Gillie & Broadbent, 1989; Kinsbourne, 1981, 1982; Navon, 1984). As the similarity among information cues increases, interference between the information associated with the primary task and the interruption task occurs within working memory (Anderson & Milson, 1989). This interference creates attentional overload and results in performance degradation as resources from working memory are inappropriately allocated among tasks (Norman, 1981).

On the other hand, Iselin (1988) found that greater diversity in information content results in lower decision quality and increased decision time. Diversity, operationalized as more information cues and types of information processing necessary, increases the likelihood that the decision maker's limited cognitive capacity will be exceeded. Similar information decreases the demand for cognitive processing resources (Biggs, Bedard, Gaber, & Linsmeier, 1985) and results in decreased information load (Evaristo et al., 1995).

These conflicting results may relate to differences in the type of tasks studied. Iselin's (1988) research used cognitively complex decision-making tasks, while the research in cognitive psychology used relatively short memory and association problems. Because our ultimate aim is to address more cognitively complex decision-making tasks, we state the following proposition:

> **Proposition 4:** Decision-making performance on complex tasks degrades when the information content of the interruption and decision-making task is dissimilar.

RESEARCH METHODOLOGY

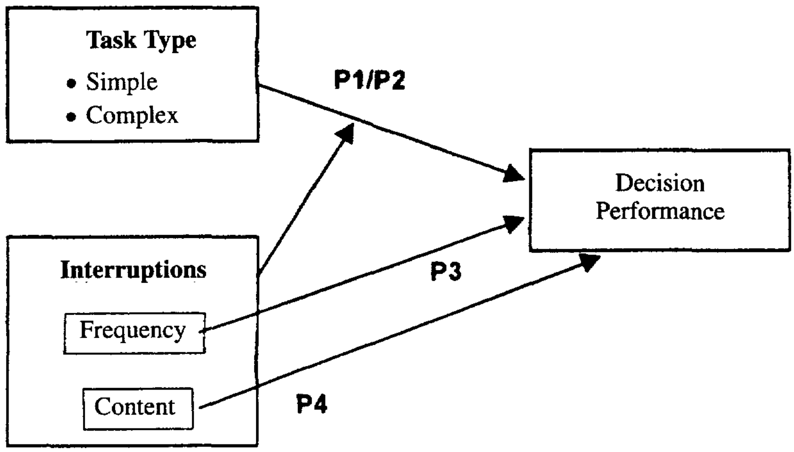
Two laboratory experiments were conducted to investigate the propositions articulated in the prior section and presented in Figure 1. Both experiments required subjects to respond to multiple decision and interruption tasks, each having optimal solutions (i.e., intellective tasks as defined by McGrath, 1984). Both experiments used the same dependent and control variables.

Tasks (both experimental and interruptions) were delivered to subjects via a computer-based decision support system. Interruptions were presented to subjects by inserting a clear screen on the monitor of the PC announcing that the subject's manager wanted them to find/calculate a specific piece of information. The system then placed the information needed to respond to this question on the subject's monitor. Once they had entered the information into the appropriate location on the screen, the subject clicked an OK button and automatically returned to the experimental task.

Subjects

Subjects in this research were 238 undergraduate students enrolled in an introductory production management (PM) course. They were randomly assigned to one of the eight treatments (explained below) across the two experiments. There were no significant differences across treatments with respect to gender, age, year in school, major, and prior PM experience. All subjects were volunteers and received

Figure 1: Research model highlighting variable relationships and propositions.



1% credit towards their final course grade. To encourage subjects to work both quickly and accurately, cash incentives (of up to $10) were awarded to the highest performing subjects, measured by decision accuracy per unit time.

General Task Environment

The experimental and interruption tasks were all production management (PM) problems. Because the literature distinguishes between two types of tasks: spatial, which require perceptual processes, and symbolic, which require analytical processes, we used both types of tasks in our experiments. The order of presentation of spatial and symbolic tasks was counterbalanced in each experiment. Hence, the four types of tasks used were simple-symbolic, simple-spatial, complex-symbolic, and complex-spatial. These simple and complex tasks are more fully defined in the Task Complexity section.

Experimental Design

The designs for the two experiments are presented below and illustrated in Figure 2. Note that the two experiments used a common experimental setting, common procedures, and where applicable, the same tasks.

Experiment 1: Influence of work environment

Experiment 1 assessed the effect of interrupted and noninterrupted work environments on decision performance on both simple and complex tasks (i.e., two 2×1 experimental designs). *Work Environment* was examined at two levels (interruptions, no interruptions) for both simple and complex tasks.

Experiment 2: Interruption characteristics

The second experiment focused on the influence of interruption frequency and content on decision-making performance on complex tasks. This experiment also

Figure 2: Research design for Experiments 1 and 2.

	Experiment 1		Experiment 2			
	Interruptions		Interruption Frequency		Interruption Content	
Proposition	No Interruptions	Interruptions	Low Frequency	High Frequency	Similar Content	Different Content
1	Simple	Simple				
2	Complex	Complex				
3			Complex	Complex		
4					Complex	Complex

consisted of two separate 2 × 1 experimental designs in which *Interruption Frequency* at two levels and *Interruption Content* at two levels were manipulated for two types of complex tasks. The two complex tasks, setting, and procedures (as described below) were the same as those used in Experiment 1.

Factors Investigated

The experimental procedures and operationalized levels of the independent and dependent variables were tested and validated in pilot studies.

Independent variable—Task complexity

Simple tasks were defined as tasks that required acquiring information cues only or acquiring cues together with some simple calculations. The simple task involved scheduling workloads on multiple machines over a six-month period (see Umanath, Scamell, & Das, 1990, and Appendix A for examples). Each simple task consisted of six different questions, each presented as a separate screen during the computer simulation. The simple-symbolic task required subjects to obtain specific data (directly looking up values or performing routine addition or subtraction calculations), whereas the simple-spatial task required subjects to identify trends in the data.

Using Wood's (1986) definition, complex tasks require significantly more information processing than simple tasks. Furthermore, complex tasks involved interrelated outcomes where the processing of one part of the task influences processing of another part of the task. The two complex tasks consisted of a facility location task (the complex-symbolic task) (Buffa, 1990), and an aggregate planning task (the complex-spatial task) (Holt, Modigliani, Muth, & Simon, 1960; Davis & Kotterman, 1994; Remus, 1984, 1987) (see Appendix A for examples), and were selected and constructed to meet the theoretical definition of complex tasks developed by Wood. Decision time differences between the simple and complex tasks were assessed in pilot testing to validate the appropriateness of the simple and complex classification. Results indicated that there were significant differences in decision task completion time (< .05) for each of the simple/complex task pairs.

In the facility location task, subjects were provided with five different cost estimates associated with six warehouse locations. Subjects were asked to determine which locations to develop and to rank order the locations based on cost. In the aggregate planning task, subjects were provided with a three-period forecast for four types of paint, current inventory, and current workforce size, and were asked to determine the total number of gallons of paint to produce. They were also requested to make any necessary changes in the workforce level to minimize the total production cost.

Independent variable—Work environment

Work environment was manipulated by having the decision support system introduce interruptions while subjects were performing each type of task (see Appendix B for example). Interruptions consisted of four simple information acquisition tasks (both spatial and symbolic), which occurred during each of the four experimental tasks (e.g., start of Task 1 followed by four interruptions during Task 1, end of Task 1, start of Task 2, etc.). These interruptions were unpredictable (i.e., they did not occur after each subtask) and subjects could not anticipate when or if an interruption would occur. Interruptions during problem solving were timed to occur 7-15 seconds into the task.

Subjects in the no-interruption treatment of Experiment 1 also performed all interruption tasks. Fifty percent of these subjects performed the interruption tasks first, followed by the four experimental tasks, while the remaining 50% received the tasks in the reverse order to control for fatigue effects.

Independent variables—Interruption characteristics

Interruption frequency was operationalized as the number of interruptions that occurred during a task. Low and high interruption frequencies were operationalized as four and 12 interruptions per task. Interruption content manipulated the actual data used when solving the interruption task. In the content-similar condition, the data used in solving the interruption task was identical to the data in the experimental task, whereas data in the content-different condition involved different data from the experimental task.

Performance variables

The dependent variables were *decision accuracy* and *decision time*. Given that there were four independent and quite different tasks, decision accuracy needed to be measured somewhat differently for each task. To obtain a meaningful score when simple and complex tasks were pooled and to provide a consistent mechanism for interpreting results, z-scores were used for all tests. Accuracy for each task was calculated by subtracting the percentage deviation from the optimal score and then normalizing to generate a z-score. The z-scores for the individual tasks were combined to create an overall z-score (e.g., the z-scores from the two simple tasks were pooled to provide an overall simple task z-score). A higher absolute mean z-score indicates higher accuracy. Decision time was the time required to perform the decision task less the time needed to respond to any interruption tasks and is measured in seconds. Finally, Corragio's three-item scale for measuring the perceived influence of interruptions was used on each task to collect data for post hoc examination (Corragio, 1990).

Controlled variables

Three individual characteristics that were thought to influence decision-making performance either directly or indirectly were controlled statistically in this experiment. They are domain expertise, spatial ability, and gender. Both greater domain expertise (Mackay & Elam, 1992; Ramamurthy, King, & Premkumar, 1992) and greater spatial abilities when performing spatial tasks (Loy, 1991) result in improved decision performance. Gender is included because females have been found to be distracted more easily than males when performing complex tasks (Silverman, 1989).

Domain expertise was measured as performance on production management examination questions relevant to the tasks being performed in the experiment. Gender was measured through self-report data, whereas spatial ability was measured using the Kit of Factor Referenced Cognitive Tests (Ekstrom, French, Harman, & Dermen, 1976). In addition to the individual difference characteristics, accuracy and time data for the interruption tasks were also collected and controlled statistically when necessary. It was possible for subjects to click on an OK button of an interruption task and return to the primary task without attempting to solve this task. Therefore, it was important to control for this possible behavior because "skipping" the interruption task would reduce the influence of the interruption. These measures also provided data to enable post hoc examination of decision maker performance on the interruption tasks.

RESULTS

Domain expertise, gender, and spatial ability were included as covariates in all tests as they were significant in most but not all of the statistical tests. Given that these variables influenced decision performance most of the time and they represent enduring characteristics of our subject pool, we included these variables as covariates in all tests. Decision accuracy and time were significantly correlated on simple tasks ($r = .21$; $p = .03$), but not on complex tasks ($r = .07$; $p = .24$). Proposition 1 was therefore evaluated using MANCOVA, whereas Propositions 2, 3, and 4 were evaluated using ANCOVA. Linear regression was used to assess whether decision accuracy and time on the interruption tasks significantly influenced the dependent variables in the primary task. The results indicated that the analyses for interruption frequency and content (Propositions 3 and 4) required controlling for both accuracy and time on the interruption task. Hence, these variables were included as covariates in the respective ANCOVA models. The means, standard deviations, and results of the statistical tests associated with Propositions 1 through 4 are presented in Table 1.

Results of Proposition Testing

Proposition 1 states that interruptions improve performance on simple tasks. Results from the one-way MANCOVA indicate that interruptions significantly improved decision-making performance (Wilks Lambda (2, 127) = .923, $p = .006$). Hence Proposition 1 is supported. Independent ANOVAs were run for each dependent variable to determine whether the effect is manifested in accuracy

Table 1: Summary of statistical testing for each proposition.

Experimental Treatment (Proposition)	Task Accuracy			Task Time		
	Mean (*SD*)	Test Value (*df*)	*p*-value	Mean (*SD*)	Test Value (*df*)	*p*-value
Simple Task (Proposition 1)						
No Interruption	0.18 (0.70)	.850 (1, 132)	.358	110.3 (27.59)	14.594 (1, 132)	**.001**
Interruption	0.29 (0.67)			90.8 (30.83)		
Complex Task (Proposition 2)						
No Interruption	0.13 (1.07)	7.851 (1, 132)	**.006**	608.3 (284.39)	8.043 (1, 132)	**.005**
Interruption	0.08 (0.52)			760.8 (293.76)		
Complex Task (Proposition 3)						
Low Frequency	0.22 (0.33)	9.146 (1, 88)	**.003**	831.3 (238.70)	17.829 (1, 88)	**.000**
High Frequency	0.05 (0.55)			1702.5 (526.80)		
Complex Task (Proposition 4)						
Similar Content	0.12 (0.46)	.667 (1, 88)	.416	1317.4 (613.85)	6.464 (1, 88)	**.013**
Different Content	0.05 (0.49)			1842.0 (741.59)		

Boldface = significant at $\leq .05$

or in time. These tests indicate that decision makers experiencing interruptions completed the simple tasks with comparable accuracy to those not experiencing interruptions (0.29 cf. 0.18) ($F(1,132) = .850$, $p = .358$). However, those subjects experiencing interruptions completed their decisions more quickly than those not experiencing interruptions (90.8 cf. 110.3 seconds) ($F(1,132) = 14.594$, $p = .001$). Because accuracy and time are not independent, the finding that the improved performance on interrupted simple tasks is driven by the decreased time needed to perform the task must be treated with caution.

Proposition 2 states that interruptions result in decreased performance on complex tasks. Results from the one-way ANCOVA indicate interruptions led to a significant decrease on decision accuracy (0.08 cf. 0.13) ($F(1, 129) = 7.851$, $p = .006$) and increase in decision time (760.8 cf. 608.3) ($F(1, 132) = 8.043$, $p = .005$). Decision makers experiencing interruptions performed the complex tasks less accurately and required more time. Thus, Proposition 2 is supported.

Proposition 3 states that task performance decreases as interruption frequency increases. Results from the one-way ANCOVA indicate that frequency of interruptions led to a significant decrease in decision accuracy (0.05 cf. 0.22) ($F(1, 88) = 9.146$, $p = .003$) and increase in decision time (1702.5 cf. 831.3) ($F(1, 88) = 17.829$, $p = .000$). Decision makers experiencing more frequent interruptions performed the complex tasks less accurately and required more time. Thus, Proposition 3 is supported.

Finally, Proposition 4 states that dissimilar information content in the primary and interruption tasks decreases performance on complex tasks. Results from the one-way ANCOVA indicate that content did not have significant effect on decision accuracy (0.05 cf. 0.12) ($F(1, 88) = .667$, $p = .416$), but that dissimilar information led to an increase in decision time (1842.0 cf. 1317.4) ($F(1, 88) = 6.464$, $p = .013$). Decision makers experiencing interruptions containing information different from the experimental task required more time to complete the task. Thus, Proposition 4 is partially supported.

Results of Post Hoc Analyses

Proposition testing focused on the analysis of decision-making performance for the primary task. To obtain a deeper understanding of the effects of interruptions, we conducted post hoc analyses examining both (1) performance on the interruption tasks and (2) subjects' perceptions about interruptions. Performance on the interruption task was measured as the deviation from optimal where the answer to each interruption task was assessed as either correct or incorrect. We used the average decision accuracy (average deviation from optimal) on interruption tasks when reporting interruption frequency and interruption content scores. Decision time was the amount of time required to complete the interruption task. ANCOVA was again used to test for significant differences between each of the treatments. The results of the statistical testing for the interruption tasks are summarized in Table 2.

First, there were no differences in interruption task accuracy between the interruption and no-interruption treatments for either the simple (2.80 cf. 2.95) ($F(1, 132) = .850$, $p = .358$) or complex tasks (7.41 cf. 7.54) ($F(1, 129) = .018$, $p = .893$). Subjects in the interruption condition, however, completed the interruption

Table 2: Summary of statistical testing for interruption task performance.

Experimental Treatment (Proposition)	Task Accuracy			Task Time		
	Mean (*SD*)	Test Value (*df*)	*p*-value	Mean (*SD*)	Test Value (*df*)	*p*-value
Simple Task (Proposition 1)						
No Interruption	2.95 (.83)	.850 (1,132)	.358	53.9 (18.02)	11.013 (1, 132)	**.001**
Interruption	2.80 (.99)			45.0 (12.91)		
Complex Task (Proposition 2)						
No Interruption	7.54 (1.90)	.018 (1, 132)	.893	86.0 (25.17)	28.445 (1, 132)	**.001**
Interruption	7.41 (1.72)			63.9 (23.25)		
Complex Task (Proposition 3)						
Low Frequency	0.60 (.07)**	13.379 (1,88)	**.001**	37.6 (15.06)**	43.876 (1, 88)	**.001**
High Frequency	0.71 (.21)**			21.3 (6.84)**		
Complex Task (Proposition 4)						
Similar Content	0.63 (0.18)**	1.846 (1, 88)	.178	27.7 (11.11)**	1.728 (1, 88)	.192
Different Content	0.684 (0.15)			31.7 (17.01)**		

**Average accuracy (deviation from optimal) and decision time were calculated on the interruption tasks for both the frequency and content manipulations. A measure of overall interruption accuracy and time would not enable a performance comparison because some subjects would have preferred four interruption tasks while others preferred 12. Therefore, average accuracy was calculated for assessing differences in interruption performance for both frequency and content types. A lower score represents high average accuracy across the complex tasks.

tasks significantly faster than those in the no-interruption condition for both the simple (45.0 cf. 53.9) ($F(1, 132) = 11.013, p = .001$) and complex tasks (63.8 cf. 86.0) ($F(1, 132) = 28.445, p = .001$).

Second, we investigated whether interruption frequency influenced performance on the interruption tasks. Subjects in the high frequency interruption condition performed the interruption task significantly less accurately (0.71 cf. 0.60) ($F(1, 88) = 13.379, p = .001$) and in a shorter time (21.3 cf. 37.6) ($F(1, 88) = 43.876, p = .001$) than those in the low frequency condition. Third, there were no significant differences (accuracy: 0.68 cf. 0.63; $F(1, 88) = 1.846, p = .178$; time: 31.7 cf. 27.7 seconds; $F(1, 88) = 1.728, p = .192$) on the interruption performance measures for the manipulation of interruption content resulting in similar findings for similar and dissimilar information content.

Finally, in addition to assessing interruption task performance, we analyzed perceptions of interruptions across the different treatments using ANOVA. Subjects in the interruption treatment had a more negative perception of interruptions whether performing simple (3.06 cf. 3.58) ($F(1, 105) = 13.578, p = .001$) or complex tasks (3.34 cf. 3.56) ($F(1, 134) = 4.511, p = .035$). Further, subjects in the similar information content condition perceived interruptions as more negative than those in the different information condition (3.32 cf. 3.64) ($F(1, 97) = 4.503, p = .036$). No other differences were found.

DISCUSSION AND CONCLUSIONS

This section discusses the research findings and the implications of those findings, the limitations in interpreting the results, implications for practice, and future research.

Discussion of the Findings

The theoretical development of the influence of interruptions on decision performance tested in these propositions is based on prior cognitive psychology research on information overload and distractions. These findings lend credence to the premises underlying the study that interruptions induce information overload, and that distractions and interruptions result in similar cognitive effects. More specifically, Propositions 1 and 2 were supported, indicating that interruptions facilitate performance on simple tasks while hindering performance on complex tasks. Further, those interruption effects can be explained by distraction/conflict theory.

Further insight was gained from this research regarding characteristics of interruptions. Increased interruption frequency resulted in both decreased decision accuracy and increased decision time, supporting Proposition 3.

Interruptions containing information dissimilar from the primary task took longer to complete than those with similar information. However, they were completed with equivalent accuracy. Hence, Proposition 4 is partially supported. Interruptions with dissimilar information content were also perceived as impairing task performance more than those with similar content. Overall, these results are consistent with the effects of information diversity espoused by Iselin (1988): diverse information increases information overload and therefore either increases processing time or decreases accuracy. However, this finding conflicts with those reported in the cognitive psychology literature (Gillie & Broadbent, 1989; Navon, 1984). In those studies, tasks typically consisted of very short data acquisition activities (2-3 seconds) involving the manipulation of short-term memory with no information processing. On the other hand, the tasks used in this study (and that of Iselin) required the acquisition of additional information cues, and the actual use and manipulation of information. It appears that the increased processing required for the primary task resulted in subjects being more familiar with the information available to them, leading to less time being required to find information when interrupted.

Closer examination of data from the interruption tasks also provides interesting insights into decision maker processing of frequent interruptions and reaffirms the findings associated with the interruption task covariates. Accuracy on the interruption task decreased significantly as interruption frequency increased; conversely, decision time decreased. These findings indicate that the interruptions in the high frequency treatment were processed very differently than those in the low frequency treatment. Although psychological/emotional data was not collected, it is plausible that the frequency of interruptions became too high for decision makers to either process the interruption task cognitively, or be interested in processing it due to frustration or some other psychological/emotional state, an argument akin to that of cost/benefit theory (Payne, 1982).

Limitations

The meaningfulness of the findings from any study can only be assessed in light of the study's limitations. For this study, the increased control afforded by a laboratory experiment must be traded off against inherent limitations of the approach, primarily that of generalizability. The use of student subjects, the nature of the tasks, and the operationalization of the interruptions, also limit the generalizability of the results.

Although tight controls over the operationalizations of interruptions are a strength of these experiments, the interruptions used were devoid of social characteristics. Here, an interruption mimicked a face-to-face interruption as subjects were forced to attend to the interruption at the expense of the primary task. However, the interruption could not convey social characteristics such as the status of the interrupter. Therefore, the restricted types of interruptions used in this study should be taken into account prior to generalizing these results across work environments.

Implications for Research and Practice

Interruptions in the workplace are a fact of life. The findings of this study indicate that interrupted work environments in which complex intellective tasks are performed leads to lower quality decisions and decreased efficiency. Furthermore, even "helpful interruptions," those that facilitated completion of simple tasks, were perceived negatively by decision makers. This negative perception could well manifest itself in more traditional work-related concepts such as stress and job satisfaction.

Our study suggests several directions for future research. First, given the existing work environment of many decision makers, further research should be conducted into the negative influence of interruptions. For example, our findings regarding interruption frequency are particularly problematic given current thinking in organizational design. Many organizations are creating open workflow offices to better support the flexibility, responsiveness, and global nature of today's business environment, and it is likely that these business characteristics will be magnified in the future. Open workflow environments are, however, quite likely to result in increased frequency of interruptions over other office configurations. Therefore, interruptions are unlikely to be "managed away" by restructuring work environments and must be addressed using other mechanisms.

These findings also lead to suggestions and additional research regarding individual job design. For example, more careful consideration of the tasks decision makers are assigned, and when they need to be completed, is needed. For example, a decision maker who has to determine the location of a new distribution facility while monitoring a number of ongoing activities may make a less effective decision. Organizations may wish to consider flex "telecommuting" time whereby decision makers could work offsite to avoid/minimize interruptions in the completion of specific tasks. Alternative job design considerations include implementing "interruption-free" work periods for increasing productivity (Perlow, 1997) and the use of intelligent agents to identify only those voice and email messages to pass along to the decision maker for immediate processing.

Second, given the role of information technology as a possible "generator" of interruptions, we also need to understand more fully the effect of technologies on decision-making performance so that we can design more effective technologies. For example, electronic mail systems have been implemented widely within organizations as a tool for more effective communication. However, the findings from this research might suggest that the instant notification feature in some instances be disabled so as to not exacerbate the number of interruptions decision makers experience. In a similar way, the organizational adoption of push technologies such as Pointcast (Pointcast Team, 1997) should be carefully evaluated from both an interruption and, therefore, an information overload standpoint prior to implementing these technologies organization-wide.

Third, further research should examine the effectiveness and desirability of building features into information system applications that mitigate the inevitable interruptions. Although this research does not directly examine this issue, future research could examine features that could be built into information system applications or desktops to alleviate the effects of interruptions on computer-based tasks. These features might include backtracking functions, the use of color or other attributes to highlight previously used information, zoom in /zoom out capabilities to better focus attention, etc.

Finally, the effect of interruptions should be examined across other problem domains (e.g., that of creative problem solving) and organizational settings. Conventional wisdom, for example, encourages programmers to "take a break" when they cannot solve a debugging error, indicating that there may be differences in problem types that would be important to understand to build more effective systems. Examining the influence of interruptions within organizational settings would enable researchers to identify strategies used by decision makers to actively deal with interruptions and would therefore enhance the generalizability of the findings.

Conclusions

This study provided an initial examination of the influence of interruptions on decision performance. The findings provide some insights regarding the detrimental influence of interruptions on a common type of decision-making task. We believe that there are many ways to mitigate the negative influence of interruptions—through job redesign, information technology, etc. Much research remains to gain a more complete understanding of the effects of interruptions and the methods to mitigate their influence on decision-making performance of individuals.
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APPENDIX A: Examples of Experimental Tasks.

Figure A1: Simple-spatial task with a tabular information presentation format.

	Work Center Load Profiles (values in hours)					
	May	June	July	August	September	October
Work Center A						
Capacity	380	380	380	380	380	380
Load	400	380	440	360	280	300
Work Center B						
Capacity	330	330	330	330	330	330
Load	360	320	400	280	300	330
Work Center C						
Capacity	360	360	360	360	360	360
Load	420	300	400	340	320	360

In which month is there the greatest load on all three workcenters?	0	< – Input

Figure A2: Simple-symbolic task with graphical information presentation format.

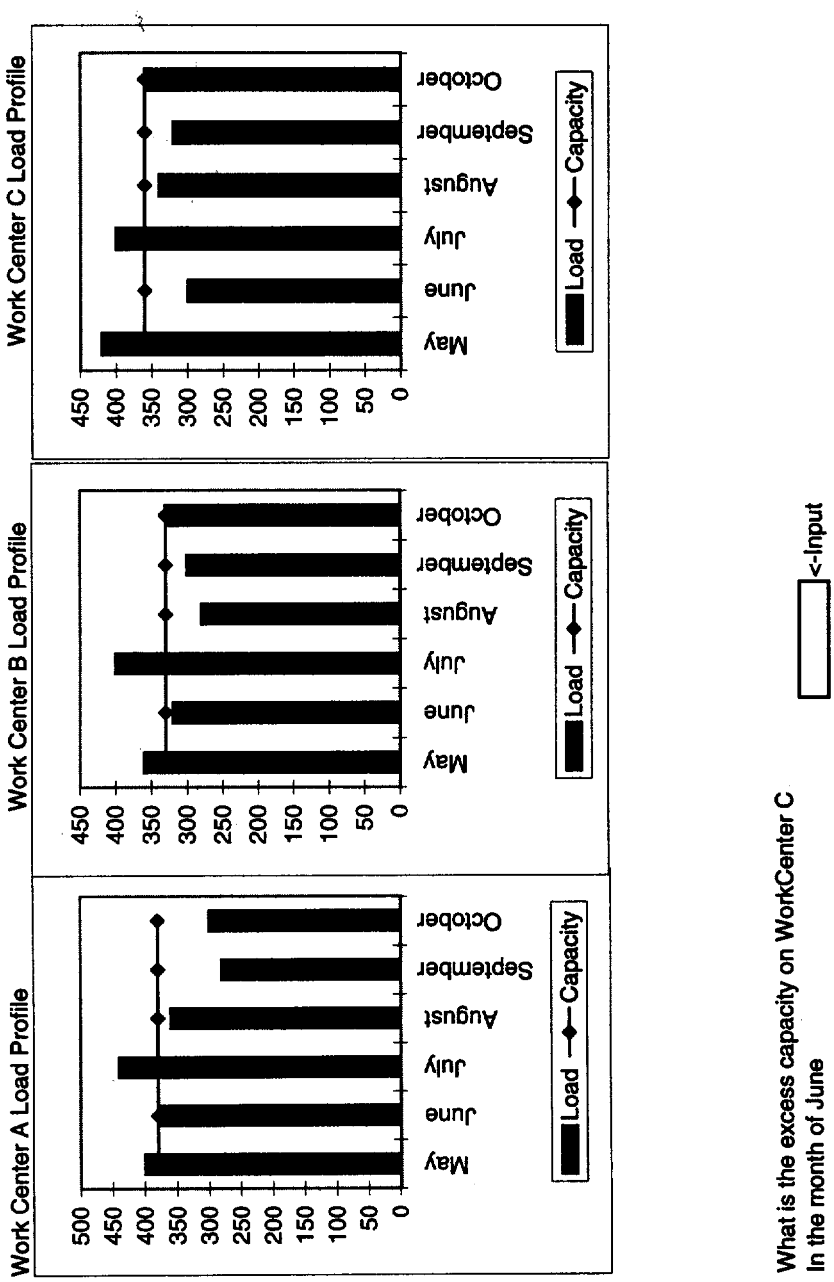
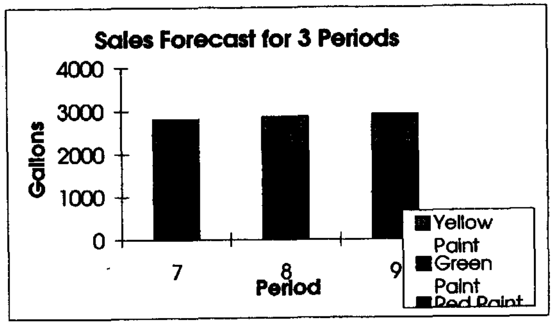


Figure A3: Complex-spatial task with graphical information presentation format.

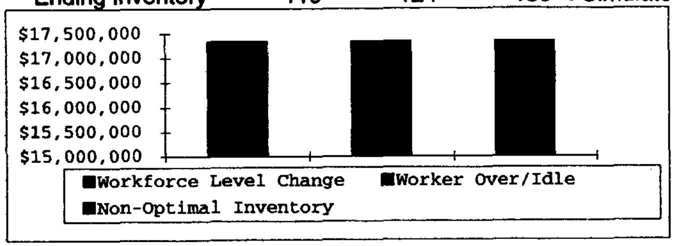
Total Cost to Date	$13,870.00
Avg Cost/Period	$2,310



The Optimal Level of Inventory is 320 Gallons

Current Inventory	350
Current Workforce	200

	Potential Solution 1	Potential Solution 2	Potential Solution 3	
Units to Produce	3455	3000	2345	<-Input
Workforce Level	343	200	250	<-Input
Ending Inventory	-119	-124	-130	<-Simulated



Final Solution		
Units to Produce		<-Final Input
Workforce Level		<-Final Input

Figure A4: Complex-symbolic task with tabular information presentation format.

	Transportation Costs	Labor Costs	Marketing Costs	Taxes	Total Cost
A	35000	22500	7500	16500	81500
B	45000	13000	6000	14500	78500
C	30000	16000	4000	18000	68000
D	33000	17000	5000	15000	70000
E	38500	25000	6000	15500	85000
F	34000	17000	6500	16000	73500

Decision Rules

1. Total cost less than or equal to $78,500.
2. Transportation costs no more than 50% of Total Cost.
3. Marketing costs no more than 10% of Total Cost.

Enter the Warehouses you wish to open in order, beginning with the lowest cost warehouse. Only open warehouses that meet the decision rules.

1		< –Enter
2		< –Warehouse
3		< –Locations
4		
5		
6		

APPENDIX B

Figure B1: Example of interruption task.

Product (Paint)	Period 6	Period 7	Period 8
Blue	600	650	700
Red	700	700	700
Green	700	700	700
Yellow	500	500	500
Gold	400	500	400
Brown	800	1000	1100
Black	1000	1200	1500
White	2000	2200	1800
Maroon	200	150	100

Which color paint has the lowest forecasted demand?	0	< – Input