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Should I send this message? Understanding the impact of interruptions, social hierarchy and perceived task complexity on user performance and perceived workload

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ABSTRACT

Instant messenger technologies have become a common place for collaborative work and group decision support. Managers need to understand the potential impact of using IM in an organization. This paper contributes to the literature on instant messaging and primary task performance by theorizing and empirically testing how the interruption frequency of IM could intertwine with the social characteristics of IM communication and jointly influence user task performance and perceived workload. Using experimental design, we found that the effect of interruption on primary task completion time is dependent upon the hierarchical level of the message sender. Interruptions from a supervisor were found to reduce primary task completion time whereas interruptions from a peer increased primary task completion time. On the other hand, interruptions from a supervisor aggravated the negative impact of interruptions on task quality. Thus, it may be important for members and leaders of group decision teams to be more careful in the use of instant messaging with their peers and subordinates.

1. Introduction

As organizations become more virtual, their communication processes evolve over time [21]. The role of communications mode and its impact on organizational performance have been studied for quite some time in decision support literature. For example, Fjermestad [23] reported on a meta-analysis of 145 experiments on communication mode in group support systems. Barkhi et al. [6] studied the influence of communication mode and incentives on group decision support (GDSS) process as well as outcomes. Another example of such studies is an experiment to study the impact of task type and communication media in GDSS [48]. Thus, the basic GDSS research has focused on communications media for a long time. Although many GDSS researchers focused on collaborative media such as decision rooms, the time/space framework described by DeSanctis and Gallupe [20] has become an acceptable way to recognize all collaborative systems. Bafoutsou and Mentzas [4] provide a good overview and classification of collaborative systems as well as a review of previous studies. Along with all the other collaborative technologies, they recognize instant messaging as one of the technologies that provides support for group work. Because of the ease of use, low bandwidth requirement and standardization, instant messaging has been widely adopted for social communication in daily life, but its popularity for more formal as well as complex workplace interactions is also increasing at a phenomenal pace. Osterman Research [44] found that more than 90% of organizations in North America use instant messaging (IM) in their networks. Gartner predicts that "by the end of 2011, IM will be the de facto tool for voice, video and text chat with 95 percent of workers in leading global organizations using it as their primary interface for real-time communications by 2013. The worldwide market for enterprise IM is forecast to grow from $267 million in 2005 to $688 million in 2010" [26]. According to the Pew survey report on IM usage in the United States [51], approximately 53 million American adults use instant messaging programs and about 11 million of them use IM at work. Several studies have been conducted to understand the application, adoption, and potential negative consequences of IM in the workplace [10,32]. Some recent studies on IM have focused on various decision making aspects such as selection of communication media at workplace [11], negotiation process using IM [33], deception detection using IM [57]. Though there is plenty of research on IM adoption in the workplace, for example related to usage characteristics and patterns, little empirical research has been conducted to assess the role that hierarchical level plays in influencing the performance in workplaces utilizing IM.

Several IM features can benefit workplace communication. For example, the ease of coordination and scheduling; its immediacy, with nearly-synchronous communication; its informal nature [8], its social presence features, and privacy make it a very useful tool. However,

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some of these features have actually started to result in inefficiencies related to their use in the workplace. The deployment of instant messenger often creates a multitasking work environment [10,16,50] where a sender can preempt a receiver from the receiver's ongoing tasks at any time period with a message 'pop-up,' thereby disrupting the processing of primary tasks. Because of the inherent presence awareness features of IM, senders are usually aware of the receiver's presence and therefore, expect responses in a near-synchronous mode. This is rarely a problem with other technologies such as emails or telephone calls, where the lack of such social awareness features enables a receiver to choose whether to process the message now or later. However, these features can be technically enabled within emails when used in certain contexts such as email embedded within a social networking platform such as Facebook. Our research aims to investigate some of the social characteristics of IM usage specifically at workplace and the impact of IM interruptions on the primary task performance and work overload. In particular, our research questions are 1) What is the impact of interruptions from IM on users' task performance as influenced by the sender's hierarchical level? 2) What is the impact of interruptions from IM on users' overall mental workload? and, 3) How does perceived primary task complexity influence user performance and overall perceived workload?

This study makes unique theoretical and research contributions. Through this study, we bring in one social characteristic of IM, i.e. the hierarchical level of message sender, in an interrupted work environment and understand the role it plays in influencing the impact of interruptions on individual performance and overall mental workload at workplace. Other studies on interruptions have focused on different aspects of tasks and GUI such as interruption task characteristics [27], presentation format and primary task characteristics [52,53], user interface development [40,41]. McFarlane [40] focuses on developing a user interface design that mitigates the negative effects of interruptions. Gillie and Broadbent [27] focused on interruption characteristics — length, complexity and similarity while conducting a series of four different experiments to find particular characteristics that influence disruptiveness. McFarlane and Latorella [41] and McFarlane [40] focused on developing user interface guidelines for four different types of interruptions — immediate, negotiated, mediated and scheduled. All these studies have not examined the hierarchical level, perceived complexity and any resulting interaction effects, which is the centerpiece of this study. Also, Speier et al. [53] looked into a work environment consisting of two levels of interruptions, i.e. interruptions vs. no interruptions. Our study looks at how the influence of (high vs. low) interruptions is moderated by an embedded social characteristic of the sender, i.e. the hierarchical level of the message sender.

Distraction conflict theory (DCT) [7] serves to provide a concrete theoretical foundation for this study. According to DCT, in the presence of interrupters, an individual performing a task engages in attentional conflict between the interrupters and the task. This, in turn, heightens the arousal level of the individual (i.e. the status of being alert and vigilant) and facilitates the performance of simple tasks. This study extends the existing research by adding the novel context of IM, which results in immediate interruption [40], and bringing in the social characteristics of the interruption. This study also provides important directions for future research of IM by emphasizing the fit between technology and the hierarchical level of the sender. This study focuses on the most prevalent situation at workplace where an interruption originates when a sender needs additional information from the receiver. Therefore, the scope of this study is restricted to conditions where an interruption task arrives at random and in nature is dissimilar to the ongoing primary task processing.

The remainder of the paper is organized as follows. In the next section we review the literature, and propose our research model and the hypotheses underlying the model. Next, we describe our experiment, followed by a discussion of the findings of this study. Finally, we present the limitations of the study, followed by concluding remarks.

2. Literature and research hypotheses

2.1. Usage of IM in workplace

Instant messaging is typically used to complement existing communication media such as email and telephone. In some companies, workers are required to leave their instant messenger client application running while performing other primary tasks. For example, Quan Haase et al. [47] found that employees in a high-tech firm are expected to log on to the IM once they are physically present in the company so others know who is available for contact. Instant messaging has built-in awareness features, and recipients are usually expected to respond immediately. This expectation may increase the disruptive nature of IM.

A majority of IM studies have focused on the nature of IM characteristics and usage practices in the workplace. For example, early research by Grinter and Palen [28] revealed IM's strength as a medium for social communication. Handel and Herbsleb [31] found that the content of IM tasks primarily focuses on discussing work tasks and negotiating availability. Likewise, an ethnographic study by Nardi et al. [43] found that IM tools are suitable for informal workplace communication. Though a plethora of studies look at issues such as IM acceptance and adoption e.g. [9,29], there is a paucity of research that empirically investigates both the positive and negative impact on knowledge worker performance within the typical IM usage and work relationship context. A recently published field study in *Decision Support Systems* on IM usage at workplaces reported the negative impact of interruptions as well as improved mutual trust and group outcomes [45]. Li et al. [36] investigated the polychronic behaviors of IM users in an interruption context and studied the influence of position powers on process satisfaction and perceived task complexity. Avrahami and Hudson [3] studied various sender–receiver interpersonal relationships such as work relationships and social relationships and found that underlying basic communication characteristics such as messaging rate and duration differ significantly across different relationships. Stephens [54] proposed a theoretical cost-optimizing framework for instant messaging use in the workplace without actually testing the framework. The study by Stephens [54] identified three separate components of costs associated with IM use: delay cost (e.g. composing the message, and seeking additional information for IM response), access cost (IM access and use), and error cost (discrepancies, misunderstandings, etc.). More interruptions through IM could increase one or more of the three cost components.

In our study, we consider the usage context of IM to explore its potential impact on primary task performance and mental overload. Fig. 1 describes the research model and various proposed hypotheses in the study. The research model depicts how the interruptive features of IM may intertwine with the hierarchiacial level of the sender and jointly influence user performance and mental overload.

2.2. Task performance and work overload

Our study uses two objective measures of primary task performance: primary task time and primary task quality. IM is typically used in a multitasking environment. Knowledge workers process some main tasks while responding to instant messages. We are interested in how interruption(s) from IM may influence the performance on the main task. Therefore, task time refers to the time to perform the main task excluding the time spent on IM interruptive tasks; task quality is measured by the degree of correctness of the main task.

Work overload is another dependent variable used in this study. Work overload has been found to be the strongest predictor of the exhaustion of IT workers and further leads to high job turnover intention [42]. In this study, we examine overall mental workload as a dependent variable capturing the mental workload resulting from working on both the tasks — main task and IM task during the entire experimental experience. Multitasking resulting from deploying IM in the work setting

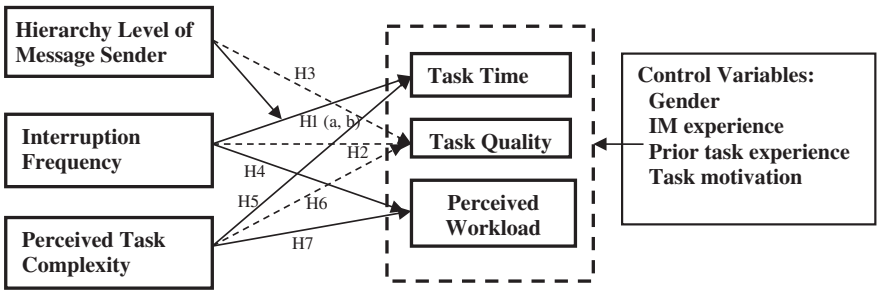

Fig. 1. Research model.

could have an impact on the work overload of a knowledge worker as well.

2.3. Interruptions

According to distraction theory, interruptions have been defined as externally generated, unpredictable events that break the continuity of cognitive focus on a primary task [15,53]. In addition, interruptions typically require immediate attention and use the same sensory channel as those used by the primary task [53]. Therefore, interruptions could lead to attentional conflicts between the ongoing primary task and interruptions as both need to be accomplished and compete for the limited attention and cognitive processing resources. One fundamental premise of distraction conflict theory is that attentional conflicts will facilitate simple task performance and impair complex task performance [7].

At the same time, it is recognized that the interruption may in some cases be relevant to the primary task and indeed help complete the primary task sooner. But the timing of the interruption does not necessarily coincide with the time when the knowledge worker is going to need the specific information coming through that interruption. Thus the information may indeed be useful and necessary to receive, but the timing of its arrival can in many cases still cause a temporary interruption to the micro-step of the primary task the user is working on.

When an interruption arrives, a knowledge worker may adopt one of the four approaches — attend to interruption immediately, use a negotiated approach, use a mediator or schedule the interruption for later processing [40]. Being a near-synchronous collaborative technology, an IM interruption requires immediate attention of the resource and therefore, preempts the knowledge worker from the ongoing primary task. This additional activity of switching from primary task to the IM task entails a small but non-value added time, referred to as switching time. While the knowledge worker is attending the IM task, a certain amount of unlearning of the preempted primary task is happening. After the IM task is accomplished, the process of relearning happens, which is necessary to regain the lost train of thoughts but in turn adds a non-value added time to the overall task accomplishment time. This defines the recall time, T_R. Finally, the remaining part of the primary task is accomplished, if no further interruptions happen (Fig. 2).

The total time spent by knowledge worker on processing primary task (T_p) comprises of three components: time spent on processing primary task prior to the interruptions (T'_p); time spent on recalling the preempted task (T_R) and time spent on processing the remaining task after the interruption has departed (T''_p). An additional non-value-added time represents the task switching time (T_S), which is incurred before the time is spent on IM interruptive tasks (T_{IM}). Various studies and approaches have been adopted to study the effects of interruptions. For example, Gupta & Sharda [30] + used simulation modeling approach to suggest that a knowledge worker may lose as much as 5% of their workday due to interruptions. Speier et al. [52] applied distraction conflict theory to investigate the effect of frequency and content relevancy of interruptions on task performance and found that the negative impact of interruptions on complex tasks was more severe when the content of the interruption was dissimilar to the primary task.

Our study focuses on the frequency and social characteristics of interruptions. We compare the effects of low interruption frequency with high interruption frequency. For the social characteristics of the interruption, we examine the effect of the hierarchical level of the sender on primary task performance. Social message receivers are more likely to give a high priority to messages from a supervisor resulting in the alteration of the mechanisms used to process a primary task accordingly. We, therefore, posit that interruption messages generated by a supervisor may have a different impact on receivers' primary task performance than do messages from a peer or coworker. Few studies have examined the interruptions from a social perspective. The effect of interruptions should be investigated in the context of the social ties between message sender and receiver. The hierarchical level of the message sender reflects whether the direction of the social tie between message sender and receiver is horizontal (peer-to-peer) or vertical (peer-to-supervisor). It may interact with the effect of interruptions on primary task performance.

In the context of real work environments, *supervisor* is one type of managerial position, representing a higher level in the management hierarchical while *peer* refers to colleagues with equal standing or

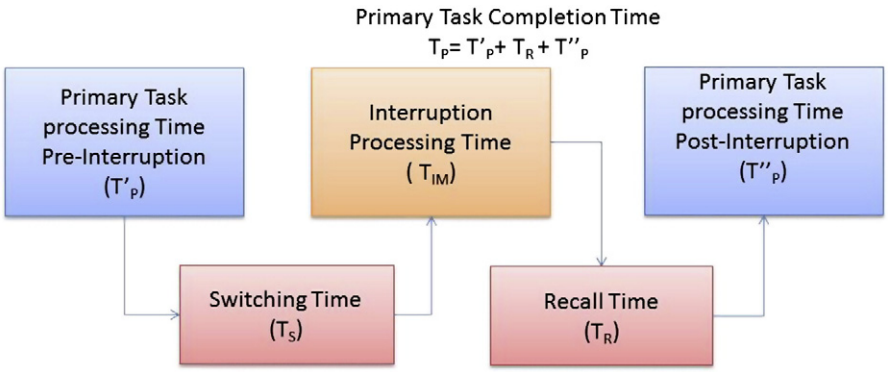

Fig. 2. Interruption process.

position power. For simplicity, in this paper, we will use the term *supervisor* to refer to a message sender with higher position power than the message receiver. *Peer* is used to refer to a message sender with about the same position power as that of the message receiver.

Prior studies have also examined the effect of task relevance on the degree of disruptiveness of interruptions [18,27] with inconsistent findings. For example, the study by Gillie and Broadbent [27] suggested that an interruption task having similarity with the ongoing primary task had greater negative impact on the performance of ongoing task due to immediate demands imposed on attention. However, another study conducted in the IM context found that the relevance of IM interruptions to the primary task reduced the disruptive effect on primary task productivity [18]. Since the majority of interruptions are meant to satisfy the sender's requirements, there is usually a mismatch between the nature of information cues needed to be processed for accomplishing IM interruption task and the ongoing primary task. We, therefore, focus on IM tasks that are dissimilar to receiver's ongoing primary task.

In addition to interruptions, task characteristics and individual factors could also drive the impact of IM. Speier et al. [53] found that interruptions compromise the performance of complex tasks but facilitate the performance of simple tasks. A few studies have focused on the interruptive nature of IS technologies such as email and instant messaging on primary task performance [17,18,52,53] and suggested that the intensity of the interruption effect, among several things, may depend on the degree of complexity of the primary tasks. Our study looks at overall perceived task complexity considering both the primary tasks and interruptive tasks.

Therefore, we explore the impact of interruption frequency, perceived task complexity, and one social characteristic of IM, i.e. hierarchical level of sender, on primary task performance and overall mental workload. The following subsections illustrate each independent variable and its impact.

2.4. Interruptions and hierarchical level of message sender

Decision makers have limited cognitive capabilities. According to distraction conflict theory [7], interruptions represent one of the situations that could generate attentional conflicts and seriously challenge or strain decision makers' cognitive capabilities such as their attention or their memory. Decision makers may adopt different information processing strategies to respond to interruptions. They tend to adopt a heuristic information processing strategy to avoid straining their attentional capacity when facing strong attentional conflicts [7]. Heuristic processing relies on cognitive shortcuts (i.e. heuristics) and excludes some information cues in the primary task from cognitive processing to achieve a satisfying decision [7,53]. Here, *information cues* refer to pieces of information that are relevant or irrelevant to completing the primary task successfully [53]. Conversely, decision makers may choose *not* to use heuristic processing but use other information processing strategies such as substantive processing [24]. For example, individuals may choose to process available information substantively when they still have adequate processing capacity or do *not* experience attentional conflicts to a level that seriously challenges their cognitive capabilities. To this end, decision makers are more likely to use heuristic processing in the presence of strong attentional conflicts and more likely to use substantive processing under a low level of attentional conflicts.

When receiving interruptions, a knowledge worker could experience not only time pressure but also evaluative pressure [7]. Evaluative pressure reflects one's concern about being evaluated by others. Due to the near synchronous expectation of IM communication, the knowledge worker may feel being evaluated immediately on his performance of the interruption tasks assigned by the message sender. The degree of evaluative pressure will vary with the hierarchical level of the message sender. The knowledge worker tends to face a high level of evaluative pressure when the message sender is a supervisor. According to distraction conflict theory, evaluative pressure from distracters/interrupters will escalate the degree of attentional conflicts and heighten the effect of distractions/interruptions [7]. Conversely, non-evaluative others may "not have been sufficiently distracting to trigger attentional conflict" p [7,9]. Therefore, interruption tasks assigned by a supervisor tend to create a higher level of evaluative pressure and stronger attentional conflicts than those from a peer. The interruption messages from a peer may not even create attentional conflicts if the peer is not perceived to play any evaluative role by the message receiver. Hence, the message receiver will be more likely to use heuristic processing to perform the primary task when the message sender is a supervisor in order to cope with the high evaluative pressure on interruption tasks and strong attentional conflicts. Heuristic processing will cause decision makers to reduce the time spent on the primary task (T_p) as a reduced number of information cues in the primary task are processed. On the other hand, the message receiver will challenge his attentional capacity to a less extent when the message sender is a peer and be more likely to use substantive processing to perform the primary task. In this case, frequent interruptions may cause longer values of T_p as extra time (T_R) is often needed to recover memory cues relevant to the main task that is lost while interruption tasks are processed.

Thus, the hierarchical level of the message sender may interact with interruption frequency and determine when heuristic processing takes place. Therefore, we hypothesize:

H1. The hierarchical level of the message sender moderates the impact of interruption frequency on receiver's primary task time, such that:

H1a. The higher the interruption frequency, the shorter the time spent on a receiver's primary task when the interruption message is sent from a supervisor.

H1b. The higher the interruption frequency, the longer the time spent on a receiver's primary task when the interruption message is sent from a peer.

Interruption has also been found to influence primary task quality at the receiver's end. Speier et al. [52,53] found that interruptions could reduce task quality for complex tasks. Their study suggested that the narrowing in attention triggered by interruptions is likely to cause omission of the necessary cues for successful completion of the complex task. Such negative impact of interruptions on the quality of complex tasks may even occur for relatively simple tasks at a high level of interruptions as more interruptions would mean more information cues to be processed and higher chance to omit the important cues in the primary task. In this study, we examined the effect of interruption frequency while controlling for the perceived primary task complexity level. The increase in interruption frequency is expected to augment the degree of narrowing in processing attention and, at high interruption levels, the primary task quality of all types of tasks being processed at the receiver's end may be compromised. Therefore, we propose:

H2. Interruption frequency has a negative impact on primary task quality at the receiver's end.

In addition, the hierarchical level of the message sender may also influence primary task quality at the receiver's end. Interruptive messages sent from a supervisor may be more disruptive than those from a peer. Knowledge workers are likely to allocate extra attention to respond to interruptive messages generated by their supervisor and opt for a heuristic strategy to process the primary task. As a result, accuracy gets compromised since fewer information cues relevant to the primary task will be processed [7,58]. On the other hand, the receiver

may not allocate complete attention or processing capabilities to the message from a peer [53]. The quality of a primary task is expected to be compromised more severely by the interruption from a supervisor than by that from a peer. This leads to the following hypothesis:

H3. The position power of the message sender has a negative impact on primary task quality of receiver's end.

Perceived workload is the perception that one has too much to do [35]. Perceived workload is a strong predictor of work exhaustion, which further influences the job turnover intention of IT workers [2,42]. Interruptions from IM could also increase knowledge workers' perception of mental overload. Besides the increase in the number of information cues to be processed, interruptions from IM are more likely to trigger the feeling of time pressure than other asynchronous communication media. The presence awareness feature of IM urges the message receiver to immediately address instant messages. Under high interruption frequency, message receivers are likely to feel time-pressured and experience mental overload. Further, interruptions may share the same sensory channels as the primary task, causing potential loss of working memory or confusion of cues for different tasks [53], which suggests that interruption messages at a high frequency may increase the perceived mental overload. Therefore, we hypothesize

H4. Interruption frequency increases overall perceived workload.

2.5. Perceived task complexity

Recent studies have found that subjective task complexity is also an important determinant of task performance and that the effect of objective task complexity is partially mediated through subjective task complexity [39]. Individuals who perceive the task to be complex are more likely to exclude some information cues for consideration and focus their attention on cues that are *perceived* to be most relevant. As a result, cues that are necessary to correctly solve the primary task could get neglected. If they neglect necessary information cues, workers could achieve sub-optimal instead of optimal decisions, thereby leading towards degradation in terms of primary task quality. Tasks that are perceived to be relatively complex will also require more time (T_P) since more cues need to be processed. Conversely, the perception of a task being simple may encourage an individual to consider more available information cues for decision making. This also implies that individuals may feel more overloaded with information if too many cues are vying for their attention, which is a scarce resource, as is the case with a task perceived as complex. On the other hand, a task perceived as simple is less demanding and therefore is likely to lead to less overall mental workload. Hence, we have

H5. Perceived primary task complexity has a positive impact on the time spent on a primary task.

H6. Perceived primary task complexity has a negative impact on the quality of a primary task.

H7. Perceived primary task complexity is positively associated with overall perceived workload.

2.6. Control variables

In addition to the independent variables mentioned above, the research model consists of four control variables: gender, IM experience, primary task motivation, and prior task experience. The impact of the communication medium on task performance may be dependent on the experience with the medium and the task [56]. For instance, IM experience and previous task experience are expected to improve task performance. Also, individuals' motivation to perform the task is likely to influence their task performance [39].

3. Research methodology

3.1. Study design and procedures

An experimental design was used to manipulate the frequency of interruption and the hierarchical level of the message sender. The frequency of interruption was manipulated at two levels: low interruption and high interruption. Subjects received one instant message at the low interruption level and four instant messages at the high interruption level. The hierarchical level of the message sender was manipulated at two levels: peer and supervisor. So, the two manipulated variables jointly form four treatment conditions.

In this experimental design, IM tasks are treated as immediate interruption [40] that cannot be postponed rather than scheduled, mediated or negotiated interruptions. As in a typical collaborative workplace environment, instant messages in this study are treated at par in priority relative to the primary ongoing primary task and therefore the resource gets preempted upon their arrival. Both tasks needed to be accomplished.

Subjects were students at a major university in the upper Midwest United States. All subjects were volunteers and received less than 1% extra credit for participation. 112 usable responses (50 females and 62 males) were included in our final data analysis. The age range of the subjects is 19 to 39 and the average age is 23.

Subjects were randomly assigned to only one of four treatment conditions. Each subject assumed the role of a knowledge worker engaged on a group project that aimed to improve the supply chain of a company. The primary task and IM tasks were all designed in this supply-chain task context. The main task was to browse the websites of UPS and the U.S. Postal Service and search for costs of shipping two types of packages to a warehouse (Appendix I). Each subject searched for four shipping costs. While subjects were performing the search tasks, they were interrupted by instant message(s) sent from either their project member or project manager depending upon their interruption-hierarchy scenario.

The instant messenger used in this study is Yahoo messenger, which allows the researcher to send a single message to multiple recipients at the same time. Yahoo messenger has built-in text, audio and video channels. In our study, we focused on text exchange. All communications between the message sender and recipient are delivered in plain text. All interruption messages were sent out by researchers. Each subject was involved in dyadic communication, i.e. only interacting with the researcher. All subjects performed the same types of primary task and interruption tasks as we controlled the task relevance.

The IM interruptive messages requested subjects to compare eight suppliers based on account payable terms, delivery time, or product costs. The information for the eight suppliers was provided in a printed table (Appendix II). Subjects were instructed to respond to instant messages once they received them. Their responses need to be sent out in plain text as well. Appendix III shows the questions that were sent through IM to interrupt the subjects. Each interruptive IM task typically takes about 30 s to be completed. The design of the IM task is consistent with the typical usage profile of IM, i.e. used for short, simple, and quick communications [10,32]. After searching for the shipping costs and entering the results in an Excel worksheet, subjects were required to fill out an online survey. No time constraints were imposed on the time spent in searching for shipping costs, which is a component of T_P. Researchers recorded the time each subject spent on the interruptions (i.e. T_{IM}) while subjects were asked to record the time spent on primary tasks (T_p), which included the time spent on searching for shipping information.

3.2. Measures

All latent constructs in the research model were measured using existing published scales. Some items were reworded slightly to reflect the research context. Perceived task complexity and task motivation for primary task were measured using the instruments by Maynard and Hakel [39]. Perceived workload was adapted from the instruments by Moore [42]. Besides acting as one of the dependent variables in our research model, perceived work overload was also used to check the manipulation on interruption. A single question ('Mr. Smith,' who I just interacted with, has higher position power than I have) was developed to check whether the manipulation on direction of the social tie or hierarchical level of the message sender was successful. All these items were measured on a five-point Likert scale with 1 being *strongly disagree* and 5 being *strongly agree*. The detailed measures for each latent construct and control variables are listed in Appendix IV.

Objective performance was assessed using completion time (T_p) and quality of the primary task. T_p only includes the time spent in searching for the shipping cost (in seconds). T_{IM}, the time spent on IM tasks, has been excluded. The primary task quality was computed as the number of correct shipping costs found from the two websites. A completely correct answer was scored as 4 points while 0 was given to a solution with no correct shipping costs.

3.3. Data analysis

T-tests were conducted to check the manipulation on the direction of the social tie. The position power of message senders in the subordinate-to-supervisor condition was perceived to be significantly higher than that in the peer-to-peer condition with a p-value <0.01. Therefore, the manipulation of the direction of the social tie was successful. No manipulation check was performed on the interruption frequency. Instead, we used prior literature to justify the high level of interruption used in our experiment. According to Mark [38], one interruption every three minutes is a high level of task interruption. In our experiment, the average total task time (i.e. $T_P + T_{IM}$) is fourteen minutes in the high interruption group. Therefore, four interruptions during the total task time are about one interruption every three and half minutes, which is comparable to the high level of interruptions reported by Mark [38].

A partial least squares (PLS) technique was performed to test the measurement model and research hypotheses. PLS combines features from principal component analysis and multivariate regression [1], which tests not only the significance level of paths among constructs but also the measurement quality of latent constructs. In addition, PLS requires a smaller sample size than other SEM techniques [12]. The minimum sample size required by PLS is ten times the larger number of paths leading to an endogenous construct when all constructs are reflective. In our research model, the maximum number of paths entering an endogenous variable is eight including the control variables and the interaction variable between interruption and hierarchy level of the message sender. Therefore, a sample size of 112 was found to be sufficient for PLS analysis. Moreover, PLS does not assume a multivariate normal distribution and interval scales. Our model consists of two binary manipulated variables. PLS is considered more appropriate for our study than other SEM techniques.

Table 1
Correlation matrix, reliability (CR) and average variance extracted (AVE) of latent constructs.

Constructs	Mean (STD)	Reliability	AVE	Complexity	Workload	Motivation
Complexity	2.6 (0.9)	0.94	0.79	**0.89****		
Workload	3.1 (0.7)	0.88	0.66	0.51**	**0.81****	
Motivation	3.5 (0.7)	0.86	0.68	0.33**	0.20*	**0.82****

Note: Diagonal elements are the square root of the AVE values. Off-diagonal elements are the correlations among latent constructs; *p<0.05, **p<0.01.

Table 2
Results of factor analysis on latent constructs. **p<0.01.

Loadings of measurement instruments				
		Loadings and cross loadings		
Constructs/items		Complexity	Workload	Motivation
Complexity (primary)	COMP1	**0.81****	0.34	0.14
	COMP2	**0.91****	0.50	0.28
	COMP3	**0.92****	0.51	0.38
	COMP4	**0.91****	0.43	0.34
Workload (overall)	LOAD1	0.39	**0.88****	0.12
	LOAD2	0.37	**0.86****	0.12
	LOAD3	0.50	**0.78****	0.27
	LOAD4	0.35	**0.71****	0.09
Motivation (primary)	MOTI1	0.27	0.18	**0.88****
	MOTI2	0.29	0.16	**0.86****
	MOTI3	0.25	0.15	**0.71****

3.4. Measurement model

We examined convergent validity, reliability, and discriminant validity of all latent constructs before testing the hypotheses. Convergent validity is suggested if item loadings are 0.60 or higher [5]. All indicators had loadings above 0.7. All measurement items loaded significantly on their respective latent constructs. All these confirm the convergent validity of the measurement model. A scale is considered reliable if its composite reliability (CR) is above 0.7 and average variance extracted (AVE) above 0.5 [5]. As shown in Table 1, all scales used in our study have CR values above 0.8 and AVE values above 0.6. Two criteria were used to further assess discriminant validity based on the loading and cross-loading matrix (Table 2) and the correlation matrix (Table 1). All measurement items should load more strongly on their respective construct than on other constructs. Second, the square root of the AVE of each construct should be higher than the inter-construct correlations, i.e. the correlations between that construct and any other constructs [25]. As shown in Tables 1 and 2, all constructs in our model satisfy these two criteria for discriminant validity. Therefore, our measurement model demonstrates sound reliability and validity and should warrant further analysis on our research hypotheses.

3.5. Results

Fig. 3 summarizes the results of testing the hypotheses. The model could explain 19.1% of the variance in T_p, 17.1% of the variance in the correctness of the primary task and 30.9% of the variance in overall perceived workload. All these three R^2 values exceed the 10% threshold for substantive explanatory power suggested by Falk and Miller [22]. We further computed the F statistics and p-values associated with each R^2 value. The model F statistics are 3.04 with 8 and 103 df for task time (T_p), 3.06 with 7 and 104 df for task quality and 7.83 with 6 and 105 df for perceived workload. Their corresponding p-values are all less than 0.01. Therefore, our research model could explain a significant amount of variance in each dependent variable.

We first analyzed the moderation effect of the hierarchical level of message senders (Hypothesis 1) and then tested other main effect hypotheses. Following the procedures by Chin et al. [12], we examined both effect size and statistical significance of the moderation effect. The effect size of interaction (f^2) was 0.09, which satisfies the 0.02 cutoff for small effect size [14].[1] The moderation effect is also found to be

[1] $f^2 = [R^2$ (interaction model) - R^2 (main effects model)]/[1- R^2 (main effects model)].

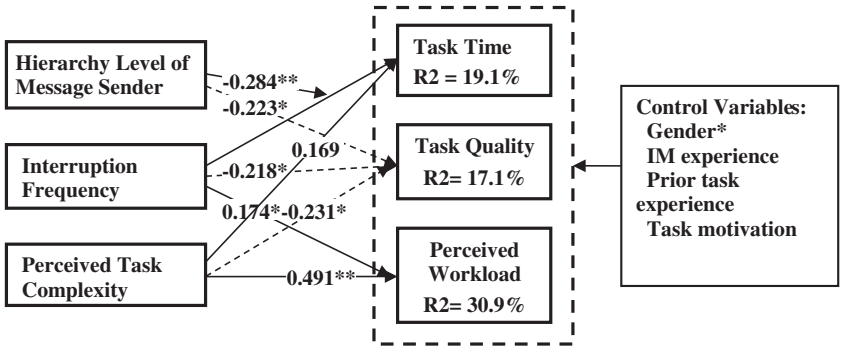

Fig. 3. Results of testing hypotheses using PLS analysis; completely standardized estimates, controlled for control variables in the research model, *p<0.05, **p<0.01 (two-tailed).

statistically significant ($p<0.01$). Therefore, the effect of interruptions on task completion time, T_p, is moderated by the position power of the message sender. The interaction pattern, shown in Fig. 4, is consistent with the hypotheses. The interaction utility by Preacher et al. [46] was then applied to test statistical significance. We found that, when the message sender is a supervisor, the relationship between interruption frequency and task time, T_p, is negative and marginally significant ($p<0.1$). When the message sender is a peer, the relationship becomes positive and statistically significant ($p<0.05$). Overall, H_1 was supported.

We went on to examine the other hypotheses. They were all found to be statistically significant except H_5. Perceived task complexity is not found to significantly influence the primary task completion time, T_p. Overall, the research model is well supported. In addition, among the four control variables, gender was found to significantly increase task quality. The number of correct answers from females is significantly higher than that from males ($p<0.05$).

4. Discussion and post-hoc analysis

4.1. Summary of findings and limitations

As instant messaging grows in popularity within organizations for collaborative work and decision support, it is important to understand its impact on primary task performance and overall perceived workload. Our findings suggest that interruptions from IM reduce primary task quality and increase overall perceived workload. Interestingly, we found that social characteristics are important. Social characteristics could moderate the relationship between interruption and primary task time, T_p. The effect of interruptions on T_p depends on the hierarchical level of the message sender. Interruptions significantly increase T_p when the message sender is a peer and reduce T_P when the message sender has higher position power than the message receiver. This result suggests that the higher position power of the message sender triggers the message receiver to give a higher priority to the interruption messages and adopt a heuristic strategy to process the primary task at hand through processing fewer information cues. Thereby, the message receiver has a chance to reduce the time to complete the primary task, T_p, even after considering the extra T_R, time spent in recovering memory cues of the primary task lost from interruptions. However, when the message sender is a peer, the message receiver tends not to adopt a heuristic strategy to process the primary task. As a result, interruptions will cause the message receiver to spend a longer time completing the primary task (T_P) because of the time wasted on recovering memory cues (T_R).

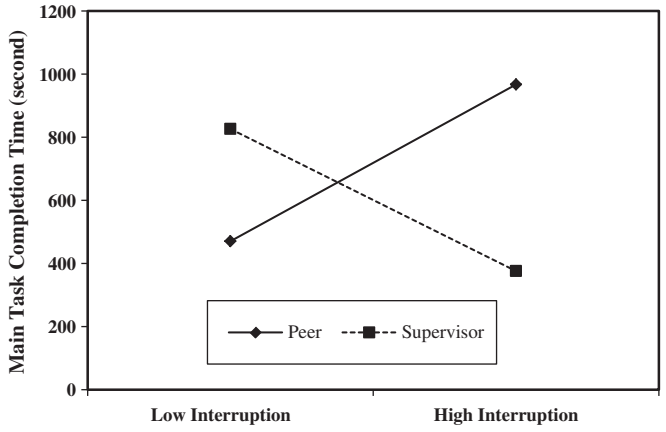

Fig. 4. The moderation effect of the hierarchical level of message sender on the relationship between interruption frequency and main task completion time, T_p.

Since the interaction between interruption and hierarchical level of message sender is disordinal, the main effects of these two variables on T_P, primary task completion time, cannot be interpreted. In addition to the moderation effect, the hierarchical level of the message sender was also found to directly influence primary task performance by reducing the quality of the primary task. The results suggest that message receivers may be more pressured to respond to instant messages from their supervisor and, therefore, take a heuristic strategy to process the primary task. The heuristic processing strategy may cause the message receiver to omit some of the relevant cues necessary for the successful completion of the primary task. Therefore, the position power of a message sender will escalate the disruptive effect of instant messages and compromise the quality of the primary task performed by the message receiver.

The results of our study demonstrate that the subjective perception of the primary task complexity could influence the objective task performance. Subjects who perceive the task to be complex perform worse in terms of primary task quality than those with low task complexity perception. As expected, subjective task complexity positively influences knowledge workers' perceived overall workload. However, subjective task complexity has no significant impact on T_p. The impact of subjective task complexity on T_p may be partially overridden by other variables in the model. To test this, we reran our research model by excluding the three insignificant control variables, i.e. primary task motivation, IM experience, and supply chain task experience. The path between subjective task complexity and primary task completion time, T_p, becomes significant ($p<0.05$). Among the three excluded variables, previous experience in supply chain task may influence both perceived task complexity and objective task completion time. When supply chain task experience is included in the model, subjective task experience does not have sufficient unique influence on T_p.

In this study, we have found a positive impact of interruption frequency on perceived overall workload. It is interesting to examine whether the social characteristics of interruptions, i.e. the hierarchical

level of the message sender, may influence perceived overall workload. The interruption message from a supervisor may cause higher perceived overall workload in the message receiver than the one from a peer. In addition, the hierarchical level may moderate the effect of interruption frequency on perceived overall workload. For example, a supervisor may escalate the effect of interruptions on perceived overall workload. As such, a post-hoc analysis was conducted by including two additional paths for predicting perceived overall workload. One path is from the hierarchical level to perceived overall workload. Another path is from the interaction term of interruption frequency and hierarchical level to perceived overall workload. However, the standardized path coefficients of both paths are below 0.1 and not statistically significant ($p > 0.05$). Therefore, the hierarchical level of the message sender was *not* found to significantly influence perceived overall workload or significantly moderate the impact of interruption frequency on perceived overall workload.

Moreover, as message receivers are more pressured to use heuristics to reduce the number of information cues processed in the primary task when the message sender is a supervisor, we conjecture that the hierarchical level may influence the overall perceived task complexity. The message receiver may perceive the overall task to be less complex as a result of heuristic processing triggered by a supervisor. Therefore, we conducted another post-hoc analysis by including an additional path between the hierarchical level and perceived task complexity. However, we did not find a significant relationship between the two. The standardized path coefficient is −0.17 and has a p-value greater than 0.05. Other factors may override or adjust the effect of the hierarchical level on perceived task complexity. For example, the study by Li et al. [37] found that the relationship between the hierarchical level and perceived task complexity is moderated or conditioned upon the polychronic orientation of the message receiver.

Before we discuss the implications of our study, we point to some of its limitations. First, the study used student subjects, which restricts the external validity of the study to a certain extent. Future studies using knowledge workers in organizations will provide stronger support for our results. To alleviate the restrictions on external validity imposed by student subjects, this study controlled for subjects' task experience. In addition, the age range of the subjects of this study is 19–39, which is representative of the current users of IM at the workplace to some extent. Recent studies have found that IM is used more often by younger employees (<35) in the workplace [13,34]. Second, we tested our research model based on primary tasks with moderate mental processing. The average perceived task complexity is around 2.6 (Table 1). Further studies are needed to extend the results to tasks of different complexity levels. Complex primary tasks require intensive mental processing or memory. The detrimental effects of interruption may be augmented for complex tasks. T_p may be dramatically increased when primary tasks requiring high memory processing are interrupted by IM. The role of the hierarchical level of message senders may also be different for complex tasks. Position power may have less influence over T_p but an even stronger negative effect on primary task quality. Finally, our paper investigated the effect of interruptions on the performance of the primary task at an individual level, namely, with respect to a message receiver. Future studies could examine the impact of interruptions at an organizational level such as whether the interruptions from a supervisor might also influence the performance of the organization as a whole.

4.2. Implications for research

This study has several important implications for research. First, instant messaging is interruptive. Instant messages sent at a higher frequency exert greater negative impact on primary task quality than those sent less frequently. An interesting direction to pursue could be to understand how various penalty and reward systems associated with processing information through IM are intertwined, which may eventually help us uncover the paradox associated with information processing i.e. whether to respond to information now or later.

The findings highlight the important role of social characteristics. The position power of the message sender moderates the impact of interruptions on T_p and reduces the quality of the primary task. Task completion time, T_p, and completion quality could also be influenced by other social characteristics such as the strength of the social tie (i.e. closely related peer versus remotely related peer) and density of the social ties using IM. For instance, instant messages from a closely related peer may be more interruptive than messages from a remotely related peer. Knowledge workers may give more attention to interruption messages and take a heuristic strategy to process the primary task. Future IM studies are needed to provide a better understanding of the effect of other social characteristics. More research needs to be done to understand a better fit among task, technology, and social context.

The results support the conclusion that subjective task complexity decreases objective task performance, i.e. task quality and increases perceived overall workload. This further emphasizes the need for developing human–computer interfaces or techniques that can assist in presenting tasks and information in a manner that will reduce the perceived complexity of tasks.

Another interesting dimension to pursue would be to understand IM use under extreme underloaded and overloaded work environments. Previous research has shown an inverted U-shaped relationship between primary task performance and overall workload [49]. Less information leads to productivity loss through boredom whereas overwhelming information leads to productivity loss through fatigue. However, this remains to be tested in an IM context.

In this study all subjects performed the same types of primary and interruption tasks as we controlled the task relevance. The study represents the most prevalent scenario in the workplace, where an interruption originates when a sender needs some additional information from the receiver i.e. an interruption occurring at any particular point in time is relevant to the sender but irrelevant to the primary task of the receiver; interruptions happen at the random needs of the sender, making it difficult for the receiver to predict their arrival time. The findings of this study are valid for the scenario that we have modeled in our experimental design. It would be interesting to study other situations where interruptions are relevant to the receiver. This will require major changes in modeling the primary and IM task design for each scenario and will also completely alter the context of this study. For example, the scenario where the interruption is relevant to both parties at any point in time may represent a virtual collaborative project type of work environment rather than a routine task. The likelihood of the scenario where interruptions are immediately relevant to the receiver but irrelevant to the sender is relatively low since a sender doesn't always know the exact nature and processing stage of the receiver's primary task in the absence of any awareness mechanism or technologies either embedded in IM or in the workplace.

Future studies could focus on understanding the impact of interruptions on tasks that involve innovation. This study has looked into tasks that do not require any unorthodox or creative problem solving approaches such as *lateral thinking* processes. According to one definition, "*lateral thinking*" is an innovative problem solving approach that exhibits characteristics such as exploring different alternatives, non-sequential or logical thinking approaches, and shift in attention [19,55]. It would be interesting to see how the impact of interruptions varies between routine and innovative tasks. Moreover, just as email has taken on the role of DSS (Luck, 2006), IM's fit in this role should be further investigated as this technology becomes more prevalent in the workplaces.

Finally, despite the IM research context of this study, the results of our study could also provide important theoretical implications for general effect of interruptions, i.e. may very well apply to other communication technologies. For example, interruption frequency of email messages will likely influence the task quality of knowledge workers

in a similar way as found in our study and may potentially interact with the hierarchy level of email senders.

4.3. Implications for practice

Results of this study provide some important insights for organizations that promote IM for collaborative work and decision support. First, interruptions from IM could negatively influence the task quality of knowledge workers. Such negative effect of IM interruptions is especially salient for IM communication with built-in presence awareness feature as knowledge workers are urged to respond to IM interruptive messages immediately. The negative impact of IM interruptions may be alleviated by giving more control to employees with respect to using the presence awareness features so that they are less pressured to respond to the messages in a synchronous mode.

Second, this study provides the first empirical evidence on the important role of the hierarchical level in task performance. The negative impact is aggravated when the message sender has higher position power than the message receiver. Supervisors may need to consider other communication channels if immediate responses are not necessary. Our results show that any message from a supervisor is given higher processing priority, resulting in smaller task time but greater perceived workload. This could be accomplished by building agents at either client or server side that control messages flow based on who the sender is (e.g. message from supervisor list are shown promptly on top). The agent could also conditionally alter the status of recipient based on sender's hierarchy. At the same time, we should exercise caution in extending such negative impact to the level of a group or an organization. IM interruptions may help improve the overall performance of an organization despite the negative impact on the task quality of individual message receivers. Future studies are necessary to test the impact of IM interruptions at the group or organizational level.

Third, knowledge workers suffer from increased overall mental workload when receiving frequent instant messages. The subjective perception of primary task complexity also influences overall mental workload. Companies may need to monitor instant messages received by employees and set up policies or use technical approaches to control the frequency of IM usage. In addition, companies could manipulate the subjective task complexity to reduce the overall mental workload of instant message receivers. For example, the training on IM is one approach that may enhance technology experience and reduce both subjective primary task complexity and overall mental workload. Knowledge workers need to be trained on how to turn off the presence awareness feature set their status and use proper instant messaging etiquette. As such, the message recipient will have less of a chance to be influxed with interruptive tasks and perceive the overall task to be less complex. Alternatively, this could also be achieved by using better graphical interfaces. Research in human–computer interaction has shown that interruption problem is also a user interface design issue (McFarlane, 2002). Interfaces of instant messaging could be enhanced with added functionalities that support the multitasking work environment in various ways such as an embedded intelligent agent with capabilities to provide support during the post interruption (recovery phase), perform a mediating role and schedule the interruption based on who the sender is.

5. Conclusions

As IM becomes more popular as a collaborative and decision support technology, it becomes increasingly important to gain further understanding on various positives and negatives associated with the use of IM technology in a social and technological context. Drawing upon the theoretical foundations of research on interruptions, we adopt a social perspective to further increase our theoretical and empirical understanding of the impact of instant messaging on primary task performance and perceived overall workload. Our results suggest that interruption messages sent from IM are found to decrease primary task quality and increase mental overall workload. The position power of the message sender moderates the impact of interruptions on T_p, primary task time. Interruptions from a supervisor could reduce T_p whereas interruptions from a peer increase T_p. In addition, interruptions from a supervisor aggravate the negative impact of interruptions on primary task quality. These findings highlight the importance of considering various social aspects of the technology that may assist in devising a more intelligent use of IM at workplaces and provide some guidance for companies developing IM to address socio-technical aspects. This study sets the stage for further research in this promising area.

Appendix I. Main task

Exact start time (Use the clock on computer):Your firm is located at Albany, New York (Zip: 12250) and ships two types of boxes (Type A and Type B) to each of the warehouses on a daily basis. The approximate value of one Type A box or one Type B box is about $100.

Box A: Length: 13 inches, width: 17 inches, height: 9 inches, weight: 45 pounds
Box B: Length: 6 inches, width: 12 inches, height: 10 inches, weight: 16 pounds

Compare the Ground Shipping and Priority Mail rates of two companies and fill the below cells:

UPS http://wwwapps.ups.com/calTimeCost?loc=en_US
Select these options: Shipment type: Package/letter, Destination type: Commercial address, Quote type: Detailed time and cost, Select: 'I will drop off my prepaid package(s)', Daily pickup: No, packaging: My packaging,
U.S. Postal Service http://postcalc.usps.gov/
Select these options: Rectangular box, Priority Mail and add an Insurance of $100 under extra services.

Destination	UPS (Ground shipping)		U.S. Postal Service (Priority mail)	
	1 A Cost	1 B Cost	1 A Cost	1 B Cost
Rye, New York (Zip 10580)				

Shipping rate
Exact finish time (Use the clock on computer):
Enter your Yahoo ID name:

Appendix II. Information search file

Orders and suppliers						
Vendor name	Vendor no.	Item no.	Item description	Item cost	A/P terms	Avg. delay time (in days)
Hulkey Fasteners	1	1122	Airframe fasteners	$ 4.25	30	−0.27
Hulkey Fasteners	1	3166	Electrical connector	$ 1.25		
Hulkey Fasteners	1	9966	Hatch decal	$ 0.75		
Hulkey Fasteners	1	5066	Shielded cable/ft.	$ 0.95		
Spacetime Technologies	2	4111	Bolt–nut package	$ 3.55	25	4.00
Spacetime Technologies	2	9752	Gasket	$ 4.05		

(continued on next page)

Appendix II (*continued*)

Orders and suppliers

Vendor name	Vendor no.	Item no.	Item description	Item cost	A/P terms	Avg. delay time (in days)
Spacetime Technologies	2	6489	O-ring	$ 3.00		
Spacetime Technologies	2	5125	Shielded cable/ft.	$ 1.15		
Durrable Products	3	1369	Airframe fasteners	$ 4.20	45	0.00
Durrable Products	3	4569	Bolt–nut package	$ 3.50		
Durrable Products	3	5454	Control panel	$ 220.00		
Durrable Products	3	9399	Gasket	$ 3.65		
Durrable Products	3	7258	Pressure gauge	$ 90.00		
Durrable Products	3	5275	Shielded cable/ft.	$ 1.00		
Fast-Tie Aerospace	4	5166	Electrical connector	$ 1.25	30	1.00
Fast-Tie Aerospace	4	6321	O-ring	$ 2.45		
Fast-Tie Aerospace	4	7268	Pressure gauge	$ 95.00		
Fast-Tie Aerospace	4	5462	Shielded cable/ft.	$ 1.05		
Fast-Tie Aerospace	4	5689	Side panel	$ 1 75.00		
Alum Sheeting	5	1243	Airframe fasteners	$ 4.25	30	1.75
Alum Sheeting	5	4224	Bolt–nut package	$ 3.95		
Alum Sheeting	5	5417	Control panel	$ 255.00		
Alum Sheeting	5	5634	Side panel	$ 185.00		
Steelpin Inc.	6	4312	Bolt–nut package	$ 3.75	30	2.53
Steelpin Inc.	6	5234	Electrical connector	$ 1.65		
Steelpin Inc.	6	8008	Machined valve	$ 645.00		
Steelpin Inc.	6	5677	Side panel	$ 195.00		
Steelpin Inc.	6	5319	Shielded cable/ft.	$ 1.10		
Manley Valve	7	9955	Door decal	$ 0.55	30	0.36
Manley Valve	7	9967	Hatch decal	$ 0.85		
Manley Valve	7	8148	Machined valve	$ 655.50		
Manley Valve	7	6431	O-ring	$ 2.85		
Manley Valve	7	9977	Panel decal	$ 1.00		
Manley Valve	7	7258	Pressure gauge	$ 100.50		
Pylon Accessories	8	9764	Gasket	$ 3.75	15	2.60
Pylon Accessories	8	6433	O-ring	$ 2.95		

* Negative delay time means the order arrived earlier than promised by the vendor.

Appendix III. IM tasks

Low level of interruption:

1. Which supplier has the longest A/P term?

High level of interruption:

1. Which supplier has the longest A/P term?
2. Which supplier is the best in terms of on-time delivery?
3. Which supplier has the lowest price for Airframe fasteners?
4. Which supplier has the lowest price for Shielded Cable?

Appendix IV

Survey instrument

Perceived task complexity [39] — *for main task*
COMP1 I found this to be a complex task.
COMP2 This task was mentally demanding.
COMP3 This task required a lot of thought and problem solving.
COMP4 I found this to be a challenging task.

Task motivation [39] — *for main task*
MOTI1 I was motivated to perform well on this task.
MOTI2 This task was interesting to me.
MOTI3 I put a lot of effort into coming up with the best possible solution.

Perceived workload [42] — *for entire experimental experience (main and IM task)*
LOAD1 I feel busy or rushed.
LOAD2 I feel pressured.
LOAD3 I feel that the number of requests, or problems I deal with is more than expected.
LOAD4 I feel that the amount of work I do interferes with how well it is done.

Hierarchical level of message sender
'Mr. Smith,' who I just interacted with has higher position power than I have. (Strongly agree, Agree, Neutral, Disagree, Strongly disagree)

Gender
What is your gender? (Female Male)

IM experience
Approximately how long have you been using Instant Messenger?

Prior task experience — for main task
How much experience have you had in the past with supply chain related tasks similar to those that you have just worked on? (None, A little, Some, A lot)

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