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# Effects of Interruptions on the Computerised Clerical Task Performance

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**Abstract.** This paper presents results of an exploratory experimental study of the effects of interruptions on the execution of computerised clerical tasks, provides classification of interruption handling strategies, and gives some recommendations for the user interface design for frequently interrupted work conditions.

**Keywords:** interruptions, computerised office work, user interface design

## 1. Introduction

With recent trends in labour requirements moving from manual labour to cognitive oriented tasks, the need for understanding of the factors that influence skilled cognitive task performance has never been greater. One of such factors are interruptions during performing computer aided mental tasks. "Interruptions" are defined as events which result in the suspension of an ongoing activity. Typical for interruptions is that the activity is resumed after a certain lapse of time. Thereby, interruptions are distinguished from "disruptions" which are defined as events leading to the cessation of an ongoing activity, without taking up the execution of the task in a short time.

We have chosen interruptions as a topic for study for a number of reasons. First, due to the fact that computerised mental work places high demands on the cognitive system, it is likely that this type of work is very sensible to interruptions. For example, Reason (1990) distinguishes a particular class of errors called "omissions following interruptions", which are related to a failure in the necessary attentional monitoring. Second, interruptions appear to be typical for the working conditions of many occupations in which computerised mental work predominates (e. g. office workers, secretaries), which makes it interesting to find out how people deal with them while carrying out their duties. Third, interruptions may negatively affect the person's state and performance, thereby exerting an influence on workers' well-being and productivity. A final, practical consideration has been that interruptions represent an aspect of mental work with relatively high accessibility. Interruptions can be observed in practice, but they can also be evoked and studied under controlled conditions in a laboratory setting. This opens the possibility of doing laboratory research with great ecological validity, and testing methods and findings used in the laboratory under real-life conditions.

The ultimate goal of the study was to propose cognitive engineering solutions to the user interface of computer systems aimed at preventing negative consequences of interruptions.

The experimental study has been conducted jointly by HCI Laboratory, Moscow State University (Russia) and Work and Organization Research Centre, Tilburg University (The Netherlands). Here we report results obtained by Russian team.

## 2. Background

There is no uniform paradigm for the study of interruptions during work processes. In the past, interruptions have been studied in various ways and with diverging objectives. The research on the effects of interruptions on the mental work dates from classic Zeigarnik (1927) experiments. Zeigarnik's experiments became the starting-point to a massive research into the effects of interruptions on the non-computerised mental and physical tasks (see Heckhausen (1980) for review).

However, up to now there exist only several studies with heterogeneous theoretical background that reveal particular aspects of the influence of interruptions on performing computerised mental tasks.

A number of studies have been conducted from a stress perspective (Johansson and Aronsson, 1984; Aronsson and Strömberg, 1993; Carayon and Hajnal, 1993; Yang and Carayon, 1993). It has been shown that stress and mental strain occurred in association with delayed response times in the computer system and unforeseeable interruptions of system operation. Interruptions were regarded as naturally occurring events (computer slowdowns and breakdowns, i. e. problems that are beyond the operator's control) in these studies. The nature of interruptions and their effects on the cognitive processes were not research objective in these cases.

Gillie and Broadbent (1989) have conducted several experiments in order to study the phenomenon of everyday experience that some interruptions are disruptive while others are not. To that end they manipulated the length, the complexity, and the similarity to the task of the interruptions. The main task they used was a computer-based adventure game, where subjects need to issue commands to the computer in order to achieve certain goals. During this game, subjects had to "take" several items (bread at the baker store, meat at the butchers', and so on). The list of items that needed to be taken varied from five to seven items (manipulation of memory load). The interruptions were disturbances by secondary tasks. These tasks varied from simple mental arithmetic tasks to a free recall task, and also the length of the interruption was manipulated. Authors compared the time spent on each problem before and after the interruption and the amount of requests for help. The results suggest that the length of interruption as well as the opportunity to control the point at which the main task is stopped and the interruption begins, are not important factors in determining whether or not an interruption will disrupt subsequent performance. Rather, the nature of the interruption (in terms of similarity to the continuing task) and the complexity of the interruption (in terms of the amount of information processing or memory storage required) seem to determine which interruptions will be disruptive and which will not.

Several researchers have manipulated interruptions to compare different interfaces for calculators and computer databases (Kreifeldt and McCarthy, 1981; Field, 1987). Their interest was to find out how easily people can take up their task when they left off after an interruption when using different interfaces. The performance of two groups of subjects was compared after completion of a task with different interfaces. Although the design of the experiments did not allow control over the moment of interruption, and in general the design was not directed to study the interruptions, Field claims to have shown a significant disruptive effect of the interruptions on users' post-interruption activity.

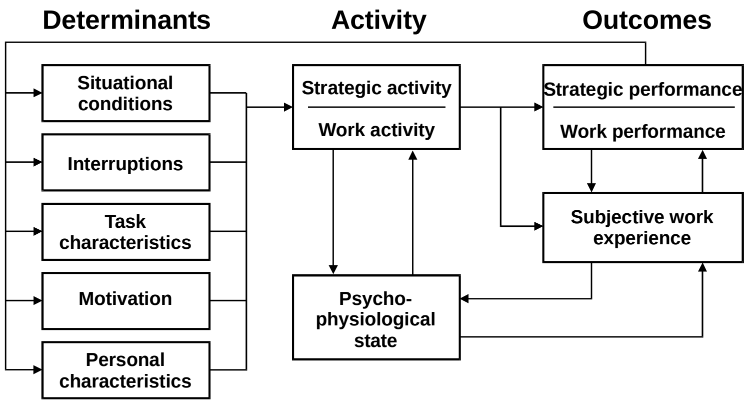


*Figure 1. Conceptual model underlying the study.*

In the conceptual model of the study presented in this paper, developed in the context of a broader research programme (WORC, 1992), three sets of variables are taken into account (see Figure 1):

(1) Variables that refer to determinants of work activity, i. e. various situational working conditions, interruptions, task characteristics, motivation, and personal characteristics.

(2) Variables that relate to activity, i. e. strategic activity and work activity, and the psychophysiological state.

(3) Variables that relate to the outcomes of work activity, i. e. strategic performance, work performance, and subjective work experience.

Regarding activity, a distinction was made between work activity *per se* and strategic activity. We assume that people carry out certain activities that do not directly result in the completion of work tasks, but are conductive to work activity by creating and/or maintaining the necessary conditions for it. Neutralising interruptions or other disturbances, ensuring the supply of work material or information, can be mentioned as examples of strategic activity. Work activity and strategic activity are supposed to imply the use of the same functional systems. Their distinction refers exclusively to the goal of the activity, i. e. either the performance of tasks, or the creation of appropriate conditions for task performance.

## 3. Research questions

The conceptual model presented above leads to the formulation of several hypotheses:

(1) Interruptions affect task performance depending on the nature of interruption (duration, complexity): (a) when interruptions occur more time is needed for completing the task; (b) these effects are stronger for complex interruptions than for simple interruptions.

(2) Interruptions may invoke additional compensatory activities (strategic activities), directed at either immunisation (taking away the influence of the disturbance) or recovery (facilitating the resumption of the work activity).

## 4. Experiment

### 4.1 Design

31 subjects performed a computer-assisted task (text editing) bearing high similarity to real-life office tasks during two pairs of experimental sessions on two days. All subjects had experience in text processing tasks. The experimental task was to make corrections in a computer file, based on a hard-copy version of a text containing hand-written corrections. During the experimental sessions subject's work activity was disturbed by a number of interruptions (phone calls). Interruptions were made according to a certain scheme which has been designed in such a way that the effects of the presence (vs. absence) and complexity of interruptions could be ascertained. Interruptions affected three types of editing operations: (a) regular editing (making simple corrections) – *regular*; (b) typing in new text – *new*; (c) moving a block of text to a new location – *move*. Interruptions were made in predefined points, e. g. operation *move* (which consists of several sequential actions: select block – cut block – find its new location in the paper-printed brochure – find the same in the computer file – paste block) was interrupted after cutting the block of text, but before pasting it from the clipboard. During the telephone call the subject was told to perform another task, referred to as "interruptive task".


*Figure 2. Interruption: a frame from the experimental video transcript.*

The independent variables were the presence/absence of interruption and the complexity of interruption (two levels of interruption complexity were investigated: simple and complex interruptions). An example of simple interruptive task was to find the telephone number in the telephone book. Complex interruptive task was to correct all the typing faults in a short article. The dependent variable was editing latency (time to complete particular editing operation such as typing in new text or moving a paragraph to a new location).

### 4.2 Apparatus and Materials

The experiment took place in a simulated office environment. The 40 $m^2$ laboratory was divided into two rooms by a wall. One room has been equipped as an office workplace (with furniture, personal computer, intercom telephone), while the other was used as a control room. At the office location a movable tripod video camera was placed to monitor the subject. The video signals from the camera and from computer screen were routed to a video mixer in the adjacent control room. From this room the experimenter controlled the experiment and watched the mixed video signal (view of the subject plus contents of the subject's computer screen) via the video monitor. The mixed video signal was also recorded on a VCR (see Figure 2 for an example of the experimental video transcript). An intercom phone was used for communication between the control room and the office location.

### 4.3 Procedure

Four passages for editing were randomly selected from four unpublished psychological manuscripts in order to ensure novelty.

To begin, the experimenter gave written instructions to each subject explaining the nature of the task:

*You are participating in a research on the use of modern offices. During this research you have to perform some simple office tasks. We are interested in how people perform their work in the present, modern, offices. All data are only accessible to the researchers. The analysis of the data will be done anonymously: your name will not be used. So, you are sitting in an office with work-units, computers and piles of papers. Your colleagues are not in today, so you are the only one who is working today. The task you have to perform is an office task: corrections in a text input to the computer. You see the non-corrected text is on the computer screen, the corrected text, which you have to input, is on paper. You have to process all corrections and assignments. During your work, the instructor may call you by phone and ask you to do some additional tasks. When you have finished the task, you can call the instructor by phone.*

Instructions for simple interruptions were:

*Find the telephone number in the telephone book.*

or

*Find the English equivalent for the Russian term in the vocabulary.*

Instruction for complex interruptions was:

*In the drawer next to you, you will find a short article. But this article has not been corrected yet. Can you mark all the typing faults. When you have finished this you can continue with your work.*

The subjects were instructed to make a phone call to the experimenter when they had completed their task. No *a priori* time limits for completing the tasks were given, and subjects could work at their own pace. Experimental sessions took approximately 40 minutes each, depending on the individual speed.

## 4.4 Times measured and time intervals calculated

The general scheme of times measured in the experiment and time intervals calculated for data processing is presented in Figure 3.

### 4.4.1 Times measured

$T_{start}$ and $T_{end}$: start and end of operation. $T_{start}$ and $T_{end}$ were not registered for *regular* operations, because it is very difficult to determine start and end of such operations, especially when they are very short in time and involve only several keystrokes. However, everything is clear with coding $T_{start}$ and $T_{end}$ for operations *new* and *move*. Operation *new* starts with first letter of new paragraph and ends with final dot. Operation *move* starts with selection of first letter of the block being moved and ends with *Paste* command.

Ringing of the phone ($t_{ring}$).

Picking up the phone has been considered to be the start of the interruptive task ($t_{start}$). The last visible operation of the interruptive task has been considered to be the end of the interruptive task ($t_{end}$).

Stop of performing the main task, i. e. full switch to the interruptive task ($T_{stop}$). $T_{stop} \geq t_{start}$.

Resumption of the main task ($T_{resumption}$): return of subject's attention to the main task after finishing the secondary task.

Point of continuation ($T_{continuation}$): first action in continuation of the main task after interruption.

### 4.4.2 Time intervals calculated

Operation time ($T_{operation} = T_{end} - T_{start}$): time spent to perform the operation including interruptive task.

Duration of interruption ($t_{interruption} = t_{end} - t_{start}$): time between picking up the phone and the last visible operation of the interruptive task.

Returns to main task ($T_{returns}$): sum time of returns to the main task while working on the secondary task.

Break-between ($T_{break\text{-}between} = T_{resumption} - t_{end}$): time between the last visible operation of the interruptive task and starting the resumption of the main task.

Orientation ($T_{orientation} = T_{continuation} - T_{resumption}$): time between starting the resumption of the main task and the first action in continuation of the main task.

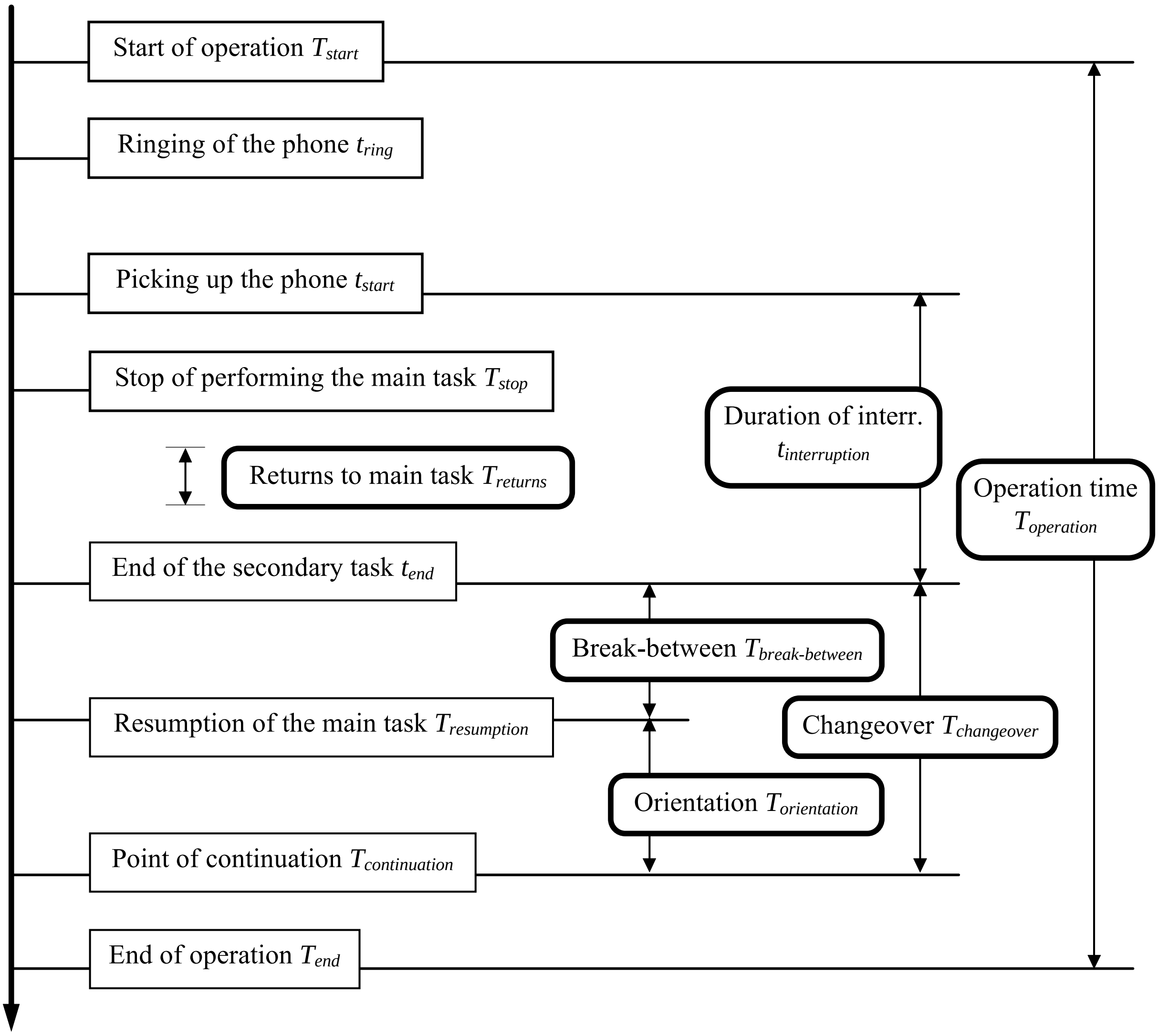


*Figure 3. Times measured in the experiment and time intervals calculated for data analysis.*

Changeover ($T_{changeover} = T_{break\text{-}between} + T_{orientation}$): a sum of break-between and orientation.

Net operation time ($T_{net} = T_{operation} - t_{interruption} + T_{returns}$): operation time minus duration of interruption plus returns to the main task.

Net operation time minus time of orientation ($\Theta_{net} = T_{net} - T_{orientation}$).

Measure calculated only for operation *new:* speed of typewriting ($S_{typewriting}$). Since the length of new paragraphs being typed in was different for four text passages used in the study, we calculated the speed of typewriting as a measure of subjects' performance and used this measure in comparisons between experimental conditions.

## 5. Results

### 5.1 Effects of presence of interruptions on task performance

Only operations *new* and *move* were included in the analysis.

### 5.1.1 Operation *new*

Paired-samples *t*-test showed no significant effect of the presence of interruption on the speed of typewriting ($S_{typewriting}$).

### 5.1.2 Operation *move*

The ANOVA revealed significant main effect of the presence of interruption on the net operation time ($T_{net}$), $F(1,93)=9.91$, $p=0.0022$.

After obtaining this result, we made an attempt to answer the question why net operation time increases when operation is interrupted. Our working hypothesis was that this increase could be explained by changeover ($T_{changeover} = T_{break\text{-}between} + T_{orientation}$), an additional time interval which appears after interruptive task being finished. Since $T_{break\text{-}between} \approx 0$ in the overwhelming majority of cases we have observed, we might suppose that the increase has been caused by the time of orientation in main task after completing secondary task ($T_{orientation}$). In order to confirm this hypothesis, we conducted the same analysis for the net operation time minus time of orientation ($\Theta_{net}$). Difference between experimental conditions *Yes* and *No Interruption* became nonsignificant. This finding suggests that namely orientation ($T_{orientation}$) is mainly responsible for increase in net operation time ($T_{net}$) if operation is interrupted.

See Figure 4, Figure 5, and Table 1 for a summary of results.

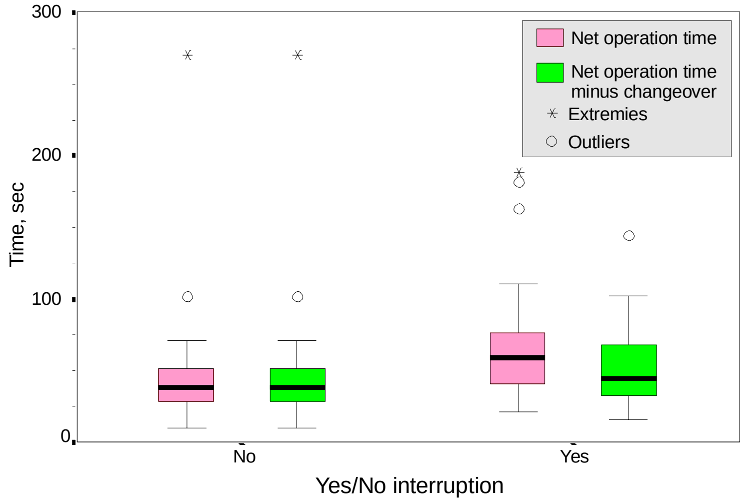


*Figure 4. Effects of the Presence of Interruptions: boxplot of the median, quartiles and extreme values for net operation time ($T_{net}$) and net operation time minus time of orientation ($\Theta_{net}$).*


*Figure 5. Effects of the Presence of Interruptions: means and 95% confidence intervals for net operation time ($T_{net}$) and net operation time minus time of orientation ($\Theta_{net}$).*

## 5.2 Effects of interruption complexity on task performance

Analysis of the influence of interruption complexity on task performance has been conducted only for operation *move* because we had only one observation of operation *new* for experimental condition *Complex Interruption*.

*Table 1. Effects of the Presence of Interruption: t-tests for net operation time ($T_{net}$) and net operation time minus time of orientation ($\Theta_{net}$).*

| | | $T_{net}$ | | $\Theta_{net}$ | |
|---|---|---|---|---|---|
| Interruption | Number of observations | Mean | SD | Mean | SD |
| NO | 59 | 44.2 | 33.9 | 44.2 | 33.9 |
| YES | 36 | 68.2 | 39.4 | 54.6 | 32.3 |
| | | $t = -3.15$<br>$p = 0.002$ | | $t = -1.47$<br>*n/s* | |

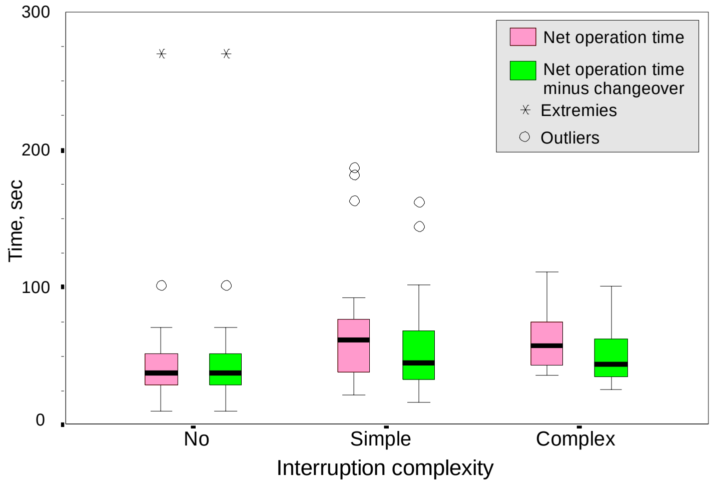


*Figure 6. Effects of Interruption Complexity: Boxplot of the median, quartiles and extreme values for net operation time ($T_{net}$) and net operation time minus time of orientation ($\Theta_{net}$).*

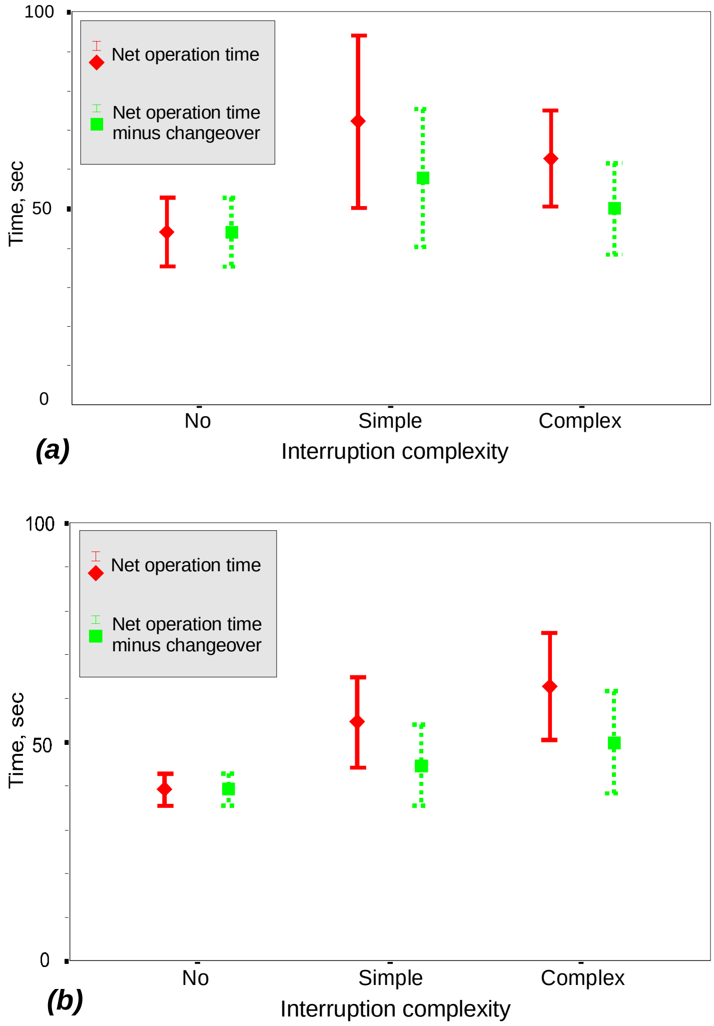


*Figure 7. Effects of Interruption Complexity: Means and 95% confidence intervals for net operation time ($T_{net}$) and net operation time minus time of orientation ($\Theta_{net}$):*
*(a) – extremies and outliers included in the analysis,*
*(b) – without extremies and outliers.*

The ANOVA revealed significant effect of interruption complexity on the net operation time ($T_{net}$), $F(2,93)=5.24$, $p=0.007$. However, Tukey HSD *post hoc* comparison test showed significant difference only between conditions *No Interruption* and *Simple Interruption*. Moreover, the mean value for the net operation time for *Simple Interruption* ($M$=72.2 seconds) was unexpectedly greater than that for *Complex Interruption* ($M$=62.7 seconds). We believe this fact was primarily caused by many extremely high values observed namely for condition *Simple Interruption* (see Figure 6, Figure 7a).

After excluding extremies and outliers from the analysis, the effects of interruption complexity became more smooth and predictable (see Figure 7b). However, even in this case, although Tukey HSD test showed significant differences not only between conditions *No Interruption* and *Simple Interruption*, but also between conditions *No Interruption* and *Complex Interruption*, the difference between conditions *Simple Interruption* and *Complex Interruption* did not reach statistical significance. These findings suggest that only the presence of interruption itself, but not the complexity of interruption, is responsible for increase in editing latencies. (Note that this is asserted only for operation *move*. See next section for the analysis of influence of interruption complexity on the editing latencies of all three operations, *move*, *new*, and *regular*, taken together.)

Similarly to analysis of presence of interruptions, there were no significant effect of interruption complexity on the net operation time minus time of orientation ($\Theta_{net}$). This also supports our hypothesis that namely orientation interval mostly accounts for increase in net operation time when operation is interrupted.

### 5.3 Factors that influence orientation interval

In order to explore factors that may influence orientation interval ($T_{orientation}$), we have calculated Pearson correlations among orientation and duration of interruption ($t_{interruption}$), and among orientation and complexity of interruption. These analyses were conducted for all three types of operations (i. e., *new*, *regular*, and *move*) taken together. Both correlations were significant, $r(102)=0.17$, $p=0.045$ among $T_{orientation}$ and $t_{interruption}$; $r(102)=0.19$, $p=0.027$ among $T_{orientation}$ and interruption complexity.

We have also analysed the dependence of orientation interval ($T_{orientation}$) on the type of interrupted operation. Mean values for $T_{orientation}$ for operations *new*, *regular*, and *move* were 5.4, 8.7, and 12.8 seconds, respectively. The difference was significant between operations *new* and *regular*, $t(38)=-2.15$, $p=0.038$, and between operations *new* and *move*, $t(55)=-3.04$, $p=0.004$.

### 5.4 Interruption handling strategies

Based on the analysis of videotaped subjects' behaviour, an empirical classification of interruption handling strategies (for text editing tasks) has been proposed:

*Strategy [0]: no attempts to continue the main task.* This is the case when subjects fully switch to the secondary task immediately after the phone ring, $t_{ring} \approx t_{start} \approx T_{stop}$. Subjects used this strategy in 24% of cases we observed.

*Strategy [1]: attempts to **complete** the current operation.* Three different types of this strategy [1A, 1B, and 1C] were observed in 31% of cases.

*Strategy [1A]: attempts to complete the current operation before picking up the phone,* i. e. subjects ignore phone rings until they complete the current action or reach some intermediate point in performing it, $t_{ring} < t_{start} \approx T_{stop}$.

*Strategy [1B]: attempts to complete the current operation during the secondary task,* i. e. temporary return to the main task after some work on the secondary task, $t_{ring} \approx t_{start} \approx T_{stop}$, but $T_{returns} \neq 0$.

*Strategy [1C]: attempts to complete the current operation in parallel with secondary task,* e. g. subject speaks to the experimenter and continues editing the text at the same time, $T_{stop} > t_{start}$.

*Strategy [2]: activity on **memorising** the current state of the main task:* two types [2A and 2B].

*Strategy [2A]: solely visual memorisation,* when subject's visual attention is focused on the computer screen during receiving instructions from the experimenter. This was the most frequent strategy that has been observed in 47% of cases.

*Strategy [2B]: use of software or hardware tools for memorisation,* e. g. subject positions mouse cursor on the *Paste* command on the computer screen after cutting a paragraph, and then starts working on the secondary task (memorisation of an action in the main task he should do next after completing the secondary task), or subject positions and keeps his finger on a keyboard in order to memorise the action he should do next (e. g. placing and keeping finger on <*PgUp*> or <*Delete*> key).

*Strategy [3]: activity on **preventing** possible errors by avoiding potential error-prone situations.* 6% of observations involved activities that could be attributed to this strategy. Subjects might deselect marked text before starting interruptive task as they consider situation with selected block of text to be "dangerous", because occasional press of any key may replace any marked text with that key. Another example of this strategy was when subjects performed *Undo Cut* operation or pasted the contents of the clipboard into inappropriate place, returning the block of text from clipboard to the screen in order to avoid possible loss of that block.

## 6. Discussion

Statistical analyses revealed the significant effects of both presence/absence of interruptions and interruption complexity on the editing latencies for cognitively complex editing operations (e. g. moving a paragraph to a new location), while the performance indices for cognitively simple editing actions (e. g. typing in a new paragraph) were not affected by interruptions. In our opinion, a probable explanation to this fact may be that operation *new* is the simplest operation in text editing. It involve neither search and location of some point in the text (as for *regular*) nor include complex sequences of actions and additional mental load caused by the necessity to track the contents of the clipboard (as for *move*). Operation *move* is an example of a "functional thread" (Hix and Hartson, 1993), i. e. a series or group of commands or actions, and effects of interruptions on this class of operations were more dramatic.

Our results also suggest that an additional orientation activity, that appears after completing the secondary task, is mainly responsible for increase in net operation time ($T_{net}$) if operation is interrupted. Nevertheless, mean value for net operation time minus time of orientation ($\Theta_{net}$) for condition *Yes Interruption* was still greater than that for condition *No Interruption* (see Figure 4, Figure 5, Table 1). This consistent but nonsignificant difference may be associated with additional compensatory activities (referred to as "strategic activities") invoked by interruptions and directed at either immunisation (taking away the influence of the disturbance) or recovery (resuming the work activity at an appropriate point). These activities were observed in our experiment, and classified above in the section "Interruption handling strategies".

## 7. Recommendations for interface designers

In our opinion, many contemporary office software systems do not provide users with sufficient support of interrupted work. This is why users have to invent a variety of different interruption handling strategies which help them in performing interrupted tasks. Based on the analysis of interruption handling strategies, we have developed some recommendations for the user interface design for frequently interrupted work conditions:

1. Interface should give the possibility to instantaneously "freeze" the current state of the system in order to prevent occasional damages of the information while working on the interruptive tasks. (Fortunately, *Pause* key is already presented on the conventional keyboards.)

2. Interface should implement complex operations (functional threads) as a single operation and provide efficient on-line assistance to the user in performing complex operations. For example, "Select – Cut – Find new position – Paste", the sequential group of actions for moving a paragraph to a new location should be organised as a single command *Move paragraph* invoking an appropriate "wizard" which guides the user in performing necessary steps. That would avoid or reduce the necessity for using such strategies as [1A], [1B], [1C], [2A], [2B], and [3].

3. Many contemporary system designs depend on the user tracking information which is not immediately available on the display – for example, tracking the contents of a hidden buffer (clipboard) in text processors. When user performs any operation that changes the contents of the clipboard, the state of the system changes, but these changes are not visible on the screen and are only known to the user if he mentally keeps track of the effects of the operation (cf. Blandford and Young, 1995). Frequently interrupted work conditions require more apparent indication of the presence of information in the clipboard (e. g. in a small floating window). Otherwise users may lose clipboard information when their attention is occupied by interruptive tasks.

4. Metaphor of "cooling down text" or "drying up ink" is also suggested. We recommend to use colour coding for indicating recently changed or inserted information on the screen, colours being "cooling down" in course of document-specific time from hot colour (most recently changed information) to cold colour (old or unchanged information). This improvement could reduce the time of orientation in main task after completing interruptive task.

## 8. Acknowledgements

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