THE EFFECTS OF TASK INTERRUPTION AND INFORMATION PRESENTATION ON INDIVIDUAL DECISION MAKING

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Abstract

Interrupted work environments are commonplace in today's organizations. In addition, organizational work is increasingly performed using some form of computer support. Consequently, there is a need to examine how the design and delivery of information systems can help to mitigate the potentially deleterious effects of interruptions on decision-maker performance. This paper reports the results of two experiments that investigate the influence of interruptions on different types of tasks and the ability of information presentation formats to alleviate them. Interruptions were found to facilitate performance on simple tasks, while inhibiting performance on more complex tasks. Furthermore, there was some evidence that the frequency of interruptions and similarity of the content of the primary and interruption tasks also negatively influenced performance. Finally, interruptions moderated the relationship between information presentation format and specific types of tasks.

Keywords: Decision making, decision support systems, information presentation formats, interruptions.

1. INTRODUCTION

Interruptions permeate knowledge worker environments (Markels 1997) and have been characterized as fragmented activities that occur at an unrelenting pace (Kurke and Aldrich 1983; Mintzberg 1973) and as a stream of disjointed activities (Carlson 1951; Guest 1956; Stewart 1967). More recent studies continue to highlight the relationship between interruptions and knowledge worker activities. For example, telephone interruptions and drop-in visitors have been identified as significant corporate time-wasters (Dahms 1988), which knowledge workers often allow to take precedence over other activities (Jones and McLeod 1986). Additionally, Watson et al. (1991) indicate that many executives are permitted very little uninterrupted time when using executive decision-support technologies. Therefore, an interrupted work environment is commonplace for the typical knowledge worker.

Increasingly, a knowledge worker's day-to-day activities involve the use of computers (Panko 1992). Computer-based tasks often involve high cognitive loads that might be susceptible to interference from interruptions (Baecker et al. 1995). In addition, "productivity" tools integrated into many organizations can actually instigate task interruptions. For example, e-mail systems that immediately notify knowledge workers of new messages can provide constant interruptions throughout the work day. Furthermore, the instantaneous nature of e-mail produces a false sense of urgency regarding the speed and timeliness of response by the recipient (Markels 1997). Therefore, a typical knowledge worker environment consists of completing computer-aided work while dealing with a variety of interruptions.

The paper proceeds as follows: Section 2 reviews the relevant prior research and develops propositions to be tested in this research. Section 3 presents the research methodology used to test propositions while section 4 presents the results of the two laboratory experiments. Finally, section 5 discusses the empirical findings, limitations, and future research opportunities.

2. THEORY DEVELOPMENT AND PROPOSITIONS

This section characterizes interruptions in terms of theories from the literature on distractions. The effects of symbolic and spatial information formats are then analyzed to develop a model of the mitigating effects of information formats on the accuracy and speed of interrupted decision making.

2.1 Interruptions

An interruption is an "externally-generated, randomly occurring, discrete event that breaks continuity of cognitive focus on a primary task" (Corragio 1990, p. 19). An interruption typically "requires immediate attention" and "insists on action" (Covey 1989, pp. 150-152). The above definitions imply that another person or event creates an interruption and that the timing of an interruption is beyond the control of the individual. Furthermore, an interruption breaks a decision-maker's attention on a primary task and forces the decision-maker to turn his or her attention toward the interruption—if only temporarily.

A decision-maker's attention is broken and refocused because the interruption cues typically use the same sensory channel as those used while processing another activity and demand much, if not all, of a decision-maker's attention. Interruptions can therefore create both capacity and structural interference (Kahneman 1973). Capacity interference occurs when the number of incoming cues is more than a decision-maker can process. Structural interference, on the other hand, 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 can be considered severe attentional distractions that can place greater demands on cognitive processing resources than the available capacity can handle (Norman and Bobrow 1975). In such cases, interruptions are likely to result in the loss of memory contents or confusion between cues in memory resulting in decreased decision accuracy and/or increased decision time for the interrupted task.

2.2 Interruptions and Task Complexity

Distraction/Conflict Theory (Baron 1986; Sanders and Baron 1975) provides a theoretical grounding to explain the influence of distractions (e.g., industrial noise or background music) on decision performance. This theory suggests that distractions facilitate performance on simple tasks and inhibit performance on complex tasks. Distraction/Conflict Theory has been used to explain the influence of distracting noise on performance in a broad range of settings (Boggs and Simon 1968; Hockey 1970). Because both distractions and interruptions disrupt and potentially overload the finite cognitive capabilities of the decision-maker, it is likely that the effects of interruptions on decision performance will be similar to those of distractions.

The different effects of distractions/interruptions on simple and complex tasks may be the result of the differing number of cues that must be processed and the number and the complexity of the individual processes required (Wood 1986). Simple tasks require the processing of fewer cues than complex tasks and are less likely to challenge the cognitive capacity of the decision-maker (Baron 1986). When distractions/interruptions occur, attention narrows and irrelevant cues are more likely to be dismissed or ignored. When processing simple tasks, the decision-maker has excess cognitive capacity and there is little or no loss of task-relevant cues, and performance may therefore be facilitated. In other words, distractions/interruptions help decision-makers focus on the relatively few information cues of their primary task, resulting in faster completion times and little or no loss in decision-making performance (Baron 1986). However, as the severity of the distraction/interruption increases, performance starts to decrease.

Decision-makers performing complex tasks, on the other hand, have little if any excess cognitive capacity. Narrowing one's attention due to the interruption is therefore 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, overload on one's attention is exacerbated and performance deteriorates more severely. In addition to reducing the number of 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). Thus, the following propositions are stated:

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

Proposition 2: Interruptions inhibit decision-making performance on complex tasks.

2.3 Interruptions and Information Presentation Characteristics

Investigating the influence of interruptions on decision performance applies knowledge of distractions to interruptions and provides an initial understanding of factors that influence knowledge worker productivity. However, a more interesting question, particularly for MIS professionals, relates to what features or functionality can be built into information systems to facilitate recovery from interruptions.

Prior research has identified information presentation formats as an important feature of information systems that influences decision performance (Bettman and Kakkar 1977; DeSanctis 1984; Vessey 1991). For example, pictorial representations reside in short-term memory for a longer period of time, often making graphs more effective than tables (Anderson 1980; Nickerson 1965). The effects of information presentation formats on decision making has led to the widely-shared belief that the effectiveness of a specific presentation format depends on the task that is being performed (Benbasat et al. 1986; DeSanctis 1984; Jarvenpaa and Dickson 1988; Tan and Benbasat 1990; Vessey 1991).

Vessey's (1991) Cognitive Fit Theory, which applies, in its narrow form, to simple (information acquisition) tasks, provides a theoretical basis for the expected differences in performance across information presentation formats. When the information emphasized in a particular presentation format matches that required to complete the task, a match or cognitive fit occurs. Symbolic formats (e.g., tables) result in better performance when completing a symbolic task (e.g., extracting a specific value); on the other hand, spatial formats (e.g., graphs) result in improved performance when completing a spatial task (e.g., examining relationships between variables or deciphering trends) (Vessey 1991). Cognitive fit facilitates decision making because the specific process used to act on the problem representation is the same as that needed to solve the problem. Specifically, analytical processes are used to act on symbolic formats and tasks and perceptual processes on spatial formats and tasks. On the other hand, when the information presentation format does not match the task, an individual must exert greater cognitive effort to transform the information into a usable form. This increased effort will result in decreased performance, specifically, a decrease in decision accuracy, time, or both.

The vast majority of research investigating the effectiveness of different information presentation formats has not included a broader work context such as interruptions. There has, however, been some research into the effects of information presentation on decision-making performance under time constraints. Note that time constraints most likely result in similar effects to interruptions. Results from these studies suggest that when time is limited, decision-makers rely on whatever perceptual cues (e.g., shape of a figure, trend suggested by a line in a graph) are available in the data (Coury and Boulette 1992). Specifically, symbolic data results in decreased decision accuracy as individuals experience greater difficulty finding and processing information (Coury and Boulette 1992). Similarly, Schwartz and Howell (1985) found that spatial displays resulted in increased decision accuracy and decreased time when performing complex tasks under time constraints. However, neither presentation format provided a statistically significant advantage when ample time was available. These findings suggest that decision-makers using spatial formats might be able to recover from work interruptions more effectively than those using symbolic formats.

This leads to the following propositions:

> *Proposition 3a: Interruptions do not moderate the effects of the relationship between simple-symbolic tasks and information presentation format (tables best support the task).*
>
> *Proposition 3b: Interruptions moderate the effects of the relationship between complex-symbolic tasks and information presentation format (graphs best support the task).*

2.4 Characterization of Interruptions

It is likely that different types of interruptions will have different effects on decision-maker performance (Kahneman 1973). Unfortunately, very little research has explicitly manipulated characteristics of interruptions to understand the resulting effects on performance. Moray (1993) states that there appears to be "no systematic body of research on what physical or psychological characteristics make an interrupt" (p. 120). Prior literature does, however, suggest broad categories of interruption characteristics, namely those that affect cognitive processing (Kahneman 1973), and social characteristics that influence the manner in which the decision-maker responds to the interruption (Kirmeyer 1988). Characteristics that primarily influence cognitive processing include frequency, duration, content, complexity, and timing of the interruption (see also Corragio 1990). Social characteristics that influence how the knowledge worker responds to the interruption include the form of the interruption, the person or object generating the interruption, and social expectations that exist regarding responsiveness to the interruption. Because the focus of this research is on the cognitive aspects of interruptions, the research investigated the cognitive processing characteristics, interruption frequency and interruption content.

A recovery period, which involves reprocessing of some information, is needed each time a decision-maker responds to an interruption and then returns to his or her primary task (Kahneman 1973). It is likely that each recovery period requires additional time and has the potential for increasing the number of errors. Consequently, as the frequency of interruption increases, the number of recovery periods increases. Likewise, with increased interruption frequency, the recovery time and the number of potential errors is also likely to increase. Eschenbrenner (1971) and Woodhead (1965) found that decision accuracy decreased as the frequency of distractions increased. Corragio, on the other hand, found no performance effect (accuracy or time) related to interruption frequency. Such a finding might occur if the interruption frequency manipulation were not sufficiently strong to manifest itself. The following proposition is therefore stated:

> *Proposition 4: As the frequency of interruptions increases, decision-making performance decreases.*

From the viewpoint of interruption content, research has demonstrated that task performance is less accurate when two tasks using the same or similar information are processed simultaneously (Gillie and Broadbent 1989; Kinsbourne 1981, 1982; Navon 1984). As the similarity among information cues increases, interference occurs in working memory between the information associated with the primary and the interruption tasks (Anderson and Milson 1989). Such interference may lead to performance degradation if resources from working memory are allocated inappropriately among tasks (Norman 1981). Thus, the following proposition is stated:

> *Proposition 5: Decision-making performance is inhibited when the information content of the interruption and decision-making task is similar.*

2.5 General Research Model

Prior research examining individual decision making has identified three characteristics influencing performance: (1) task type, (2) individual characteristics, and (3) information presentation format. Each of these factors has the potential to have direct and interactive effects on cognitive processing and ultimately on decision-making performance (DeSanctis 1984). Task and information presentation format characteristics are examined explicitly in this research. Although prior research indicates equivocal support for the importance of individual differences in decision-making contexts (Alavi and Joachimsthaler 1992; Ramamurthy et al. 1992), this research examined three individual characteristics that appear to be relevant to decision-making performance in general, and to this study in particular.

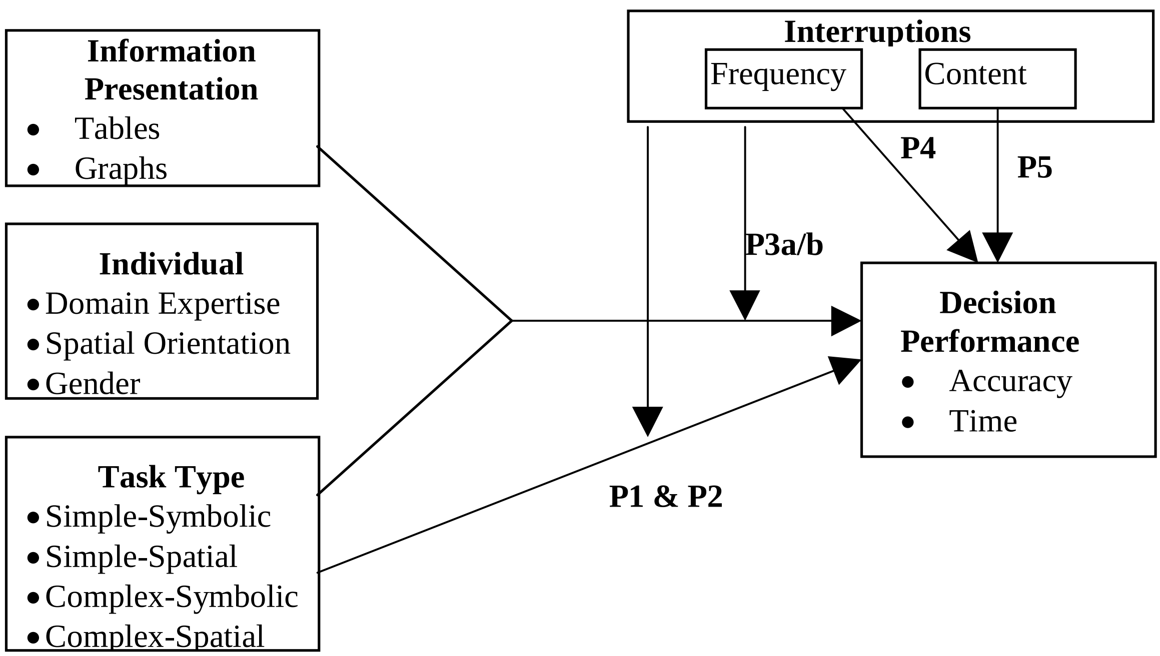

Figure 1. Research Model and Propositions

The individual characteristics examined in this study are domain expertise, spatial ability, and gender. Both domain expertise (Mackay and Elam 1992; Ramamurthy et al. 1992) and spatial abilities when performing spatial tasks (Loy 1991) have been shown to result in improved decision performance. Gender is examined because females have been found to be more easily distracted than males when performing complex tasks (Silverman 1970).

Figure 1 presents the integrated model of the decision making, information presentation, and attention factors discussed above. Characteristics of the individual, task, and information presentation format affect task performance (decision accuracy and decision time). Furthermore, interruptions moderate the effect of decision-making characteristics on decision performance, as well as having a direct effect on performance.

3. RESEARCH METHODOLOGY

Two laboratory experiments were conducted to investigate the propositions presented in section 2 and illustrated in Figure 1. The two experiments shared a number of characteristics: (i) subjects responded to multiple decision and interruption tasks; (ii) all tasks had optimal solutions; (iii) the experimental and interruption tasks were based on production management (PM) concepts; (iv) they used the same dependent and control variables; (v) experimental subjects were drawn from the same population; (vi) data collection occurred at the same time; and (vii) tasks were delivered to subjects by a computer-based decision support system.

3.1 Subjects

Subjects were 238 undergraduate students enrolled in an introductory production management (PM) course that volunteered to participate in the experiment. They were randomly assigned to one of the eight treatments 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 received a credit of 1% toward their final course grade. To encourage subjects to work both quickly and accurately, cash incentives were awarded to the highest-performing subjects as measured by decision accuracy per unit time.

3.2 Experiment 1: Influence of Work Environment

A 2x2x4 within-subjects full factorial design with *work environment* at two levels (interruptions, no interruptions), *information presentation format* at two levels (tables, graphs), and *task type* at four levels (simple: spatial/symbolic; complex: spatial/symbolic) was used in Experiment 1. The task type manipulation was within-subjects, while work environment and information presentation format were manipulated between subjects. The experimental procedures and operationalized levels of the independent and dependent variables were tested and validated in pilot studies.

3.2.1 Independent Variables

Work environment was manipulated by introducing interruptions while subjects were performing each type of task. Interruptions consisted of four simple information acquisition tasks, which occurred during each of the four experimental tasks (e.g., start of task 1 followed by interruptions during task 1, end of task 1, start of task 2, etc.). Subjects in the no-interruption treatment 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.

Two levels of information presentation format were examined: tables and graphs. The data for the tasks (both experimental and interruption) were presented as a single table or graph. All experimental tasks used either graphs or tables, while the interruption tasks were constructed so that 50% used tables and 50% used graphs.

The task type (within-subjects) variable consisted of four different tasks (two simple: simple-symbolic and simple-spatial; and two complex: complex-symbolic and complex-spatial) with presentation order counterbalanced within cells.

Each simple task consisted of six different questions presented as separate screens 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), while the simple-spatial task required subjects to identify trends in the data. Subjects were presented with a table or graph containing machine workload schedules and available capacity for multiple machines over a six month period and were asked to respond to either a symbolic or spatial question (see Umanath et al. 1990).

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) (Davis and Kotterman 1994; Holt et al. 1960; Remus 1984, 1987).[1] 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 3-period forecast for four types of paint, current inventory, and current workforce size and 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.

3.2.2 Dependent Variables

The dependent variables were *decision accuracy* and *decision time*. Given the nature of the tasks, decision accuracy was measured somewhat differently for each of the four tasks. To obtain a meaningful score when 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. When pooling was necessary, the z-scores for the individual tasks were combined to create an overall 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.

Corragio's instrument for measuring the perceived influence of interruptions was also used on each task to collect data for post-hoc examination.

3.3.2 Controlled Variables

Three individual factors thought to influence decision performance either directly or indirectly were controlled statistically: domain expertise, spatial ability, and gender. Domain expertise was measured as performance on production management exam questions relevant to the tasks being performed in the experiment. Spatial ability was

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[1]The complex tasks were selected and constructed to meet the theoretical definition of complex tasks developed by Wood (1986). Decision time differences between the simple and complex tasks were assessed in pilot testing to validate the appropriateness of the simple and complex classification for each task. Results indicated that there were significant differences in decision task completion time ($< .05$) for each of the simple/complex task pairs. There were no significant differences in decision time between the simple/simple and complex/complex task pairs.

measured using the Kit of Factor Referenced Cognitive Tests (Ekstrom et al. 1976), while gender was measured via self-report data. In addition to the individual difference characteristics, decision accuracy and time data for the *interruption tasks* was also collected and controlled statistically when necessary

3.3 Experiment 2: Interruption Characteristics

The second experiment was conducted to better understand the influence of interruption frequency and content on decision-making performance. This experiment consisted of a 2x2x2 within-subjects factorial design in which *interruption frequency* at two levels (low versus high: four versus 12 interruptions per task), *interruption content* at two levels (information similar to or different from the primary task) and *task type* at two levels (complex: spatial/symbolic, within subjects) were manipulated, resulting in four treatments. The two complex tasks, the setting, and the procedures were the same as those used in Experiment 1.

4. RESULTS

Decision accuracy and time were significantly correlated on simple tasks ($r = .21$; $p = .05$), but not on complex tasks ($r = .07$; $p > .05$). Therefore, propositions 1 and 3a were evaluated using MANCOVA, while propositions 2, 3b, 4, and 5 were evaluated using ANCOVA. Domain expertise, spatial ability, and gender were included as covariates in all tests.

Linear regression was used to assess whether decision accuracy and time on the interruption tasks significantly influenced the dependent variables in the main task. The results suggested that two tests, those for interruption frequency and content, required controlling for both decision accuracy and time on the interruption task. Hence, those variables were included in the respective ANCOVA models. The means and standard deviations for the measures associated with propositions 1 and 3a are presented in Table 1, while Table 2 presents the results of testing propositions 2, 3b, 4, and 5.

4.1 Results of Proposition Testing

Proposition 1 investigated whether interruptions resulted in improved decision performance on simple tasks. An examination of Table 1 shows that decision-makers experiencing interruptions (accuracy: -.287; time: 90.82) completed their decisions more accurately and quickly than those not experiencing interruptions (accuracy: -.184; time: 110.25). The differences were statistically significant (Wilks Lambda (2, 127) = .923, $p = .006$). Hence, these findings support proposition 1.

Proposition 2 investigated whether interruptions resulted in decreased performance on complex tasks. Examination of Table 2 shows that decision-makers experiencing interruptions performed the complex tasks less accurately (-.076) and required more time to complete the task (760.78) than those not experiencing interruptions (accuracy: .129; time: 608.30). The differences were statistically significant for both decision accuracy ($F(1,129) = 7.851$, $p = .006$) and time ($F(1,132) = 8.043$, $p = .005$). Thus, these findings support proposition 2.

Proposition 3a suggested that interruptions would not moderate the relationship between information presentation format and simple symbolic tasks, while proposition 3b suggested interruptions would have a moderating effect on complex-symbolic tasks. For the simple symbolic task, the interaction effect between information format and the presence of interruptions was not statistically significant (Wilks' Lambda (2, 128) = .998, $p = .889$). Accuracy with

Table 1. Influence of Interruptions and Information Presentation Format on Task Performance Results of Testing Proposition 1 and 3a Using MANCOVA

Propo-sition	Task Type	Presentation Format	Accuracy Mean 1* (s.d.)	Accuracy Mean 2* (s.d)	Time Mean 1 (s.d.)	Time Mean 2 (s.d)	Wilks' Lambda (dof)	p-value
			No Interruption	**Interruption**	**No Interruption**	**Interruption**		
1	Simple		-.184 (.698)	-.287 (.673)	110.247 (27.595)	90.815 (30.835)	.923 (2, 127)	.006
3a	Simple Symbolic	Tables Graphs	-.563 (1.018) .026 (1.278)	-.459 (1.135) -.198 (1.399)	169.343 (60.416) 139.515 (48.158)	147.800 (53.501) 130.091 (50.691)	.998 (2, 128)	.889

* Accuracy means are presented as z-scores.

Table 2. Influence of Interruptions on Task Performance Results of Testing Propositions 2, 3b, 4, and 5 Using ANCOVA

Proposition	Task Type	Dependent Variable	Presentation Format	Mean 1 (s.d.)	Mean 2 (s.d).	F (dof)	p-value
				No Interruption			
2	Complex	Accuracy *		.129 (1.074)			.006
2	Complex	Time		608.302 (284.395)			.005
3b	Complex Symbolic	Accuracy	Tables Vs.	.829 (.167)			.000
			Graphs	.679 (121)			
3b	Complex Symbolic	Time	Tables Vs.	1343.714 (174.591)			.388
			Graphs	1277.939 (141.817)			
				Low Frequency			
4	Complex	Accuracy		.222 (.327)			.003
4	Complex	Time		831.3 (238.7)			.000
				Similar Content			
5	Complex	Accuracy		.115 (.462)			.416
5	Complex	Time		1317.437 (613.85)	September 9, 1997		.013

* Accuracy means are presented as z-scores.

both tables and graphs decreased with interruptions as did decision time. There was a main effect for information presentation format (Wilks' Lambda (2, 128) = .930, p = .010), indicating a significant difference in performance between graphs and tables: tables provide significantly better support than graphs for simple-symbolic tasks regardless of the work environment. Hence, proposition 3a is supported.

For the complex-symbolic task, the interaction effect between information presentation format and task type was significant for decision accuracy (F(1, 129) = 15.78, p = .000), but not for decision time (F(1, 129) = .741, p = .388). Without interruptions, tables resulted in higher accuracy (mean = .829 compared with .679 for graphs). However, with interruptions, graphs resulted in more accurate decisions (mean = .729) than tables (mean = .678). Hence, proposition 3b is partially supported.

Proposition 4 investigated whether performance on complex tasks decreased with increasing frequency of interruptions. Decision-makers experiencing more frequent interruptions performed the complex tasks less accurately (-.053) and required more time (1702.5) than decision-makers who were interrupted less frequently (accuracy: .222; time: 831.2). The difference between high and low frequency interruptions was significant for both decision accuracy (F(1,88) = 9.146, p = .003) and decision time (F(1,88) = 17.829, p = .000). Hence, these findings support proposition 4.

As stated earlier, there were significant differences in interruption task performance between the low and high interruption frequency conditions. Interestingly, subjects in the high frequency interruption condition had significantly lower decision accuracy on the interruption task (F(1, 88) = 13.379, p < .001) and shorter interruption task time (F(1, 88) = 43.876, p < .001) than subjects in the low frequency condition. Figure 2 shows the effect of interruption frequency on interruption task performance. It is clear, then, that subjects experiencing high frequency interruptions paid much less attention to the interruption task yet still performed worse on the primary task than those experiencing low frequency interruptions.

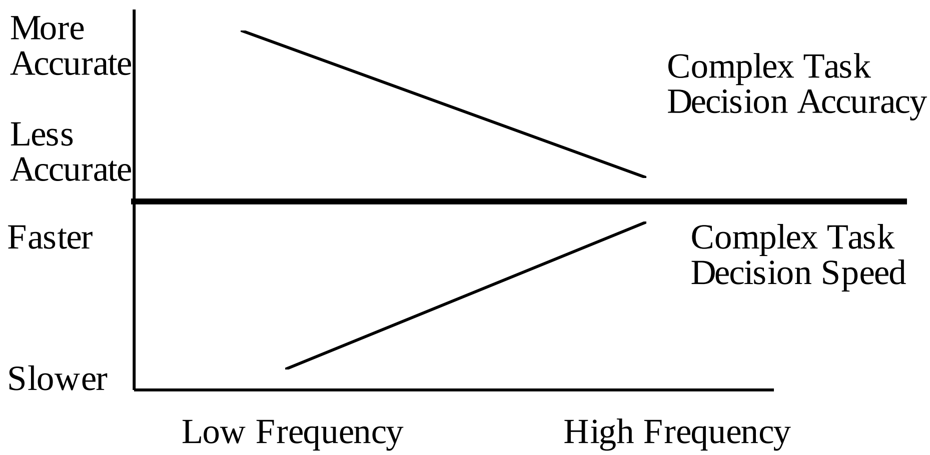

Figure 2. The Influence of Interruption Frequency on Interruption Task Performance

Finally, proposition 5 suggested that decision performance on complex tasks decreases when the information in the primary and interruption tasks is similar. Decision-makers experiencing interruptions containing information *different* from the experimental task performed the task less accurately (.050) and required more time to complete the task (1841.98) than those with similar information (accuracy: .115; time: 1317.44). The differences were statistically significant for time (F(1,88) = 6.464; p = .013), but not for accuracy (F(1,88) = .667; p = .416). Thus, proposition 5 was not supported and was, in fact, partially contradicted.

4.2 Results of Perception Analyses

The purpose of the post-hoc analysis was to tease out subjects' perceptions regarding the influence of interruptions on the decision tasks. ANCOVA was used to test for significant differences in perceptions between each of the treatments. The only significant difference was that subjects experiencing interruptions had a more negative perception of interruptions on both simple (F(1,105) = 13.578, p = .000) and complex tasks (F(1,97) = 3.731, p = .056) than subjects not experiencing interruptions.

5. DISCUSSION AND CONCLUSIONS

This section discusses the research findings, the limitations in interpreting the results, and the implications of the findings for future research and for practice. As predicted, interruptions facilitated decision making when addressing a simple task and inhibited performance when addressing a complex task, thus providing support for the belief that distractions and interruptions impose similar cognitive affects as predicted by the guiding theory of distraction/ conflict theory. Further, as predicted, increased interruption frequency inhibited decision performance. In contrast to predictions, highly dissimilar information content between the primary task and interruption resulted in decreased decision-making efficiency. Finally, when experiencing interruptions, graphical displays enhanced decision-making effectiveness for complex tasks that theoretically and empirically have been best supported in non-interrupted decision contexts using tabular presentation formats.

5.1 Implications of the Findings

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. Specific to this research, limitations in generalizability involve the use of student subjects, the nature of the tasks, and the operationalization of the interruptions.

Interruptions in the workplace are an inevitable part of a knowledge worker's daily experience. The results of this study suggest that interrupted work environments lead to lower quality decisions and reduced speed on intellective tasks. Furthermore, even "helpful interruptions," those that facilitated completion of simple tasks, were perceived negatively by decision-makers. This negative perception may well manifest itself in more traditional work-related arenas such as stress and job satisfaction.

Furthermore, many organizations are moving to new organizational forms such as self-organizing teams and open workflows to better support the flexibility, responsiveness, and global nature of today's business environment. These organizational forms are likely to increase the frequency of interruptions experienced by an individual, exacerbating the (negative) influence of interruptions.

An important question is whether the effects of interruptions can be mitigated within the knowledge worker environment itself. The results of this study point to a possible solution: to support knowledge workers working on complex symbolic problems with graphs rather than tables because it appears that the perceptual nature of graphs allows these types of tasks to be solved more effectively. These results therefore encourage greater use of icons or pictures to help acquire and process complex information. Similarly, annotating tools might enable decision-makers to highlight, or in some other way identify, data used in decision processing.

5.2 Conclusions

In this research, an attempt was made to examine those characteristics of interruptions that are the most inhibiting to decision-makers. By understanding the characteristics of such interruptions, corresponding features of information systems can be identified and implemented as mechanisms to aid decision-makers to recover more effectively. Research could also be conducted to better understand interruptions across different task domains and problem types. For example, conventional wisdom encourages programmers to "take a break" when they cannot solve a debugging error while coding (a creative problem). Hence, it may be important to understand differences in problem types if we are to build more effective systems to support a range of knowledge worker activities. Further, the inconsistency in findings (between psychology research and this study) on the effects of similar/dissimilar information in primary and interruption tasks across tasks of varying complexity demonstrates the need for further research in this area.

From the viewpoint of cognitive fit, interruptions, like time constraints, appear to moderate the relationship between information presentation format and task type for complex intellective tasks. This result is interesting because it suggests that interruptions change the way information is perceived, used, and processed. A more complete understanding of how interruptions influence information acquisition and processing will facilitate the design of systems to support decision making more effectively. Further, this finding provides some evidence that the effects of interruptions can be mitigated.

The results of this research therefore hold promise that systems builders will be able to design features into information systems to mitigate the effects of a "normal" interruption-filled work environment. Such features include backtracking functions, the use of color or other attributes to highlight previously used information, and zoom in/zoom out capabilities to better focus attention.

Finally, the results of this research sound a warning for systems such as organizational electronic mail systems that have been implemented to enhance productivity. Such systems have been widely implemented as tools for more effective communication. One feature of many of these systems notifies users immediately upon receipt of a new message. The findings from this research suggest that this instant notification feature should be disabled in order to avoid exacerbating the number of interruptions knowledge workers experience.

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