Examining the Qualitative Gains of Mediating Human Interruptions during HCI

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Abstract

Recent trends in software development directed toward intelligence, distribution, and mobility have brought sophisticated software artifacts that often come with some unwanted side effects; frequent interruptions, for instance. In general, people are less effective when exposed to interruptions. We have created a framework that helps in selecting the most appropriate timing for interruption as a way to mediate human interruptions by the computer. The proposed framework is based on a new Interruption Taxonomy and uses Bayesian Belief Networks for selecting the best timing when mediating interruptions. An empirical study was conducted to empirically measure the qualitative gains of mediating interruptions compared to condition with no interruption control i.e., interruptions were presented immediately at random-generated points. The experimental results suggest that mediated coordination of interruption was effective in decreasing some disruptive effects of interruptions on a socio-emotional level, such as: the feelings of frustration, distraction, annoyance and workload.

1 Introduction

Computers pervade nearly everything we do, and they have changed the way we live, work and communicate. It appears that the more sophisticated computing tools become, the more frequently they interrupt and distract our everyday actions and social encounters. Given that interruptions typically degrade user performance, and they are natural accompaniment of human-computer interaction, user interface (UI) designers need guidance in designing, and evaluating user interfaces that support user performance in context of interruptions.

There are number of factors that influence user performance in context of interruptions. Steady progress has been made toward identifying and understanding what factors make some interruptions more disruptive than others. Task complexity (Bailey et al., 2000), (Cutrell et al., 2001), coordination method used to handle interruptions (McFarlane, 2003), interruption point at which interruptions arrive (Cutrell et al., 2001), similarity between the ongoing and the interruption task (Gillie & Broadbent, 1989), interruption modality (Latorella, 1998), etc. have proven to affect task performance and user's emotional state in context of interruption.

Many recommendations and guidelines have been proposed, however major open issues still remain, especially how these recommendations could be applied in complex domains, how different context factors inter-relate and to what extent they contribute to the disruptiveness of interruptions. Even though a proper identification of types of information that bear on the efficiency of mediating interruptions is crucial for modeling human behavior in the presence of interruption, there is no general framework to help UI designers focus their attention on the relevant factors that can be traced and measured.

This research examines the feasibility of mediating human interruption by the computer, specifically by selecting the most appropriate timing for interruption based on the proposed conceptual framework. The proposed conceptual model is based on the new Interruption Taxonomy and uses Bayesian Belief Networks as a decision-support aid for mediating interruptions. In the paper, we will discuss the results of an exploratory user study, conducted to examine the qualitative gains of mediating human interruptions by using the first version of the interruption mediator that is based on the proposed framework.

2 Interruption Taxonomy

The motivation behind this work is the belief that effective coordination of interruptions during human-computer interaction cannot be accomplished without an appropriate interruption model. As a basis for the model a new

Interruption Taxonomy is outlined to categorize a variety of traceable information needed to exhaustively describe the task space, disambiguate user's goals, and the uncertainty of an environment. The key concepts and attributes that are relevant for selecting the most appropriate timing of interruptions were identified and interruption-related information is categorized according to context: Task Context, User Context, and Environment Context (Figure 1). Two categories, User Workload and Task Difficulty, are theoretical constructs. This framework proposes mapping these categories to other context variables that belong to all three taxonomy dimensions.
The Task Context dimension includes a number of attributes to capture the pragmatics of domain tasks. Some of these categories represent invariant properties of tasks that can be obtained from the domain-specific background knowledge about the application space, and the specifics of the particular interaction. Others should be drawn from the information gathered from a variety of sources (e.g., perceptive devices, interaction event tracing). To a large extent, the appropriateness of system behavior is also a function of the state of the individual's own comfort level. A user perspective and preferences may constrain the space of solutions and possible ways of handling interruption. Our first attempt to identify and represent the user characteristics that could help the system account for individual differences related to interruption is represented by a set of traceable categories along the User Context dimension. The inclusion of the environment-related categories attributes substantially greater sensitivity to the system, namely, the ability to adapt to a social setting, physical and organizational constraints, or the particularity of the current situation. Four types of environmental conditions are included in the taxonomy, but the addition of others is also possible.
This research builds upon previous research works regarding interruptions as they pertain to the design of intelligent user interfaces. The taxonomic approach was aimed to help UI designers focus attention on relevant tangible context factors and aspects in the user interface design. By organizing the context information needed for mediating interruptions in a coherent framework, this research attempts to improve the methodology of the design process.

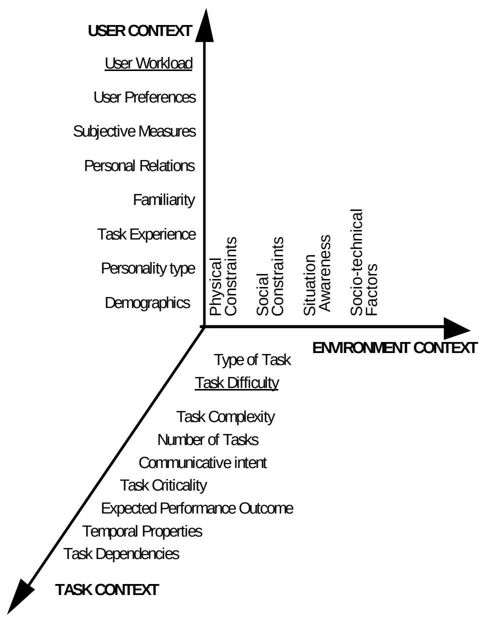


Figure 1: Interruption Taxonomy

3 Interruption Model

Individual pieces of knowledge or a collection of categories from the Interruption Taxonomy do not constitute an interruption model. The effort to find out how those pieces of information are related to one another (i.e., causal relationship between the factors) is far more challenging. We have adopted an approach based on Bayesian Belief Networks (BBNs) to represent the causal relationship between different pieces of information and to integrate rules for how to use, maintain, and reason with interruption-related knowledge. BBNs have proved suitable for making predictions and decisions from incomplete and uncertain data (Horvitz et al., 1999), (Jameson et al., 1999).
The Bayesian network constructed for selecting the most appropriate timing of the interruption is shown in Figure 2. As shown, the decision on the most appropriate timing of interruption (i.e., Interruption Timing) depends on

inferring the state of several hypothetical (non-observable) variables: *Interruption Relevance* (A), *Sensitivity to Interruption* (B), *Individual Differences* (C), *Environmental Conditions* (D) and *Urgency of interruption* (E). The circled areas in Figure 2 represent the parts of the graph that relate each of these variables with the relevant taxonomic categories. Most of the nodes in the network drawn as oval boxes correspond to the taxonomy categories. It should be noted that Figures 2 depict variables and relations only on the highest level. In practice, parts of the network could become quite complex by adding more exhaustive context representation.

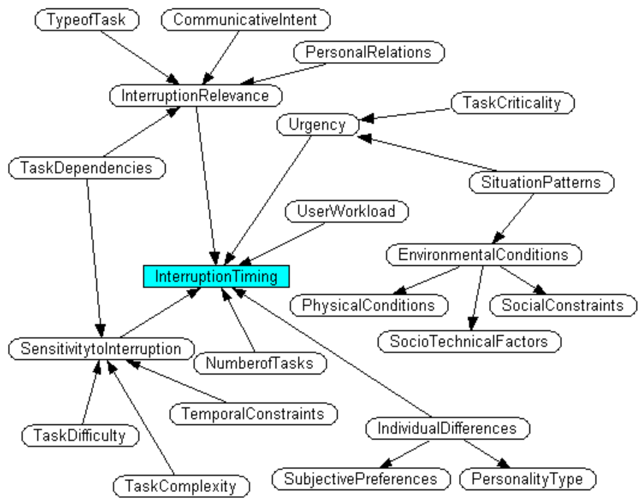


Figure 2: Interruption Model

As stated previously, the theoretical constructs, User Workload and Task Difficulty are inferred using the interruption-related knowledge represented by the taxonomy. For instance, a set of taxonomic categories are used for inferring the difficulty of a task as shown in Figure 3. They could be broken down into three groups: (1) factors that are used to portray the "objective" difficulty of a task based on what is known about that task in general, (2) factors reflecting the particularities of a given situation, (3) characteristics to account for the individual (i.e., "subjective") perspectives on how difficult a task is, and (4) environmental influences. The justification for the selection of the characteristics is based on the theory and empirical evidence reported in relevant literature.

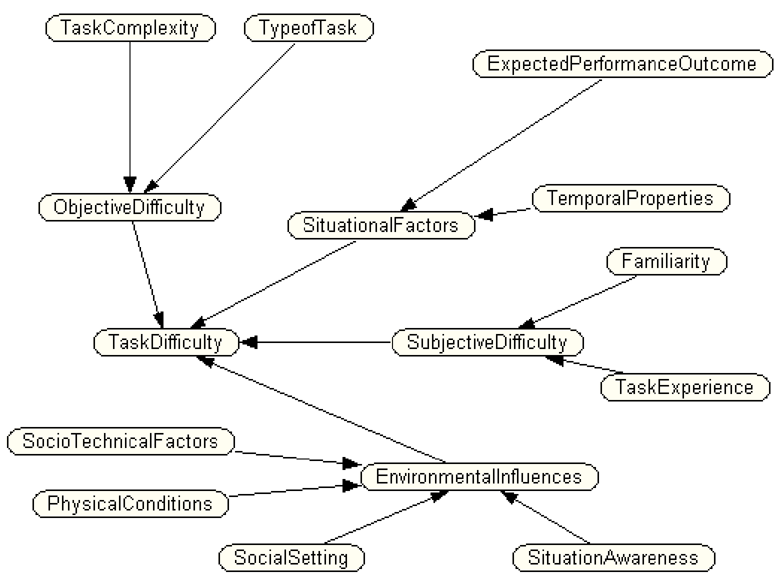


Figure 3: The BBN-based Model for Inferring the Task Difficulty

4 Experiment

The effects of mediating interruptions on user's performance were tested in a formal experiment that involved dual-task scenario with varying frequency of interruption. The effectiveness of the model was measured in terms of improved user performance, and decrease of the disruptive effects of interruption on a socio-emotional level, such as: feelings of stress, distraction, annoyance, frustration, etc. A detailed description of the results of the objective measures analyses is presented in (Gievska & Sibert, 2004), so the discussion of these results in this paper will be limited. The effects of mediating interruption on the qualitative aspects of the interaction are presented in the following sections. It was anticipated that users will be more satisfied with computer-mediated coordination of interruption than with immediate coordination method (the condition with no interruption control). It was anticipated that users will perceive interruptions as being less stressful, annoying, frustrating, and distractive when they are mediated than when they are not.

4.1 Participants and Apparatus

A total of 24 volunteers, 12 females and 12 males, were run as participants in this study and were not compensated for their effort. The participants were a mix of students and professionals, between ages of 18 and 41. A background questionnaire has been administered to each participant at the beginning of the experiment. They were asked to rate their experience and proficiency in areas such as computer use, planning, multitasking, video games, etc.

All practice and experimental trials were run on Macintosh iMac, running Mac OS 9.0.4. The built-in VGA monitor with 1024x768 pixel resolution and 16-bit color was used as the display. The interruption mediator was implemented using Lisp 4.4.3.

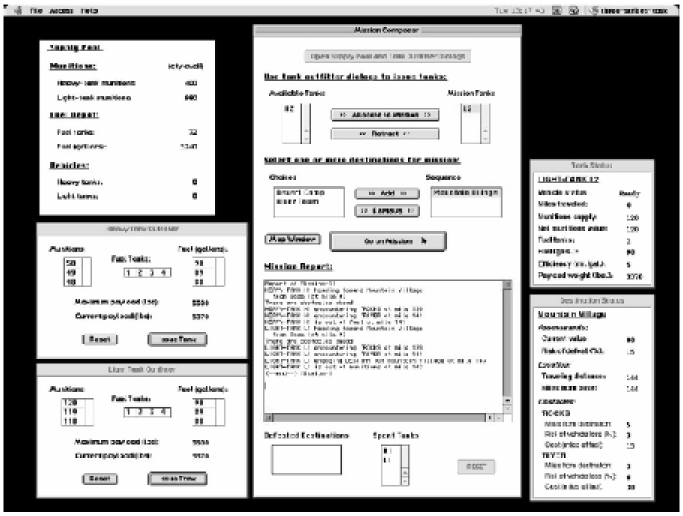
4.2 Experimental Design

The independent variables in the experiment were Coordination Method and Frequency of Interruption, each set at two levels in a full factorial design, with standard ANOVA used for the analyses. Coordination methods were immediate and mediated, and frequency was set to nine and twelve interruptions per 15-minute session. Within-subject difference in task performance between the condition with immediate, and computer-mediated coordination of interruption under different frequency of interruption was analyzed. Data analyses were conducted within-subject and within-context to compensate for the variability caused by differences between participants or other contextual factors. The number and the type of situations in which an interruption occurs were experimentally controlled (within-context), while still preserving the frequency of interruptions randomly distributed across condition. Interruptions were generated according to a certain scheme, which has been designed in such a way that the targeted situations and interruption points could be ascertained. The experiment employed a balanced Latin square design to counterbalance the order effect. Male and female users were randomly assigned to one of the four order groups.

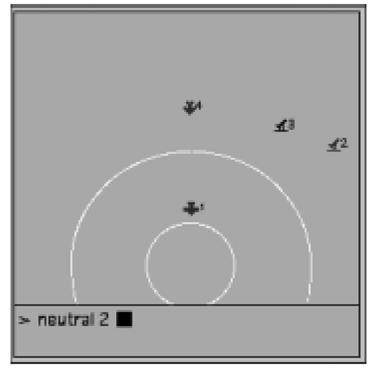
4.3 Dual-task Scenario

As a test-bed application, we used a two-task experimental system developed at the US Naval Research Laboratory (NRL) in Washington D.C that has already been used for interruption-related studies (Trafton et al., 2003). Two experimental tasks bear high resembles to military-like computer games and simulations. There also appear to be motivational attraction of using game-like tasks; users know right away when they are making progress and get satisfaction from this success at a challenging task. The experimental dual-task could also be seen as simplified scenario of people performing resource-allocation (planning) task, while responding to interrupting task generated as random points. The underlying assumption was that once interrupted, the primary TS task is resumable after the point of interruption.

The primary (interrupted) task is a resource-allocation task named Three-Strike (TS). The objective is to attack and destroy three destinations utilizing available resources, ten heavy and ten light tanks and a certain amount of fuel and munitions. On their missions, users are encountering resistance from differing locales and different kinds of obstacles based on a stochastic model of the TS task. User's interactions are limited to mouse point-and-click events with several dialog-box style windows presented in Figure 4 a.



a) Primary Task Interface



b) The Interface of the Interrupting Task

Figure 4: Dual-Task Scenario

The interrupting task is Tactical Assessment (TA) task presented to a user at random points while she is performing the primary task (Fig. 4 b). In this task, the user plays the role of a fighter aircraft pilot looking at a radar-screen-like display where three types of moving objects appear. The objective is to indicate whether the approaching object is hostile or neutral. The decision of the "pilot" is assisted by an intelligent-automated component that colors the objects as red (hostile), blue (neutral) or yellow (when the assessment can not be made). The user is to confirm the hostile/neutral indications or give the appropriate classifications of the yellow objects based on a set of rules. User's interactions consisted of two keystrokes per object using the right-hand numeric key pad. The first keystroke was the object classification (5-neutral, 6-hostile) and the second was the track number that appears next to each object.

At times of interruptions, the primary task is paused, the computer screen clears, and the window of the interrupting task appears on a black background totally obscuring the primary task windows. The interrupting task is considered "finished" when the last flying object is classified, or the last object disappears when the timeout expired. Then, the control switches back to the primary task. At that point, participant's attention returns to the interrupted task; the primary task is restored to the state at the time of interruption. Participants were instructed to attempt performing both experimental tasks effectively.

4.4 Treatments and Procedure

The experiment involved testing participants under four treatment conditions and their short description follows:

Treatment 1: "Immediate 9" - The interrupting task was generated at nine random interruption points, and presented to a user immediately after generation (no control of interruption).

Treatment 2: "Mediated 9" - The primary task was interrupted nine times at most appropriate interruption points as selected by the interruption mediator. The system adjusts in such a way that a user is not interrupted during interruption points sensitive to interruptions, deferring the interruption task for the next appropriate moment.

Treatment 3: "Immediate 12" - This treatment condition is similar to treatment 1 with twelve interruptions presented immediately to the user at random generated points.

Treatment 4: "Mediated 12" – The primary task was interrupted twelve times at most appropriate interruption points as selected by the interruption mediator.

Twenty four participants were run through the experiment. Each participant was instructed and trained on the primary and the interruption task, independently, followed by a 15 min. practice trial in the context of interruptions (dual-task scenario). The practice session lasted for approximately 1 hour including the time for completing the background questionnaire. After short break, the participants concluded four 15-minute trials of the TS task interrupted by a number of times, either 8 or 12, by the interruption task. Subjective exit questionnaires were distributed at the end of the experimental trials to measure the subjective level of stress, motivation, distraction and anxiety experienced by a user during all four treatment condition. At the conclusion of the experiment the participants were debriefed. Each participant spent approximately 2 hours 30 minutes.

5 A Summary of the Objective Measures Results

The results of the formal experiment, described in detail in (Gievska & Sibert, 2004), have confirmed the hypothesized performance advantage of mediating interruptions compared to condition with immediate coordination. To measure effectiveness, a variety of performance metrics were used. Domains selected for measurement were those reported to be affected by interruption (e.g., correctness, timeliness, completeness, disturbance). Primary task resumption time defined as time from completing the interrupting task (restoring the TS window) to resuming the primary task was chosen to measure the impact of interruption on user's performance on the primary task. User accuracy (i.e., percentage of correct object classifications) and reaction time on the interrupting task were analyzed to examine the effect of interruption on the interrupting task performance. Several types of errors were also defined for a more exhaustive measure of correctness when performing the interrupting task.

The analyses of variance have enabled the effect of coordination method and interruption frequency on the primary task resumption time to be quantified and have given statistically plausible results. Users receiving immediate interruptions took significantly more time to resume the primary task than users receiving computer-mediated interruption $F(1, 23) = 48.707$, $p < 0.00001$. The results also indicated that as the level of interruption frequency increases, participants were more likely to trade-off considerate planning with speed, therefore resumption times decreased $F(1, 23) = 9.85$, $p = 0.0046$.

Three out of five performance indices defined for the cognitively simpler interrupting task were not affected by coordination method or varying frequency of interruption. Neither coordination method $F(1, 23) = 1.675$, $p = 0.215$, nor interruption frequency $F(1, 23) = 0.244$, $p = 0.878$ influenced user's accuracy in performing the interrupting task. The coordination method did not significantly affect users' speed. The average time needed to classify an object was consistent across conditions $F(1, 23) = 0.196$, $p = 0.665$. The lack of differences in these performance metrics may in part reflect the fact that the interrupting task was short, less cognitively-demanding task consisting of independent and unrelated trials.

Incorrect object classifications were approximately evenly distributed across all four conditions. Neither coordination method, $F(1, 23) = 1.245$, $p = 0.276$, neither frequency of interruption, $F(1, 23) = 2.735$, $p = 0.112$, showed significant difference. A more accurate and realistic indicator of user's success on the interrupting task in the dual-task scenario was the examination of two other types of errors. The results have shown that the improved performance on the interrupting task during mediated conditions was related to two types of errors, the number of missed objects and manipulation errors. The coordination method had significant difference on the number of manipulation errors, $F(1, 23) = 4.744$, $p = 0.039$, and the number of objects not classified, $F(1, 23) = 12.951$, $p = 0.0015$.

The comparison of the number of manipulation errors between conditions suggests that selecting more appropriate moments for interruption during mediated condition contributes significantly to providing omission-free environment. In addition, participants classified more objects i.e., achieved better completeness on the interrupting task in the mediated conditions. In other words, user's success when performing the tactical assessment task depends on omissions (unintentional mistakes) and missed opportunities rather than just the number of correct and incorrect classifications.

6 Results of the Subjective Measures Analyses

The exit questionnaire administered at the conclusion of each experimental trial was a 15-item self-reported assessment of subjective perceptions and feelings experienced overall and during four different treatment conditions. Participants were asked to rate their overall feelings of boredom, motivation, and anxiety on a five-point scale from "1 - least" to "5 - most". A set of questions elicited user's ratings of the four experimental trials in terms of how stressful, and distractive were interruptions, and how annoyed and frustrated they felt in each particular treatment. There were questions that elicit user's perceptions of her success in performing both tasks, and of the workload experienced during experimental tasks. The participants were also asked to rate the effectiveness of mediating interruptions. An important measure, preference, was left out, and replaced with satisfaction, which was thought to be appropriate. The rationale was that differences between immediate and mediated coordination, although detectible for some participants, were very subtle and passed unnoticed by overwhelming majority of the participants. The questions concerning individual treatments were administered after each experimental treatment to avoid potential confusion, observed on the part of the participants during pilot trials. Participants experienced difficulties in recalling early treatments and distinguishing between treatments. These questions were asked separately in order to obtain absolute estimate of the effects of interruptions in each treatment condition. A five-point Likert scale was used for this set of questions. The participants were asked to state whether they perceived any variations in the control and frequency of interruptions, and whether they would recommend this type of mediated control as a way of lessening the negative effects of interruptions. They marked their answers by circling the Yes or No answers.

The users' answers have confirmed that the experimental tasks were a good choice against boredom by keeping the motivation at acceptable level through the experiment. All participants indicated that they experience very little anxiety during the experiment. This pattern of consistency found in the overall metrics (i.e., anxiety, boredom and motivation) did not apply to the rest of the ratings. On the contrary, participants showed great variances in their opinions and ratings. Within-subject analyses of variance (ANOVA) were used to measure the significant results on the subject topics covered in the questionnaire. The purpose of the ANOVA analyses was to test the Hypothesis saying that users would be more satisfied with mediated coordination of interruptions over no coordination. Moreover, it was anticipated that they may have found it less stressful, and the interruptions less distractive and annoying, if interruptions were carefully coordinated to appear at appropriate (less sensitive) points.

Table 1 shows the significance of the ANOVA results. Five out of eight subjective metrics that were used to compare participants' opinion for different treatment conditions showed significant results. The results show consistency in some data obtained as self-reported measures, in particular, the perceived workload, feelings of distraction, annoyance, frustration, and the perceived success in the interruption task performance. The performance indices for stressfulness, satisfaction, and easiness in resuming the primary task were not significant.

People were more consistent in reporting differences in the level of annoyance (Fig. 5) and frustration, and these subjective effects were statistically significant. The effect of the coordination method on the level of annoyance was $F(1, 23) = 11.717$, $p = 0.0023$, while the frequency effect was $F(1, 23) = 28.279$, $p < 0.00001$. There was no significant interaction. The effects of the independent variables on the level of frustration were revealed with $F(1, 23) = 43.793$, $p < 0.00001$ for the coordination method and $F(1, 23) = 50.243$, $p < 0.00001$ for the interruption frequency.

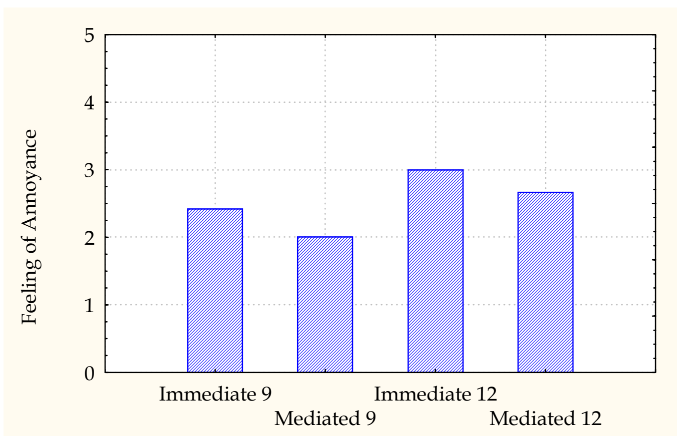


Figure 5: Means of Annoyance Separated by Conditions

Statistical analyses revealed a significant effect for distractiveness as shown in Figure 6; the frequency effect was revealed with $F(1, 23) = 85.773$, $p < 0.00001$, while the coordination method was found not significant, $F(1, 23) = 0.0022$, $p = 0.883$. The lack of significant effect of the coordination method could be explained by the fact that the participants were performing the cognitively-demanding task in a presence of frequent interruptions that increased the likelihood of considering all treatment conditions as particularly distractive. The interaction effect was also not significant, $F = 0.223$, $p = 0.641$.

The effect of coordination method on the cognitive workload was significant for both independent factors, coordination method $F(1, 23) = 86.078$, $p < 0.00001$, and interruption frequency, $F(1,23) = 9.471$, $p = 0.0053$, with significant interaction effect, $F = 14.024$, $p = 0.001$. The means of cognitive workload metric for each treatment condition is presented in Figure 7.

We could trace inconsistency in participants' explicit ratings of the level of stressfulness during different conditions. It appears that differences between coordination methods were masked by the overall impression of working in the context of interruptions; there was no significant effects found for either coordination method, F (1, 23) = 1.2, p = 0.285, or interruption frequency, F (1, 23) = 0.5188, p = 0.479. The fact that participants performed the dual-task in experimental conditions could also be used to explain this outcome. In a real-life situation, people might experience varying levels of stress in different treatment conditions.

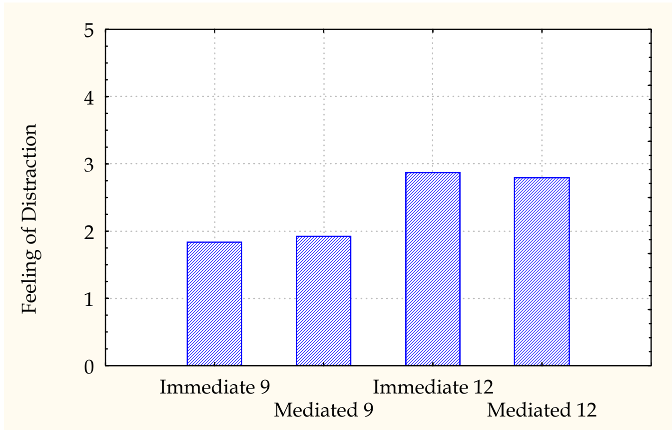


Figure 6: Means of Distractiveness Separated by Conditions

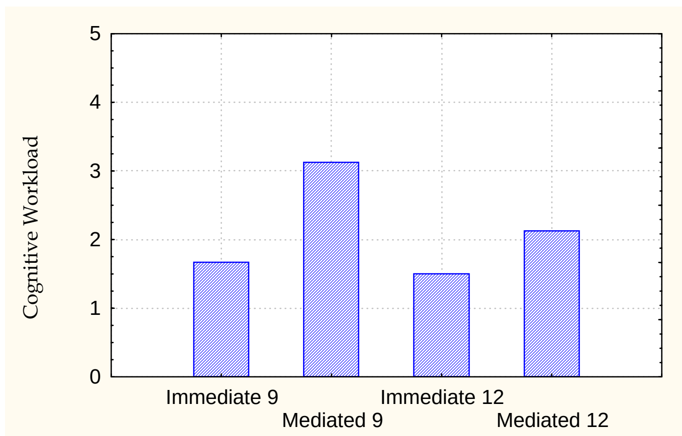


Figure 7: Means of Cognitive Workload Separated by Conditions

It was intuitively assumed that participants' satisfaction would be greater with mediated coordination method as the gains in efficiency would cause this type of coordination to be preferred. The lack of significant effect suggests that individual satisfactions are not determined by efficiency per se. One interpretation to this result is that participant's satisfaction is more influenced by the qualitative aspects of interaction; in this particular case, feelings of frustration, stress, and annoyance seemed to interfere with the participants' perceptions of accomplished performance.

An interesting trend was observed when participants were asked how easy was to resume the primary task. Despite the fact that participants were more effective during mediated conditions in terms of achieving shorter resumption times, participants reported similar ratings for their success in mediated as for immediate conditions; no significant main effect and no interaction were found. Closer inspection of data revealed that in nearly all cases the participants underestimated their success. Based on some informal inquiries, it may be speculated that the participants recalled the difficult situations (i.e., longer resumption times) better than (more frequent) satisfactory values.

Participants reported better estimates of their success in performing the interrupting task, though we should remember that there was no significant difference in many of the TA-related performance variables across conditions. The significant effect for coordination method was observed, F (1, 23) = 4.744, p = 0.039, although there was no significant effect of the frequency of interruption. No interaction between the coordination method and the interruption frequency was found.

Table 1: ANOVA Analyses of the Main Effects and Interactions for the Subjective Measures. Significant Differences are Shaded.

Subjective Measures	F	P	P<0.05
Satisfaction			
Coordination Method	0.706	0.41	No
Frequency of Interruption	1.78	0.195	No
Interaction Effect	0.031	0.862	No
Stress			
Coordination Method	1.865	0.185	No
Frequency of Interruption	1	0.327	No
Interaction Effect	3.286	0.083	No
Distraction			
Coordination Method	0.022	<0.00001	Yes
Frequency of Interruption	85.7	0.883	No
Interaction Effect	0.223	0.641	No
Frustration			
Coordination Method	43.793	<0.00001	Yes
Frequency of Interruption	50.243	<0.00001	Yes
Interaction Effect	3.055	0.09	No
Annoyance			
Coordination Method	11.717	0.0023	Yes
Frequency of Interruption	28.279	<0.00001	Yes
Interaction Effect	0.12	0.732	No
Perceived Workload			
Coordination Method	86.078	<0.00001	Yes
Frequency of Interruption	9.471	0.0053	Yes
Interaction Effect	14.024	0.0011	Yes
Perceived TA Success			
Coordination Method	4.744	0.039	Yes
Frequency of Interruption	0.091	0.766	No
Interaction Effect	1.906	0.181	No
Easy to Resume			
Coordination Method	1.588	0.22	No
Frequency of Interruption	0.056	0.814	No
Interaction Effect	1.81	0.191	No
Effectiveness of the Mediated Coordination			
Frequency of Interruption	4.77	0.039	Yes

7 Discussion of Results

The presented results suggest that mediated coordination of interruption was effective in decreasing some disruptive effects associated with interruptions. The effectiveness of the computer-mediated coordination method was demonstrated on five out of eight subjective measures. The participants tended to report higher levels of distractions, annoyance, frustration, and workload under non-coordinated (immediate) conditions. While admitting that users were less affected by interruptions on a socio-emotional level in mediated conditions, one can expressed concerns about the lack of user's satisfaction with the way interruptions were handled. There was inconsistency between the subjective measure of satisfaction, and user's responses to the question, which asked the participants to state whether they would recommend this type of mediated control as a way of lessening the negative effects of interruptions. Nearly 64% of the participants reported that they would recommend the mediated solution as an effective way of decreasing the negative effect of interruptions. We should expect that people, who recommend the employed mechanisms, would be highly satisfied with the way the system was handling interruption. On the contrary, users' responses were in the lower levels of the five-point Likert scale. These results support the view that

qualitative aspects of human computer interaction are very often more important than the commonly assumed performance factors of efficiency and task success.
The results of the statistical analyses of the subjective measures defined to measure the qualitative aspects of computer-mediated coordination could be summarized with the following statements:

- People experienced (reported) less cognitive workload under mediated condition and under lower interruption frequency.
- People were less distracted when interruptions were mediated (i.e., by avoiding interruptions during interruption-sensitive tasks).
- People were more annoyed and frustrated when performing in conditions without coordination of interruptions, and when the number of interruption per session was higher.
- People were better at judging their own success on the interruption task in the mediated conditions than in the immediate conditions.

User's cognitive state when performing complex task is extremely fragile, and sensitive to external interruptions. The disruptive effects of interruptions pose a serious consideration, especially in time- and safety-critical systems. The experience gained in this research that mediating interruptions supports users in performing complex tasks, is not likely to be unique, and we may believe that other domains and systems with similar types of tasks would also benefit from applying the proposed interruption model.

8 Conclusions

In this paper, we have discussed the results of an exploratory user study, conducted to empirically measure the quantitative and qualitative the proposed framework for a computer-mediated coordination of human interruptions in human-computer interaction. The proposed conceptual model is based on the new Interruption Taxonomy and uses Bayesian Belief Networks as a decision-support aid for mediating interruptions. The results of the analyses of the subjective measures suggest that mediating interruption could be used as a way of increasing the perceived quality of interaction by lessening the feelings of distraction, frustration, and annoyance. People's appraisal of being overloaded was significantly higher in immediate conditions compared to conditions with mediated control. The results of the experiment are exciting because they have shown that multiple task-related factors could be integrated and used as a basis for mediating interruptions to lessen the disruptive effects of interruptions on users' emotional states.

References

Bailey B. P., Konstan J. A., and Carlis J. V. (2000). Measuring the effects of interruptions on task performance in the user interface. *Proc. of SMC 2000*, IEEE. 757-762.

Cutrell E. B., Czerwinski M., and Horvitz E. (2001). Notification, disruption, and memory: Effects of messaging interruptions on memory and performance. *Proc. of INTERACT 2001*, 263-269. IOS Press.

Gillie, T., & Broadbent D. (1989). What makes interruptions disruptive? A study of length similarity and complexity. *Psychological Review*, 50, 243-250

Gievska, S., & Sibert, J. (2004). Empirical Validation of a Computer-Mediated Coordination of Interruption. *Proc. of OZCHI 2004*.

Horvitz, E., Jacobs, A., and Hove, D. (1999). Attention-sensitive alerting. *Proc. of IUI '99*, 305-313.

Jameson, A., Schafer, R., Weis, T., Berthold, A., and Weyrath, (1999). T. Making systems sensitive to the user's time and working memory constraints. *Proc. of IUI '99,* 79-86.

Latorella K. A. (1998). Effects of modality on interrupted flight deck performance: Implications for data link. *Proc. of HFES*.

McFarlane D. C. (2003). Comparison of four primary methods for coordinating the interruption of people in human-computer interaction. *Human-Computer Interaction*, 17, 1, 63-139.

Trafton J. G., Altmann E. M., Brock D. P. and Mintz F. E. (2003). Preparing to resume an interrupted task: Effects of prospective goal encoding and retrospective rehearsal, *International Journal of Human-Computer Studies*, 58, 583-603.