Attention & Interruption Management for Systems Design – A Research Overview[1]

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Table of Content

List of Used Abbreviations

Ergon	Ergonomics
Immed.	Immediate
IR	Interruption
IT	Interruption Task
IVIS	In-Vehicle-Information Systems
GAM	Goal-Activation Model
HRM	Human Resource Management
OR	Orientation Reaction
PT	Primary Task
TP	Task Performance
LTM	Long Term Memory
Psy	Psychology
STM	Short Term Memory
TAR	Theory of Activity Regulation
UAIM	Unified Attention Interruption Model
UI	User Interface

Abstract

Surrounded by more and more information systems that call for our attention and time, attention management has become a prime issue for our economy. Already in 1971 Herbert Simon noted: "What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it." And indeed, people today have to relearn to better allocate their attention where it is really needed. System designers need to ensure that machines do not overconsume users‘ attention, killing productivity and reducing well-being. Management has to make sure that information overload and frequent work interruptions do not channel employees‘ attention into unproductive work practices. Yet, our dealings with the attention resource are still marked by infancy. Even though scholars have studied attention all through the 20th century, mostly in the field of psychology, few of these insights are yet knowledgeably embraced by IS, marketing or management scholars today. Instead all disciplines have started, in theory as well as in practice, to develop their own angles of analysis of the attention phenomenon. Many scientific works are studying the same things over and over again, but are using divergent terminology. The goal of this working paper has therefore been to create one view of the dispersed interdisciplinary works created around the attention phenomenon. We identified 482 articles on attention published since the 1920s and structured and organized these into one framework. The framework serves as an overview of what has been found on the attention phenomenon across disciplines and it provides one consistent terminology on which scholars may consider to continue their future work in the field. The main theories of human attention are described as an outset for work in this field. 26 key studies on human attention interruption and incurring effects are then described and presented in the context of this terminology and framework (12 HR and psychology, 11 IS studies and 3 marketing experiments).

1. Introduction

In recent years, there has been an increased discussion of the "attention economy" (Speier et al., 1999). Essentially, this discussion suggests that due to the rising use of IT, money, labor and capital may no longer be the only important resources in modern economies, but other physical resources, such as individuals' time and attention are gaining in relevance (Adamsczyk et al., 2004, p. 271). People in industrialized nations with high IS penetration levels continue using and offloading more and more control and responsibility to IS applications. In private as well as professional environments peoples' roles are changing. More and more they are becoming supervisors of electronic processes outsourced to IT rather then being physical actors themselves. As a result, they are becoming part of IT driven work modes. Just consider modern white-collar 'nomad' workers (The Economist, 2008) organizing themselves with the help of always-on 'push' e-mail systems, distributed calendar systems, e-mail & spam filters, call-routing software, etc. The modern employee is increasingly part of IT driven and IT mediated operations. Consequently, those resources of his are becoming most precious which allow him to function effectively in such an environment. These are his time and his attention.

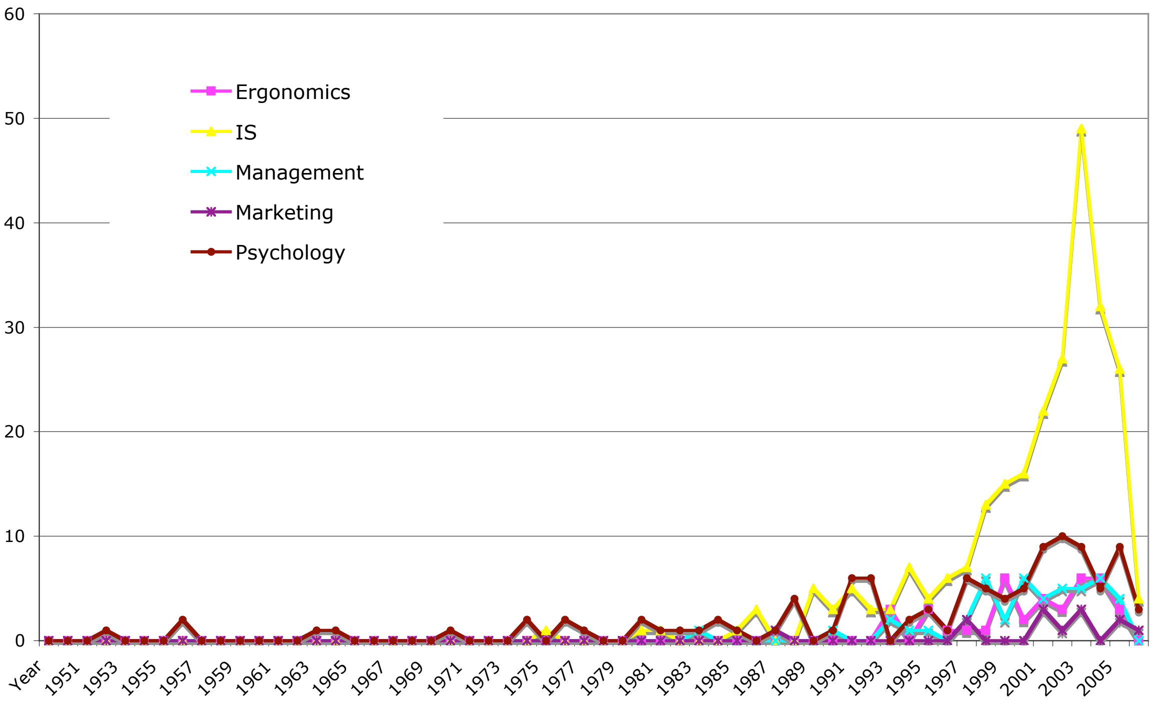
Against this background, scientific work in the area of attention management and a better understanding of the attention resource appears vital. Visionary Herbert Simon raised the importance of attention allocation as an economic issue already in 1971: "What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it." IS scholars recently defined interruptions, and thus a divergence of attention, to be the number one human-computer interaction problem of the future (McFarlane, 1999). This working paper aims to be a contribution to the field of attention research. It contains a research overview of the field accumulated to this time. In doing so it focuses on one specific area of attention studies: the conflict area between attention allocation and interruption. The goal is to give an integrated résumé of the scientific insights we have to date on the effects of interruption on productivity and well-being.

As people increasingly use IT systems in their everyday work and private lives a natural consequence is that these systems need to be maintained, controlled, informed and reacted upon. For example, electronic mail systems are often configured to notify the user immediately of new messages (Jackson, Dawson, & Wilson, 2001). Web-based push technologies send information directly to a worker's PC or Blackberry at specific times of the day or when the computer has been inactive for brief periods. As a result, user attention must be periodically interrupted for an automating application to receive additional guidance from the user (Horvitz, 1999; Maes, 1994), to ask for feedback regarding decisions made on his behalf, or to notify of some peripheral or incoming information (Bailey et al., 2001, p. 1). A survey found that knowledge workers are thus interrupted more than six times an hour (Reuters, 1997, p.12; Pitney Bowes, 1998). This represents a productivity challenge for both employees as well as management. Instant messages (Cutrell, Czerwinski, & Horvitz, 2000) and telephone calls, for example, have been identified as significant corporate time-wasters (Dahms, 1988). Unfortunately, knowledge workers often allow them to take precedence over other more productive activities (Jones & McLeod, 1986; Watson, Rainier, & Koh, 1991).

Some interruptions can even have tragic consequences. The flight crew at Detroit Metropolitan Airport was in the midst of their pre-flight checklist when they were interrupted by air traffic control prior to verifying the status of their flaps (NTSB, 1988). The interruption usurped the crew's attention, the flaps were not checked and this resulted in the subsequent crash of the aircraft (Edwards et al., 1998, p. 665). Griffon-Fouco et al. (1984) showed that the interruption of job performance accounts for more than 15% of all shutdowns of nuclear power plants (Edwards et al., 1998, p. 665). Although interruptions do not typically result in consequences as drastic as these, they do often leave the user at a loss regarding what was being performed prior to the interruption (Edwards et al., 1998, p. 665).

As a consequence of these developments and incidents, more research starts to be devoted to the interruption issue. Figure 1 shows how publications have grown over time in different scientific disciplines. A boost of interest is certainly observable in the information systems research domain. The total number of articles dealing with interruption problems (of which the authors of this paper are aware) is around 500. However, the interdisciplinary nature and youth of the topic has led to intransparency and incompleteness. Different studies use different terms to relate to conceptually similar objects and draw theoretical conclusions based on diverse models from diverse sciences. A more structured approach is therefore needed to quantify and better understand the effects of interruptions across studies and draw meaningful conclusions for system design.

Figure 1: Dynamic Development on Interruption Research



In this paper, we develop a unified interdisciplinary attention interruption model that can serve as guidance not only for system designers working on effective interruption strategies, but also provide a theoretical background for other disciplines. It can help psychologists to understand individuals' interruption reaction. It can supply human resource managers with answers of how to most efficiently design knowledge workers' space and how to increase work place satisfaction. It can give insights to marketers about the effects of interruption on advertisement success.

Interrupts can be of various types and forms which all have different effects on human performance and individuals' psycho-/ and physiological state. The paper begins by creating a broad interdisciplinary taxonomy of interruption, which grasps all the notions and concepts important for attention interruption research. The paper then delves into the empirical findings and insights that experimental research has generated on interruption effects for productivity and well-being. Proceeding evaluation and analysis of outcomes enables formulation of a Unified Attention Interruption Model. Finally, based on obtained findings, some first system design guidance is proposed for successful IT based interruption management.

2. Taxonomy of Attention Interruption Research

An attention interruption is an "externally generated, randomly occurring, discrete event that breaks continuity of cognitive focus" on an ongoing task (Corragio, 1990, p. 19) and "typically requires immediate attention" and "insists on action" (Covey, 1989, pp. 150-152). According to this definition, interruption is created by another person, object, or event at timing "beyond the control of the individual" (Speier et al., 1999, p. 339) resulting in the "cessation and postponement of ongoing activity" (Zijlstra et al., 1999, p. 169). And hence, being interrupted means that people have to divide their attention between at least two sources of stimuli: the main task and the interrupting task (Zijlstra et al., 1999, p. 171).

Generally, a primary task and an interruption task are distinguished. The *Primary task* is the main or the ongoing task on which a person places her attention (Speier et al., p. 773). The task that then interrupts her is called the *interruption task*. Primary, as well as interruption tasks, can vary in type, complexity level, presentation and design mode. In this paper we are focusing mainly on situations where the primary task of an individual is interrupted by IT.

Research on attention interruption takes different angles of analysis when studying the effects of interrupts on human performance and well-being. Available taxonomies consider four major dimensions: (1) the nature of the primary task and the interruption task, (2) the interplay between the primary task and the interruption, (3) individual characteristics of a person being interrupted, and finally (4) the effects of interruption.

2.1. The nature of the Primary and Interruption Task

When investigating peoples' reactions to interrupts it is important to consider the nature of the task being interrupted (the primary task) and the kind of interrupt confronted (secondary task).
Primary and secondary tasks can be characterized by (1) the type of cognitive processing required for task completion and (2) the level of relevance of the task.

Tasks can be characterized based on the **type of cognitive processing needed** to reach a solution (Speier et al., 2003, p. 775). The six discrete types of tasks are: analytical, perceptual, memorizing, attentive, coordinative, and mechanic. Some jobs require manipulation of discrete sets of symbols (also called symbolic tasks), which call for more *analytical* processes, e.g. calculations and budget analysis (Speier et al., 2003, p. 777). Other tasks involve more *perceptual* processes, e.g. visual comparisons, evaluations, examinations of financial statements and preparations of reports, where relationships among those discrete sets of symbols are established (Speier et al., 2003, p. 777). Additionally, tasks may also entail *memorizing* processes, e.g. practicing a presentation speech, where recollection abilities rather than evaluative abilities are required. Moreover, there are tasks demanding close attention and fast reaction, and hence will be called *attentive tasks* (Monk, Boehm-Davis & Trafton, 2004b). Besides, tasks of a more organizing and planning nature, where the ability to coordinate all users' goals are required are referred to as *coordinative* tasks (Cutrell, Czerwinski & Horvitz, 2000a). To complete the list, it is important to distinguish between tasks of automatic nature (Trafton, Altmann, Brock & Mintz, 2003), where neither cognitive process is essentially used but some mechanic actions have to be done for its completion, such as typing in or formatting some text, as well as scrolling down pages. Such tasks are called *mechanic*.

It is essential to be aware of the difficulty to apply a particular task type to any real technology based task. Most activities demand several different cognitive processes at the same time, and accordingly may be differently defined. However, to simplify comparisons and enable generalizations the paper gives its best at logically applying the various tasks to a particular cognitive process type group.

Apart from the cognitive processing required, interrupts or the tasks being interrupted can have different **levels of relevance** for people. Depending, for example, on the priority of the interruption and the gravity of possible errors as a consequence of neglecting either of the two tasks, system designers must decide upon the most suitable method of interruption coordination (McFarlane & Latorella, 2002, p.26). Another way of looking at the meaning of an interruption is by measuring its relevance to the user and his goals at the time of interruption (Cutrell, Czerwinski & Horvitz, 2000a; Edwards et al., 2002).

2.2. Different Task Complexity Levels

It is generally known that cognitive resources are apt to limited capacity (Kahneman, 1973). The more complex a task is the more cognitive resources are needed for its successful completion. A user working on a simple task, on the other hand, should have ample cognitive resources available when interruptions occur (Speier et al., 2003, p. 775). Thus, the complexity level of a task can significantly influence users' performance and his general well-being. Experiments have been looking at the complexity level of different tasks from two directions: The (1) memory load they cause and the (2) processing intensity they require.

Some researchers have tested the effects of task complexity by varying **memory intensity** or load (Gillie & Broadbent, 1989; Czerwinski, Horvitz & Wilhite, 2004; Bailey, Konstan and Carlis, 2006), where the complexity resided in users memorizing high volumes of complex information (Bailey et al., 2001, p. 6). Tasks included memorizing some multifaceted text by heart. Interruptions were especially harmful when they created memory distortions (Bailey et al., 2006, p. 696).

However, a complex task may also be one which requires a lot of **information processing**, where processing of one part of the task influences processing of another part of the task (Wood, 1986; Speier et al., 1999, 2003; Burmistrov & Leonova, 1996; Czerwinski, Cutrell & Horvitz, 2000b, 2001). Simple tasks typically require processing fewer cues (pieces of data), which are more straightforward (Payne, 1982).

Tasks can also be made difficult by increasing the **speed** with which the information has to be processed (Monk, Boehm-Davis & Trafton, 2002).

2.3. Presentation and Design of a Task

A wide variety of **media** and activities are suitable for representing the primary task or **transmitting an interruption task**. While in a marketing context, interruptions are often intrusive ads on TV or annoying pop-ups online, occupational psychologists and human resource managers are interested in the effects of interruptions at the work place (which may come from telephone calls or other colleagues). Information systems scientists analyze software (or better to say "computer-based interrupting technologies") as the source of interruption. A research question investigated is whether interruptions conveyed by different media have similar effects. Most experiments analyzed below deal with the computer screen or telephone as the medium of interruptions. As there is no direct empirical comparison available, the effects of these two distinct media-sources of interruptions are treated equally hereafter when statistical results are reported.

Apart from the medium of interruption, the **sensual nature of a task** can equally vary. Researchers revealed that interruption modality or channel of conveyance has a significant effect on users' task performance (Latorella, 1996b, 1998). Modalities reported hereafter are narrowed to *visual* or *auditory* nature. It has been found that interaction modality of the interruption task can conflict with the modalities the user is already using (Storch, 1992). For instance, interruptions presented visually as on-screen messages could be more disruptive to people performing a computer based task than interruptions occurring auditorally via telephone call or human visitors (McFarlane, 2000, p. 68).

Some research is, furthermore, interested in the ability of **information presentation formats**, an aspect of information systems design, and its interrelation between primary and interruption tasks (Speier et al., 2003). Although there are many different format features described in the literature, such as semi-transparency (Harrison et al., 1995), spatial location (Osgood et al., 1988) and windowing (Lee, 1992), the formats actually tested in attention interruption conditions are typically varied in terms of *space* and *symbolic nature* (Speier, et al., 2003).

Finally, the effectiveness of a specific presentation format depends on the kind of task performed and its **structural fit** with the interrupt (Benbasat, Dexter, & Todd, 1986; DeSanctis, 1984; Tan & Benbasat, 1990; Vessey, 1991). The theory of cognitive fit (CFT) (Vessey, 1991) states that information presentation can facilitate task solving if it matches the information required to complete the task (Speier et al., 2003, p. 777). Symbolic formats such as tables are, for example, most effective for presenting discrete sets of symbols (e.g., a table of costs and revenues) and best support analytical processes (e.g., calculations). Spatial formats such as graphs, on the other hand, are most appropriate for perceptual processes (e.g., depicting relationships among discrete sets of symbols, such as change in GDP over time) (Speier et al., 2003, p. 777). Consequently, when the information presentation format does not match the cognitive processes of the task, greater cognitive effort to transform the information into a form suitable for solving that particular type of problem is needed (Vessey, 1994). It was observed that as task complexity grows, users prefer spatial formats for fast solving of any type of task. With respect to this fact, and knowing that interruption tasks also request additional cognitive effort, researchers test whether interruptions cause similar change in format preference as more complex tasks do (Speier et al., 2003).

2.4. Task Duration and Cognitive Load

Quite a few studies have looked into whether the duration of an interruption task increases the disruptiveness (Gillie & Broadbent, 1989; Burmistrov & Leonova, 1996; Edwards Li & Lee, 2002; Monk, Boehm-Davis & Trafton, 2004). Specifically, the subject in discussion was whether or not information stored about a primary task is subject to decay during the interruption task (Gillie et al., 1989, p. 246). Also, the duration and load of the primary task have been varied in experiments, i.e. with respect to how long the task lasted and how many documents were needed for its completion (Czerwinski, Horvitz & Wilhite, 2004).

2.5. Frequency of Interruptions and Repetition of Primary Task

Frequency of interruption is a widely tested variable among attention researchers (Kirmeyer, 1988; Speier, Valacich & Vessey, 1999; Zijlstra, Roe, Leonora & Krediet, 1999; Eyrolle & Cellier, 2000; Monk, 2004). Frequent interruptions result in processing a greater number of information cues, and hence increase processing load (Casey, 1980; O'Reilly, 1980). Moreover, each interruption induces a necessity for reprocessing of some primary task's information, which consumes extra effort every time (Speier et al., 1999, p. 341). Repetition of a primary task is a similar concept to frequency; it is important to know how often the same primary task was resumed during an experiment with the same participants. Repetition causes a learning process, and hence might change the effects of interruption at later sessions (Trafton et al., 2003).

2.6. Interplay between Primary Task and Interruption Task

Most empirical investigations focus their attention on the interplay between the ongoing task and the interruption. The interrelations studied are similarities between the tasks, specific timing of the interruption within a primary task, and finally varied interruption coordination methods.

2.6.1. Task Similarity

The similarity or dissimilarity between a primary and interrupting task is of great significance to research (Monk et al., 2004b, p. 2). Attention-interruption research has been looking into similarity conditions in terms of *presentation format* (Czerwinski, Chrisman & Schumacher, 1991), *task modality* (Latorella, 1998), *content* (Speier et al., 1999; Edwards Li & Lee, 2002), as well as similarity in actual *type of cognitive processing* (Gillie & Broadbent, 1989). It has been suggested that the similarity between the primary task and the interruption might cause information interference (Gillie & Broadbent, 1989; Kinsboume, 1981, 1982; Navon, 1984; Edwards et al., 1998; Speier et al., 1999). On the other hand, it was also argued that similar information might decrease the demand for cognitive resources. Both consequences are subject for analysis and discussion (Speier, et al., 1999).

2.6.2. Timing of Interruption

The timing of interruption is relevant in two aspects. First, there might be a difference at which point of the primary task an interruption occurs. Second, an important aspect about interruption timing is whether the user has time to prepare for an interruption or not.

Different **moments for interruptions with regards to the primary task** have been tested: right at the *start* of a primary task, in the *middle* of a primary task or at the *end* (Cutrell et al., 2000a; Czerwinski et al., 2001; Monk et al., 2002; Edwards et al., 2002; Adamczyk et al., 2004; Monk et al., 2004b; Bailey et al., 2006; Moe, 2006). The Goal Activation Model predicts that there may be moments at which interruptions are less disruptive (Monk et al., 2002; 2004b). This assumption is based on the fact that memory loads vary at different points of the primary task, and that after the interruption it should be easier to restore lower volumes of information (Monk et al., 2004b, p. 653).

Another interruption timing aspect is whether there is a t**ime lag and/or warning before the actual interruption** occurs (Gillie & Broadbent, 1989, Czerwinski et al., 1991; Altmann et al., 2002; Trafton et al., 2003). Interruption timing can be delayed rather than immediate. During the delay an individual has some time to prepare for the interruption. She may thus complete a subtask, review her current activity and rehearse her current position prior to handling the interruption. This makes it easier to later resume the interrupted task (McFarlane et al., 2002, p. 30; Bailey et all, 2006, p. 686).

2.6.3. Interruption Coordination Methods

Different system design solutions are available with respect to the coordination of interruptions. These determine the level of control a user has over interruptions‘ timing, and establishes a level of flexibility optimal for task performance. McFarlane (2002) proposes four primary design solutions to coordinate user interruption, as shown in table 1: (a) *immediate interruption*, (b) *negotiated interruption*, (c) *mediated interruption*, and (d) *scheduled interruption* (McFarlane et al., 2002, p. 25). These four different methods of coordination are viewed as the most relevant characterization of interruptions for systems design (McFarlane & Latorella, 2002, p. 18). It is empirically shown that differences in interruption coordination solutions in different systems cause large differences in their effects (McFarlane, 2002, p.26; 1998, 1999). An appropriate coordination method can support users by handling interruptions while effectively minimizing performance errors (McFarlane, 2002, p. 66). In view of that, different interruption coordination methods are the basis of interruption type distinction in this paper.

Table 1: Method of Interruption (IR) Coordination (Own development)

Method	Example	Control over IR	Flexibility	System simplicity
Negotiated	User works on a text-editing task, the phone rings, user decides whether and when to pick up the phone.	High/ Medium	High	Medium
Immediate	User talks on the phone while driving the car using an IVIS. The system announces its route directions immediately, interrupting the ongoing conversation.	Low	Low	High
Scheduled	Professor schedules interruptions from students’ requests by assigning office hours.	High	Low	Low
Mediated	Before any incoming call, a PDA checks whether the person can be interrupted or not (given his schedule), and mediates interruptions when possible.	Medium	Low	High

2.6.3.1. Negotiated Interruption Method

There are many studies looking into negotiated interruption modes for empirical testing (Kirmeyer, 1988; Gillie et al., 1989; Burmistrov et al., 1996; Zijlstra et al., 1999; Mc Farlane, 1999; Cutrell et al., 2000a; Czerwinski et al., 2000b; Czerwinski et al., 2001). To illustrate this kind of interruption, take a user concurrently performing two tasks: first, indirectly driving a car by supervising a robotic driver, and second, conversing with another human passenger. Whenever the robot must initiate an interaction with its supervisor, it must first interrupt their conversation. In a negotiated solution, a robot would announce its need to interrupt and wait for an answer from the driver (McFarlane et al., 2002, p. 26). Although in this situation a negotiated interruption mode is rather inappropriate due to the importance of the (primary) driving task, there are situations where a system is more effective if it gives the user more control and flexibility over the interruption process. (McFarlane et al., 2002, p. 31) distinguishes four potential user reactions to negotiated interrupts:

1. *Immediate strategy*: accept and handle an interrupt immediately
2. *Delayed strategy*: acknowledge an interrupt and agree to handle it later
3. *Decline strategy*: explicitly refuse to handle an interrupt
4. *Withdraw strategy*: Implicitly refuse to handle it by ignoring an interrupt

McFarlane (2002) showed that negotiation-based interrupts lead to the best overall user performance when interruptions are not urgent (McFarlane, 2002, p. 82). This is, because negotiated interruptions give the user the possibility to delay, and hence to choose the moment at which he stops his primary task. The user thus enjoys a *high operational flexibility,* which can mitigate some of the normally deleterious effects of interruptions (Chapanis, 1978; Hess & Detweiler, 1994). A 'delayed strategy' allows the user to take measures to prepare for interruption, i.e. save documents, review and rehearse his current activity, and end a current subtask. This can make it easier for him to later resume the interrupted primary task (Trafton et al., 2003, p. 584; McFarlane et al., 2002, p. 30; Bailey et all, 2006, p. 686). Zijlstra et al.(1999) showed that letting the worker choose an *opportune moment* for interruption allowed him to totally compensate for the performance speed decline caused by the interruption (Zijlstra et al., 1999, p.163). However, there are equally overhead costs of negotiating interruptions (Katz, 1995) and users sometimes prefer immediate interruption solutions when that overhead cost is not justified (McFarlane, 2002, p. 71). This is particularly the case in emergency situations or when the user has explicitly requested immediate interruption.

2.6.3.2. Immediate Interruption Method

Immediate coordination type is the most tested interruption type (Gillie & Broadbent, 1989, Czerwinski, Chrisman & Schumacher, 1991; Speier, Valacich & Vessey, 1999, 2003; Eyrolle & Cellier, 2000; Monk, Boehm-Davis & Trafton, 2002; Edwards Li & Lee, 2002; Trafton, Altmann, Brock & Mintz, 2003; Adamczyk & Bailey, 2004; Cho & Cheon, 2004; Monk, 2004; Monk, Boehm-Davis & Trafton, 2004a, 2004b; Bailey, Konstan and Carlis, 2006; Moe, 2006). An immediate solution of the above 'driving' example would have the robot interrupt at any time in a way that insists that the supervisor immediately stop conversing and interact with it. Assuming that driving errors are more serious than conversational errors, a successful user interface design for a robotic driver would ensure people's attentive priority to performance of the supervised driving task, regardless of side effects on other activities. Hence, an *immediate interruption solution* is most suitable in this context, because immediate interruption produces the quickest reaction to the interruption task (McFarlane et al., 2002, p.26).

The main cost of an 'immediate' solution is that people have no control or flexibility at all. Interruptions appearing at most unfavorable moments result in a longer and more difficult process of resuming the interrupted task after the secondary task has been completed (Ballas, Heitmeyer & Pérez, 1992, cited in McFarlane, 2002, p. 71). To mitigate this cost, researchers propose the introduction of tools such as brief warnings prior to the incoming interruption, so that users have time to review their ongoing task before intrusion (Czerwinski et al., 1991a, 1991b; Trafton et al., 2003). Further, reminders of where the primary task was halted can help people resume it faster (Davies et al., 1989).

2.6.3.3. Mediated Interruption Method

The mediated interruption solution is an attractive but controversial approach (McFarlane, 2002, p. 72), which was discussed but not yet empirically tested by several researchers (Bannon, 1986; Chignell et al., 1988; Ryder et al., 1991; Gifford et al., 1992; Kirlik, 1993; Sullivan, 1993; Lieberman, 1997; Cook et al., 1999). Coming back to the example about the robotic driver, a mediated solution would have the robot indirectly interrupt and request interaction with a person through a mediating device, i.e. the supervisor's personal digital assistant (PDA). The PDA would then determine when and how the robot's message is allowed to interrupt. This gives the user some control over interruptions (he manages priorities in his PDA). However some flexibility is still lost, because the mediator works with preset rules.

The most critical disadvantage of a mediated interruption method is that the cost of delegating a task to a mediator can sometimes outweigh the benefits (Kirlik, 1993, cited in McFarlane 2002, p. 72). Design of such a coordination method is rather complex, and a poorly designed mediator can be more disruptive than the interruptions it manages. Also, adding a mediator to the UI increases the separation between the human and the task and begets a new task of supervising the mediator (Kirlik, 1993, cited in McFarlane et al., 2002, p. 35). There are five main approaches for mediation, which are all costly and complex to implement in practice (McFarlane, 2002, p. 72):

- Predict people's interruptability
- Implement intelligent user interfaces for supervision tasks
- Automatically calculate users' cognitive workload for dynamic task allocation
- Apply human factors techniques for supervisory control
- Use cognitive models to guide user interface design process

2.6.3.4. Scheduled Interruption Method

The scheduled interruption as a coordination solution was described but also not yet empirically tested with respect to attention interruption effects (French, 1982; Moray & Hart, 1990; Rouncefield et al., 1994; Des Jardins, 1998). The scheduled interruption coordination method gives users a degree of reliable expectation about when they will be interrupted. For example, the supervising of a robotic driver would restrict the user's interruptions to a prearranged schedule, such as once every 15 minutes. If people knew the when, what, where, why, and how of incoming interruptions, they could plan their other activities to minimize the negative effects of interruptions (McFarlane, 2002, p. 72). This would provide them with high control, but rather low flexibility, as preset times cannot be easily changed. However, scheduling times for unexpected activities transforms interruptions into normal planned activities. There are three kinds of possible interruption scheduling techniques (McFarlane, 2002, p. 72):

- Explicit agreement on one-time event
- Prearrangement of a regularly recurring event
- Constant stream of interruptions

2.7. User Characteristics and Reactions to Interrupts

Another part of the literature deals with the differences in peoples‘ reactions to interrupts. Three areas of study can be distinguished: (1) Study of the impact of demographics, such as *age* (Monk, Boehm-Davis & Trafton, 2004b), and *gender* (Gillie & Broadbent, 1989; Silverman, 1989; Speier, Vessey & Valacich, 2003); (2) study of the impact of elements of personality, such as *patience* (Kirmeyer, 1988) and (3) investigation of the impact of people's abilities on interruption handling, i.e., the ability to *multi-task* (Braune & Wickens, 1986; Joslyn & Hunt, 1998; Morrin, Law, & Pellegrino, 1994), the ability to *recall* information about interrupted tasks (Husain, 1987; Gillie & Broadbent), and their domain expertise (Speier et al., 1999, 2003; Mackay & Elarn, 1992; Ramarnurthy, King, & Prernkumar, 1992).

2.8. Studied Consequences and Effects of Interruption

Attention interruption research is concerned with the effects interruptions can have, their level of disruptability, and, of course, ways in which these could be minimized. Three distinct categories of interruption effects have been studied: effects on primary task performance, on interruption task performance, and finally effects on users' psycho-/ and physiological state.

2.8.1. Effects of Interrupts on Primary Task Performance

There are five different primary task performance measures identified in the literature: (1) quality, (2) timeliness (speed of performance), (3) efficiency (performance per unit of work), and finally (4) change of strategy. The quality of a task completed is measured in terms of correctness and completeness, if appropriate (Zijlstra et al., 1999, p. 173). Timeliness is measured by looking at the time needed to complete the primary task by subtracting the time lost on the interruption. Often researchers simply measure the length of the resumption period (time needed to resume the primary task after interruption) to assess timeliness, since it was found that resumption lag accounts for most of the loss of timeliness of the main task (Burmistrov et al., 1989, p. 24). The length of resumption of the primary tasks depends mostly on the level of recall of primary task goals (Czerwinski et al., (2001). The better the recall of the goal, the faster will be primary task resumption, and hence performance. It is often assumed that there is a speed-quality trade-off that takes place when time or performance pressure grows (Monk, 2003, p 297). That is, people seek to reduce effort by relying on less time-consuming processes that reduce accuracy (Johnson et al., 1985). Finally, negotiated interruption coordination offers users the possibility to choose a response strategy. The choices made and their effectiveness on improving performance was studied by (Kirmeyer, 1988; Zijlstra et al., 1999; Cutrell et al., 2000a; Czerwinski et al., 2001).

2.8.2. Interruption Task Performance

Most research has concentrated on primary task performance upon interruption. Three performance measures are typically used: (1) quality, (2) interruption acknowledgement time and (3) interruption task initiation time. The quality of interruption task performance, similar to primary task quality, is typically determined by looking at task correctness and completeness (Latorella et al., 1998; Trafton et al., 2003). Further, Latorella (1998) looked at how fast an interruption was acknowledged and how much later it was actually initiated.

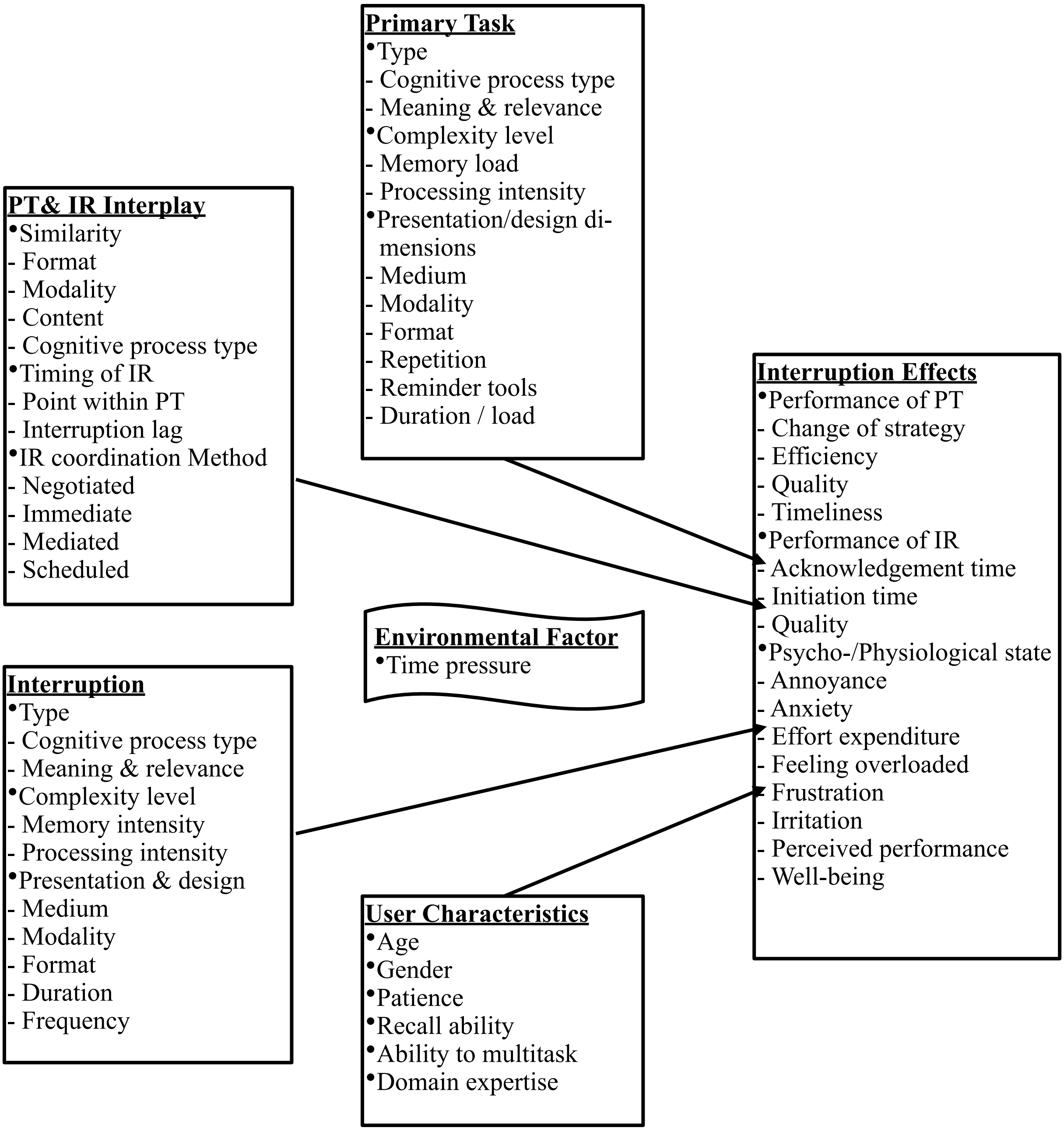
2.8.3. Effects of Interrupts on Psycho-/ and Physiological State

Finally, it is known that interruptions do not only disrupt users' performance, but also negatively affect users' psychological and physiological state (Zijlstra et al., 1999). Renowned psychologist Cohen (1980) defined interruptions as "…uncontrollable, unpredictable stressors that produce information overload, requiring additional decision-maker effort". Variables tested in this context are: (1) annoyance (Adamczyk, 2004; Cho, 2004; Bailey et al., 2006; Moe, 2006), (2) anxiety (Bailey et al., 2006), (3) frustration (Adamczyk, 2004), (4) feeling overloaded (Kirmeyer, 1988), (5) well-being (Zijlstra et al., 1999), (6) irritation (Edwards et al., 2002), (7) perceived effort expenditure (Zijlstra et al., 1999; Adamczyk, 2004), and finally (8) perceived task performance (Speier et al., 1999, 2003). In the end, all these variables are related psychological and physiological states. There is no feasible distinction made in the empirical analysis between these factors. Also, one feeling may be a direct consequence of the other, for example, feeling overloaded may result in frustration, annoyance and anxiety. A scientific scale of psycho-/ and physiological variables should be at place in order to tap an underlying construct. Until then, all mentioned variables and their antecedents will be treated as discrete elements.

2.9. Attention Interruption Research Framework

Based on the literature outlined above we developed one integrated framework for attention interruption research. It structures and summarizes all the major factors which were identified to impact the effects of interruptions and the distraction of attention from a primary task. Figure 2 gives an overview.

Figure 2: Attention Interruption Research Framework (Own development)



To facilitate understanding and evaluation of attention interruption experiments that were conducted using different design and situational frames, a logic tree comprising all independent and moderating variables was worked out. The variables, their features and components underlay an intensive analysis to enable generalization. Some notions used by the particular researchers were kept, but most were logically 'translated' and subsumed under the terminology we developed in order to make studies comparable.

Figure 3: Primary Task Variables, Features and Components (Own Development)

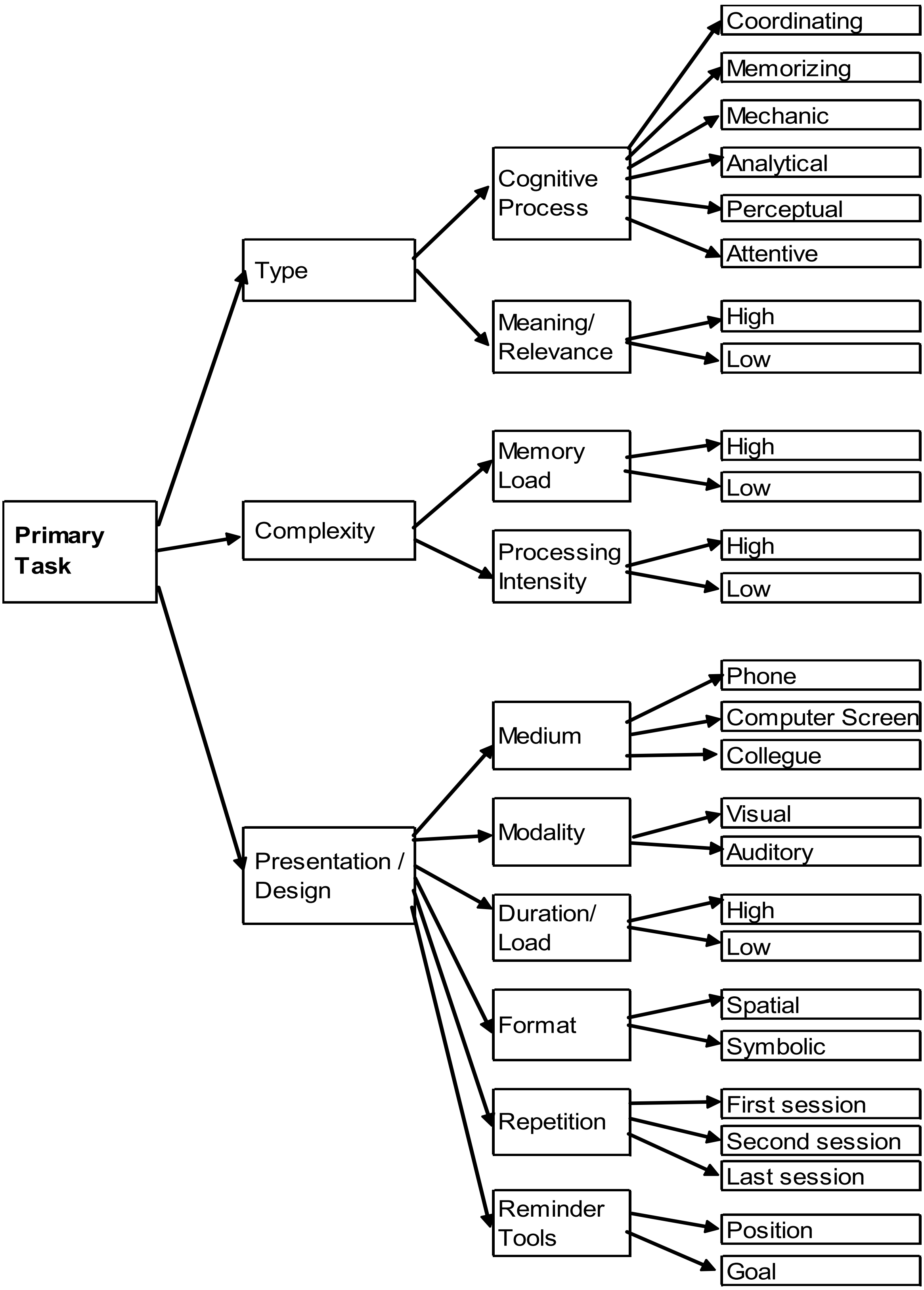
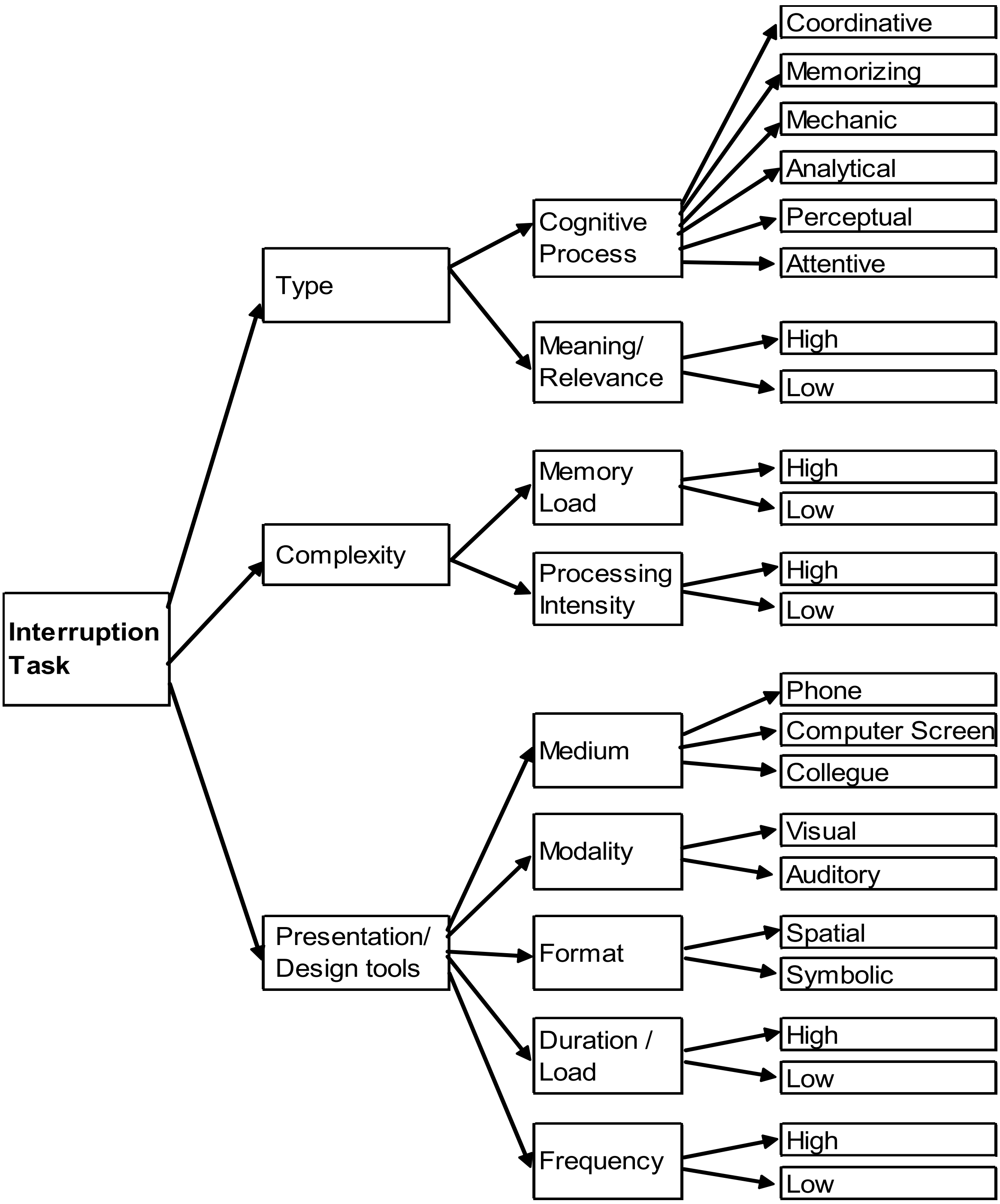


Figure 4: Interruption Task Variables, Features and Components (Own Development)



Figures 5a and 5b: Variables of the PT & IR Interplay, Features and Components

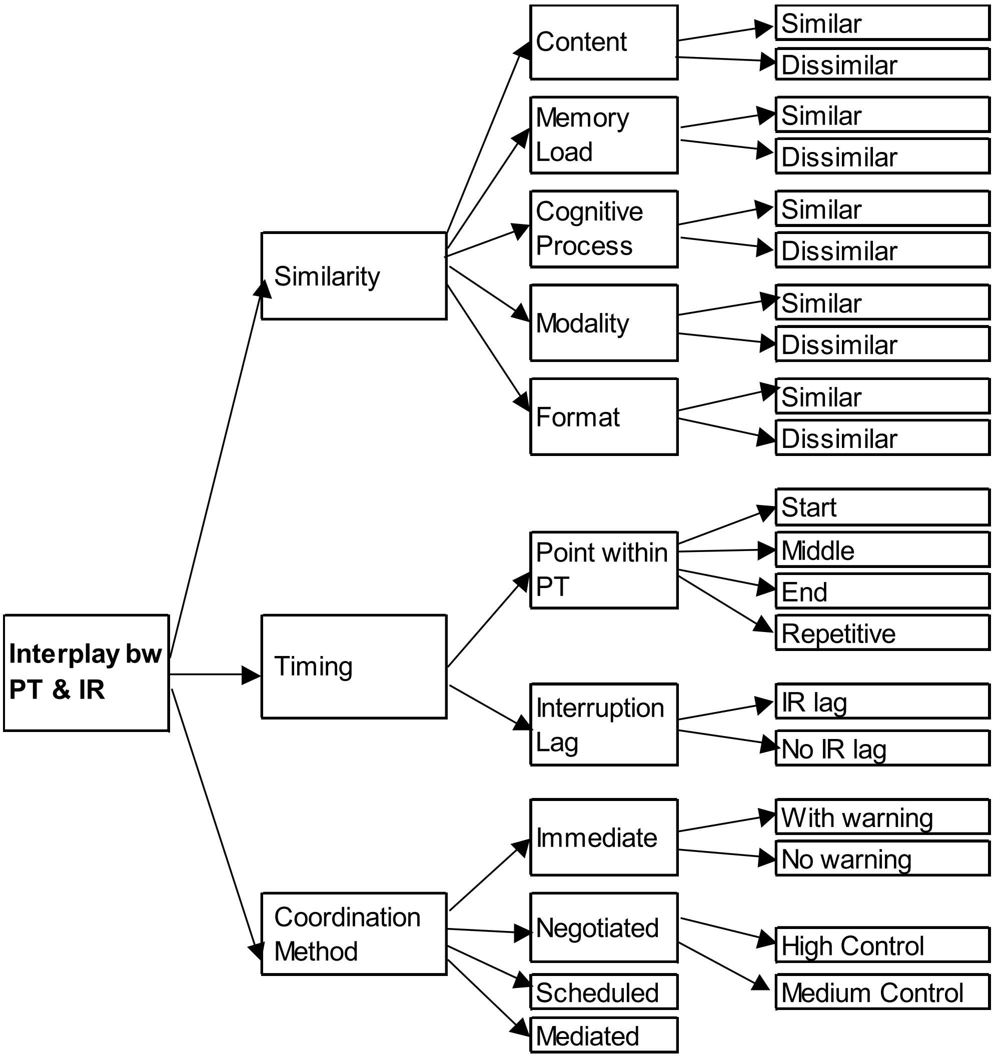
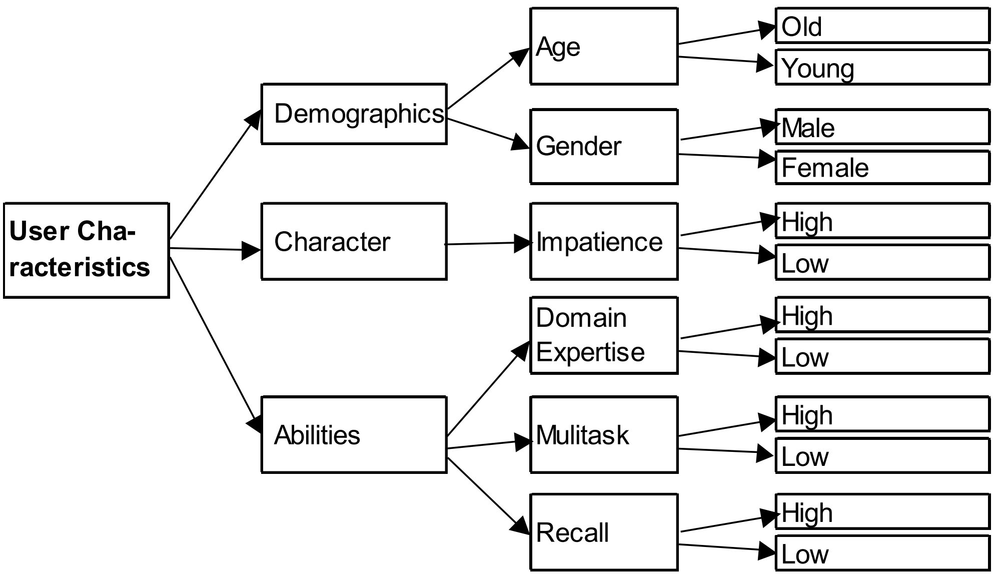


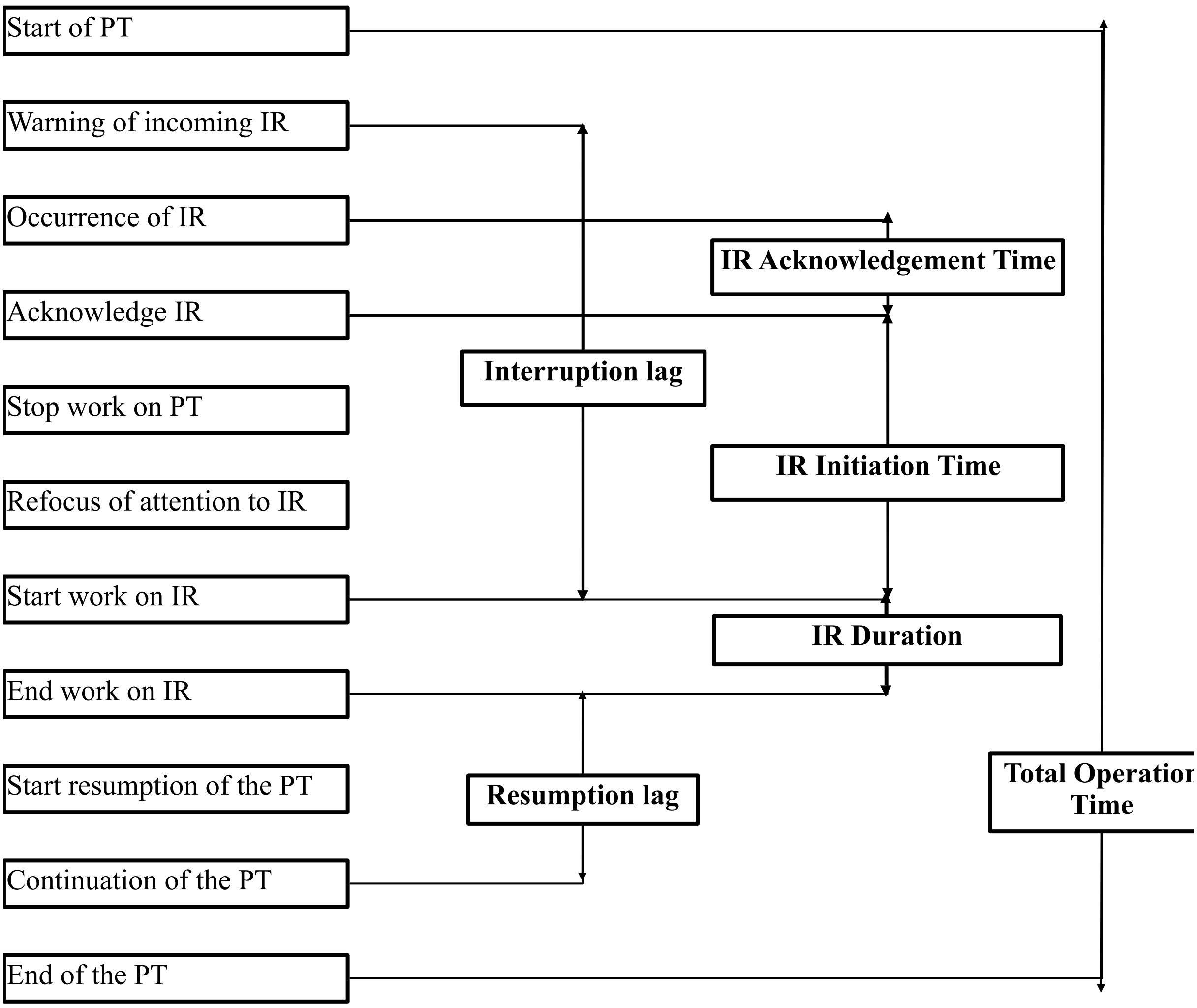
Figure 2.6e: User Characteristics Variables, Features and Components (Own Development)



2.10. Attention-Interruption Process

In order to better interpret and compare the findings of past research, the course of how an activity is interrupted must be carefully considered. Researchers do not only distinguish between primary and secondary tasks of different nature, but also distinguish the following key points (Burmistrov et al., 1989; Latorella, 1998; Zijstra et al., 1999): (1) start of the primary task, (2) occurrence of an interruption warning (applies for immediate interruption coordination method only), (3) appearance of the interruption, (4) acknowledge the interruption (only applicable for negotiated interruptions), (5) stop the work on the main task, (6) refocusing attention to the new signal, (7) start the work on the interruption task, (8) end of the interruptive task, (9) start resumption of the main task, (10) point of continuation of the first action on primary task after interruption, and finally (11) the end of the operation on the main task (see figure 2.7). The order and content of key points varies depending on the particular interruption coordination method and user's interruption response strategy.

Figure 6: Typical sequence of actions within an interrupted primary task (Own development inspired by Burmistrov et al., 1989, p. 25)



There are particular intervals between some of the key intervals which deserve attention. Latorella (1998) was interested in measuring interruption performance by looking at the time from the interruption trigger to subjects' *acknowledgement* of 'seeing' it, for example, by clicking the 'ok' button (Latorella, 1998, p. 2). Further, he distinguished a so-called interruption *initiation time* measuring the time from acknowledging the interrupting message to actually beginning to work on it (Latorella, 1998, p. 2). *Interruption duration* can also be simply measured from the start to the end of interruption work.

Moreover, sometimes a user is allowed to prepare for interruption during a period called *interruption lag* (Altman & Trafton, 2002). He can lead his current subtask to an end, then review and rehearse his current activity prior to handling the interruption, which could make it easier for him to resume the interrupted task later (McFarlane et al., 2002, p. 30; Bailey et all, 2006, p. 686). This lag emerges in the immediate interruption coordination method, when a warning of an incoming interruption is sent prior the actual interruption occurs (Trafton et al., 2003). Another possibility at which an interruption lag occurs is when users in a negotiated interruption condition delay their response until they are ready to deal with interruptions (Kirmeyer, 1988; Zijlstra et al., 1999; Cutrell et al., 2000a; Czerwinski et al., 2001). Finally, it was found that users need additional time to disengage from the interruption task, reorient back to the main task, and resume the primary task before they can continue with the task after the interruption (Burmistrov et al., 1989, p. 24; Zijlstra et al., 1999, p. 175). Hence, *resumption lag* is measured starting from the end of user's work on interruption task up to the first action he does in continuation with the primary task (Monk et al., 2002, p. 2).

3. The Theory of Attention

The previous chapter introduced an attention interruption taxonomy to provide a detailed overview of those variables in it that have been empirically tested. However, before the paper can proceed with a meta-analysis of the empirical studies, an overview of the theoretical concepts behind the attention interruption research has to be presented. This is needed for understanding the background of researchers' assumptions and their formed hypotheses. The chapter starts by first defining and providing a theoretical basis of the concept of attention and later continues with the theory behind the concept of interruption.

3.1. Selective Attention Theory

Kahneman (1973), defines attention as the process of applying oneself to some task or activity (Kahneman, 1973, p. 3). The selective aspect of attention implies that there are always alternative activities in which one can engage. Consider, for example, pigeons presented with objects of different shape and color. Some birds attend to the objects‘ shapes while others attend to their colors (Kahneman, 1973, p. 2). Hence, selective attention implies that “organisms selectively attend to some stimuli or aspects of stimulation, in preference to others” (Kahneman, 1973, p. 3). Evidence suggests that selective attention allocation is very flexible. Voluntary attention is highly responsive to the person's intentions at the moment, and involuntary attention occurs due to pre-attentive mechanisms that autonomously react to novel and surprising stimuli (Neisser, 1967 in Kahneman, 1973, p. 7).

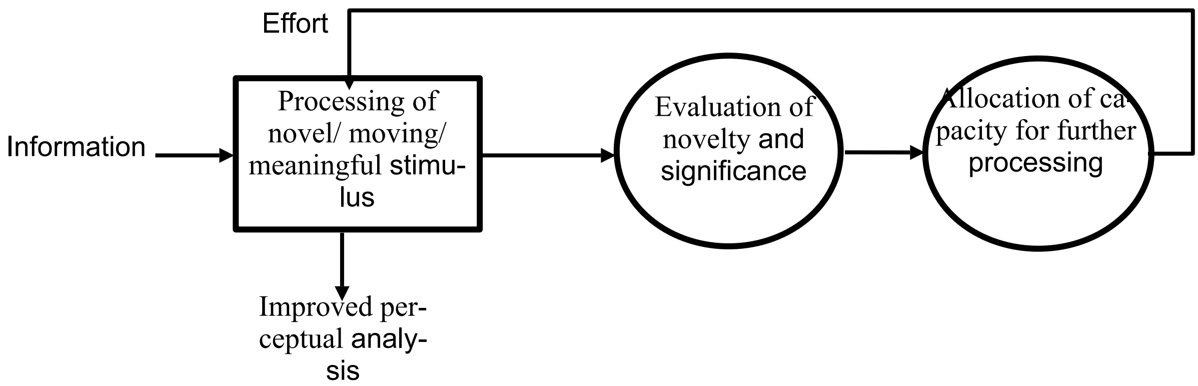
The interest of this paper is to investigate insights on involuntary attention interruption process.

3.2. Orientation Reaction

The process in which the allocation of attention to some stimulus is involuntary is named orientation reaction (OR), response or reflex (Kahneman, 1973, p. 42). Originally, OR was described by Pavlov (1927) to depict a reflex that causes an immediate response in organisms to a change of their environment. Modern experimental studies of attention regard OR as a short-term attention reaction evoked involuntarily by certain categories of stimuli, such as novel, moving, meaningful, or surprising events (Lang, 2000, p. 55). When such a stimulus surprisingly appears (as interruptions do), search for a mental representation in short-term memory (STM) fails (Ohman, 1979; Diao et al., 2004, p. 539). Then OR induces a call for information processing resources that facilitate a further search in long-term memory (LTM). Eventually, this cognitive effort leads to the registration of the novel stimulus in LTM (Diao et al., 2004, p. 539). However, a repetitively appearing stimulus is no longer novel, and since stimuli are analyzed before the decision is made to activate the system by an OR, habituation prevents recurring perceptual analysis of the same information (Kahneman, 1973, p. 45-46). As figure 8 illustrates, only information of novel and surprising stimuli causes allocation of effort to elaborate its analysis (Kahneman, 1973, p. 44). When subjects learn to expect the stimulus, they do not release effort for processing it anymore (Kahneman, 1973, p. 43).

To illustrate the concept of orientation reaction, imagine a user surfing the Web when an advertisement suddenly pops up. If he has never received a pop up of that sort before, cognitive resources will be released to process the information, i.e. an OR is triggered. However, as the pop up appears again, the user recognizes the stimulus and no further processing will take place. He then only releases effort for processing the information if he himself considers it useful.

Figure 7: Activation of the Orientation Reaction (Kahnemann, 1973, p. 44)



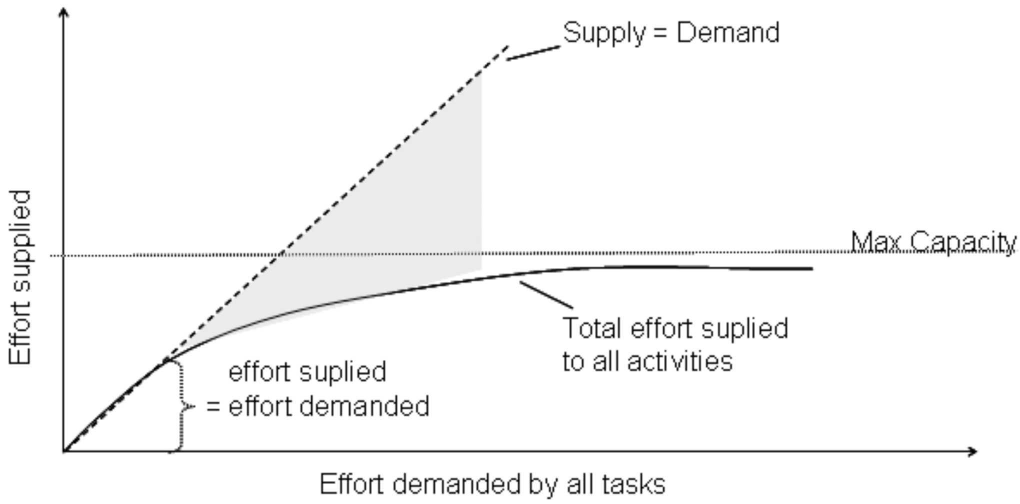
3.3. Kahneman's (1973) Capacity Model

Kahneman (1973) theorized how people pay attention to objects and activities in his Capacity Theory. He uses the terms 'exert effort' or 'invest capacity' as synonymous for paying attention (Kahneman, 1973, p. 8). The main idea behind his capacity model is that there is a general limit on a man's capacity to perform mental work due to the restricted number of cognitive resources available. It's a common observation that when two stimuli are presented at once, people perceive only one of them at a time and ignore the other. If both are perceived, the responses to them are usually made in succession rather than simultaneously (Kahneman, 1973, p. 5).

Interruptions typically enclose information to be processed, so-called information cues. A user presented with an interruption task while working on a primary task must stop the latter and refocus his attention on the interruption task. This happens because interruption cues may (a) use the same sensory channel as those used in processing the primary activity and (b) demand much, if not all, of the available capacity for processing of the interruption cues (Speier et al., 1999, p. 339). Consequently, interruptions cause both structural and capacity interference (Kahneman, 1973). S*tructural interference* occurs when a decision maker must attend to two inputs that require the same physiological mechanisms (e.g., attending to two different signals which are both visual, and hence can not be viewed in parallel), whereas c*apacity interference* arises when the number of incoming cues is too numerous for a decision maker to process at once (Speier et al., 1999, p. 339). Thus, interruptions increase the overall cognitive processing load and force an individual to narrow his attention on the interruption task, while suppressing and queuing the other. This bottleneck in human sensory and motor performance, where only one stimulus can be handled at a time, illustrates man's limited processing capacity (Kahneman, 1973, p. 9).

Furthermore, Kahneman hypothesizes that the effort invested in a task is mainly determined by the intrinsic demands of the task, rather than a person's own intentions (Kahneman, 1973, p. 15). The right level of effort required for a particular task depends on the difficulty of the task: the more difficult the task is, the more effort is required for completion. The greater the number of tasks requesting immediate attention, the more difficult it is to apply the right level of effort to each of them. Allocating less cognitive resources than demanded by the task will cause deterioration of performance. As figure 9 shows, effort allocated at completion of all tasks increases steadily with increasing demands of the tasks. However, as the amount of input requests to the system increases even further, demanded effort exceeds the limited effort supplied, discrepancy between the two starts growing (indicated by the grey area), and hence the task performance level deteriorates (Kahneman, 1973, p. 16).

Figure 8: Performance deterioration due to Limited Capacity (Kahneman, 1973, p. 15)

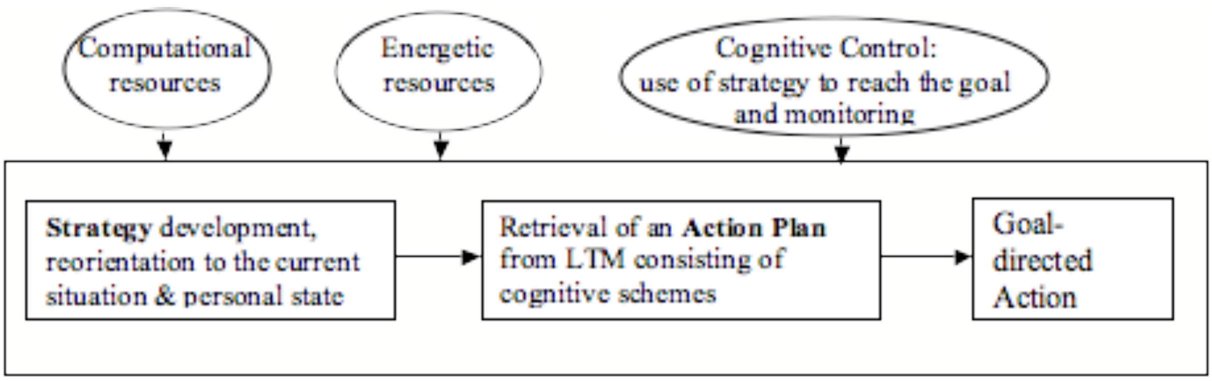


To sum up, due to Kahneman's limited cognitive capacity model, interruptions of a primary task place additional effort (attention) demands on the individual. The resulting increase in workload may cause structural and capacity interferences, and hence forces the individual to channel his available capacity away from the primary task and instead to the interruption task (Kahneman, 1973, p. 10). It follows that performance of the primary activity falters, or fails entirely, because there is not enough capacity to meet the task's demands (Kahneman, 1973, p. 10).

3.4. Theory of Activity Regulation (Hacker 1978, 1986)

The Theory of Activity Regulation (TAR) appends on to Kahneman's Capacity Theory (1973). It helps in understanding the deteriorating performance effects of interruptions by examining the cognitive activity process of a human being in more detail (Bailey et al., 2006, p. 686). TAR (Hacker, 1978) states that every activity executed is under cognitive control (Zijlstra et al., 1999, p. 166). Before actions are produced, the cognitive system develops a strategy, which is built upon a person's perceived goal, his personal state and motivations, as well as the external conditions around him. To implement a strategy, an action plan is produced which consists of cognitive schemes retrieved from long term memory. To sum up, the actual execution of activity occurs under cognitive control and, as already stated by the above models, using various cognitive resources.

Figure 9: Hacker's Theory of Activity Regulation Process (Own Development)



Working on a primary task is then interpreted as execution of a ‘goal-directed activity’ by using limited cognitive processing resources. Presentation of an interruption affects the activity regulation process in several ways. One is that another action plan must be developed, including the changes in the strategy to achieve the original goal within new constraints (Zijlstra et al., 1999, p.166). Moreover, the interruption task also requests resources for execution as well as regulation of the execution. This places greater demands on cognitive processing resources than those available, resulting in *capacity interference* (Speier et al., 2003, p. 773). Finally, additional costs of motivation to restart and resume the primary task after interruption are required (Zijlstra et al., 1999, p. 166). To sum up, interruptions often cause suspension of primary task goals, require additional resources, and impose resumption costs after the interruption task is completed (Monk et al., 2004b, p. 651).

3.5. Zeigarnik Effect

The first scientific interest in interruptions dates back to the 1927 where a psychologist investigated a phenomenon that would later be named after him and is henceforth known as, the Zeigarnik Effect. This effect describes that details of secondary tasks are often better recalled than the details of the primary task. (note that empirical testing provided rather conflicting results on this matter (Zijlstra, 2001, p. 164)). The so-called ‘tension systems’ (Lewin, 1926) in the brain keep information concerning ongoing activities available only until the ‘closure’ of a task (Zijlstra, 2001, p. 164). Hence, the essence of the ‘Zeigarnik Effect’ is first, that memory releases information concerning the task when it is completed, and second, that interrupting ongoing tasks can create confusion in the storage system (Zijlstra, 2001, p. 164).

Modern attention-interruption research applies this theory to explain why users, when interrupted, work until a natural breakpoint in a task sequence before attending to some peripheral information (Bailey et all, 2006, p. 689). One action can be split into several ‘sub-actions’, which itself may consist of several operations. Once one action or part of it has been completed, it supposedly no longer has a claim on the memory system and resources, and hence can be released from memory (Bailey et all, 2006, p. 686). For example, once a sentence has been written, one no longer has to bother with its formulation. Thus, interruptions during natural breakpoints could prevent storage disorder, and hence would facilitate recall of information associated with the interrupted primary task setting (Zijlstra et al., 1999, p. 180). The boundary period from when resources are released to when resources are allocated for the next task then represents an ‘*opportune moment*’ for interruption (Bailey et all, 2006, p. 686).

3.6. Goal-Activation Model (Altmann & Trafton, 2002)

Similarly to the Zeigarnik Effect, Altmann & Trafton’s Goal-Activation Model (GAM) is also based on cognitive theory and memory (Monk, 2004, p. 296). In attention-interruption research dealing with determinants of successful interruption recovery reference is often made to GAM (Trafton et al., 2003; Monk, 2004; Monk et al., 2002; 2004). Specifically, GAM explains the process of *‘goal encoding’* and ‘*activation*’ from memory (Monk et al., 2004b, p. 651). As noticed earlier, performing a primary task constitutes an execution of a ‘goal-directed activity’ by using limited cognitive processing resources (Hacker, 1978; Kahneman, 1973; Zijlstra et al., 1999, p.166). Whereby, an interruption suspends the primary goals, and obliges the user to remember, or encode the primary goals. To be able to continue working on the suspended primary task after completion of the interruption task, its goals must be retrieved and activated. Rehearsal of goals may facilitate goal activation and retrieval.

3.6.1. Goal-Encoding

First, an important hypothesis generated from the GAM deals with the most appropriate timing of interruption – that is, where in the primary task is interruption occurrence least damaging (Monk et al., 2004b, p. 653). Similarly to Zeigarnik implications, the GAM predicts that there may be moments at which encoding of goals is less demanding compared with others; specifically, encoding new tasks or new subtasks may be less costly than remembering the information about a mid-task operation, such as its position in the task sequence, and the next operation in the sequence (Monk et al., 2004b, p. 653). That is, in the middle of a subtask there is more information that has been processed and stored in memory than at the beginning of a task, where no information was processed yet, or at the end, where task closure emptied the memory storage. In other words, goal encoding in the middle of a task or subtask is more demanding than at the beginning or the end of the primary task, and consequently provides a less favorable timing for interruptions.

3.6.2. Goal-Activation

After completing the interruption task, to be able to continue working on the suspended primary task, its goals must be retrieved and activated. That creates a so-called *'resumption lag'*, a period during which the user reorients back to the suspended task and activates his goals. This process requires additional time and resources, and hence was found to be the main reason for the disruptive effect of interruption on task performance (Burmistrov et al., 1989, p. 24). According to the GAM, there are two determinants of goal activation. First, activation is determined by the history of recent retrievals of a given goal. The more frequent it was retrieved from memory, the higher is the level of activation (Monk et al., 2004b, p. 651). Conversely, a goal that was let behind over some time will suffer activation decay (Monk et al., 2004b, p. 651). In this way, 'forgetting' of the goal caused by an interruption of primary task is the principal cause of delayed interruption recovery, because the user must first spend time attending to environmental cues to reactivate the previous goal (Monk et al., 2004b, p. 651). Consequently, the second determinant of fast goal activation is the relationship between a given goal and the current set of mental or environmental cues. The stronger the associations of the goal with the surrounding cues, the more powerful the cue as a reminder, and hence the easier is the goal activation (Monk et al., 2004b, p. 652). To sum up, the model proposes that memory for information (i.e., goals) relevant to the interrupted task will decay during an interruption, and will need to be recalled before continuation. The occurring 'resumption lag' can be minimized by incorporating powerful reminders during the resumption period.

3.6.3. Goal-Rehearsal

A final important proposition of the GAM is that people can strategically rehearse their goals, which could be critical in terms of minimizing the disruptive effects of interruptions (Monk et al., 2004b, p. 652). Rehearsal of the relevant information is possible at two points in time: (1) just before switching to interruption, and (2) during execution of the interruption task (Monk et al., 2004b, p. 652). The former is only possible when there is an *'interruption lag',* i.e. when people know of an interruption occurring at some shortly delayed point in time. For example, in the negotiated interruption condition users are in control of interruption timing and are able to postpone them (McFarlane et al., 2002, p. 31). When the phone rings, the worker has some time to review his task before answering the phone call (Burmistrov et al., 1996). Rehearsal during execution of the interruption task usually takes place when the onset of the interrupting task requires an immediate shift of attention (McFarlane et al., 2002, p. 26). This is often the case when a pop up fills the whole screen and hence immediately disrupts attention on the ongoing task (Gillie et al., 1989). However, strategic rehearsal during the interruption may not be possible if the interrupting task consumes all of the available processing resources (Monk et al., 2004b, p. 652). To sum up, when an interruption happens, rehearsal of primary task goals counterbalances activation decay, and hence can minimize performance losses due to forgetting.

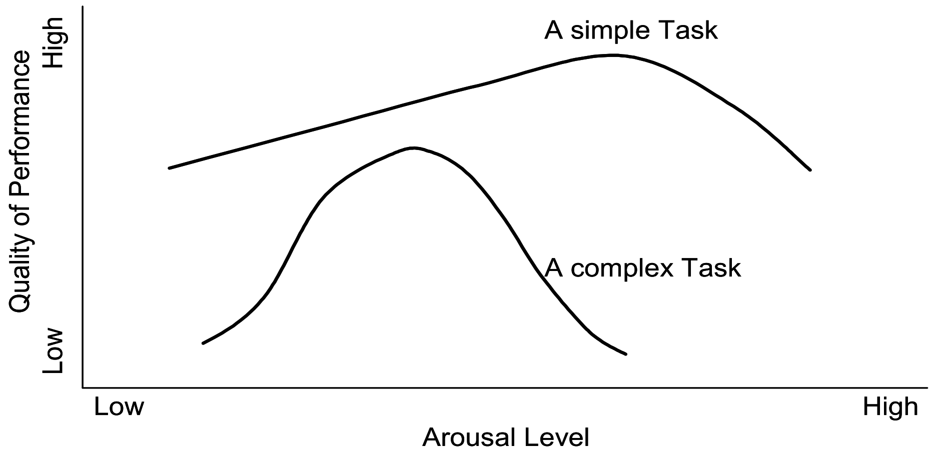
3.7. Distraction Conflict Theory & Yerkes-Dodson Law

Speier et al.(2003) compares interruptions with distractions, which can both occur while a user is performing a primary task (Speier et al., 2003, p. 773). Distraction conflict theory (DCT) suggests that distractions facilitate performance on simple tasks and inhibit performance on complex tasks (Baron, 1986, cited by Speier et al., 2003, p. 775). To illustrate, music at work may improve performance of boring repetitive tasks, but worsen concentration on demanding difficult activities.

This DCT hypothesis is based on the Yerkes-Dodson Law (Yerkes & Dodson, 1908), which states that "the quality of performance on any task is an inverted U-shaped function of arousal, and the range over which performance improves with increasing arousal varies with task complexity." (Yerkes & Dodson, 1908 cited in Kahneman, 1973, p. 34). Any task requires the simultaneous processing of a certain number of cues or aspects of the situation; the more complex the task is, the higher the number of cues to be processed (Easterbrook, 1959, Payne, 1982; Wood, 1986). With occurring interruptions, users have to process even more cues, leading to growing feelings of stress or physiological arousal which varies with the changing demands of current tasks (Kahneman, 1973, p. 10). At a low level of arousal more irrelevant cues are accepted. At higher arousal levels attention tends to be concentrated on the dominant and most obvious aspects of the situation, because irrelevant cues are restricted, and hence performance improves. At very high levels of arousal, however, growing range of cues discrimination eventually causes relevant aspects of the task to be ignored, too, and performance deteriorates. The optimal level of arousal is relatively higher in simple tasks because they have a narrower range of necessary cues to process (Kahneman, 1973, p. 37).

The underlying argument behind DCT is that as distractions occur during simple primary tasks, arousal increases and attention narrows, resulting in the possible dismissal or exclusion of irrelevant information cues (Berlyne, 1960 cited by Kahneman, 1973, p. 3). Hence, increased arousal results in the user completing the simple task faster with little or no loss of performance and/or accuracy (Speier et al., 2003, p. 775). However, as the task becomes more complex, the number of information cues increases and the worker's excess cognitive capacity decreases. Performing a complex task leaves little if any excess cognitive capacity. Narrowing one's attention as a result of the interruption is likely to result in the loss of information cues, some of which may be relevant to completing the task successfully. Under these circumstances, performance quality is likely to abate (Speier et al., 1999, p. 341). These relations are illustrated in figure 11.

Figure 10: Yerkes-Dodson Law (Kahneman, 1973, p. 34)



Application of this law gives an interesting insight into how interruptions causing higher work loads and arousal levels impact on the quality of primary performance. At lower levels of arousal, interruptions actually lead to task performance improvement. More complex or more frequent interruption tasks cause further rise in arousal level. The point of inflection at which any further increase in arousal would cause deterioration in the quality of performance is higher for simple tasks than for complex tasks. In practice it means that it is necessary to know up to which point interruptions do not have a disruptive effect on individual performance.

3.8. Cohen's Cognitive Fatigue Model

DCT inspired further research on the effects of interruptions. Cohen's Cognitive Fatigue Model (Cohen 1978, 1980) states that uncontrollable and unpredictable interruptions induce personal stress and produce information overload, thus requiring additional effort and causing cognitive fatigue. That is, overload at work, defined as "having too much to do in the time available" (Kirmeyer, 1988, p. 621), is an employee stressor which not only has important consequences for productivity and quality of task performance, but also impacts employees' health and feelings. Overload stress causes employees to feel anxiety, tension, anger, and personal failure (O'Connell et al., 1976), and is further associated with greater effort, fatigue and job dissatisfaction (Beehr et al., 1976; Caplan & Jones, 1975). It makes workers feel exhausted and stressed which affects their subsequent readiness to perform (Zijlstra et al., 1999, p.165). Therefore, people are able to allocate resources for and initiate new interruption tasks much more readily than they can resume previously suspended tasks (Bailey et al., 2006, p.698). Empirical testing supports the claim about interruptions affecting user's psycho-/physiological personal state (Gillie et al., 1989; Kirmeyer, 1988; Kreifeldt et al., 1981).

3.9. Summary of Main Theories

The theory of attention interruption provides researchers with myriad insights. First of all, users apply their attention in a highly flexible and selective way (Kahneman, 1973, p. 3). They allocate effort either voluntarily when the presented stimulus overlaps with the person's intentions, or involuntarily when their pre-attentive mechanisms autonomously react to novel and surprising stimuli (Neisser, 1967 in Kahneman, 1973, p. 7).

But users are only in control of limited cognitive resource capacity (Kahneman, 1973, p. 5 & p. 8). When there is an increase in the overall cognitive processing load, the bottleneck in human sensory and motor performance can cause capacity and structural interferences (Kahneman, 1973, p. 9). Consequently interruptions providing additional information to be processed often result in breaking off and refocusing of attention to the interruption task (Speier et al., 1999, p. 339). Thereby, interruptions can not only cause suspension of primary task goals, but also shrink the right level of resource allocation to the primary task (Kahneman, 1973, p. 10), and they can impose resumption costs after the interruption task is completed (Monk et al., 2004b, p. 651). As a result, interruptions can cause task performance disruption (Kahneman, 1973, p. 10).

The third crucial allegation deals with the disrupting effect of interruptions on memory. Interrupting ongoing tasks could create an excess in the number of information cues leading to information overload (Speier et al., 1999, p. 338). In such cases, interruptions are likely to lead to a loss of memory content or confusion among information cues, leading to performance deterioration (Zijlstra et al., 1999, p. 164, p. 166; Monk et al., 2004b, p. 651). However, this effect can be minimized by choosing a most opportune moment for interruption, for example, the boundary period from when resources are released to when resources are allocated for the next task (Bailey et all, 2006, p. 686), as well as moments with the smallest volumes of information to encode (Monk et al., 2004b, p. 653). Moreover, rehearsal of task goals during the interruption lag and during the interruption itself, plus provision of environmental cues associated with the suspended goals, could improve recall during resumption and activation of primary task goals (Monk et al., 2004b, p. 652).

The fourth critical proposition is that interruptions cause a growing feeling of physiological arousal which varies with the changing demands of current tasks (Kahneman, 1973, p. 10). Simple tasks keep arousal levels low; when interruptions occur, rising arousal focuses attention and actually may lead to task performance improvement. With more complex or more frequent interruption tasks, however, arousal is already high and hence further rise only disrupts performance.

Finally, interruptions not only affect users' primary task performance, but also affect user's psycho-/ and physiological state. Externally imposed interruptions make employees' environment less controllable and predictable, induce personal stress and produce information overload, thus requiring additional effort and causing cognitive fatigue (Cohen, 1980).

4. Attention - Interruption Studies

Different scientific streams are interested in attention-interruption. In their studies, all of them have asked participants to complete a task during which they were interrupted. They aim at identifying the determinants of how individuals respond to task interruptions. This paper discerns between three scientific branches: First, older attention-interruption experiments stemming from psychology are reviewed. Here researchers have looked at individuals' reactions in terms of psycho-/ and physiological state. Mostly, interruptions at the work place are tested and hence effects on individuals' efficiency at work is also examined. Second, we present the studies of information systems scientists. Here, the focus is IS users and the way system design can minimize disruptive effects of interruptions. Third, marketing research investigates how interrupting advertisement affects individuals.

4.1. Attention Studies in the Domain of Psychology, Ergonomics & HR

An interrupted work environment is commonplace for a typical knowledge worker (Speier et al., 2003, p. 1), where information systems are increasingly used to support knowledge-worker tasks (Panko, 1992). Unfavorable side effects of a progressively more technology-based work environment are the frequent interruptions (Speier, 1999, p. 1). For example, telephone and E-mail interruptions have been identified as significant corporate time-consumers (Dahms, 1988; Pitney Bowes, 2000), which knowledge workers often allow to take precedence over other activities (Jones & McLeod, 1986; Watson, Rainier, & Koh, 1991). Studies report that knowledge workers in the United States send and receive an average of 204 emails per day (Pitney Bowes, 2000) and experience an average of six interruptions per hour in a typical work day (Pitney Bowes, 1998). Other evidence demonstrates that managers spend 10 minutes of every working hour responding to interruptions and do not return to their initial task 41% of the time (O'Conaill & Frolich, 1995).

Experiments described below are concerned with general effects of such interruptions and their varying characteristics. Influences coming from such aspects as interruption frequency, timing, and duration, among others, are analyzed with respect to their impact on worker's feelings of being overloaded and stressed, as well as worker's strategies and efficiency to deal with interruptions.

4.1.1. Kirmeyer (1988)

AIM AND APPROACH

The present study is the first known of its kind dealing with effects of interruptions. One rationale behind the present study was to examine the hypothesis that employees exposed to higher rates of interruption (more frequent) see their work as more overloading and take more actions to cope with overload than those exposed to lower rates of interruption. A further purpose of the study was to inspect the extent to which adverse effects of interruption are exacerbated by individual differences. To be more precise, Kirmeyer wanted to analyze the difference between the workload appraisal of more impatient and competitive workers compared to their more easy-going colleagues in response to loss of environmental control due to external interruptions (Kirmeyer, 1988, p. 622). The researcher measured the impatience degree in the character of participants with the Type A score, i.e. coronary-prone behavior, such as hostility aggression, time urgency and striving for competitive achievements (Kirmeyer, 1988, p. 622). Interruptions came from telephone calls, which gave the subjects some control how to handle them, they (a) responded immediately and stopped previous work, (b) began attending to a new demand while continuing work of the previous task, and finally (c) did not attend to the interruption task prior to finishing their work (Kirmeyer, 1988, p. 623). This flexibility qualifies for negotiated interruption with high control, by definition.

RESULTS

One interesting result was that people adjust their performance strategy when they notice time pressure from more frequent interruption. Workers felt more busy and rushed when they applied an immediate strategy (i.e. processed work demands simultaneously) with rising interruption frequency (Kirmeyer, 1988, p. 626). Hence, as workload due to interruptions increased, subjects handled more requests sequentially, finishing one task before proceeding to the next, which is a typical 'delayed strategy' (Kirmeyer, 1988, p. 624). More impatient subjects (with more extreme Type A tendencies) were more likely to feel overloaded, and hence stressed, when interruption frequency increased (Kirmeyer, 1988, p. 625). Accordingly, subjects with stronger Type A scores took more delayed strategy actions to reduce overload (Kirmeyer, 1988, p. 627).

Table 2: Kirmeyer's (1988) Main Results

Independent Variable	Dependent Variable	Significance	Relation-ship	Confidence	Moderating variable
Negotiated IR 'no IR' vs. 'IR'	Real work volume	YES	+ve	p<0,001	
Frequency of IR	Real work volume	YES	+ve	p<0,05	
Negotiated IR 'no IR' vs. 'IR'	Feeling overloaded	YES	+ve	p<0,001	Individual Patience
Frequency of IR	Feeling overloaded	YES	+ve	p<0,05	
Feeling overloaded	Strategy change 'Immediate' vs. 'Delayed'	YES	+ve	p<0,05	
Frequency of IR 'low' vs. 'high'	Strategy change 'Immediate' vs. 'Delayed'	YES	+ve	p<0,001	Individual Patience
Individual Patience 'low' vs. 'high'	Feeling overloaded	YES	+ve	p<0,03	
Individual Patience 'low' vs. 'high'	Strategy change 'Immediate' vs. 'Delayed'	YES	+ve	p<0,03	

CONCLUSION

On the basis of the experimental findings, it appeared that interruption had two effects: higher cognitive appraisal of the workload, and an indirect effect of strategy change towards a more delayed response mediated through load appraisal (Kirmeyer, 1988, p. 625). This finding supports Cohen's (1978, 1980) proposition that interruptions are uncontrollable and unpredictable stressors that result in information overload and cognitive fatigue (Kirmeyer, 1988, p. 627). The researcher suggests reducing overload at work through increased personal control of interruption. She concludes that efforts to redesign service jobs to increase control and reduce interruption may prove helpful in alleviating job stress and improving quality of service (Kirmeyer, 1988, p. 628).

4.1.2. Gillie & Broadbent (1989)

AIM AND APPROACH

The experiments by Gillie and Broadbent (1989) examined the duration, similarity, and complexity of interruption as three key variables, which explain the observation that some interruptions disrupt performance of a computer-based task while others do not (Gillie et al., 1989, p. 244). At the start of an interruption (simple arithmetic problem – analytical task of low processing intensity), the computer screen clears, and subjects must attend to the interruption task before they can continue playing an adventure game (relatively complex memory task – memorize a list of items to be found, issue commands to find them, request reminders if needed) (Gillie et al., 1989, p. 246). Hence, there were two dissimilar tasks and an immediate interruption type here, one with somewhat higher memory load requirement than the other (Gillie et al., 1089, p. 245). In the first two experiments, subjects were able to rehearse information (preparation for resumption) about the primary task, as they did not have to start with the secondary task until they were ready to do so (interruption lag). The third experiment used a free recall interruption task (memorizing task) similar to PT in terms of cognitive processing type, which also prevented users from rehearsal of the main task (Gillie et al., 1089, p. 246). The fourth experiment again used a dissimilar interruption task, which was a more complicated arithmetic problem (analytical task of high processing intensity) with the possibility to prepare during the interruption lag (Gillie et al., 1089, p. 248). The disruptiveness of interruption was measured by the primary task performance timeliness.

RESULTS

First of all, it was found that short, dissimilar and simple processing based interruption does not have a disruptive performance effect (Gillie et al., 1989, p. 245). Moreover, researchers proved that having a lower memory requirement for the primary task does not guarantee immunity from the disruptive effects of interruption, nor does having a higher memory load guarantee negative performance effects (Gillie et al., 1989, p. 245). The second experiment showed that varying duration of interruptions also does not show any interaction with task performance (Gillie et al., 1989, p. 246). This fact proposes that working memory can retain information from the main task in some storage while processing the interruption. Results of the third and fourth experiments show quite clearly that having the opportunity to rehearse one's position in the main task does not automatically guarantee immunity against the disruptive effect of an interruption (Gillie et al., 1989, p. 248). Further interpretation of the outcomes suggests that similarity between the cognitive processing required for the interruption and for the main task have a negative effect on PT performance timeliness. However, this difference is definitely not a simple reflection of an individual's ability to recall (Gillie et al., 1989, p. 247). The last experiment finally illustrated that higher complexity of the interruption task also negatively affects PT performance (Gillie et al., 1989, p. 249).

Table 3: Gillie & Broadbent's (1989) Main Results

Independent Variable	Dependent variable	Significance	Relationship	Confidence	Moderating variable
Immediate IR 'short simple dissimilar IR' vs. 'no IR'	PT – Timeliness	NO			
Immediate IR 'long simple dissimilar IR' vs. 'no IR'	PT – Timeliness	NO			
Duration of immediate IR '30 sec' vs. '165 sec'	PT – Timeliness	NO			
Complexity of PT when interrupted (IR) 'low memory load' vs. 'high'	PT – Timeliness	NO			
Timing of IR 'No IR lag' vs. 'IR lag'	PT – Timeliness	NO			
Complexity of immediate IR 'low processing intensity' vs. 'high'	PT – Timeliness	YES	– ve	p<0,04	
Similarity of immediate IR & PT 'dissimilar cognitive process' vs. 'similar'	PT – Timeliness	YES	– ve	p<0,04	
Individual Recall Ability 'low' vs. 'high'	PT – Timeliness	NO			
Individual Gender 'male' vs. 'female'	PT – Timeliness	NO			

CONCLUSION

To conclude, this chain of experiments suggests that the duration of an interruption and the opportunity to rehearse are not important in determining whether or not an interruption will disrupt performance of the interrupted task. Instead, it appears that interruptions similar to the continuing task, as well as the interruptions requiring high amount of processing (high level of complexity) have a disruptive effect on the timeliness of task performance (Gillie et al., 1989, p. 249).

4.1.3. Zijlstra, Roe, Leonora & Krediet (Dutch study 1999)

AIM AND APPROACH

This study examines the effects of interruptions (telephone calls) on worker's real work task performance (time needed and quality) (Zijlstra et al., 1999, p. 169) as well as on workers' subjective psychological state (well-being measured by the emotional state) and psycho-/physiological state (level of mental effort expenditure) (Zijlstra et al., 1999, p. 170). We refer to the method of coordination used here as a *negotiated* interruption method with high control, because workers were allowed to choose themselves whether they wanted to interrupt their ongoing work and when to start with the interruption task. Moreover, the researchers manipulated the frequency and complexity (processing intensity) of interruptions to see whether they, in any way, influence the interruption effects (Zijlstra et al., 1999, p. 169).

Results

The researchers' main finding was that occurrence of interruptions can lead to an improvement, rather than a decline, in the performance of tasks (Zijlstra et al., 1999, p.171). They also found that it is not so much the amount of time that people spend on an interruption that causes them to speed up, but rather the frequency of being interrupted (Zijlstra et al., 1999, p.173). Explanation of this phenomenon lies in the fact that people change their performance strategy when they notice pressure from more frequent interruption. 'Delayed strategy', where the interruption task is addressed after resumption of the main task, becomes the prevalent strategy (Zijlstra et al., 1999, p.174). In other words, when there were fewer interruptions, people adopt an immediate strategy, but when there were frequent interruptions, they led some of their subtasks to an end before reorienting to interruptions (McFarlane, 2002, p. 105).

With respect to people's psychological and psycho-physiological state, Zijlstra et al. found that interruption caused a significant decrease in people's positive emotions (Zijlstra et al., 1999, p.177). However, they seemed not to further deteriorate with more frequent interruptions, presumably because the frequency increased only by a bit (Zijlstra et al., 1999, p.178). Further, the findings suggest that increased number of interruptions leads to increased psychological costs, as there was a significant increase in mental effort (Zijlstra et al., 1999, p.177).

Conclusion

Zijlstra's results show that negotiated interruptions can improve primary task performance by implementing different strategies to handle interruptions and to execute the main task. However, this performance improvement happens at the expense of the person's emotional well-being and higher level of effort expenditure (Zijlstra, 1999, p. 183).

Table 4: Zijlstra, Roe, Leonora and Krediet's (1999) Main Results

Independent Variable	Dependent variable	Significance	Relationship	Confidence	Moderating variable
Negotiated IR 'no IR' vs. 'IR'	PT- Timeliness	YES	+ve	p<0,001	IR Frequency
Negotiated IR 'no IR' vs. 'IR'	PT- Quality	NO			
Frequency of IR '1 IR' vs. '3 IR'	PT- Timeliness	YES	+ve	p<0,001	
Frequency of IR '1 IR' vs. '3 IR'	PT- Quality	NO			
Frequency of IR '1 IR' vs. '3 IR'	Strategy change 'Immediate' vs. 'Delayed'	YES	+ve	p<0,001	
Complexity of IR 'low processing intensity' vs. 'high'	PT- timeliness	NO	–ve		
Complexity of IR 'low processing intensity' vs. 'high'	PT- quality	NO	–ve		
Negotiated IR 'no IR' vs. 'IR'	Well-being	YES	–ve	p<0,001	
Frequency of IR '1 IR' vs. '3 IR'	Well-being	NO			
Frequency of IR '1 IR' vs. '3 IR'	Mental effort expenditure	YES	+ve	p<0,001	
Complexity of IR 'low processing intensity' vs. 'high'	Well-being	NO	–ve	p<0,1	
Complexity of IR 'low processing intensity' vs. 'high'	Mental effort expenditure	NO			

4.1.4. Speier, Valacich & Vessey (1999)

AIM AND APPROACH

Speier et al. (1999) studied the effects of interruptions on decision maker performance in IT-laden work places. Their investigation had two objectives. First, to examine the interruption effect on decision maker's performance of the primary task with varying complexity in terms of processing intensity (Speier et al., 1999, p.344). Second, to analyze how interruption task frequency and content similarity with the primary task affects performance (Speier et al., 1999, p.338). That is, in the 'similar content' condition, the data used in solving the interruption task was identical to the data in the primary task, whereas data in the 'dissimilar content' condition involved different data from the primary task (Speier et al., 1999, p.345). Specifically, Speier et al. were interested in interruption factors that are likely to induce information overload. Prior research has linked task complexity, diversity and frequency directly to information overload (Evaristo et al., 1995), as they all result in a decision maker having to process a greater number of information cues (Casey, 1980; O'Reilly, 1980; Iselin, 1988; Speier et al., 1999, p.340, p. 342). Immediate interruptions were presented to subjects while working on tasks with time and accuracy pressures. The dependent variables measured were primary task performance, quality, and timeliness (Speier et al., 1999, p.345).

RESULTS

Results showed that interruptions significantly improved speed and performance of simple tasks and had no significant effect on performance quality (Speier et al., 1999, p. 346). However, interruptions on complex tasks led to a significant decrease on decision accuracy and increase in decision time (Speier et al., 1999, p. 348). As expected, decision makers experiencing more frequent interruptions performed their primary task less accurately and required more time (Speier et al., 1999, p. 347). An interesting result was that subjects experiencing interruptions containing similar information to the primary task required less time to complete the task and kept its level of quality (Speier et al., 1999, p. 348). This finding was explained by the proposition that similar information decreases the demand for cognitive processing resources and hence results in decreased information overload (Iselin, 1988; Speier et al., 1999, p. 342). Iselin (1988) claims that diversity necessitates more information cues and types of information to process, which increases the likelihood that the decision maker's limited cognitive capacity will be exceeded. Similar information, however, decreases the demand for cognitive processing resources (Biggs, Bedard, Gaber, & Linsmeier, 1985) and results in decreased information load (Evaristo et al., 1995). This statement conflicts though with some other attention-interruption research, which discovered that similarity between interruption and the primary task increases the disruptive effect on task performance (Kreifeldt and McCarthy, 1981; Gillie & Broadbent, 1989; Czerwinski, Chrisman, & Schumacher, 1991). Finally, interrupted users had a more negative perception of interruptions, whether performing simple or complex tasks, whereby similarity between the tasks increased this negative effect even more (Speier et al., 1999, p. 350).

CONCLUSION

Most findings of Speier et al.'s experiment are consistent with attention-interruption research. The most interesting result was that decision makers experiencing interruptions containing similar information from the experimental task required less time to complete the task. This outcome contradicts Gillie & Broadbent's (1989) finding that the similarity between the interruption and the primary task have a disruptive effect. This conflicting result therefore needs further investigation. Speier et al. (1999) explain the discrepancy by the differences in the type of tasks studied: they used cognitively complex decision-making tasks, while the research by Gillie et al. (1989) used relatively short memory and association problems (Speier et al., 1999, p. 348).

Table 5: Speier, Valacich & Vessey's (1999) Main Results

Independent Variable	Dependent variable	Sig-nifi-cance	Relation-ship	Confi-dence	Moderating variable
Immediate IR 'no IR' vs. 'IR'	PT- Timeliness	YES	+ve & -ve	p<0,005	PT complexity, IR frequency, Similarity IR & PT
Immediate IR 'no IR' vs. 'IR'	PT- Quality	YES	0 & -ve	p<0,05	PT complexity, IR frequency
Immediate IR, simple PT 'no IR' vs. 'IR'	PT- Timeliness	YES	+ ve	p<0,001	
Immediate IR, complex PT 'no IR' vs. 'IR'	PT- Timeliness	YES	– ve	p<0,005	
Immediate IR, simple PT 'no IR' vs. 'IR'	PT- Quality	NO			
Immediate IR, complex PT 'no IR' vs. 'IR'	PT- Quality	YES	– ve	p<0,006	
Complexity of PT when IR 'low processing' vs. 'high'	PT- Timeliness	YES	– ve		
Complexity of PT when IR 'low processing' vs. 'high'	PT- Quality	YES	– ve		
Frequency of IR '1 IR' vs. '12 IR'	PT- Timeliness	YES	– ve	p<0,000	
Frequency of IR '1 IR' vs. '12 IR'	PT- Quality	YES	– ve	p<0,003	
Similarity of IR & PT 'dissimilar content' vs. 'similar'	PT- Timeliness	YES	+ ve	p<0,013	
Similarity of IR & PT 'dissimilar content' vs. 'similar'	PT- Quality	NO			
Immediate IR 'no IR' vs. 'IR'	Perceived PT performance	YES	– ve	p<0,001	Similarity of IR
Similarity of IR & PT 'dissimilar content' vs. 'similar'	Perceived PT performance	YES	– ve	p<0,036	

4.1.5. Speier, Vessey & Valacich (2003)

AIM AND APPROACH

Again Speier et al. (2003) were interested in decision-making performance of individuals in an interruption prevalent work place. This time, they looked at individual characteristics: (a) domain expertise, and (b) gender (Speier et al., 2003, p. 783). Furthermore, the researchers manipulated primary task features such as (a) the complexity of the PT in terms of processing intensity (Speier et al., 2003, p. 775), and (b) the type of cognitive processing needed, differentiating between analytical processing, e.g., calculations, and perceptual processing, e.g., visual comparisons (Speier et al., 2003, p. 775). The final independent variable was an information presentation format: (a) symbolic, e.g., tables, and (b) spatial e.g., graphs (Speier et al., 2003, p. 776). The effects of an immediate interruption on primary task performance (quality and timeliness) were measured (Speier et al., 2003, p. 776). The primary goal of this research was to investigate whether there was any interaction between information presentation format and task performance in interruption-loaded work environments. Speier et al. (2003) wanted to validate their assertion that information presentation formats are effective in mitigating the negative influence of interruptions on complex decision-making tasks (Speier et al., 2003, p. 788).

Results

The test showed that for interrupted *simple-symbolic* tasks, decision time is faster compared to when the task is not interrupted. However, interruption had only a small positive effect on decision accuracy (Speier et al., 2003, p. 784, 786). For *simple-spatial* tasks, primary task performance, accuracy, and speed equally improved with interruption (Speier et al., 2003, p. 784, 786). Hence, it can be concluded that interruptions on simple tasks of any kind have an effect of improving performance rather than worsening one. However, as tasks became more *complex* in terms of processing, the accuracy effect of interruption was negative when interruptions occurred, regardless of the type of cognitive processing. Deterioration in speed performance was also observed, however more significantly by spatial primary tasks than symbolic tasks (Speier et al., 2003, p. 784, 786). Thus, interruptions have a greater negative effect on performance of perceptual processes, such as establishing relationships among discrete sets of symbols (spatial task), than of analytical processes, such as manipulating discrete sets of symbols (symbolic tasks) (Speier et al., 2003, p. 775).

Moreover, the theory of cognitive fit (CFT) was empirically validated with the experiment. Simple tasks are solved better with information presentation formats that emphasize information that is required most by the tasks' cognitive process used to solve the task. In other words, analytical tasks are best supported by symbolic format (tables) and perceptual tasks are best supported by spatial format (graphs) (Speier et al., 2003, p. 786). As these tasks become more complex, users tend to prefer spatial formats for any type of task, which is how users minimize their limited effort. Speier et al.(2003) found some evidence for their hypothesis that interruptions would have a similar effect as increased task complexity, i.e., that there is an interaction effect between interruptions and information presentation format. Interruptions were found to have similar effects on task performance quality as time pressure and higher task complexity do (Speier et al., 2003, p. 779): spatial task formats tend to facilitate performance, and hence minimize the negative performance effect of interruptions. However, this finding was only true for performance accuracy, but not for timeliness (Speier et al., 2003, p. 786-787). Spatial formats led to faster solving of any complex task, independently of whether the task was interrupted or not (Speier et al., 2003, p. 787).

Finally, it was found that those subjects with greater domain expertise performed the task more accurately and faster than those with less expertise (Speier et al., 2003, p. 787). Further, there is strong evidence that interruption has a negative effect on work-related psychological state, such as stress and job satisfaction. This conclusion is drawn from the fact that even performance improving interruptions were negatively perceived by the subjects (Speier et al., 2003, p. 789).

Conclusion

Speier et al. (2003) concluded that interruptions disrupt both quality and timeliness of complex tasks, during which perceptual processes and intensive tasks are even more affected. Moreover, decision makers who are interrupted when solving complex problems, no matter whether they are analytical or perceptual, are better supported by graphs and charts rather than tables. They assert that a possible solution to the dilemma of a work environment characterized by frequent interruptions is the appropriate information presentation format, which mitigates the deleterious effect of interruptions on the quality of decision making (Speier et al., 2003, p. 791). Gender effects could not be observed in their study.

Table 6: Speier, Vessey & Valacich's (2003) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Immediate IR 'no IR' vs. 'IR'	PT-Timeliness	YES		p<0,01	PT complexity, PT cog. process type
Complexity of PT with IR 'low processing' vs. 'high'	PT-Timeliness	YES	–ve		PT cog. process type
PT cognitive process type when IR 'perceptual' vs. 'analytical'	PT-Timeliness	YES			
Immed. IR, simple – *perceptual* PT 'no IR' vs. 'IR'	PT-Timeliness	YES	+ve	p<0,00	
Immed. IR, complex – *perceptual* PT 'no IR' vs. 'IR'	PT-Timeliness	YES	–ve	p<0,03	
Complexity of perceptual PT when IR 'low processing' vs. 'high'	PT-Timeliness	YES	–ve		
Immed. IR, simple – *analytical* PT 'no IR' vs. 'IR'	PT-Timeliness	YES	+ve	p<0,01	

Immed. IR, complex – *analytical* PT 'no IR' vs. 'IR'	PT-Timeliness	NO	still –ve		
Complexity of analytical PT when IR 'low processing' vs. 'high'	PT-Timeliness	YES	–ve		
Immediate IR 'no IR' vs. 'IR'	PT-Quality	YES		p<0,01	PT complexity,format PT cog. process type
Complexity of PT with IR 'low processing' vs. 'high'	PT-Quality	YES	–ve		Type of cognitive processing
Type of cognitive processing 'perceptual' vs. 'analytical'	PT-Quality	NO			
Immed. IR, simple – *perceptual* PT 'no IR' vs. 'IR'	PT-Quality	YES	+ve	p<0,01	
Immed. IR, complex – *perceptual* PT 'no IR' vs. 'IR'	PT-Quality	YES	–ve	p<0,03	
Complexity of perceptual PT when IR 'low processing' vs. 'high'	PT-Quality	YES			
Immed. IR, simple – *analytical* PT 'no IR' vs. 'IR'	PT-Quality	NO	still +ve		
Immed. IR, complex – *analytical* PT 'no IR' vs. 'IR'	PT-Quality	YES	–ve	p<0,00	
Complexity of analytical PT with IR 'low processing' vs. 'high'	PT-Quality	YES	–ve		
PT format when IR 'spatial' vs. 'symbolic'	PT-Quality	YES			PT complexity, PT cog. processing type
PT format when IR 'spatial' vs. 'symbolic'	PT-Timeliness	NO			PT complexity, PT cog. processing type
PT format of simple PT 'no IR' vs. 'IR'	PT-Timeliness	NO			
PT format of simple PT 'no IR' vs. 'IR'	PT-Quality	NO			
PT format of complex *perceptual* PT 'no IR' vs. 'IR'	PT-Timeliness	NO			
PT format of complex *perceptual* PT 'no IR' vs. 'IR'	PT-Quality	NO			
PT format of complex *analytical* PT 'no IR' vs. 'IR'	PT-Timeliness	NO			
PT format of complex *analytical* PT 'no IR' vs. 'IR'	PT-Quality	YES			
Immediate IR 'no IR' vs. 'IR'	Perceived PT performance	YES	–ve	p<0,00	
Gender	PT-Timeliness	NO			
Gender	PT- Quality	NO			
Domain expertise	PT-Timeliness	YES	+ve	p<0,03	
Domain expertise	PT- Quality	YES	+ve	p<0,00	

4.1.6. Eyrolle & Cellier (2000)

AIM AND APPROACH

The aim of this paper was to evaluate the effects of interruptions in work activity (Eyrolle et al., 2000, p. 542). In a field study, a communication operator was interrupted by telephone calls that he had to answer immediately while working on uncomplicated file creation tasks (Eyrolle et al., 2000, p. 538). Because the computing system did not allow saving data during the processing, any interruptive task led to an irretrievable loss of data (Eyrolle et al., 2000, p. 538). Thus we have an immediate interruption type.

RESULTS

On the basis of the mean processing time of primary tasks it was seen that interruptions significantly reduce performance timeliness when processing was shared into two periods, and even more when two interruptions occurred (Eyrolle et al., 2000, p. 538). Also, mean error rates increased when the processing of the main tasks was interrupted, but not significantly (Eyrolle et al., 2000, p. 539).

Table 7: Eyrolle & Cellier's (2000) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Immediate IR 'No IR' vs. 'IR'	PT- timeliness	YES	–ve	p<0,001	IR Frequency
Frequency of IR '1 IR' vs. '3 IR'	PT- timeliness	YES	–ve	p<0,001	
Immediate IR 'No IR' vs. 'IR'	PT- correctness	NO	–ve		

CONCLUSION

To conclude, the field study verified the relevance of the problem of task interruption (Eyrolle et al., 2000, p. 542). The obtained results showed an increase in the processing time of the primary task when it was interrupted. On the other hand, results did not show any significant increase in the error rate. The researchers proposed that an increase in the processing time compensated for the constraints induced by the interruptions, and hence allowed minimization of the errors (Eyrolle et al., 2000, p. 542).

4.1.7. Trafton, Altmann, Brock & Mintz (2003)

AIM AND APPROACH

The goal of this experiment was to manipulate the opportunity to prepare for the resumption of the primary task after an interruption, and then to measure whether such an opportunity had any positive effects on task performance timeliness. To achieve this aim, an experiment was designed with two different types of interruption, 'immediate' and 'warned immediate'. The latter condition incorporated a warning form of a pop up window in a corner for eight seconds before the actual interruption, which produced an 'interruption lag' or a delay (Trafton et al., 2003, p. 589). Once the alert window appeared, the keyboard and mouse were frozen and no further actions could be taken on the primary task. The delay does not qualify the interruption for being negotiated, because the user cannot influence the time of the start of the interruption. Participants in the 'immediate' condition were faced with the secondary task with no prior warning, and hence no 'interruption lag' (Trafton et al., 2003, p. 589). The primary task was a complex perceptual task (mission development game), where participants did not have the opportunity to manipulate environmental cues in ways that would help them during resumption (Trafton et al., 2003, p. 590). The interruption was a rather simple mechanic task, totally dissimilar to the primary task in terms of cognitive process type, which lasted 30 seconds. The effect of interest was the speed with which people were able to resume the primary task after being interrupted by the secondary task (resumption timeliness) (Trafton et al., 2003, p. 592). Finally, 'talk-aloud protocols' were used to determine the amount, timing, and type of preparation, both during the interruption lag in the 'warning' condition and during the secondary task in both conditions (Trafton et al., 2003, p. 592).

RESULTS

The data proved that interruptions actually significantly disrupt the primary task performance (Trafton et al., 2003, p. 595). An interesting result was found by the verbal protocols, which show that users in the 'warned immediate interruption' condition (with an interruption lag of eight seconds) engaged in preparation activities both during the interruption lag and during the secondary task. The preparation involved 38% rehearsal of retrospective state information from the primary task prior to the interruption and 62% setting of prospective goals to be achieved at resumption time (Trafton et al., 2003, p. 593). As predicted, even by setting opportunities of preparation to be equal between the groups, warned participants prepared an average of four times more than immediate participants (Trafton et al., 2003,

p. 593). Moreover, it was found that 95% of total preparation took place during the interruption lag, rather than during the interruption (Trafton et al., 2003, p. 593). Although for session one, the 'warned' condition had a significantly lower disruption score than the immediate condition, this trend drastically diminishes in the next sessions. Researchers explained this phenomenon by the fact that participants in the 'immediate' condition were particularly able to improve their ability to resume the task due to their drive to adapt in a condition with super-disruptive interruptions (Trafton et al., 2003, p. 596). Additionally, it was shown that a significant learning process set in only in the immediate condition, where people considerably improved their resumption time in later sessions (Trafton et al., 2003, p. 595). Generally, it was found that providing participants an opportunity to prepare their goals did not affect their performance on the secondary task (Trafton et al., 2003, p. 596).

Table 8: Trafton, Altman, Brock, & Mintz' (2003) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Immediate IR 'No IR' vs. 'IR'	PT Timeliness (resumption time)	YES	–ve	p<0,001	
Repetition of PT, 'immediate IR'; '1st' vs. 'last'	PT Timeliness (resumption time)	YES	+ve	p<0,01	
Repetition of PT, 'warned IR' '1st' vs. 'last' for	PT Timeliness (resumption time)	NO			
Timing of IR 'No IR lag' vs. '8 sec. IR lag'	Preparation for resumption	YES		p<0,001	
Timing of IR in 1st session 'No IR lag' vs. 'IR lag'	IR Quality	YES		p<0,05	Preparation for resumption
Timing of IR in 2nd session 'No IR lag' vs. 'IR lag'	IR Quality	NO			
Timing of IR in last session 'No IR lag' vs. 'IR lag'	IR Quality	NO			

CONCLUSION

The critical results of the experiment are that interruptions are in fact disruptive, and that participants did use the interruption lag to prepare to resume, producing smaller disruption scores (Trafton et al., 2003, p. 599). Hence, it can be concluded that preparation boosts the activation of goals, facilitating retrieval of this information from memory during resumption (Trafton et al., 2003, p. 599). Knowing that preparation focused mostly on encoding a goal to be achieved after the interruption, system designers could apply this fact to facilitate resumption of PT. Finally, the finding that interruptions become less disruptive over time intrigues the possibility that training could improve interruption management (Trafton et al., 2003, p. 598).

4.1.8. Monk, Boehm-Davis & Trafton (2002)

AIM AND APPROACH

The purpose of this study was to identify whether attention-switching costs will vary for interruptions occurring at various task points (timing of IR) in order to allow system designers to distinguish between interruptible and uninterruptible tasks (Monk et al., 2002, p. 1). Monk et al.looked at multitasking drivers who alternatively switch their visual attention to the road and to their IVIS (In-Vehicle Information System) device while driving to find out where IVIS-style tasks are best interrupted (Monk et al., 2002, p. 1). Researchers reasoned that the time needed for resumption of the IVIS task after having switched back from tracking the road is the key cost of interruption, and hence needs to be reduced (to minimize eyes-off-the-road time) (Monk et al., 2002, p. 2). Resumption period in this experiment comprised the response time after switching from the tracking task to the first mouse-click on an IVIS button. Taking the resumption lag as the dependent variable is conceptually similar to measuring performance timeliness of the primary task. The simulated IVIS task was an information entering activity (simple memory task), which was divided in three interruption stages: (1) 'end' (after some subtask, just before the task initiation), (2) 'mid' (in the middle of and before the end of the task), and (3) 'repetitive' (repetitive inputs such as scrolling through the list) (Monk et al., 2002, p. 2). The interruptive task (tracking the road) varied between slow (simple 'attentive' type of task) and fast (complex 'attentive' type of task) (Monk et al., 2002, p. 3). Hence we have a 4x2 experimental design. As participants did not have a choice as to when they 'track the road', we have an immediate interruption type here.

RESULTS

As predicted, resumption lags were consistently present, and hence net performance time increased when the primary task was interrupted by the interruption task (Monk et al., 2002, p. 3). Moreover, the resumption lag length differed significantly for different interruption points. The least time to resume was needed in the 'repetitive' condition, closely followed by the 'end' condition, with the 'mid' condition showing the most disruptive results. The pair-wise comparisons revealed that the resumption lags between 'end' and 'repetitive' points of interruption were not significantly different (Monk et al., 2002, p. 4). Despite expectations, there was no difference between the slow and fast tracking settings (Monk et al., 2002, p. 3). Presumably, neither of the interrupting task settings were demanding enough to prevent participants from rehearsing or recalling their task state while working on the interruption task (Monk et al., 2002, p. 4).

Table 9: Monk, Boehm-Davis & Trafton's (2002) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Immediate IR 'No IR' vs. 'IR'	PT- Timeliness (resumption time)	YES	–ve	p<0,001	IR Timing
Timing of immediate IR 'end' vs. 'mid'	PT- Timeliness (resumption time)	YES	–ve	p<0.05	
Timing of immediate IR 'end' vs. 'repetitive'	PT- Timeliness (resumption time)	NO			
Timing of immediate IR 'repetitive' vs. 'mid'	PT- Timeliness (resumption time)	YES	–ve	p<0.05	
IR Complexity (processing intensity) 'low processing' vs. 'high processing'	PT- Timeliness (resumption time)	NO			

CONCLUSION

The main finding of the study is that the attention-switching cost in terms of resulting resumption lag is lowest when interrupting occurs at the end of some subtask of the primary task, or when performing a repetitive operation within a task like scrolling through a list (Monk et al., 2002, p. 3). Thus, by understanding the importance of timing at which interruptions occur, designers can attempt to develop interfaces that have natural breaking points, such as short, discrete subtasks (Monk et al., 2002, p. 3).

4.1.9. Monk (2004)

AIM AND APPROACH

The present study applied the same experimental setting as in Monk et al. (2002) (i.e. IVIS device tasks interrupted by simulated 'road tracking' task), however this time it was designed to address the effects of interruption frequency on the speed with which operators resume the primary task after an interruption, so called resumption lag (Monk, 2004, p. 296). In addition, interruption frequency effects on resumption errors (performance quality) and on the net-time on the primary task (timeliness) were also analyzed. During the experiment, participants were forced to switch between the primary and interruption tasks, hence we talk about immediate interruptions here (Monk, 2004, p. 296). Frequent interruptions occurred every 10 sec (on average, 1,3 times), while infrequent interruptions occurred every 30 sec (on average, 4,7 times) (Monk, 2004, p. 297).

RESULTS

Contrary to prediction, it was found that people were able to resume the primary task 500 ms faster when they were more frequently interrupted (Monk, 2004, p. 297). It may be that the rapid switching between tasks forced participants to adopt a more effective strategy, such as to actively rehearse their suspended goals during the interruptions, leading to faster resumption times (Monk, 2004, p. 297). Additionally, the interrupting task was not demanding, therefore goal rehearsal was possible during the interruptions (Monk, 2004, p. 297). On the other hand, in the 'infrequent' condition participants may not have been motivated enough to actively rehearse their suspended goals (Monk, 2004, p. 297). Similarly, mean resumption error rate was higher for the infrequent condition; however this difference was not statistically significant. Theoretical expectation that participants were sacrificing accuracy for speed in resuming the primary task after the interruptions was not proved (Monk, 2004, p. 297).

Table 10: Monk's (2004) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Frequency of immediate IR '1 IR' vs. '5 IR'	PT- Timeliness (resumption time)	YES	+ve	p<0,001	PT Repetition
Frequency of immediate IR '1 IR' vs. '5 IR'	PT- Quality (resumption time)	NO	+ve	p<0,15	

CONCLUSION

Generally speaking, the underlying experimental results lead to a conclusion that frequent and predictable shifts between the tasks may trigger adoption of a 'time-sharing' strategy that allows users to rehearse suspended goals during the interruptions. Such a strategy proves effective and results in faster primary task completion (Monk, 2004, p. 298).

4.1.10. Monk, Boehm-Davis & Trafton (2004a)

AIM AND APPROACH

The setting of the study was the same as in previous experiments (Monk et al., 2002; Monk, 2004), with special interest on the effect of different lengths of an interruption on the time needed by participants for resumption when switching back to primary task after the interruption. Researchers chose durations of 1 sec. and 5 sec. to test the effects of an immediate interruption (Monk et al., 2004a, p. 1).

RESULTS

The experiment confirms that the effect of interruption length on primary task resumption time is significant. Paired comparisons showed that the 5-second interruption condition had the greatest negative performance effect than the other three conditions, whereas the difference in results for the 1/4 sec. and 1 sec. conditions were insignificant (Monk et al., 2004a, p. 1).

Table 11: Monk, Boehm-Davis & Trafton's (2004a) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Immediate IR 'no IR' vs. 'IR'	TP Timeliness (resumption time)	YES	–ve	p<0,001	IR duration
Duration of immediate IR '1 sec.' vs. '5 sec.'	TP Timeliness (resumption time)	YES	–ve		

CONCLUSION

The main contribution of the study is to prove once more that interrupted primary tasks suffer performance losses as opposed to uninterrupted tasks. Moreover, the presence of a resumption cost for a very short break shows that primary task goals decay quite rapidly, even briefest interruptions might have a negative performance impact (Monk et al., 2004a, p. 1).

4.1.11.Monk, Boehm-Davis & Trafton (2004b)

AIM AND APPROACH

The research reported here was designed to explore the effects of interruption complexity, timing, and age of individuals on net task time and primary task resumption time under conditions in which attention was switched back and forth between two tasks (similarly as to when drivers shift attention between attending to the road and to an in-vehicle task) (Monk et al., 2002; Monk et al., 2004b, p. 650). In the first experiment, the primary task, an IVIS-based task (memory task), was interrupted by a 'tracking the road' task ('attentive' type of cognitive engagement) and by a 'no task' interruption (Monk et al., 2002; 2004a). That is, effects of demanding interruptions that minimize rehearsal possibility during the interruption were compared to undemanding interruptions that allowed plenty of rehearsal (Monk et al., 2004b, p. 653). Moreover, researchers looked at the differential effect of interruption timing ('end', 'mid', and 'repetitive') (Monk et al., 2002; Monk et al., 2004b, p. 655). The second experiment expands the findings of the first and the third experiments by looking at the role that age plays in task switching performance.

RESULTS

First of all, it was demonstrated that interrupting the primary task is detrimental to task performance efficiency (which confirms previous research) (Monk et al., 2004b, p. 656). The particular timing of interruption also had a significant effect. The resumption lag after the interruption at the 'end' of the primary task was significantly shorter than that after the mid-subtask point; the resumption lag after the interruption during some repetitive task was also significantly shorter than that for the mid-subtask point (Monk et al., 2004b, p. 656). Moreover, the resumption lag was also affected by the complexity of the interruption, where the resumption lag in the 'task' condition was longer than in the 'no-task' condition. This supports the argument that rehearsal of the primary task goal is much easier when participants attend to undemanding simple interruption (Monk et al., 2004b, p. 657). The third experiment showed that older participants (average of 60) took significantly longer to complete the primary task than did younger participants (average of 20), demonstrating the typical age-related decline in task performance (Monk et al., 2004b, p. 659).

Table 12: Monk, Boehm-Davis & Trafton's (2004b) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Immediate IR 'no IR' vs. 'IR'	TP Timeliness	YES	-ve	p<0,0001	Age of user
Timing of immediate IR 'end' vs. 'mid'	TP Timeliness	YES	-ve	p<0.05	
Timing of immediate IR 'repetitive' vs. 'mid'	TP Timeliness	YES	-ve	p<0.001	
Timing of immediate IR 'end' vs. 'repetitive'	TP Timeliness	NO			
Complexity of immediate IR 'no task' vs. 'task'	TP Timeliness	YES	-ve	p<0,0001	
Individual age 'young' vs. 'old'	TP Timeliness	YES	-ve	p<0,0001	

CONCLUSION

The experiment's findings clearly show that it is less disruptive to interrupt a task between subtasks, or even better during a repetitive operation, because these points have a lesser encoding demand, and hence result in shorter resumption times because there is little to rehearse about the goal state of the interrupted task (Monk et al., 2004b, p. 656). Learning from this finding, designers can attempt to develop interfaces that have clearly delineated subtasks or that "know" when best to interrupt the user (Monk et al., 2004b, p. 656). A second important finding of the study is that goal rehearsal during undemanding interruption resulted in shorter resumption lags because the activation levels of the interrupted goal was elevated enough to ensure quicker resumptions (Monk et al., 2004b, p. 661).

4.2. Attention Studies in the Domain of Information Systems

Studies in information systems focus on finding system design solutions to enable efficient interruption management. Advances in computing technologies have made it possible to build systems that allow people to perform multiple activities at the same time (McFarlane, 1999, p. 1). However, people's cognitive capabilities remain limited, which undermines the positive effect of these technological advancements. Systems that allow users to multitask by delegating tasks to autonomous processes have the unfortunate side effect of interrupting their users with various requests for feedback (i.e. regarding decisions made on users' behalf, notifications to keep them aware of peripheral information, and alerts from active applications and from applications being executed in the background) (Horvitz, 1999; Bailey et al., 2001). As users continue offloading more control and responsibility to automating applications such as interface agents, softbots, and peripheral information displays, these applications increasingly compete for their attention (Bailey et al., 2001, p. 1). As a result, human attention has been recognized as the most valuable and scarcest resource in human computer interaction (Horvitz, 1999, p. 1).

Information systems research is concerned with user interface design to accommodate people's limitations relative to being interrupted (McFarlane, 1999, p. 1). By analyzing the effects of interruptions in different experimental conditions, researchers aim at finding out whether there are features of interface design that could mitigate interruption effects. Accordingly, propositions for the most effective notification policies, least disrupting interruption strategies and most pleasant information technology based work conditions are sought.

4.2.1. Czerwinski, Chrisman & Schumacher (1991)

AIM AND APPROACH

The study by Czerwinski, Chrisman & Schumacher (1991) presents two experiments examining the effects of an interruption similar to the primary task's information presentation format, and the presence or absence of a warning prior to an interruption on an operator's primary task performance timeliness. It is claimed that a warning prior to an interruption would improve users' ability to remember information about the primary task and hence enable faster resumption after interruption. The interruption type is categorized as immediate because the experimenters simply replaced the main task information on the computer screen with peripheral information, and hence inhibited further work on the primary task (Czerwinski et al., 1991, p. 38).

RESULTS

First of all, results indicated significantly better recall and hence faster resumption of the primary tasks' values when the interruption was in a dissimilar format to the primary task (Czerwinski et al., 1991, p.38). Further, it was discovered that when subjects were explicitly told to recall particular primary tasks' parameters after the interruption and an interruption lag was presented, participants' performance was significantly better (Czerwinski et al., 1991, p. 38).

Table 13: Czerwinski, Chrisman & Schumacher's (1996) Main Results

Independent Variable	Dependent variable	Significance	Relationship	Moderating variable
Similarity of immediate IR & PT 'dissimilar format' vs. 'similar'	PT Timeliness	YES	– ve	
Timing of IR 'No IR lag' vs. 'IR lag'	PT Timeliness	YES	+ve	

CONCLUSION

The present experiment suggests that information in an unanticipated interruption should be displayed in a format that is dissimilar to the task being interrupted (Czerwinski et al., 1991, p.39). However, further testing showed that that the effect of similarity between the tasks may be less when the operator has the opportunity to take preparatory actions prior to the interruption. Researchers propose that it would be best to warn the user of an imminent interruption to reduce the deteriorating effect.

4.2.2. Burmistrov & Leonova (1996)

AIM AND APPROACH

The present experiment took place in a simulated office environment, where participants were interrupted by telephone calls while working on computer-assisted text editing tasks. The independent variables here were the presence/absence of interruption and the complexity level of interruption and primary task in terms of processing intensity (Burmistrov et al., 1996, p. 23). The measured variable was the primary task completion time (timeliness). Participants could develop different strategies to respond to interruptions (immediate, delayed response, delayed attending to interruptive task, simultaneous processing, activities to facilitate memorizing) (Burmistrov & Leonova, 1996, p. 24). This flexibility of response strategies categorizes the interruption coordination method to be negotiated.

RESULTS

Observations show that interruptions have a significant effect on the net operation time of a complex primary task. The resumption process accounted for most of the increase in task performance time (Burmistrov & Leonova, 1996, p. 26). However, there was no interruption effect on a simple primary task performance. Furthermore, correlations between the length of the resumption period (performance timeliness) and interruption complexity, as well as between the length of the interruption itself and the length of the resumption period were found to be significant (Burmistrov & Leonova, 1996, p. 27).

Table 14: Burmistrov & Leonova's (1996) Main Results

Independent Variable	Dependent variable	Significance	Relationship	Confidence	Moderating variable
Negotiated IR 'no IR' vs. 'IR'	PT Timeliness	YES			PT Complexity
Complexity of PT with IR 'low processing' vs. 'high'	PT Timeliness	YES	– ve		
Negotiated IR on complex PT 'no IR' vs. 'IR'	PT Timeliness	YES	–ve	p<0,002	
Negotiated IR on simple PT 'no IR' vs. 'IR'	PT Timeliness	NO			
Complexity of negotiated IR 'low processing' vs. 'high'	TP Timeliness (resumption time)	YES			PT Complexity
Complexity of IR complex PT 'low processing' vs. 'high'	PT Timeliness (resumption time)	YES	–ve	p<0,027	
Complexity of IR simple PT 'low processing' vs. 'high'	PT Timeliness (resumption time)	NO			
Duration of negotiated IR 'short' vs. 'long'	PT Timeliness (resumption time)	YES	–ve	p<0,045	

CONCLUSION

The researchers concluded that interruptions' disruptive effects grow with the complexity of the main tasks and with the complexity of the interruption tasks. Hence, contemporary office software must provide users with sufficient supportive tools that help to handle interrupted tasks, such as color-coding to indicate recently changed text. This should shorten the resumption time and thus improve performance (Burmistrov & Leonova, 1996, p. 29).

4.2.3. Latorella (1998)

AIM AND APPROACH

This experiment is interested in the modality attributes of interruption and primary tasks. It addresses the performance implications when the interrupting task is visual or auditory and intrudes upon a visual or auditory ongoing task (Latorella, 1998, p. 1). The ultimate concern of the study was to test a pilot's performance implications of replacing traditional voice communications to the flight deck (such as air traffic control instructions) with visually-presented communications afforded by digital data link technology. As pilots were flexible when choosing when to acknowledge and initiate the interruption task, we assume the interruption coordination method to be negotiated. Measured variables were (a) interruption acknowledgment time, to see how fast pilots react to visual or auditory interruptions, (b) interruption initiation time, (c) errors made in interruption tasks (IR quality), and finally (d) primary task performance, measured by 'procedural errors' which could be attributed to quality.

RESULTS

The results showed that interruptions while working on auditory tasks were acknowledged more slowly than interruptions in visual tasks (Latorella, 1998, p. 3). Further, interruption acknowledgment and initiation times for cross-modality (different modality by PT and IR) conditions were slower than for same-modality conditions (Latorella, 1998, p. 3). At the same time, interruption initiation time was slowest when primary tasks were presented auditorally (Latorella, 1998, p. 3). That is, pilots began performing interruption tasks most slowly when they were working on an auditory task and were presented with a visual one. By looking at the interruption task's quality of performance, it was found that subjects made much more errors in cross-modality conditions than in same modality conditions. In contrast, more primary task performance errors were made in same-modality conditions, specifically in auditory-auditory conditions than in cross-modality conditions (Latorella, 1998, p. 3).

Table 15: Latorella's (1998) Main Results

Independent Variable	Dependent variable	Significance	Relationship	Confidence	Moderating variable
Modality of PT 'auditory' vs. 'visual'	Negotiated IR Acknowledgment time	YES	+ve	p = 0,0585	
Similarity of PT & negotiated IR 'cross modality'/ 'same modality'	Negotiated IR Acknowledgment time	YES	+ve		
Modality of PT 'auditory' vs. 'visual'	Negotiated IR Initiation time	YES	+ve		
Similarity of PT & negotiated IR 'cross modality'/ 'same modality'	Negotiated IR Initiation time	YES	+ve	p = 0.0175	
Modality of PT 'auditory' vs. 'visual'	Negotiated IR Quality	NO			
Similarity of PT & negotiated IR 'cross modality'/ 'same modality'	Negotiated IR Quality	YES	+ve	p = 0.0401	
Modality of PT 'auditory' vs. 'visual'	PT Quality	NO			
Similarity of PT & negotiated IR 'cross modality'/ 'same modality'	PT Quality	YES	-ve	p = 0.0099	

CONCLUSION

In essence, Latorella (1998) validated that the modality of interruptions and the primary task had a significant role in influencing interruption effects. System designers therefore need to pay attention to same or cross modality features of tasks and interrupts. To conclude, same modality features are better used when *interruption* performance is most essential; however, when it is more important to improve the performance of the *ongoing task*, cross modality is more appropriate. The researchers also noted that visual interruptions of visual tasks resulted in the best overall performance during interruptions (McFarlane & Latorella, 1999, p. 22).

4.2.4. McFarlane (1999, 2002)

AIM AND APPROACH

McFarlane (1999, 2002) empirically compared the basic design solutions for coordinating human interruption (immediate, negotiated) in computer-based multitasks. The goal of his work was to reveal critical user interface design issues to effectively handle interruption performance problems (McFarlane, 2002, p. 66). He looked at the effects of the different kinds of interruptions on participants' performance. In his experiment, he tested effects on all measurements of performance (quality, efficiency, timeliness) (McFarlane, 2002, p.82).

RESULTS

The results validate the basic assertion that being interrupted affects peoples' behavior (McFarlane, 1999, p. 300). Further, the data shows that the two different types of interruptions affect users' performance differently (McFarlane, 2002, p. 88, 90). Negotiated interruption causes the best overall user performance (McFarlane, 2002, p. 82). However, the immediacy-based solution causes better performance on the timeliness of handling interruption tasks and is better for cases where small differences in the timeliness of handling the interruption tasks are critical (McFarlane, 2002, p. 82) (i.e. emergency situations).

Table 16: McFarlane's (2002) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Interruption 'no IR' vs. 'IR'	PT Performance (general)	YES	–ve	p<0,0001	
Interruption 'no IR' vs. 'IR'	PT Quality	YES	–ve	p<0,0001	
Interruptio n 'no IR' vs. 'IR'	PT Efficiency	YES	–ve	p<0,0001	
Interruption 'no IR' vs. 'IR'	PT Timeliness	YES	–ve	p<0,0001	
Immediate IR 'no IR' vs. 'IR'	PT Performance (general)	YES	–ve	p<0,05	
Immediate IR 'no IR' vs. 'IR'	PT Quality	YES	–ve	p<0,05	
Immediate IR 'no IR' vs. 'IR'	PT Efficiency	YES	–ve	p<0,05	
Immediate IR 'no IR' vs. 'IR'	PT Timeliness	NO			
Negotiated IR 'no IR' vs. 'IR'	PT Performance (general)	YES	–ve	p<0,05	
Negotiated IR 'no IR' vs. 'IR'	PT Quality	YES	–ve	p<0,05	
Negotiated IR 'no IR' vs. 'IR'	PT Efficiency	YES	–ve	p<0,05	
Negotiated IR 'no IR' vs. 'IR'	PT Timeliness	YES	–ve	p<0,05	
IR coordination method 'immediate'/'negotiated'	PT Performance (general)	YES	+ve	p<0,05	
Gender 'male' vs. 'female'	Task performance	NO			

CONCLUSION

The conclusion of McFarlane's work was that there is no "best" method for coordinating interruptions for all kinds of human performance. Instead, there are tradeoffs that need to made such as between emergency and performance (McFarlane, 2002, pp. 95-96). Nevertheless, the researcher's results indicate that negotiation is often the better solution for all user performance, except in situations where fast handling of the interruptions is critical. In this case, the immediate solution is best (McFarlane, 2002, p. 96). When people are forced to handle interruptions immediately, they get the interruption tasks done promptly, at the overall cost of making more mistakes.

4.2.5. Cutrell, Czerwinski & Horvitz (2000a)

AIM AND APPROACH

Cutrell, Czerwinski & Horvitz (2000a) are interested in how the content and context of instant messaging interruptions impact performance during realistic computing tasks. The content of an interruption as an independent variable measures how relevant a particular message is to a primary task (meaning of interruption to the user) (Cutrell et al., 2000a, p. 99). The context of interruptions is measured by the type of cognitive process activity performed at the moment of interruption (Cutrell et al., 2000a, p. 99). Researchers broke a primary task into three activities: planning (coordinating), execution (mechanic) and evaluation (perceptual). Short interruptions are used in the form of instant messaging, which requires reading and an "OK" reply before returning back to the main task (Cutrell et al., 2000a, p. 99). As participants are free to choose when they actually attend to the interruption, this type of interruption coordination is 'negotiated'.

RESULTS

As expected, the total time spent on resuming the primary task was longer when the IM was irrelevant than when it was relevant. As resumption time directly influences task performance efficiency, the results showed that irrelevant interruptions induce higher costs (Cutrell et al., 2000a, p. 100). Also, tests showed that when interrupting notifications occurred during the evaluation phase (perceptual cognitive process type), participants were slower in this phase than in any other (Cutrell et al., 2000a, p. 100). It appears that it was less costly if interruption occurred early in the task, during the coordination phase, before the user had become deeply engaged in the task goal (Miyata & Norman, 1986; Czerwinski, Cutrell & Horvitz, 2000b, p. 2). Another interesting finding was that the more users were engaged in their task (towards the middle of the primary task), the more often they adopted a 'delayed strategy' i.e., took longer to switch to the interruption. This phenomenon can be described by 'chunking behavior' (Sellen, Kurtenbach, & Buxton, 1990). It refers to the tendency to delay switching to another task until completion of a subtask within the primary task (Cutrell et al., 2000a, p. 100).

Table 17: Cutrell, Czerwinski, & Horvitz' (2000a) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Negotiated IR 'no IR' vs. 'IR'	PT Timeliness	YES	–ve	p<0,01	PT cog. process type, Timing of IR
Meaning of IR to PT 'low' vs. 'high'	PT Timeliness	YES	+ve	p<0,001	
PT cognitive process type 4.2 'perceptual'/ 'mechanic'/ 'coordinating'	PT Timeliness	YES			
Timing of negotiated IR 'start' vs. 'mid'	PT Timeliness	YES	–ve	p<0,01	
Timing of negotiated IR 'start' vs. 'mid'	Strategy change 'Immediate' vs. 'Delayed'	YES	+ve		

CONCLUSION

This experiment shows that participants profit from a negotiated type of interruption rather than an immediate interruption that does not allow any delayed response. Further, it suggests that it is more difficult to get back to the primary task following an unrelated interruption. Interruptions relevant to the PT are less disruptive. Finally, the authors show that certain cognitive processing tasks are more robust to interruptions. For instance, perceptual processing is more disreputable than coordination and mechanical tasks. Moreover, timing of the interruption is significant. For example, at the beginning of the primary task, interruption causes a lower negative effect because the user has not yet become deeply engaged in his task goal. This result may reflect that at moments with greater goal engagement, and hence, greater working memory loads, interruption leads to forgetting and require longer resumption times. The researchers concluded that intelligent systems might one day be used to govern the timing and nature of interruptions to optimize user satisfaction and performance (Cutrell et al., 2000a, p. 99).

4.2.6. Czerwinski, Cutrell & Horvitz (2000b)

AIM AND APPROACH

This experiment builds on earlier work by Czerwinski et al. (2000a) exploring the influence of interruptions from instant messaging at different times during a primary task (goal directed web search). It was found that users' performance timeliness suffers when interruptions occur at moments of greater working memory loads, leading to longer resumption times. To build on this finding, the present study investigated the value of leaving a displayed "marker" as a reminder to users where they left off in their primary task when returning from the interruption task in order to facilitate resumption (Czerwinski et al., 2000b, p. 3). Moreover, it was tested whether the difficulty of remembering the goal during the resumption period after the interruption affected the differing complexity of the primary task in terms of processing intensity (visual scanning versus semantic scanning) (Czerwinski et al., 2000b, p. 3). Interruptions were totally irrelevant and dissimilar to the primary task, however participants could delay, but not ignore, their responses to them, and hence it was a negotiated interruption type with a medium level of control.

RESULT

Again, it was found that interrupting notifications reliably slowed down performance on the primary task (Czerwinski et al., 2000b, p. 4). However, there was no evidence that having a marked position within the primary task to act as a reminder of the point of interruption improved users' general performance timeliness. There was only a small effect during the less effortful PT. This means that performance slow-down is not rooted in the difficulty in visual reorienting to the PT after interruption, but probably comes from the influence of the interruption on memory (Czerwinski et al., 2000b, p. 4). Finally, researchers' observations provided evidence that interruptions harm faster, stimulus driven, straight forward search tasks more than effortful, cognitively demanding search tasks (Czerwinski et al., 2000b, p. 5). This result has been explained by the authors by the fact that high speed visual scanning needs a particularly effortful disengagement and re-engagement (Czerwinski et al., 2000b, p. 5).

Table 18: Czerwinski, Cutrell & Horvitz' (2000b) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Negotiated IR 'no IR' vs. 'IR'	PT Timeliness	YES	–ve	p<0,001	PT Complexity (processing intensity), PT reminder tool (marker)
PT reminder tool 'no marker' vs. 'marker'	PT Timeliness	YES			PT Complexity (processing intensity)
PT reminder, complex PT 'no marker' vs. 'marker'	PT Timeliness	NO			
PT reminder, simple PT 'no marker' vs. 'marker'	PT Timeliness	YES	+ve	p<0,047	
Complexity of PT with IR 'low processing' vs. 'high'	PT Timeliness	YES	+ve	p<0,001	

CONCLUSION

In total, Czerwinski, Cutrell & Horvitz' (2000b) second experiment replicated earlier work, showing the general harmful effects of interruptions. They looked into where this effect becomes stronger for less effortful but speedy primary tasks. Markers as reminders did not show any significant effects. Still, the researchers remain optimistic that reminders about an interrupted task might prove to be valuable in reducing the disruptiveness of notifications (Czerwinski et al., 2000b, p. 5).

4.2.7. Cutrell, Czerwinski & Horvitz (2001)

AIM AND APPROACH

This experiment continues testing the effects of negotiated interruptions on different search types. Further manipulations of design aspects were included to analyze the negative effect of interruption on memory. One manipulation was to improve the navigational confound to again test the 'marker' effect on primary task performance. The other manipulation was a further complication of the primary task (Cutrell et al., 2001, p. 3). Moreover, reaction time to the interruptions (response strategy to interruptions in terms of 'immediate' and 'delayed') was once more tested. Finally, interruptions occurred at two different time points during the primary task, right at the start ('start') and later in the task before the end ('mid').

RESULT

While a significant main effect of interruption on task timeliness was found, there was again no overall effect of providing a marker as a reminder (Cutrell et al., 2001, p. 5). Again, visual search tasks were reliably faster than semantic searches. Furthermore, participants took longer to switch to an instant message notification in the more cognitively demanding condition. These results confirm the findings of the previous studies (Czerwinski, Cutrell & Horvitz, 2000a, 2000b), despite the use of a more prominent marker and despite complicating the primary tasks (Cutrell et al., 2001, p. 5). Moreover, a significant relationship was found between the use of goal reminders and the timing of the interruption. The earlier an interruption took place, the more likely participants were to request a goal reminder, and hence the worse was their recall of the primary task's goals and setting, and the longer the resumption. The explanation of this finding might have to do with the amount of time users had available to focus on or rehearse the target prior to getting interrupted (Cutrell et al., 2001, p. 6).

Table 19: Cutrell, Czerwinski & Horvitz' (2001) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Negotiated IR	PT Timeliness	YES	–ve	p<0,001	Complexity of PT (process intensity)
Complexity of PT with IR 'low processing' vs. 'high'	PT Timeliness	YES	+ve	p<0,001	
Complexity of PT with IR 'low processing' vs. 'high'	Strategy change 'Immediate'/ 'Delayed'	YES	+ve	p<0,01	
PT reminder tool 'no marker' vs. 'marker'	PT Timeliness	YES			Complexity of PT (process intensity)
PT reminder, complex PT 'no marker' vs. 'marker'	PT Timeliness	NO			
PT reminder, simple PT 'no marker' vs. 'marker'	PT Timeliness	YES	+ve	p<0,047	
Timing of negotiated IR 'start' vs. 'mid'	PT Timeliness	YES	-ve		

CONCLUSION

Despite all of the changes made to the experimental design, the findings from this experiment closely replicate and extend those from the previous work (Czerwinski, Cutrell & Horvitz, 2000a, 2000b). It was also found that recall was more difficult if interruptions occurred at the beginning of a task rather than at the end. As opposed to outcomes in similar studies (Cutrell et al., 2000a), this finding suggests that interruptions delayed more to the end of a task may be less disruptive than at the initiation of a new task, when users have not had enough time to learn and rehearse their goal (Cutrell et al., 2001, p. 6). Finally, the authors claim that the negative effects of interruption are rooted in its negative effect on memory, and thus they suggest that methods for securing and recovering task focus can provide value (Cutrell et al., 2001, p. 6).

4.2.8. Czerwinski, Horvitz & Wilhite (2004)

AIM AND APPROACH

During previous studies it was found that interruptions might place high costs on primary tasks due to their negative effects on prospective memory (O'Conaill B. et al., 1995; Czerwinski et al., 2004, p. 175). Increasing the number of interruptions can disrupt a person's ability to remember the goal of the previous tasks, as well as prevent recall at the appropriate moment in time, and hence can reduce an office worker's productivity (Czerwinski et al., 2002; Czerwinski et al., 2004, p. 175). The aim of this work was to provide additional insights into the degree and types of multitasking and interruption that information workers experience over a work week in their real environment (Diary study) in order to guide the development of software tools that can assist workers with multitasking by e.g.: facilitating the remembering process (Czerwinski et al., 2004, p. 176).

RESULTS

Generally, it was found that it is significantly more difficult to switch 'back' to interrupted tasks after an interruption than simply to switch to another task after completion (Czerwinski et al., 2004, p. 178). The analysis of workers' diaries showed that users spent 13% of their time tracking their tasks (re-sumption), for example by using their PDA or saving and organizing files and drives, before leaving their task to switch to another one (Czerwinski et al., 2004, p. 179). Another finding showed that the difficulty in recovering from interruptions lies in the difficulty to understand what users were doing be-fore an interruption (Czerwinski et al., 2004, p. 180). It is more difficult to switch back to long-lasting complicated tasks (in terms of high memory load) that include many documents (Czerwinski et al., 2004, p. 178), which suggests interruption-based prospective memory failure and productivity loss for these types of tasks in particular. To facilitate the change-over process, workers called out for software support which provides them with the ability to organize project-related documents, email and other windows together in the Windows XP taskbar (Czerwinski et al., 2004, p. 180).

Table 20: Czerwinski, Horvitz & Wilhite's (2004) Main Results:

Independent Variable	Dependent Variable	Signifi-cance	Relation-ship	Confi-dence	Moderating variable
IR 'no IR' vs. 'IR'	PT Timeliness (resumption time)	YES	–ve	p<0,001	Volume/Length of PT, Complexity of PT (memory load)
Volume/Length of PT 'low' vs. 'high'	PT Timeliness (resumption time)	YES	–ve		
Complexity of PT 'low memory load' vs. 'high'	PT Timeliness (resumption time)	YES	–ve		

CONCLUSION

Overall, the diaries demonstrated that returning to more complex, lengthier projects that require more documents is significantly more difficult. The main proposition of this study is that there are methods to help users multitask and recover from task interruptions, potentially increasing productivity. Tools that record and reconfigure (by returning to the previous task after an interruption) the layout of multiple windows of content (e.g.: documents, files, sites) on demand, and applications associated with the primary task, may be valuable in both reminding users about suspended tasks, and in assisting users to switch among the tasks (Czerwinski et al., 2004, p. 181).

4.2.9. Bailey, Konstan & Carlis (2001) and Bailey & Konstan (2006)

AIM AND APPROACH

The goal of this research was to provide quantitative evidence of the disruptive effects of an application-initiated interruption on a user's task performance (timeliness) and his subjective level of annoyance and anxiety. In a later article, results with respect to analysis of the error rates (quality) were reported (Bailey & Konstan, 2006, p. 688). Researchers wanted to see whether the level of difficulty (memory load) of the primary task had any significant consequences on the effects of interruption (Bailey et al., 2001, p. 3-4). Their work measured the quantitative effects of manipulating the time of interruption (after completion of a task ('end') and during the primary task ('mid')). A display of peripheral information was used as immediate interruptions, which was "nonessential information that is helpful or of interest to the user but not necessarily related to the user's current task" (Bailey et al., 2001, p. 1).

RESULTS

The results indicate that timing of interruptions are very important for performance. There was no performance degradation when the interruption was presented at the end of a subtask (Bailey et al., 2006, p. 697). However, there was a disruptive effect of a 'mid' point interruption in terms of task timeliness, which also worsened with increasing complexity of the primary task (memory load) (Bailey et al., 2001). More difficult tasks are likely to induce higher mental loads on working memory, and hence users require more time to re-orient to the suspended task (Bailey et al., 2006, p. 696). The analysis of the annoyance ratings demonstrates that any interruption leads to user annoyance. Further, the level of annoyance experienced by a user due to an interruption depends on both the complexity of the task being performed and the time at which that interruption is presented (Bailey et al., 2001, p. 7). Users experienced about 64% more annoyance when the interruption was presented during a primary task ('mid') than when it was between the tasks ('end') (Bailey et al., 2006, p. 700). Moreover, they found that an interruption causes a greater increase in anxiety when it is presented during a primary task than when it is presented just after the completion of that task (Bailey et al., 2001, p. 7). This result is in accordance with earlier outcomes that participants prefer a moment of interruption when a particular part of the action they were currently doing is completed (Zijlstra et al., 1999, p.180).

Table 21: Bailey, Konstan and Carlis's (2001, 2006) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Timing of IR 'mid' vs. 'end'	PT Timeliness	YES			PT Complexity (memory load)
Timing of IR 'no IR' vs. 'end IR'	PT Timeliness	NO			
Timing of IR 'no IR' vs. 'end IR'	PT Quality	NO			
Timing of IR 'no IR' vs. 'mid IR'	PT Timeliness	YES	–ve	p<0,001	PT complexity (memory load)
Timing of IR 'no IR' vs. 'mid IR'	PT Quality	NO			
PT Complexity, 'mid' IR 'low memory load' vs. 'high'	PT Timeliness	YES	–ve	p<0,001	
PT Complexity, 'mid' IR 'low memory load' vs. 'high'	PT Quality	YES	–ve	p<0,002	
Immediate IR 'no IR' vs. 'IR'	Annoyance	YES	+ve	p<0,001	PT complexity, Timing of IR
Timing of IR 'mid' vs. 'end'	Annoyance	YES	-ve	p<0,001	
PT complexity 'low memory load' vs. 'high'	Annoyance	YES	+ve	p<0,001	
Immediate IR 'no IR' vs. 'IR'	Anxiety	YES	+ve	p<0,03	
Timing of IR 'mid' vs. 'end'	Anxiety	YES	-ve	p<0,05	

PT complexity ‘low memory load’ vs. ’high’	Anxiety	YES	+ve		
Individual Gender ‘male’ vs. ‘female’	PT Timeliness	NO			
Individual Gender ‘male’ vs. ‘female’	Annoyance	NO			
Individual Gender ‘male’ vs. ‘female’	Anxiety	NO			

CONCLUSION

The conclusion of their results is that by having interruptions occur at opportune moments can mitigate their disruptive effects (Bailey et al., 2001, p. 8). They describe an opportune interruption moment as a “period of low memory load occurring within a user’s task sequence such as at a task boundary or during a delayed system response” (Bailey et al., 2001, p. 8; Miyata & Norman, 1986).

4.2.10.Adamczyk & Bailey (2004)

AIM AND APPROACH

In this study, researchers measured the disruptive effects of interrupting a user at different moments within primary task execution in terms of psycholo-/physiological state variables (annoyance, frustration and mental effort) (Adamczyk et al., 2004, p. 271). Prior to the testing, moments for interruption were identified using participants’ common perception of the tasks’ broad segments (e.g. planning, execution, and evaluation) and its subtasks (Adamczyk et al., 2004, p. 272). Theoretically, the best point for interruption is when a user is moving from one well-defined and commonly understood task to another, not simply between any two subtasks (Zacks et al., 2001a; Zacks et al., 2001b; Zacks et al., 2001c), which we call ‘end’. The presumed worst point is one where a user is involved in the execution of some ill-defined and user specific subtask (Adamczyk et al., 2004, p. 273), which we call ‘mid’. Thus, the effects of the immediate interruptive tasks (title selection from tree options) in the form of a full screen pop-up window were compared between the ‘end’, ‘mid’, and ‘no interruption’ conditions (Adamczyk et al., 2004, p. 273). To see whether the study results were broadly applicable, the testing occurred on distinctively realistic primary tasks, which differed in complexity in terms of processing intensity (Adamczyk et al., 2004, p. 274).

RESULTS

First of all, it was shown that the total time spent on the primary tasks differed across task complexity levels (Adamczyk et al., 2004, p. 277). Further, task complexity had a significant main effect on reported mental effort expenditure. Also, tasks became more effortful when they were interrupted (Adamczyk et al., 2004, p. 276). More interestingly, interruption timing had a significant main effect on a subject’s reported frustration and annoyance levels, where from the ‘end’ to ‘mid’ conditions the values rose by ca. 50% (Adamczyk et al., 2004, p. 276). Expectedly, the ‘no interruption’ condition showed the least annoyance and frustration levels (Adamczyk et al., 2004, p. 276).

Table 22: Adamszyk & Bailey’s (2004) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Complexity of PT with IR ‘low processing’ vs. ‘high’	PT Timeliness	YES	-ve	p<0,034	
Immediate IR ‘no IR’ vs. ‘IR’	Mental effort expenditure	YES	+ve	p<0,004	
Immediate IR ‘no IR’ vs. ‘IR’	Annoyance	YES	+ve	p<0,001	Timing of IR
Timing of immediate IR ‘mid’ vs. ‘end’	Annoyance	YES	-ve	p<0,002	
Immediate IR ‘no IR’ vs. ‘IR’	Frustration	YES	+ve	p<0,001	Timing of IR
Timing of immediate IR ‘mid’ vs. ‘end’	Frustration	YES	-ve	p<0,002	

CONCLUSION

The main contribution of this work is the prediction of the 'best' moment for interruption, which is at the end of some subtask within the primary task. Delaying interruptions to these points proved to be effective at minimizing the disruptive effects of an interruption, with values significantly closer to the 'no interruption' condition. Hence, their results show that an 'attention manager' could minimize the upsetting effects of interruptions on users' emotional state by identifying opportune moments in a user's task sequence for an interruption to occur (Adamszyk et al., 2004, p. 277).

4.3. Attention Studies in the Domain of Marketing

Studies of attention-interruption in marketing aim at providing an understanding of how consumers experience forced exposure situations in interactive environments. In addition, the studies highlight implications for advertisers who seek to increase the effectiveness of interrupting advertising (Edwards et al., 2002, p. 83). Pop-ups, known formally as 'interstitials', are one of the popular techniques to deliver rich media ads with more sophisticated messages on the Web (Milward Brown Interactive 1999a). Such advertising can be programmed to appear when entering or exiting a Web page, after a certain amount of time on a Web page, or when a link is selected (Edwards et al., 2002, p. 84). The ad window then can be programmed to remain open for a preset length of time or until the user chooses to shut the window (Edwards et al., 2002, p. 84). When the ads appear, Web users are interrupted and forced to react to the unrequested commercial messages. Such interruptions force users to respond cognitively, affectively, or behaviorally, which possibly has either positive or negative consequences for the advertiser. According to Kahneman (1973), such exposure elicits involuntary attention, which results in positive effects such as greater processing and increased memory for the advertising message. Such prediction was confirmed by some industry studies, showing increases in ad recall, awareness, and purchase intention for pop-up ads compared with conventional banner ads (Milward Brown Interactive, 1999b, p. 7). On the other hand, other research has found that forced exposure could lead to a negative perception of the advertising due to interruptions of a viewer's ongoing primary task, and a delay in the downloading of large file sizes (Edwards et al., 2002, p. 84).

Although interrupting advertisements may enhance recall, they also may result in negative attitude formation (Ha, 1996) or avoidance of the ads altogether (Abernethy, 1991). Thus, an important theoretical issue in marketing attention-interruption research is how to minimize the negative perceptions of interstitials, while taking advantage of the effectiveness benefits (Edwards et al., 2002, p. 84). As the focus of this paper lies on attention-interruption findings applicable to effective systems design, only findings satisfying this interest are reported. Hence, marketing research focusing on increasing effectiveness of advertisings via better recall due to improved design was not analyzed. On the other hand, advertising research directed at minimizing disruptive effects of interruptions caused by advertising are of high interest for the underlying analysis. In general, intrusive advertising usually does not contain any interrupting task; hence it can be treated as a cognitively undemanding interruption that still disrupts peoples' primary activity goal (Edwards et al., 2002, p. 85).

4.3.1. Edwards, Li & Lee (2002)

AIM AND APPROACH

This paper explores forced viewing of 'pop-up ads' on the Internet to better understand how viewers come to define ads as irritating and decide to avoid them. The purpose of this research is to investigate what characteristics of pop-up ads cause negative emotions, such as irritation and the feeling of being intruded. Specifically, the study examines four aspects of such interruptions: (1) timing of the display, (2) duration of the ad, (3) congruence with editorial content, and (4) perceived informational value of the ad (Edwards et al., 2002, p. 83). All four measures can be found in the generalized attention-interruption research framework (see chapter 2.7): (1) interruption timing with respect to memory load at the time of interruption, (2) interruption duration, (3) content similarity between interruption and primary task, and finally (4) meaning and importance level of the interruption.

Content similarity of IR with the editorial unit is presumed to have a positive impact on viewers' emotions, because intrusiveness is defined by the degree to which a person deems the presentation of information as contrary to his or her goals (either functional or hedonic) (Edwards et al., 2002, p. 85). The meaning and importance of the interruption can be associated with its informativeness, and hence its perceived value (Ducoffe, 1995; 1996). If a forced interruption does not provide value, it may be perceived as irritating (Edwards et al., 2002, p. 85). Furthermore, effects of interruption timing are analyzed, hypothesizing that ads occurring during mental engagement in an activity ('mid') will be perceived as more disrupting, and hence intrusive, than ads displayed upon closing the browser ('end') (Edwards et al., 2002, p. 86). Similarly, duration of the ad was manipulated (10 sec. vs. 20 sec.), predicting that longer interruption will have greater negative impact on psychological discomfort (Edwards et al., 2002, p. 86). The experiment used 2 (similarity) x 2 (duration) x 3 (timing) factorial design, where the primary task was a Web search, which was 'immediately' interrupted by a pop-up ad (Edwards et al., 2002, p. 86).

RESULTS

First of all, the perceived duration of the interruption caused by the ad was not significantly related to the perceived intrusiveness (Edwards et al., 2002, p. 90), maybe because users could click the ad away, and hence were not affected by its length. The more informative the ad was rated, the greater was the meaning of the ad to the participant and the less irritating and intrusive was it experienced (Edwards et al., 2002, p. 90). This indicates that the more value users perceive in an ad, the less intrusive is it for them (Edwards et al., 2002, p. 92). Moreover, the cognitive intensity variable (timing of the interruption) was found to have a significant impact on perceived intrusiveness (Edwards et al., 2002, p. 91). That is, ads were found to be more intrusive by participants highly engaged in the content than by those who were less cognitively occupied. Similarly, ads were perceived as less intrusive when they related to the participant's task (Edwards et al., 2002, p. 91). Finally, a strong positive relationship was found between perceptions of intrusiveness and feelings of irritation (Edwards et al., 2002, p. 92).

Figure 23: Edwards, Li & Lee (2002) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Duration of immediate IR '10 sec.' vs. '20 sec.'	Perceived Intrusiveness	NO			
Meaning of IR to PT 'low' vs. 'high'	Perceived Irritation	YES	-ve	p<0.01	
Meaning of IR to PT 'low' vs. 'high'	Perceived Intrusiveness	YES	-ve	p<0.01	
Timing of IR (memory load) 'mid' vs. 'end'	Perceived Intrusiveness	YES	-ve	p<0.001	
Similarity of IR and PT 'similar content' vs. 'different'	Perceived Intrusiveness	YES		p<0.001	
Perceived Intrusiveness	Perceived Irritation	YES	+ve	p<0.001	

CONCLUSION

To conclude, it was proven that interruptions perceived as similar in content and valuable to the user are less intrusive, and hence less irritating. Also, advertising interruptions occurring at the end of the users' primary task, or within the breaks between its subtasks, has a smaller negative impact on users' emotions. Knowing this, advertisers could minimize the negative perceptions of interstitials by designing valuable ads, which do not disrupt cognitive engagement of the user.

4.3.2. Cho & Cheon (2004)

AIM AND APPROACH

The underlying study assesses possible reasons for advertising avoidance on the Internet (Cho, 2004, p. 89). It was found that ad avoidance is significantly related to negative emotions (annoyance) and goal impediment. Researchers view the Internet not simply as an entertainment medium, but more as a 'task-performing' tool with which users perceive some task goal (Cho, 2004, p. 90). Hence, the experimenters expect goal interruption and annoyance level to be the main reasons for ad avoidance (Cho, 2004, p. 91). Interruptions in the form of pop-ups are an immediate interruption type.

RESULTS

First of all, it was confirmed that perceived goal impediment is significantly related to search hindrance, disruption and distraction (Cho, 2004, p. 92). As anticipated, interruptions in the form of pop-up ads cause negative emotions, such as annoyance, and impede on users' primary task goals (Cho, 2004, p. 93).

Table 24: Cho & Cheon's (2004) Main Results

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Immediate IR 'IR' vs. 'no IR'	Goal impediment	YES		$p<0.05$	Search hindrance, Disruption, Distraction
Immediate IR 'IR' vs. 'no IR'	Annoyance	YES		$p<0.05$	

CONCLUSION

The study proves that people perceive internet ads as an impediment on their primary goals (Cho, 2004, p. 94). The unexpected appearance of ad messages disrupts the user's tasks, annoys him, and causes him to extensively avoid the 'nuisance'. Authors suggest that marketers should attempt to use less intrusive and unexpected formats of advertising, and deliver more customized and context-congruent messages in order to reduce the perception of goal impediment, and hence increase advertising attendance (Cho, 2004, p. 94).

4.3.3. Moe (2006)

AIM AND APPROACH

Web-site visitors may find pop-up ads interrupting browsing activities as annoying and may cause them to exit the site earlier than otherwise intended (Moe, 2006, p. 35), and hence cause the user to stop his primary activity altogether. This research explores whether by manipulating some characteristics of pop-up promotions a more positive reaction to this marketing tool is generated (Moe, 2006, p. 35). The variables tested in the experiment were the interruption timing of the pop-up messages, as well as the complexity type of the primary task in terms of processing intensity (Moe, 2006, p. 36). Timing of the pop-up was varied between the start of site occurrence ('start'), and the middle of site reading ('mid') (Moe, 2006, p. 37). The dependent variable was the number of web pages viewed by the user in a session, which could give insight as to whether pop ups or interruptions annoy the user and make him leave the primary task.

RESULTS

By showing the pop-up message immediately at the beginning, the individual's inclination to exit the site slowed down compared to an interruption when the user was already fully engaged in the site (Moe, 2006, p. 41). Primary task complexity also had a significant effect on the number of pages viewed in total (Moe, 2006, p. 41). That is, a pop-up appearing during a less demanding task is less likely to be perceived as an interruption and more likely to enhance the online browsing experience than one that appears during a complex processing task (Moe, 2006, p. 41).

Table 25: Moe's (2006) Main Results:

Independent Variable	Dependent Variable	Significance	Relationship	Confidence	Moderating variable
Timing of immediate IR 'start' vs. 'mid'	Annoyance	YES	+ve	P<0.02	
Complexity of PT 'low processing intensity' vs. 'high'	Annoyance	YES		p<0,0001	

CONCLUSION

The findings of the study imply that interruptions appearing before the user gets engaged in his task minimize viewer's formation of a negative attitude towards his primary task (Moe, 2006, p. 41). Moreover, the finding that interruptions during less demanding tasks are better perceived supports the overload theory, which suggests that during heavy content processing tasks overloading due to an interruption is more likely (Moe, 2006, p. 41).

5. Evaluation of Attention-Interruption Research Findings

As already noticed in the taxonomy of interruption research above, the effects of interruptions can be categorized into three distinct groups: effects on primary task performance, effects on interruption task performance effects on users' psycho-/physiological state. The table 5.1a shows how the interest of research has been distributed between these three categories among the papers reviewed in this publication.

5.1. Distribution of Research Focus

Table 26: Distribution of the research interests among the interruption effect categories

Focus of studies	% of all studies with this focus
Focus on psycho-/physiological state of individual	37,5
Focus on PT performance	83,3
Focus on IR performance	8,3

Table 27: Distribution of research interest within a particular school of thought

Focus of studies	% in IS studies	% in Psy., Ergon., HRM	% in Marketing
Focus on psycho-/physiological state of individual	20	37	100
Focus on PT performance	90	100	0
Focus on IR performance	10	9	0

By looking at the distribution of interests of the most cited empirical attention interruption studies, it becomes obvious that their main concern is to look at the disruptive effect of interruptions on users' primary task performance, such as quality, timeliness and efficiency. Finding ways to overcome this problem is definitely of high importance for managers who wish to minimize human resource costs. Information system designers are interested in providing the best IT solutions to satisfy this need. However, the value of providing user satisfaction in terms of psycho-/and physiological costs should not be underestimated. In the long term, users' will better accept systems that not only provide them with the most efficient solutions, but also make technology usage as enjoyable as possible (Adamsczyk et al., 2004, p. 1). Table 5.1b shows that only 20 percent of information system related studies dealt with psychological effects of interruptions which suggests that IS research may have a blind spot here. In the next chapter, a detailed analysis of the actual significance of interruption effects on users' psychological and physiological state is highlighted.

5.2. Analysis of Interruption Effects on Users' Psycho-/ Physiological State

Previous analysis has shown that a bit about 30% of attention interruption research has looked into the psychological and physiological effects of interruptions. The research taxonomy in chapter 2 lists the different variables investigated in detail. Given that a clear definition of the variables as well as a distinction between psychological and physiological context is not provided in the attention interruption research literature the variables investigated included users' annoyance, anxiety, frustration, well-being, irritation, feelings of being overloaded, perceived effort expenditure and perceived task performance. All of these variables might be describing similar psychological and physiological states and may be interrelated. For example, feeling overloaded may result in frustration, annoyance and anxiety. From the user's own perspective physiological measures may include more direct descendants of workload, such as feelings of being overloaded, high effort expenditure and low performance. Psychological variables again describe users' emotional states. No matter what kind of psycho- or physiological effects interruptions cause, IS researchers believe that they can cause users to turn away from applications (Adamszcyk et al., 2004; Hudson et al., 2002; Shneiderman, 1998). Their investigation therefore deserves extra room.

5.2.1. Physiological Variables

The theory predicts that interruptions could have highly disruptive effects on users psycho-/ and physiological states. Cohen's Cognitive Fatigue Model (Cohen 1978, 1980) states that uncontrollable and unpredictable interruptions induce personal stress and produce information overload, thus requiring additional effort and causing cognitive fatigue. Interruptions of ongoing tasks produce an additional task, and hence present even more cues to be processed by users' limited capacity during limited time. The more frequent, complex, and dissimilar in content the tasks to accomplish are, the higher the workload is during the time available. The higher the processing load then, the more users feel overloaded after such interruptions (Kirmeyer, 1988). Similarly, the more a user has to accomplish, the more effort he has to invest, as the primary task has to be resumed and restarted after an interruption (Zijlstra et al., 1999; Adamczyk, 2004). Such high load pressure and stress necessarily leads to users grading their own performance lower and expecting personal failure (O'Connell et al., 1976; Speier et al., 1999, 2003). It was concluded that such stress not only has important consequences for productivity and quality of task performance, but also impacts users' health and feelings (Kirmeyer, 1988, p. 621).

5.2.2. Psychological Variables

Stress and exhaustion due to interruptions cause employees to feel anxious and frustrated. This disruptive effect on users' emotional state depends on the user's mental load at the point of interruption (Bailey et al., 2001, p. 1). When interruption occurs during a highly demanding and complex primary task or at a moment of a high concentration and memory load, interruptions are more likely to frustrate the user and make feel him anxious about not being able to finish his task (Adamsczyk et al., 2004; Bailey et al., 2006).

Yet, as interruptions occur, they do not only make workers feel anxious and exhausted, but also affect their subsequent readiness to perform (Zijlstra et al., 1999, p.165). To diminish this effect, an opportune timing of interruption must be chosen (Adamsczyk et al., 2004; Edwards et al., 2002; Moe, 2006). Similarly, psychologically negative effects are smaller not only in moments of lower mental load or at a favorable moments, but also during rather simple primary and interruption tasks (Bailey et al., 2006; Moe, 2006). Simple tasks provide fewer cues to be processed and diminish mental load (Speier et al., 2003, p. 775). Likewise, similar primary and interruption tasks provide less information to be processed than totally dissimilar ones (Edwards et al., 2002).

5.2.3. UAIM on Psycho-/ and Physiological Interruption Effects

To conclude, all studies we investigated from all the different scientific domains have come to similar conclusions: interruptions have a negative impact on users' psycho-/ and physiological state. This impact is greatest for frequent, complex, and dissimilar interruptions that distort complex tasks at moments of high mental load. Although all the experiments used an immediate type of interruption, the importance of interruption timing predicts a substantial difference in the effects between the negotiated and the immediate type of interruptions. The results suggest that allowing users to choose the most opportune interruption moment can minimize the disruptive effects on psycho-/ and physiological state. Table 28 summarizes the key findings and produces a unified attention interruption model with respect to psycho-/ and physiological interruption effects.

Table 28: Research findings of the interruption effects on users' psycho-/physiological state

Studies	Interruption effects	Independent Variables	Explanation
Adamczyk & Bailey (2004); Cho & Cheon (2004); Bailey, Konstan and Carlis (2006); Moe (2006)	Annoyance	IR Complexity (processing intensity) IR Timing (memory load) PT Complexity (memory load)	Effect is stronger for processing intensive interruptions occurring in moments of high memory load of memory intensive primary tasks
Bailey, Konstan and Carlis (2006)	Anxiety	IR Timing (memory load) PT Complexity (memory load)	Effect is stronger for interruptions occurring in moments of high memory load of memory intensive primary tasks
Zijlstra, Roe, Leonora & Krediet (1999)	Well-being	none	Frequency of IR and complexity of IR in terms of processing intensity seemed to have no significant effect
Adamczyk & Bailey (2004)	Frustration	IR Timing (memory load)	Effect is stronger interruptions occurring in moments of high memory load
Edwards Li & Lee (2002)	Perceived irritation	IR Meaning Content Similarity between PT& IR IR Timing (memory load)	The effect is stronger for IR of different content than PT, of IR irrelevant for PT and for IR occurring in moments of high memory load. IR duration had no effect
Kirmeyer (1988)	Feeling overloaded	Frequency of IR Individual impatience	Effect is stronger for impatient men and for more frequent IR
Zijlstra, Roe, Leonora & Krediet (1999); Adamczyk & Bailey (2004)	PT Effort expenditure	Frequency of IR	IR increases users effort expenditure, the effect is stronger for more frequent IR
Speier, Vessey & Valacich (1999), (2003)	Perceived task performance	Content Similarity between PT& IR	IR has a negative effect on workers own performance perception. The effect is stronger for IR of different content than PT

5.3. Analysis of Interruption Effects on Users' Interruption Task Performance

There are only a few studies concerned with users' performance in the interruption task itself (Latorella, 1998; Trafton et al., 2003). The three variables measured were the quality of interruption performance, as well as how soon the user acknowledged or checked the type of interruption, and finally how soon he actually initiated execution of the interruption task.

5.3.1. Acknowledgment and Initiation Time of Interrupts

As the theory did not make any explicit predictions about interruption task performance, obtained research findings should be able to fill this gap. Latorella (1998) concentrated on the modality of interrupts and primary tasks. It was found that the users acknowledge interruptions fastest when it is presented visually rather than auditorally, and the fastest reaction was when both tasks use visual modality (Latorella, 1998, p. 3). Similarly, interruption initiation time is shortest when interruptions are presented in the same modality as the primary task, and even shorter when both are presented visually (Latorella, 1998, p. 3). Such results imply that users' concentration on the primary task is distorted fastest when the same modality is used to present the interruptive task. This is rather logical due to structural interference predicted by when a user must attend to two inputs that require the same physiological mechanisms (Speier et al., 1999, p. 339). For example, during an on-screen text editing task, user's attention can be gained in the fastest way by an on-screen pop-up; whereas a sound indicating interruption without any visual presentation will most probably be heard but not necessarily attended to until the user feels ready to do so. The decision over the modality of interruption presentation and its similarity to the primary task should be taken in conjecture with the consideration of how important the interruptive message is and how urgent its completion is.

5.3.2. Quality of Interruptions

With respect to interruption task quality in terms of task correctness and completeness, it does not seem to matter much whether primary and secondary tasks are performed in a visual or auditory modality. What seems to matter is the similarity in modality between the two tasks (Latorella, 1998, p. 3). Interruption quality suffers more in cross-modality conditions (Latorella, 1998, p. 3). Moreover, Trafton et al. (2003) investigated whether the interruption task quality suffers when users prepare for the primary task resumption during the interruption task execution. Users tend to engage in the rehearsal of retrospective information about the primary task as well as engage in the setting of prospective goals to be achieved at resumption time when they are immediately interrupted (Trafton et al., 2003, p. 593). Such preparatory activities were found to worsen interruption task performance as users' concentration on the secondary task is divided from the beginning. An important implication here is that when an interruption is of an immediate coordinating type that leaves the user no time for preparatory activities prior to the interruption task, the quality of the interruption task suffers. On the other hand, McFarlane proved that interruption task accuracy can also be best when an interruption appears immediately rather than negotiated (McFarlane, 2002, p. 97). This is particularly the case in less complex primary tasks. The diverse results suggest a need for further research showing why users sometimes engage in rehearsal during interruption tasks and sometimes don‘t.

5.3.3. UAIM on Interruption Task Performance

To conclude, research on interruption performance is rather deficient and needs further exploration. Many questions remain unanswered, for example, how similarity, complexity, and timing of an interruption affect the interruption task performance. The table below summarizes the research findings and constitutes an attention interruption model predicting outcomes on interruption performance.

Table 29: Summary of research findings of interruption effects on IR task performance

Studies	Interruption effects	Independent Variables	Explanation
Latorella (1998)	IR acknow-ledgement time	PT Modality Modality similarity between PT and IR	IR acknowledgement time is shorter IR occurs during visual PT and when the same modality is used for both tasks
Latorella (1998)	IR initiation time	PT Modality Modality similarity between PT and IR	IR initiation time is shorter IR occurs during visual PT and when the same modality is used for both tasks
Latorella (1998); Trafton, Altmann, Brock & Mintz (2003)	IR Quality	Modality similarity between PT and IR IR coordination method	IR Quality suffers in cross-modality conditions and when interruptions are presented im-mediately

5.4. Analysis of Interruption Effects on Users' Primary Task Performance

This attention interruption research summary finds that that most research interest has been devoted to interruption effects on primary task performance. Four distinct primary task performance measures have typically been investigated: (1) timeliness, (2) quality, (3) efficiency, and (4) change of execution strategy.

5.4.1. Timeliness of Primary Task Completion

The most frequently measured variable of primary task performance is the timeliness or the speed with which a user accomplishes his interrupted primary task, excluding the time lost for the interruption itself. Although most studies came to the same conclusion that people need more time to complete their tasks when they are interrupted, the outcome is not as straightforward as it might seem.

5.4.1.1. Primary Task Complexity

First of all, the degree and even the existence of the negative effect on timeliness depends on the primary task complexity. Although a distinction was made between tasks being complex due to processing versus memory intensity, the two were never actually directly compared in their influence patterns. However, by looking at the outcomes of different studies, both measures of complexity showed the same impact, and hence can be treated equally. The Distraction Conflict theory predicts that the more complex a task is the more cognitive resources are needed for its successful completion. A user working on a simple task, on the other hand, should have ample cognitive resources available when interruptions occur (Speier et al., 2003, p. 775). Empirical testing supports this expectation. It turns out that the disruptiveness of an interruption on primary task performance grows with its complexity. The interesting phenomenon here is that interrupting simple tasks may actually have a positive, rather than negative, performance effect (Speier, et al., 1999, 2003; Burmistrov et al., 1996). According to Yerkes-Dodson Law (Yerkes & Dodson, 1908), when executing simple tasks, arousal level is low and more irrelevant cues are accepted (Kahneman, 1973, p. 37). With reoccurring interruptions, users have to process more cues, which leads to growing feelings of stress or physiological arousal (Kahneman, 1973, p. 10). This feeling induces higher concentration on the dominant and most obvious cues of the situation, restricting waste of effort on irrelevant stimuli. Due to this process of narrowing attention, performance actually improves (Speier et al., 2003, p. 775). This finding implies that there is an optimal level of arousal, and hence optimal level of interruptions, that maximizes primary task performance. Moreover, the optimal level of arousal is somewhat higher in simple tasks because there is a narrower range of necessary cues to process (Kahneman, 1973, p. 37). Or, in other words, interrupting a complex task will most likely disrupt performance, whereas interrupting a simple task could actually improve the timeliness of performance.

5.4.1.2. Interruption Frequency and Timing

However, not only the simplicity of primary tasks may induce performance growth. Zijlstra's results (1999) show that negotiated interruptions can even improve primary task performance by implementing different strategies to handle interruptions and to execute the main task. However, this performance improvement happens at the expense of the person's worsened psychological state and higher level of effort expenditure (Zijlstra, 1999, p. 183). Close examination of the results reveals that users faced with rapidly growing pressure change their strategies in dealing with interruptions (Kirmeyer, 1988; Cutrell et al., 2000a; Czerwinski et al., 2001; Zijlstra et al., 1999). Such pressure can come from highly frequent interruptions (Kirmeyer, 1988; Zijlstra et al., 1999), from complex primary tasks (Czerwinski et al., 2001), and finally from unfavorable interruption timing when users' mental load is very high (Cutrell et al., 2000a). People put under pressure look for ways to minimize effort expenditure (Speier et al., 1999, p. 8), and hence develop more efficient strategies to deal with pressure resulting from interruptions. A strategy that is typically used is to delay interruption response until a natural break point within the primary task execution is reached, i.e. bring some of the subtask to an end before reorienting to interruptions (Cutrell et al., 2000a, p. 100).

Certainly, strategy change is only possible when the interruption coordination method is negotiated. Being presented with an immediate interruption does not give the user any strategic flexibility (McFarlane, 2002, p. 71). Hence, frequent immediate interruptions have a negative impact on users' primary task performance timeliness. Theoretically, by looking at the number of interruptions alone, it follows that resumption performance should be better when there are fewer interruptions. Each time an interruption occurs, a goal must be suspended, maintained, and resumed. More interruptions should therefore lead to greater goal retrieval interference (Monk et al., 2004, p. 296).

With respect to interruption timing, there are several key findings with important implications for systems design. Timing can be understood in two different ways: particular moment within the primary task, and the timing measured by the interruption lag. The former is based on the Model of Goal Activation (Altman et al., 2002), which states that memory loads vary at different points during the primary task. At less disruptive moments of interruption there are lower volumes of information to restore (Monk et al., 2004b, p. 653). The experiments showed that users' memory loads are lowest at natural breakpoints in a task sequence (Bailey et all, 2006, p. 689). According to Zeigarnik (1927), once one action or part of an action has been completed, it supposedly no longer has a claim on the memory system and resources, and hence can be released from memory (Bailey et all, 2006, p. 686). These moments are most opportune for interruptions (Bailey et all, 2006, p. 686).

The second way to look at interruption timing is by measuring the interruption lag. This is the period between the interruption warning or interruption acknowledgment and the actual interruption initiation (Gillie & Broadbent, 1989, Czerwinski et al., 1991; Altmann et al., 2002; Trafton et al., 2003). During the delay, the individual has some time to prepare for the interruption, which helps facilitate resumption. He can lead his current subtask to an end, review his current activity, and rehearse his current position (McFarlane et al., 2002, p. 30; Bailey et all, 2006, p. 686). However, provision of an interruption lag that allows preparatory activities does not always improve primary task performance timeliness (Gillie et al., 1989). The disruptive effect of interruption on people's memories is not caused solely by people's inability to rehearse the information in their memories before handling the interruption. If the primary and interruption tasks are very similar or complex, people have problems resuming interrupted tasks, even if they have the opportunity to review the ongoing activity (McFarlane et al., 2002, p. 34).

5.4.1.3. Similarity between Primary Task and Interruption Task

Performance timeliness is also affected by the similarity of the two tasks' characteristics. From the five similarity dimensions found in attention interruption research, only three were tested with respect to primary task performance timeliness: content, presentation format, and type of cognitive processing. Interestingly, the three have opposite effects on timeliness. Whereas similarity in the presentation format and cognitive processing type worsens timeliness (Czerwinski et al., 1991, p. 1), similarity in content improves it (Speier et al., 1999, p. 348). The former quite logically provides similar information, which decreases the demand for cognitive processing resources, and hence results in decreased information overload (Biggs et al., 1985; Iselin, 1988; Evaristo et al., 1995; Speier et al., 1999, p. 342). Iselin (1988) claims that diversity necessitates processing of more information cues and types. This increases the likelihood that the decision maker's limited cognitive capacity will be exceeded.

The latter, on the other hand, worsens the primary task performance timeliness. Similar presentation of information ,as well as similar cognitive processing in both tasks, is likely to cause memory interference (McFarlane et al., 2002, pp. 22-23). The user gets confused between the two tasks and suffers low recall during the resumption of the primary task (Czerwinski et al., 1991, p. 1). Not even by allowing users to review their current activity prior to handling an interruption could their performance be improved (Gillie et al., 1989, p. 248). It is worth noting that the negative effect on timeliness might also be due to the dissimilar content of the primary and interruption tasks.

5.4.1.4. Interruption Duration and Meaning

Primary task information stored in temporary storage is subject to decay over longer interruption durations (Monk et l, 2004a, p. 651). Yet, the role of interruption duration still seems to be controversial when looking at experiments conducted (Gillie et al., 1989; Burmistrov et al., 1996; Monk et al., 2004a). Most research concluded that the longer the interruption task, the less primary task information remained in the short-term memory storage, and hence the longer the resumption (Burmistrov et al., 1996; Monk et al., 2004a). The user must remember all the information about the primary task setting, his position within the subtask sequence, and the processing cues at the moment of interruption. Gillie et al. (1989), however, could not establish any significant effect of interruption duration. A more careful analysis explains the controversy. There are tasks that require storage of information less subject to decay over time than others (Gillie et al., 1989, p. 246). Users may not struggle remembering simple every-day terms put do so in logical ordering over longer interruption periods (Gillie et al., 1989, p. 244).

Another variable that influences the timeliness of the primary task performance is the interruption meaning and its importance to the user and his current task. Interruptions are irrelevant to the task result in longer processing times, and hence longer task resumption times occur than with relevant messages (Cutrell et al., 2000a, p. 1). The longer an interruption task is processed the higher the interruption and hence the more likely users are to forget their primary task goals.

5.4.1.5. Primary Task Type and Volume

Some implications can be taken from the empirical research with respect to a task's type of cognitive processing. It was shown that depending on the type of cognitive processing of the ongoing task there is a significant difference in timely completion. For instance, deterioration of performance speed was observed for perceptual primary tasks more often than for analytical ones (Speier et al., 2003, p. 784, 786). Thus, interruptions have a greater negative effect on processes such as establishing relationships among discrete sets of symbols than on manipulating them (Speier et al., 2003, p. 775). Moreover, Cutrell et al.(2000a) showed that evaluation tasks suffer greater timeliness losses than planning and execution tasks (Cutrell et al., 2000a, p. 100).

Empirical testing also showed that users need more time to switch back to long lasting complicated tasks that include many documents (Czerwinski et al., 2004, p. 178). The reasoning here is similar to complex tasks: the greater the volume of a task, the more information cues have to be processed and the more cognitive resources are needed for its successful completion (Speier et al., 2003, p. 775). Interrupting such a task necessitates restoring a greater volumes of information (Monk et al., 2004b, p. 653).

5.4.1.6. Repetition of Primary Task

Repeating a primary task implies learning of the same and also developing a most efficient way to deal with interruptions of the same. For example, during frequent and predictable shifts between a primary task and an interruption task, a user may adopt a 'time-sharing' strategy (Monk, 2004) that allows him to rehearse suspended goals while simultaneously working on the interruption task. Thus, repetitiveness triggers learning to rehearse before the interruption and during the interruption to facilitate resumption of the primary task. Such learning occurs in particular when interruption tasks are not very demanding (Monk, 2004). The more demanding the interruption task is, the more cognitive resources it uses and hence the less capacity is left for preparatory activities.

5.4.1.7. User Characteristics

Finally, it is interesting to ask whether interruption effects on timeliness of the primary task varies for different individuals. User characteristics tested to answer this question are gender, age, recall ability and domain expertise. No significant effect has been observed with respect to gender (Gillie et al., 1989; Speier et al., 2003). However, it has been found that older participants (average of 60) take significantly longer to complete a primary task than younger individuals (average of 20) (Monk et al., 2004b, p. 659). Rather strange is the finding that users' individual abilities to recall does not show any significant result (Gillie et al., 1989). Finally, Speier et al. (2003) observed that people with higher domain expertise performed better when interrupted.

5.4.2. Primary Task Quality

The second performance measurement of interest is the investigation of how interrupts affect primary task quality. This variable is measured in terms of correctness and completeness of the primary task. Similarly to performance timeliness, quality can improve despite interruption. Mostly, however, it either worsens or remains equal with interruptions.

5.4.2.1. Primary Task Complexity, Type and Format

Primary task complexity is typically varied by manipulating the degree of processing intensity. The results show that interruptions have no significant effect on performance quality of simple tasks (Speier et al., 1999, p. 346), but, instead, may even improve its quality of performance (Speier et al., 2003, p. 784, 786). Interruption of complex tasks, in contrast, lead to a significant decrease of accuracy (Speier et al., 1999, p. 348). The reasoning here is similar to the explanation of the positive effects of some interrupts on timeliness. When performing simple tasks, individuals perceive that the task is "too easy", and therefore do not dedicate their full attention and processing capabilities to performing it. Instead, they may think about other work-related or personal issues (Speier et al., 2003, p. 789). Users that are put under pressure focus their attention and concentrate on the task at hand, making less mistakes (Moe, 2006, p. 36). When performing more complicated tasks, there is no spare capacity to deal with interruptions. Overloading then leads to negative quality performance. Speier et al.(2003) also compared the results for different tasks in terms of cognitive processing. Nevertheless, the implication remained the same: interruptions can improve the quality of performance on simple tasks and reduce it as tasks became more complex, regardless of the type of cognitive processing (Speier et al., 2003, p. 784, 786).

Speier et al.(2003) not only clearly differentiated between two discrete cognitive processing types, but also defined and tested the most suitable information presentation format for a particular processing type in an interruptive environment. It is known that when the individuals' working environment becomes more demanding, either through higher time pressure or through disturbing interruptions, the worker perceives higher workload and stress (Speier et al., 2003, p. 779). It turned out that to cope with the overloading demands he will change his performance and processing strategy (Speier et al., 2003, p. 779). Due to limited cognitive capacity, people minimize the information cues to be processed by dismissal or exclusion of less relevant cues (Speier et al., 2003, p. 775). By analogy, presentation formats that minimize information load and enable faster information acquisition will be more appropriate (Speier et al., 2003, p. 775). For example, presenting information in ways that enhance the use of perceptual processes, such as comparisons, facilitates the acquisition and processing of complex information and minimizes information overload due to interruptions (Speier et al., 2003, p. 789-790).

Nevertheless, what remains unanswered is whether tasks that require more memory, rather than tasks that are processing intensive, follow the same structure. Goal Activation Theory (Altmann & Trafton, 2002) would claim that recall is facilitated by providing mental or environmental cues. It could be argued that formats improving memorization and recall under pressure are those that provide logical mnemonic features, such as pictorial concentrated presentation tools. Such a proposition, though, still needs to be tested in further research.

5.4.2.2. Interruption Frequency and Complexity

Interruption frequency has a much weaker effect on primary task quality than on timeliness. Most research did not observe any significant outcomes (Zijlstra et al., 1999; Monk, 2004). However, this result could also be due to rather sparse frequency conditions (Speier et al., 1999). It is assumed that decision makers experiencing more frequent interruptions perform their primary task less accurately (Speier et al., 1999, p. 347). Clearly, when frequency is very high, users become overloaded and stressed (Speier et al., 2003, p. 779). People will minimize the information cues to be processed by dismissal or exclusion of less relevant cues (Speier et al., 2003, p. 775). This results in the user completing the task faster at the cost of task quality resulting from the elimination of relevant cues (Speier et al., 1999, p. 341).

The argument concerning interruption complexity is similar. Although there are no clear empirical results, it can be expected that the quality of the primary task performance suffers when interruption tasks are very complex (Zijlstra et al., 1999). Users that are put under pressure due to interruptions often attempt to finish all their tasks faster at the cost of accuracy. The more complex a task is, the more cognitive resources are needed for its completion. Therefore, a user working on a simple interruption task has ample cognitive resources available when interruptions occur. On the other hand, when processing complex tasks, people minimize their expenditure of scarce cognitive resources, and hence change the way in which they process information. It is assumed that such a process implies a less critical examination of relevant cues (Baron, 1986) during which performance quality suffers (Speier et al., 2003, p. 775). That is, people seek to reduce effort by relying on less time consuming processes which reduce accuracy (Johnson & Payne, 1985). This phenomenon is described as a trade-off of accuracy against the time required to complete the task, where users under stress want to keep the deadline at the cost of quality of their performance (Speier et al., 2003, p. 778).

5.4.2.3. Similarity between Primary and Interruption Task

Contrary to the positive effect of interruptions containing similar information on primary task timeliness, the level of quality remained unchanged (Speier et al., 1999, p. 348). Not surprisingly, presenting an interruption with the same or similar content cannot improve an already high performance quality. However, similarity in terms of presentation modality had a negative effect on the quality of primary task performance. Here, as opposed to interruption task quality, more primary task performance errors were made in same-modality conditions, specifically in auditory-auditory conditions than in cross-modality conditions (Latorella, 1998, p. 3). Supposedly, same-modality conditions lead to confusion of information after the interruption was completed.

Although there was no empirical testing on other similarity dimensions, it should be possible to predict its outcomes. Similarity between the interruption and the primary task should disrupt task performance quality (Kreifeldt and McCarthy, 1981; Gillie & Broadbent, 1989; Czerwinski, Chrisman, & Schumacher, 1991). The user gets confused between the two tasks and makes mistakes as a result of the interruption (Czerwinski et al., 1991, p. 1). For example, if a worker uses some specific colors to highlight different data in a table, an interruption task on the same screen presenting a similar table using different colors might confuse the user. He then starts using wrong colors after the interruption.

5.4.2.4. Interruption Coordination Method

The main finding here is that immediate and negotiated interruptions cause different levels of user performance quality on interrupt-laden computer-based multitasks (McFarlane, 2002, p. 82). The “best” minimizing quality of disrupting effects of interruptions is a negotiated interruption (McFarlane, 2002, p. 97). This is, because negotiated interruptions allow strategic flexibility and opportune interruption timing. Negotiated interruption allows users to change their strategy to deal with interruptions, which sometimes gives them more time space (Speier et al., 1999, p. 8). Feeling less time pressure reduces confusion of information and hence keeps the quality level of performance.

5.4.2.5. User Characteristics

User characteristics tested were gender and domain expertise. No significant effect was observed with respect to gender (McFarlane, 1999; Speier et al., 2003). However, Speier et al. (2003) observed that people with higher domain expertise performed better when interrupted.

5.4.3. Primary Task Efficiency

Unfortunately, efficiency of performance was rarely measured. This could be due to its rather complicated calculation and measurement: average performance per unit of work. Only a few tasks can realistically be subdivided in units of work. Nonetheless, McFarlane measured performance of the different interruption coordination methods and its effect on primary ask efficiency. His result was similar to other primary task performance measures. The “best” solution, one that maximized performance efficiency, is a negotiated type of interruption (McFarlane, 2002, p. 97).

5.4.4. UAIM on Interruption Effects on Users’ Primary Task Performance

Clearly, the conclusions derived from the different scientific domains are not always consistent and therefore further investigation into the effects of interruption on users‘ task performance is warranted. However, many important implications can already be stated from the meta-study we conducted. All the studies, for example, come to the conclusion that interruptions have a negative impact on users’ primary task performance measures. This impact is greatest for long lasting, frequent, complex, irrelevant and dissimilar interruptions that distort tasks at moments of high mental load. Furthermore, the effect varies for different users’ domain expertise and diverse types of the primary tasks. Negative effects are reduced for repetitive primary tasks. Finally, the results show that an appropriate coordination method can support users by handling interruptions, effectively minimizing performance errors and timing (McFarlane, 2002, p. 66). Table X summarizes the key findings and produces a unified attention interruption model of interruption effects on primary task performance.

Table 30: Summary of research findings of interruption effects on primary task performance

Studies	Interruption effects	Independent Variables	Moderating Variable	Explanation
Gillie et al., (1989); Burmistrov et al.(1996); McFarlane (1999); Speier et al.(1999); Zijlstra et al.(1999); Eyrolle et al.(2000), Cutrell et al.(2000a); Czerwinski et al.(2000b), (2001), (2004); Monk et al.(2002), (2004a), (2004b); Speier et al., (2003); Trafton et al.(2003); Bailey et al.(2006)	PT Timeliness	PT Complexity (memory load, processing intensity)		The negative effect is stronger for more complex PT. The effect might be even positive for simple PT.
		IR Frequency IR Timing (memory load)	Change in strategy	The negative effect is stronger for more frequent IR occurring in moments of high memory load. The negative effect diminishes and can become positive when users change their strategy.
		IR Timing (interruption lag)	PT Complexity	Providing interruption lags has a positive effect on timeliness. The effect is stronger for complex tasks.
		Content, Cognitive Processing Type and Format Similarity between PT& IR		The effect is positive for similar content and negative for similar format and processing type.
		IR Duration		The negative effect is stronger for higher duration when information stored is illogical and uncommon.
		IR Meaning		The negative effect is stronger for irrelevant IR.
		PT Type (cognitive processing)		There is a significant effect.
		PT Repetition	IR Complexity	Repetition has a positive effect on timeliness, which diminishes with increasing IR complexity
		User Characte-ristics (Age)		The negative effect is stronger for older users.
		User Characte-ristics (domain expertise)		The negative effect is smaller for users with greater experience in the area.
		IR Coordination Method		There is a significant effect.

Latorella (1998); Zijlstra et al.(1999); McFar-lane (1999); Speier et al., 1999; Eyrolle et al.(2000), Speier et al., (2003); Bailey et al.(2006)	PT Quality	PT Complexity		The negative effect is stronger for more complex PT. The effect might be even positive for simple PT.
		PT Format		There is a significant effect.
		IR Frequency		The negative effect is stronger for more frequent IR.
		Similarity between IR & PT (modality)		The negative effect is stronger for simi-lar conditions.
		IR Coordination Method		There is a significant effect.
		User Characte-ristics (domain expertise)		The negative effect is smaller for users with greater experience in the area.
McFarlane (2002)	Efficiency	IR Coordination Method		There is a significant effect.

5.5. System Design Guidance & Propositions

This paper reports the findings of empirical research on attention interruption effects. These findings show that there is great opportunity for user-interface design to increase people's ability to success-fully handle interruptions and prevent expensive errors. Unfortunately, the literature still contains little concrete design wisdom on how to solve interruption problems in user interfaces (UIs) (McFarlane, 2002, p. 66), but the following paragraphs summarize what empirical research suggests.

5.5.1. Interruption Timing and Coordination Method

Humans have some natural abilities to dynamically adapt their behaviours to accommodate interrup-tion (Clark, 1996, cited by McFarlane, 2002, p. 71). They can potentially manage multiple concurrent activities if they have specific kinds of control and interaction support (McFarlane, 2002, p. 65). One way for system designers to provide users with some control over interruptions, and hence enable strategic flexibility, is by coordinating interruptions in a negotiated way. There is empirical evidence that people actively avoid mid-task interruptions by postponing engaging interruptions until they finish a task (McFarlane, 2002). Negotiated interruptions aid users in deciding whether to take an interrup-tion lag for reparatory activities and at which point within the primary task to stop their work. Hence, system designers should incorporate this feature when dealing with interruptive systems. However, an appropriate interruption coordination method should also be decided by looking at the importance and urgency of the interruption task. Negotiated interruptions in cases of high urgency can cause tragic consequences, for example, take a pilot that delays an interruption informing him of the bad health of an airplane engine. To conclude, there is no one "best" method for coordinating interruptions for all kinds of human performance. There are, instead, tradeoffs where a system designer must conduct a careful analysis of what kind of interruption coordination method suits best the situation (McFarlane, 2002, p. 95).

5.5.2. Rehearse and Reminder Tools

When designers chose an immediate interrupt for their system they can incorporate possibilities and tools for preparatory activities, enabling faster resumption processes. Trafton et al. (2003) empirically proved that given enough capacity and performance pressure, automatic rehearsal of suspended goals does take place, and that this rehearsal diminishes the disruptive effects of the interruptions (Monk et al., 2004b, p. 652). To facilitate the resumption of activity goals, memory lists, position markers and other reminders may be of useful (Czerwinski, Cutrell & Horvitz 2000b; Trafton et al., 2003). For example, some software programs can save all commands previously exercised and provide them when requested (Renaud, 2000). Website links can change their colors to help the user remember which links he has already seen. Test editing software offers a curser that reminds the user of his current position. A more extensive tool is the Remembrance Agent (Rhodes et al., 1996). It is an automatic text retrieval system based on a user's current location. The system returns information about other users or items available in the system based on the user location and the relatedness of the items. A similar application was developed for users of mobile devices (Lamming et al., 1992). Here, users' physical locations, workstation activities, file exchanges, printing, phone calls, email, and colleagues present at meetings, etc. are continuously logged. The system later displays these events and allows the user to filter content on key event details, like time, person, place, etc. (Czerwinski et al., 2004, p. 176). Finally, after an experiment, participants called out for a software support that provided them with the ability to organize project-related documents, email, and other windows together in the Windows XP taskbar (Czerwinski et al., 2004, p. 180). After an interruption of a long lasting, complicated task including many documents, switching back was found to be especially difficult. A tool that saves all the project-related files could highly facilitate such work conditions. To conclude, there different reminders and rehearsal tools that are already designed which give ideas for the most appropriate reminder tool in a particular interruption situation. By using them system designers could make some users‘ work more agreeable and less stressful, and hence improve technology acceptance in the long term.

5.5.3. Presentation Format and Modality

One key finding of the meta-study is that system builders aiming at mitigating the effects of stressful work conditions due to interruptions should be aware of the fact that graphical formatting could minimize interruption disruptiveness (Speier et al., 2003, p. 790). Storch (1992) found that interruptions expressed as on-screen messages were more disruptive to people performing a computer data-entry task than interruptions expressed as telephone calls or as human visitors (McFarlane, 2000, p. 68). Furthermore, usage of different expression methods, such as semi-transparency (Harrison et al., 1995), spatial location (Osgood et al., 1988) and windowing (Lee, 1992) can help disambiguate between concurrent tasks (McFarlane & Latorella, 2002, p. 21). Finally, when designing interruptions, an attempt should be made to minimize memory and structural interferences. A careful consideration of the conveyance channel should be made when designing an interruption-laden system. When the focus lies on primary task performance, interruptions should be displayed in a different modality condition (Latorella, 1998, p. 3). Likewise, similar formatting between the ongoing and the interruption tasks may lead to confusion of information after the interruption is completed.

6. Conclusion

This working paper is the first meta-study on attention interruption research. To facilitate understanding and evaluation of the interdisciplinary attention interruption research domain, an intensive analysis of the independent and dependent variables, their diverse meanings and components was conducted. The derived taxonomy and Unified Attention Interruption Model enables the HCI field to make comparisons and analysis of research findings. It provides common guidelines for system designers looking for effective solutions for interruption management.

However, in order to answer more design questions further research in interruption effects in information and system-laden environments is warranted. The analysis of the psycho-/and physiological cost of interruption has been widely neglected in IS research. In the long term though users may adopt systems more readily if they provide them not only with the most effective solutions, but also make their technology usage as agreeable and enjoyable as possible (Adamsczyk et al., 2004, p. 1). Successful technology should not only increase performance efficiency, but also lead to high user satisfaction.

The key finding of this paper is that the increased offloading of control and responsibility to automated systems lead to highly interruption-laden and hence stressful environment. Through interruptions systems cause degradation of user performance, as well as dilapidation of users' psychological and physiological state. Luckily, there is great opportunity for user-interface design to increase people's ability to successfully handle interruptions, and prevent expensive errors. By choosing the most appropriate interruption coordination method, designers can give users the highest possible strategic flexibility. As users have natural abilities to choose the most efficient strategies. The right coordination method can minimize overloading and allow preparatory activities to mitigate interruption disruptiveness. Stress and performance can be addressed by providing users with effective rehearsal and reminder tools. Finally, interface designers should be careful in choosing the most appropriate task presentation formats and modalities. Similar arrangements can produce memory interferences and storage confusion.

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