Attention Management in Organizations
Four Levels of Support in Information Systems

Claudia Roda[1] & Thierry Nabeth[2]
[1] The American University of Paris – France
[2] INSEAD, CALT – France

Abstract

People attention represents one of the most precious intangible asset of modern organizations. In this paper we propose a model that describes how to better support attentional processes using virtual environments. The model relies on four different levels of attention support: (1) a **perception level,** aiming at optimising the observation and the selection of information; (2) a **deliberative level**, aiming at supporting people's deliberate choices of attention allocation and decision making; (3) an **operational level**, aiming at making the execution of tasks more effective in terms of allocation of cognitive resources; and (4) a **meta-cognition level**, aiming at helping users in reflecting about their attentional practices and possibly learning more effective ones.

1 Introduction

The advent of modern Information and Communication Technologies (ICT) has radically changed access and communication of knowledge within organisations. Nowadays, knowledge workers have wide access to both formalised (e.g. information repository) and informal (e.g contacts with experts) knowledge resources. The problem faced most often by knowledge workers is not related anymore to the scarce access to knowledge, but rather to the choice they have to make in the allocation of their limited cognitive abilities to a wide variety of knowledge sources. Management of *attention* has thus become the issue that needs to be addressed. This state of things directly impacts processes of knowledge creation which demand careful management of individual and collective attentional resources (Belmondo, 2006). New methodologies and tools for managing the wide range of data, knowledge, and opportunities that have become available are needed.

It is increasingly recognised that ICT, whilst providing access to information and communication, should also support human limited cognitive abilities in the selection of the most relevant information and tasks. Such support, by facilitating human attentional processes, may represent a critical factor in fostering innovation.

Knowledge workers are faced with situations in which: (1) they have access to a very large amount of, mostly de-contextualised, information, (2) they need to collaborate or communicate with colleagues of whom they may know very little, and (3) they may have to attend to several tasks at once (multi-tasking).

In modern organisations, many interactions take place in shared virtual environments that allow knowledge workers to access information and people necessary for the achievement of various goals. However shared virtual environments (such as virtual communities, and other collaborative systems), whilst supporting increasingly complex interactions (Nabeth & Roda, 2006; Schroeder & Axelsson), enable new interruption channels which have become an almost constant factor in many working environments. Although interruptions may bring to one's attention information possibly useful for the primary (current) task, it has been widely reported that such interruptions increase the load on attention and memory (Gillie & Broadbent, 1989), may generate stress (Bailey, Konstan, & Carlis, 2001; Zijlstra, Roe, Leonova, & Krediet, 1999), and compromise the performance of the primary task (Franke, Daniels, & McFarlane, 2002; McFarlane & Latorella, 2002; Nagata, 2003; Speier, Vessey, & Valacich, 2003). In order to cope with these new dynamic and far-reaching environments a certain number of practices have been developed to improve the effectiveness of information acquisition and communication, and the interaction with others. Such practices have been often explicitly stated (an online search for "netiquette" will result in a large number of such statements) and are normally accepted amongst ICT users. However, whilst the appropriate use of ICT tools by individuals may reduce the attentional effort required of the community for accessing and managing knowledge, ICT tools themselves represent an important mean to support people's attention.

Within the study of modern management processes Goldhaber (1997), and Davenport and Beck (2001) have stressed that attention is the element that counts the most in the information economy as it is the scarcest resource and it is critical to organizations' success. In the context of work and business, attention is defined as a "focussed mental engagement on a particular item of information", and can be considered both at individual and at organizational level (Davenport & Beck, 2001). For individuals, the focus of attention corresponds generally to the activity they are currently engaged with (such as writing a report, or having a conversation). For the organization, attention represents the number of strategic items that have the focus of the employees within the organization. It has to be noted that, as for an individual, an organization can only focus its attention on a limited number of items. Several studies have been conducted and systems have been proposed to address the alignment of the individuals' goals and the company's goal (and ensure that the attention of the employees is properly oriented toward items relevant to the strategic objectives of the organization). For instance Wright and Snell (1998) propose a unifying framework for strategic human resource management addressing the fit of people and organization. Goal alignment, appraisal, or performance systems (Summers & Dahod, 2003) have also been designed as tools for helping to enforce the focus of the employees on items that are the most critical to the organization. However, information system helping to align the individual and the organizational attention, and more generally Human Resource Management systems, remain very primitive and largely underdeveloped (Chew, 2003).

Attention represents also an important element for businesses in their interaction with the external world. Organizations need to manage effectively their communication to "get the attention" of their customers and of their potential business partners, since this visibility is increasingly difficult to obtain in a world flooded with information. Managing this communication represents a domain that is however well known and occupied by the media and advertising industry, even if it is facing major transformation (following the advent of the Internet). Although we will not address here the communication dimension of attention in management, this dimension has an important impact on knowledge workers who are both more solicited (and therefore must establish effective filtering strategies) and must ensure that their messages obtain the proper level of attention from receivers without overwhelming them.

In this paper, after briefly discussing the conflict between human bounded cognitive abilities and the increasing demands imposed on knowledge workers, we propose that such conflict may be, at least partially, addressed by appropriately supporting attentional processes in digital environments, and we detail four possible levels of interventions: support to perception, support to deliberation, support to operation, and support to meta-cognition.

2 Reaching the limits of human and organizational bounded cognitive capabilities and capacities

The advent of the knowledge-based economy has radically transformed the nature of work and business in organizations. Employees, who once used to fulfil relatively routine tasks in stable environments, have now transformed into autonomous knowledge workers who are engaged into rich, diverse, changing, and creative activities in which information processing and participation in virtual community environments play a central role. Learning organisations (Argyris & Schon, 1978; Dodgson, 1993) operate in a continuously changing world and focus on supplying a large diversity of services highly customized to the needs of a multitude of customers. These organisations must rapidly adapt to open, complex, and ever changing environments involving the interaction with a variety of actors and stakeholders. Success factors for these organizations include their capability to listen to their customers, to constantly innovate (Nonaka & Takeuchi, 1995), and to compete with others often by reinventing themselves (Senge, 1994).
For the employees, these new conditions have translated in the acceleration of time, the multiplication of projects in which they are involved, and the increased number of collaborations often based on digital interactions. They have to process a considerably larger amount of information and solicitations than in the past (Heylighen, 2004), originating from a multitude of sources and tools. They also must interact with a variety of people, with different functions, cultural backgrounds (Nisbett, 2003), and from different organisations. These interactions increasingly include less formal forms of communication, for which the filtering strategies are more fuzzily defined (for instance Nardi, B., Whittaker, S, Schwarz, H. (2000) indicate that social networks, a filtering mechanisms based on the social process, have become a key source of labour and information).

Yet, humans have not radically changed: people have still very limited capacities for manipulating more than a few concepts at a given time, have difficulties with multi-tasking, and can only maintain relationships with a limited number of people. For example, Miller's (1956) work on short term or working memory indicates that human being have a maximum capacity to manipulate 7 +- 2 chunks of information at one time; Rubinstein, Meyer, and Evans (2001) have experimentally demonstrated the high cost of

switching from one task to another, making multitasking a not very effective strategy when one wants to be more productive; and Dunbar (1993) identifies "a cognitive limit to the number of individuals with whom any one person can maintain stable relationships" and evaluates at 150 people this limit (Dunbar's principle has been for instance applied by the Goretex company to define the maximum number of employees in a factory (Gladwell, 2000)).
Notwithstanding these limitations, increased competition and pressure to augment shareholders value has conducted many organisations more frequently to downsizing rather than to expanding man-power: people are asked to do more in less time. Besides, as indicated previously, they are engaged for completing their work with interactions with a larger number of people than in the past.

How to address the productivity challenge in the information economy, with activities that can not be really automated and without having the possibility to increase the number of employees in the organization or their cognitive performance?

We propose in the next section that better support to attentional processes in general, and in particular in the context of shared virtual environments, may help organizations and individuals in addressing such challenge. We also briefly indicate the work already done towards the development of systems capable of supporting users in their attentional choices (Roda & Nabeth, 2007; Roda & Thomas, 2006).

3 Supporting attention

Studies in cognitive psychology have clearly established (see for example review in (Roda & Thomas, 2006)) that attention allocation depends both on perceptual and deliberative processes. At the **perceptual level**, what we perceive (e.g. see, hear, feel) impacts on what we pay attention to. At the **deliberative level** our goals, motivations, and intentions, also play a role in the determination of our attention focus. Therefore, a natural way to study the support of attention consists in the exploration of mechanisms facilitating the perception of the environment, and the interpretation and the reasoning on this information.
At a different level of observation, it is clear that actions require a varying degree of cognitive effort depending on the form and the nature of the task being accomplished. For instance, some activities may require a high level of concentration to get focussed, a higher degree of vigilance, the switching between many subtasks, or be subject to a significant number of interruptions. Therefore at the **operational level** the provision of mechanisms allowing the users to be more effective in term of the cognitive effort allocated to fulfil an objective represents another means of supporting attention.
Finally, we are able, as we are doing here, to reflect about our own strategies for allocating attention, and to learn more effective attention allocation strategies. Therefore, mechanisms supporting the **meta-cognitive level** elaboration and evaluation of strategies for attention allocation can be proposed as another means of supporting user's attention.

To summarize, we propose that attention should be supported at four levels:

- At the perceptual level by, for example, facilitating access and selection to relevant information or presenting interruptions at the appropriate level of prominence.
- At the deliberative level by, for example, supplying tools for the control of task priorities, by motivating individuals who are loosing focus, or by giving the possibility to the user to better assess the impact of their actions.
- At operational level by, for example, simplifying some attention related operations such as restoring the context of interrupted tasks, filtering incoming information, or reducing the required level of vigilance over planned activities. For instance in the latter case, mechanisms such as watch lists or notification, may release the user to regularly check for the availability of an important information
- At the meta-cognitive level by, for example, providing self-diagnostic tools, helping the acquisition of more effective attention allocation strategies.

This division in "levels of support" is obviously artificial but it is fundamental for a detailed analysis of attentional breakdowns and possible support strategies. A combination of processes at several levels normally craft human attention allocation strategies.

3.1 Supporting attention at the perceptual level

Supporting perception means increasing both the ability to notice relevant information and to discard the irrelevant. We recognise at least four different manners in which perception may be enhanced: (1) facilitating the selection of relevant information (2) facilitating information comprehension, (3) supporting group perception, and (4) presenting interruptions at the correct level of prominence. These four issues (information selection, information comprehension, group perception, and presentation prominence) are strongly related. Access to information, in fact, has become problematic not only because of the sheered quantity of information available, but also, and especially, because individuals have very little tools and facilities enabling them to easily perceive what the content of a resource may be, how, when, and by whom the resource was created, edited, and accessed. Not only more resources are available but also more people may be related to each resource. Purposely designed digital tools may however support individuals in their perception of resources.

<u>Information selection</u> may be facilitated by the use of information filtering, and visualisation mechanisms. The former allow the user to select, statically (i.e. once for all) or dynamically, relevant types of information. Information filtering mechanisms may be based on more or less sophisticated selection algorithms or, in the case of social filtering, may use human evaluators who classify or assign ratings to various items. Visualization mechanisms aim at representing information to the user in the most appropriate format (see Toet (2006) for a review) and they should deal with the subtle processes that regulate human perception (Healey, 2005). Our ability to "see" something, in fact, does not depend solely on what we are presented with, but also on what we are looking for, or we expect (Egeth & Yantis, 1997; Rensink, 2000; Wolfe, Klempen, & Dahlen, 2000). Visualisation mechanisms may be coupled with, or replaced by information presentation based on non-visual modalities (Abowd, Mynatt, & Rodden, 2002) whereby several

channels are employed in order to communicate with the user. Further, in certain situations information may be made more visible, credible, and comprehensible by being communicated by an embodied agent (Lester, Converse, Kahler, Barlow, Stone, & Bhogal, 1997; Picard, 1997, 2004).

Several techniques have been, or may be, used in order to facilitate information comprehension, and therefore reduce the cognitive load associated to selecting the most relevant pieces of information, or the most appropriate action to perform. They involve providing meta-level / abstract information about people, documents, or tasks. For instance, indicators that abstract the information related to a document may include the category of the document, the size of the document, the date of creation of the document, the author, but also the popularity of the document. Similarly, the indicators that abstract a discussion space may include the number of threads, the number of messages that have been posted in the last day, or the topics generating most debate. A recent project addressing the collection of attention related meta-data is *Attention. XML* (Sifry, Marks, Çelik, & Hayes, 2006) which targets blogs and feeds. *Attention. XML* tracks data such as: what has been read, what the user has spent time on, recommendations, etc.
Extending the Attention XML framework, Wolpers and his colleagues (Wolpers, Martin, Najjar, & Duval, 2006) propose to "unobtrusively capture the attention of employees at the workplace (e.g. through workflow systems, knowledge management systems, human resource management systems, etc.) and use the captured information to enable a targeted steering of learning process of the employee in companies in accordance with company's and employee's aims and goals."
Abstract information may also display relationships amongst documents or tasks in the form of graphs allowing users to quickly understand and navigate a web of interrelated items.
Bier and colleagues (Bier, Stone, Pier, Buxton, & DeRose, 1993, p.73) also use meta-data information as part of Magic Lens as "filters that modify the presentation of application objects to reveal hidden information, to enhance data of interest, or to suppress distracting information".

When working or learning in a group physically co-present, the group's activity influences group perception and the focus of attention of each individual in several manners. The following are three examples of such influence. First, devoting one's attention to a given activity may be necessary in order to ensure the good functioning of the whole group (as in the case when one allocates attention to a task because the completion of the task is a prerequisite for the activity of other members of the group). Second, mechanisms of peer pressure may result in diverting one's attention from its natural course. Third, one's decision on whether to interrupt the activity of others may be guided by social cues, social rules, and knowledge about what the other person is doing.
As physical co-presence is increasingly reduced in favour of device-mediated presence, many of the cues necessary for the group activity to influence individual and group attention became more fuzzy or disappear completely. In order to enable people to appropriately allocate attention in situations such as the ones exemplified above, attention aware systems may support individual and group perception by supplying cues of others' activity, their level of involvement in the activity, their role, etc. Erikson and his

colleagues (Erickson, Halverson, Kellogg, Laff, & Wolf, 2002) address this problem in their research on *social translucence*.
It is interesting to note that, whilst many of the issues discussed above are due to the introduction of device-mediated communication, Vertegaal and his colleagues (Vertegaal, Chen, Shell, & Mamuji, 2006) propose to introduce device mediation in co-located environments and use information about individual's attention in order to dynamically adapt the configuration of the work environment to different attentional needs.

<u>Presenting interruptions at the correct level of prominence</u> may significantly reduce load at the perceptual level. Whilst in co-located communication we have developed a vast range of interruption strategies that vary in their level of prominence (e.g. standing next to a person waiting for the previous conversation or activity to be finished, making signs to signal the intention to communicate, intrude into one's conversation or activity in a more or less polite or urgent manner), the choice of the strategy is not only based on the knowledge of the message we want to communicate but also on some knowledge of the activity of the person we want to interrupt. In the case of device-mediated communication, knowledge workers are once again lacking half of the picture. This makes the choice of the appropriate interruption prominence much more difficult to evaluate. Notification can take a variety of forms, such as the sending of an email or of an instant message, the posting of a message in a chat box, the displaying of an item in the home page of a portal, the display of a blinking icon, or the intervention of an artificial character. The most appropriate format depends on a variety of factors, including the current state of the receiver (e.g. he/she is busy and should not be disturbed, or he/she is consulting the mailbox), the amount and complexity of information that needs to be communicated, the urgency of the communication, and the relevance of the information being communicated to the receiver. Whilst it has been shown that supplying information about pending tasks improves people's ability to manage interruption (C. Y. Ho, Nikolic, Waters, & Sarter, 2004), the notification modality may impact on the user activity at various levels: it may go completely unnoticed, it may smoothly integrate with the user's current task, or it may capture the user's attention and cause a temporary or durable focus switch. McCrickard and his colleagues (McCrickard, Catrambone, Chewar, & Stasko, 2003; McCrickard & Chewar, 2003) propose to measure the effects of visual notification with respect to four parameters: (1) users' interruption caused by the reallocation of attention from a primary task to a notification, (2) users' reaction to a specific secondary information cue while performing a primary task, (3) users' comprehension of information presented in secondary displays over a period of time, and (4) user satisfaction. They provide recommendations indicating, for example, that small sized in-place animation can be defined as best suited for goals of minimal attention reallocation (low interruption), immediate response (high reaction) and small knowledge gain (low comprehension). Bartram, Ware, and Calvert (2003) propose the use of moticons (icons with motions) as an effective visual technique for information rich displays that minimise distraction. Finally, Arroyo and Selker (2003) study the effects of using different modalities for interruption in ambient displays concentrating on the effects of heat and light channels.

3.2 Supporting attention at the deliberative level

Whilst at the perceptual level attention is influenced by external stimuli, at the deliberative level attention is influenced by one's goals, motivations, and intentions; further, these two processes (perceptive and deliberative) constantly interact to determine one's attentional state. For example, although an external stimulus may effectively attract someone's attention, a lack of motivation for the proposed focus will quickly divert his/her attention to another item. On the other hand, one may be motivated to focus on a certain item (because, for example, he/she is pursuing a certain goal) but an inappropriate presentation of the content (at the perceptual level) may hinder the establishment of the desired focus. This section analyses how attention may be supported at the deliberative level. It considers situations in which the knowledge worker:

- Looses motivation and/or stops actively pursuing a worthwhile focus;
- Looses track of the planned sequence of activity and/or experiences difficulties in prioritising his/her activity;
- Does not make best use of time resources or looses track of time
- Has difficulties in selecting the most effective focus for the goal of the group

Many experiments as well as folk wisdom tell us that loss of motivation, together with tiredness, is one of the main reasons for loosing focus of attention. Motivations may be provided in many different forms. In certain situations it may be enough to remind the knowledge worker what he/she was doing, in other cases it may be necessary to supply some help in order to encourage him/her pursuing the activity.

3.2.1 <u>Support to prospective memory</u>

Two problems often encountered in situations of heavy cognitive load and multitasking are related to the correct continuation of planned activities, and the evaluation of relative priorities of concurrent tasks. These problems have been studied in relation to *prospective memory* failures. Differently from *retrospective memory*, which allows us to remember facts of the past (e.g. people's names, the lesson studied yesterday), prospective memory allows us to remember planned activities in the future (e.g. go to a meeting, complete writing a paper, turning off the stove in 30 minutes) (Meacham & Leiman, 1982) and it is closely related to intentionality (Marsh, Hicks, & Bryan, 1999; Sellen, Louie, Harris, & Wilkins, 1996). Whilst prospective memory is essential for the normal functioning of our daily activity, prospective memory failures may account for up to 70% of memory failures in everyday life (Kvavilashvili, Messer, & Ebdon, 2001). Prospective memory failures have been shown to significantly hinder performance in working environments (M Czerwinski & Horvitz, 2002) and to intervene differently depending on the age of the subjects (Kvavilashvili, Messer, & Ebdon, 2001).

Prospective memory doesn't simply require remembering something, but it also requires remembering it at the *correct time*; such *correct time* may be represented by an actual time (e.g. going to a meeting at 2pm) or by the occurrence of an event or a series of events (e.g. publish the minutes once everyone has approved them). This has brought the distinction between *event-based* and *time-based* remembering tasks (Sellen, Louie, Harris, & Wilkins, 1996).

One obvious way to support prospective memory is through reminder services. As the need for reminder services has become ubiquitous amongst knowledge workers, we have seen the usage of tools such as digital diaries and Personal Digital Assistants (PDAs) increase dramatically. However these tools are still very primitive if compared to the real needs of knowledge workers. Systems offering reminders services should be able to issues reminders at a specified time or at the occurrence of a given event. These reminders should also help knowledge workers remembering to resume tasks that have been interrupted (a study reports that in over 40% of the cases in which tasks are interrupted, they are not resumed (O'Conaill & Frohlich, 1995)). Further, resuming a task doesn't only require remembering to restart the task but it entails being able to somehow re-establishing the context of that task. This may require a significant cognitive effort on the side of the knowledge worker. As a consequence, whilst at deliberative level a system may support task continuation via reminders, at the operational level, task resumption should be further supported by enabling individuals to easily re-establishing the task context (see section 3.3.1).

Since, in some situations it isn't possible for the system (or even the user) to know the set of subtasks required to continue a resumed task, presenting the user with information about the context of the interrupted task may facilitate resumption. A few researchers have already explored this possibility by developing systems that create logs of events that may help the user remembering about the context of an interrupted task; see (M Czerwinski & Horvitz, 2002) for an overview of this research.

Multitasking and interruptions not only impose the cognitive load related to remembering what one was doing when resuming a task, but also generates the problem of keeping a clear idea of what other important tasks lay ahead. In situations of multitasking, in fact, it may be difficult to keep track of relative priorities between tasks. Several mechanisms may be used to help knowledge workers in the allocation of attention to the most urgent tasks; these include the explicit definition of prerequisites or constraints for task execution, tasks deadlines, as well as interruption management. For instance an agenda can be used to help people keeping track and organizing the execution of different tasks. Such an agenda may reduce the cognitive load by giving an overall view of the way tasks are ordered, facilitating the planning and execution of tasks, allowing individuals to limit the number of tasks executed concurrently, and reducing the need for the knowledge worker to think about a particular task until it is necessary. On the basis of the contents of the agenda, digital systems may automatically send notifications about tasks due soon, relieving the knowledge worker from remembering about these events. Task agendas may also include information enabling the automatic evaluation of the satisfaction of prerequisites for actions execution, helping people to allocate attention only to those actions whose prerequisites are fulfilled.

Another consequence of task complexity and/or multitasking is an increased difficulty in the selection of the most appropriate information or task to attend in the available time. For example, given a limited amount of time available to perform a task, and two pending tasks of similar urgency but different durations, if one of the two tasks can be completed within the available time and the other one cannot, it is often more profitable to attend the task that can be completed within the available time rather than the other one. Knowledge workers often disregard these types of time-allocation evaluations when they work in complex multitasking environment.

3.2.2 Support to group level attention

In classic, strictly structured, collaborative environments, the role of the group manager is often that of a moderator capable of identifying information and tasks that are relevant and beneficial for the whole group. This can be reflected in at least two different types of attention-related actions.

First, managers are aware about task dependencies between tasks performed by different group members, and therefore they are able to suggest to a group member to attend a certain task because that task is critical for the action of other group members. Second managers are often aware of the overall foci of all the members of a group and they can therefore make sure that relevant information on resources and tasks can be diffused within the group.

In more decentralised collaborative environments typical of modern organisations, collaborative groups don't always have an individual manager with control on the attention-related actions mentioned above. Digital systems could partially support group level attention by enabling individuals to take-on those actions themselves. For example, by tracking access to, and actions on documents, digital systems may be able to inform group members about those tasks that are receiving the most attention from other knowledge workers. Similarly, the most popular action sequences may be used by the system to recommend task continuation strategies. This type of system behaviour is similar to the behaviour of collaborative recommender systems (a recent review of recommender systems can be found in (Adomavicius & Tuzhilin, 2005)). In a similar line, such tools may make users aware of the impact of their actions on others, therefore contributing to their motivation. Indeed, as proposed by (Bandura, 1994) with the concept of self-efficacy, people do not usually sustain their actions if they do not believe that what they do produces the desired results. Finally, we can mention the advent of new mechanisms that have emerged as part of the web 2.0 (O'Reilly, 2005), and which aim at creating conditions facilitating the emergence of collaboration (McAfee, 2006). In particular collaborative tagging (Marlow, Naaman, Boyd, & Davis, 2006), that can be found in services such as *del.icio.us*, provides the possibility to display, via tag clouds, topics that are receiving the highest level of attention from the community of its users.

In relation to group level support for task dependencies, it may happen that delaying, or minimising the impact of a notification message in order to optimise the performance of one user, results in sub-optimal performance for the group as a whole (as in the case when the activity of some members of the group depends on the prompt notification and consequent response of another member). In these situations strategies optimising individual attention allocation may not be sufficient and the selection of the notification strategy must take into account also the state of other users. Although most of the work on the evaluation of the cost/benefits of interruptions has been done taking the point of view of the user being interrupted, some analysis takes into account also the cost/benefit to the interrupter, and the joint cost/benefit (Hudson, Christensen, Kellogg, & Erickson, 2002; O'Conaill & Frohlich, 1995).

3.3 Supporting attention at the operational level

Different approaches can be proposed to support the actions of the user in a way that is more attention effective, i.e. leading to the same result whiles mobilising less cognitive effort.

A first way of supporting users at the operational level is to help them to be more effective at managing several tasks. For instance some mechanisms may make the interruption of tasks less disturbing, whereas some other mechanisms may help users in recovering more easily from an interruption.

A second approach consists in providing mechanisms automating some tasks that can help reducing cognitive load. For instance a notification mechanism or a watch list may relieve users from the need to dedicate a portion of their attention to the monitoring of a particular source of information.

3.3.1 Support for multi-tasking and interruption

As indicated previously, people are very ineffective at working on too many things at the same time because of the limited human multitasking capabilities, Rubinstein, Meyer, and Evans (2001) for example, evaluated the high costs of switching from one task to another. People are also subject to burnout (Maslach, Schaufeli, & Leiter, 2001) when they are the objects of excessive overload and when they feel they are loosing control of the situation.

The operational support of attention consists in providing mechanisms helping knowledge workers to efficiently allocate attention amongst many tasks and interruptions sources.

In many ways, support at operational level is similar to the support we obtain by writing ourselves little notes to remind us what to do; or by hiring a secretary who acts as a filter for interruptions, helps us remember about engagements, people, or important information, and takes over the execution of certain tasks. Here we consider situations in which the knowledge worker:

- Needs to resume an interrupted task;
- Deals with frequent interruption at various degrees of urgency;
- Delegates task execution

In situations characterised by frequent interruptions or tasks alternation, a significant increase in cognitive load is related to the actions necessary to restoring the context of an interrupted task at resumption time. A diary study tracking the activity of knowledge workers over a week reports that participants in the study rated as significantly more difficult to switch to those tasks that required “returning to” after an interruption, that "the *returned-to* tasks were over twice as long as those tasks described as more routine, shorter-term projects", and that "*returned-to* tasks required significantly more documents, on average, than other tasks" (Mary Czerwinski, Horvitz, & Wilhite, 2004, 178 - 179). As a large part of the activity of knowledge workers happens on computers, systems capable of saving the context of interrupted tasks and restoring this context on demand may significantly reduce cognitive load and minimise task resumption time. Task resumption is particularly critical in the context of current desktop interfaces because such interfaces force an “application oriented” rather than “task oriented” approach to computer based activities (Clauzel, Roda, & Stojanov, 2006; Kaptelinin & Czerwinski, 2007; Roda, Stojanov, & Clauzel, 2006). In order to complete a task (say write a report) the user is forced to fragment the task in subtasks (such as using a word processor to write some text, collecting data from a spreadsheet in order to paste it in the text). This artificial fragmentation of the original task imposes an increased cognitive load on the user. An innovative approach allowing users to organise their work in a task oriented, rather than application oriented manner is presented in (Clauzel, Roda, & Stojanov, 2006; Roda, Stojanov, & Clauzel, 2006).

As multi-tasking and interruptions have become the norm in modern working environments (Mary Czerwinski, Horvitz, & Wilhite, 2004; Gonzalez & Mark, 2004; Mark, Gonzalez, & Harris, 2005), an obvious manner for attention aware systems to support attentional processes is to supply personalised and adaptable notification systems that reduce the disruption provoked by digital interruptions. Notification systems have been studied in a wide variety of application domains including messaging systems (Cutrell, Czerwinski, & Horvitz, 2001; M. Czerwinski, Cutrell, & Horvitz, 2000; Horvitz, Kadie, Paek, & Hovel, 2003), alerting in military operations (Obermayer & Nugent, 2000), shared document annotation (Brush, Bargeron, Gupta, & Grudin, 2001), and end-user programming (Robertson et al., 2004). Interruption and notification management must take into account many factors (see for example the taxonomy in (Gievska, Lindeman, & Sibert, 2005)) that span across the various levels of support for attention (from perception, to meta-cognitive) and collectively contribute to making an interruption more or less appropriate or disruptive. Research on interruption management has covered many of these aspects which include: the context of interruption, the timing of the interruption, and its content.

Interruptions bring to one's attention events or information that may have different degrees of utility and may provoke more or less disruption in the current activity. Whilst it has been argued that in certain situations (simple primary tasks) interruptions may facilitate task performance (Speier, Vessey, & Valacich, 2003), a significant body of research reports on the negative effects of interruptions both on the effectiveness and agreeableness of task performance (Bailey, Konstan, & Carlis, 2001; Zijlstra, Roe, Leonova, & Krediet, 1999) (Franke, Daniels, & McFarlane, 2002; McFarlane & Latorella, 2002; Nagata, 2003; Speier, Vessey, & Valacich, 2003).

The cognitive load of the task being interrupted, as well as the level of involvement of the user with this task are deciding factors for the effect that an interruption may have (Fogarty, Ko, Aung, Golden, Tang, & Hudson, 2005). In general, the effects of interruption will depend on how well the new information is integrated in the context of the current activity. For example, Carroll and his colleagues (Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003), focussing on the support of collaborative activities, argue that awareness information should be related to the user's current activity. Deciding what exactly the user is doing (i.e. what the current task is) is one of the most crucial aspects in interruption management. However, in current computer supported collaborative environments not only it is difficult to exactly evaluate what people are doing, but even establishing whether they are at all available may be a challenge (Fogarty, Lai, & Christensen, 2004; Horvitz, Koch, Kadie, & Jacobs, 2002). In face to face situations, human being are quite capable, in a very small time, and with a limited knowledge of people's activity, of deciding whether an interruption would be acceptable or not. Studies that have tried to replicate this human ability to evaluate interruptibility include sensor based predictive statistical models of interruptibility (Fogarty et al., 2005; Fogarty, Hudson, & Lai, 2004) and methods for learning models from data that can be used to compute the expected cost of interruption for a user (Horvitz & Apacible, 2003; Horvitz, Koch, & Apacible, 2004).

The exact point in time when the interruption is delivered may make a significant difference on whether and how the interruption is perceived and on how much disruption it will bring to the current task, see, for example (Rudman & Zajicek, 2006).

One of the most influential works in notification timing proposes four design solutions to coordinate user interruptions: ‘‘immediate, negotiated, mediated, and scheduled. Interruptions can be delivered at the soonest possible moment (immediate), or support can be given for the person to explicitly control when they will handle the interruption (negotiation). Another solution has an autonomous broker dynamically decide when best to interrupt the user (mediated), or to always hold all interruptions and deliver them at a prearranged time (scheduled)’’ (McFarlane & Latorella, 2002, p.5) and conclude that in most situations negotiation is the best choice.

More recent work however has aimed at a much finer grained analysis of interruption time. In particular, several authors propose that interruptions taking place at "break points" in the user activity (e.g. when the user has finished a task and is about to start another one) are less disruptive (Bailey & Konstan, 2006; Iqbal, Adamczyk, Zheng, & Bailey, 2005).

Appropriate selection of interruption time is particularly critical in wireless devices because the user may be carrying/wearing such devices in a wide variety of situations. Ho and Intille (2005) propose a context-aware mobile computing device that "automatically detects postural and ambulatory activity transitions in real time using wireless accelerometers This device was used to experimentally measure the receptivity to interruptions delivered at activity transitions relative to those delivered at random times" (J. Ho & Intille, 2005, p.909).

The content presented to knowledge workers with a notification mechanism may range from a notification of information availability (e.g. a flashing icon indicating the presence of email) to complex awareness mechanisms (e.g. awareness display in a distributed collaborative system), to a complete switch of context (e.g. opening of a new window with a new application).

Whilst notification modality has been often studied, few authors have directly addressed the problem of the adaptation of the message content to the attentional state of the user. An example of a system that addresses this problem is READY. READY is a natural language interface that dynamically adapts to the user’s time pressure, and working memory limitations. For example shorter messages are used if the user is under time pressure, longer ones if the user is more available (Bohnenberger, Brandherm, Grossmann-Hutter, Heckmann, & Wittig, 2002; Jameson, Schafer, Weis, Berthold, & Weyrath, 1999).

3.3.2 Tasks delegation, automation

Linda Stone (Stone, 2006) defines the concept of *continual partial attention* as a constant state of vigilance, high alert, always on. “To pay continuous partial attention is to pay

partial attention – continuously". This state of continuous awareness is not without mobilising some cognitive resource from the user, in some case causing some stress. Mechanisms automating some processes and for instance supporting this state of "constant vigilance" with less effort contribute to supporting the user at the operational level. Examples of such mechanisms include all the notification mechanism that relieve the user from monitoring resources, such as calendar systems reminding the user just in time of particular deadlines. Portals, rss feeds, and systems aggregating information in a single place, also provide operational support to attention by reducing the number of sources that the users have to monitor.
More generally, systems supporting task delegation reduce the cognitive effort required of the knowledge worker by reducing the complexity and the steps necessary to accomplish a task. We have already discussed above how task continuation may represent a problem in situations of frequent interruption. In that section it was proposed that the system may support knowledge workers by reminding them the continuation plan for a task at resumption time. A further support strategy consists in the, possibly partial, delegation of the action in the plan, to the system itself. For example, when knowledge workers create messages that need to be distributed within a certain community, they may also be allowed to indicate the time of delivery, and the operations that should take place after delivery (for instance the message may be archived after it has been read by all recipients, or a reminder may be sent to recipients who did not reply). The system may take charge of completing some *after delivery* actions.

3.4 Supporting attention at the meta-cognitive level

Finally individual and group attention may be supported by fostering a better understanding of the way attention is managed. Support at this level consists in the provision of mechanisms helping knowledge workers in observing their current attention related practices, and contribute to the learning process of more attention effective practices.

A first mechanism that can be used consists in displaying a statistical visualization of how knowledge workers are allocating their attention. For instance users may be presented with a graphical representation including information such as the different activities in which they are involved, the time allocated to each activity, the distribution of the their efforts over time (e.g. are knowledge workers allocating long periods or short periods of time to certain activities?), etc. Another types of graphical views may visualize statistics reflecting the number and nature of interruptions, or particular behavioural practices, such as the time between the reception of a message, and the processing of this message by the knowledge worker. This is for instance the approach that has been adopted by Davenport & Beck (Beck & Davenport, 2001; Davenport & Beck, 2001) who have proposed a system named AttentionScape, that maps the attention allocation of the users or of the organization in different dimensions. Some of this information may be private for the individual; other may be presented to the community at large.

A second set of mechanisms supporting attention at the meta-cognitive level consist in diagnostic tools helping to assess the communication or working practice of the knowledge workers, and in particular to measure their level of effectiveness. One of the simplest mechanisms may consist in the comparison of the individual's practices with one another. More sophisticated mechanisms may consist in more intelligent diagnostic tools trying to discover patterns of behaviour and interpret them. Suggestion tools may provide guidance about how to improve a current attention-management practice.

4 Conclusions

Digitally-mediated collaboration and interaction in modern organisations has opened a new range of opportunities for collaboration, improved productivity, knowledge creation, and innovation. Several studies however demonstrate that modern Information and Communication Technologies also place an unprecedented strain on human attentional abilities by increasing considerably the amount of information and interaction the user has to process, and by inducing frequent interruptions, and situations of extreme multi-tasking. In this paper we have argued that digital environments should have built-in support for appropriate attention allocation both at the level of the individual and of the community. We have analysed such support at four different levels: perceptual, deliberative, operational, and meta-cognitive and we have discussed how computer-mediated activity in modern organisations has been, or could be enhanced by attention-related services at these four levels.

5 Acknowledgement

The work described in this paper was partially sponsored by the EC under the FP6 framework project Atgentive IST-4-027529-STP. We would like to acknowledge the contribution of all project partners.

6 References

Abowd, G. D., Mynatt, E. D., & Rodden, T. (2002). The human experience. IEEE Pervasive Computing, 1(1), 48-57.

Adomavicius, G., & Tuzhilin, A. (2005). Toward the next generation of recommender systems: A survey of the state-of-the-art and possible extensions. IEEE Transactions on Knowledge and Data Engineering, 17(6), 734 - 749.

Argyris, C., & Schon, D. (1978). Organizational learning: A theory of action perspective. Reading, MA: Addison-Wesley.

Arroyo, E., & Selker, T. (2003). Self-adaptive multimodal-interruption interfaces. Proceedings International Conference on Intelligent User Interfaces (IUI'03), 6-11.

Bailey, B. P., & Konstan, J. A. (2006). On the need for attention aware systems: Measuring the effects of interruption on task - performance, error rate, and affective state. Computers in Human Behavior, 22(4), 685-708.

Bailey, B. P., Konstan, J. A., & Carlis, J. V. (2001). The effects of interruptions on task performance, annoyance, and anxiety in the user interface. Proceedings INTERACT '01, 593-601.

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), Encyclopedia of human behavior (Vol. 4, pp. 71-81). New York: Academic Press.

Bartram, L., Ware, C., & Calvert, T. (2003). Moticons: Detection, distraction and task. International Journal of Human-Computer Studies, 58(5), 515-545.

Beck, J., & Davenport, T. H. (2001). How corporate leaders can help their companies manage the scarcest resource of all: Attention. Retrieved June 2007, from http://www.accenture.com/Global/Research_and_Insights/Outlook/By_Alphabet/HowAttention.htm

Belmondo, C. (2006). Ressources attentionnelles and processus de creation de connaissance. In A. Bounfour (Ed.), Capital immatériel, connaissance et performance (pp. 57-86): L'Harmattan.

Bier, E. A., Stone, M. C., Pier, K., Buxton, W., & DeRose, T. D. (1993, September). Toolglass and magic lenses: The see-through interface. Proceedings 20th annual conference on Computer graphics and interactive techniques, 73-80.
Bohnenberger, T., Brandherm, B., Grossmann-Hutter, B., Heckmann, D., & Wittig, F. (2002). Empirically grounded decision-theoretic adaptation to situation-dependent resource limitations. Künstliche Intelligenz., 3, 10-16.
Brush, B., Bargeron, D., Gupta, A., & Grudin, J. (2001). Notification for shared annotation of digital documents (Technical Report No. MSR-TR-2001-87): Microsoft Research Microsoft Corporation.
Carroll, J. M., Neale, D. C., Isenhour, P. L., Rosson, M. B., & McCrickard, D. S. (2003). Notification and awareness: Synchronizing task-oriented collaborative activity. International Journal of Human-Computer Studies, 58(5), 605-632.
Chew, J. (2003). Helping hr apps unlock human capital: Forrester Research, Inc. March 2003.
Clauzel, D., Roda, C., & Stojanov, G. (2006). Tracking task context to support resumption. Workshop on computer assisted recording, pre-processing, and analysis of user interaction data). Proceedings HCI 2006 - Engage, London, UK.
Cutrell, E., Czerwinski, M., & Horvitz, E. (2001, July 2001). Notification, disruption, and memory: Effects of messaging interruptions on memory and performance. Proceedings Interact 2001 IFIP Conference on Human-Computer Interaction, Tokyo, Japan.
Czerwinski, M., Cutrell, E., & Horvitz, E. (2000, 5-8 September 2000). Instant messaging: Effects of relevance and time. Proceedings HCI 2000 University of Sunderland, 71–76.
Czerwinski, M., & Horvitz, E. (2002). Memory of daily computing events. Proceedings HCI 2002 People and Computers XVI, 230-245.
Czerwinski, M., Horvitz, E., & Wilhite, S. (2004). A diary study of task switching and interruptions. Proceedings SIGCHI conference on Human factors in computing systems, Vienna, Austria, 175-182.
Davenport, T. H., & Beck, J. (2001). The attention economy. Harvard Business School Press.
Dodgson, M. (1993). Organizational learning: A review of some literatures. Organizational Studies, 14(3), 375-394.
Dunbar, R. I. M. (1993). Coevolution of neocortical size, group size and language in humans. Behavioral and Brain Sciences, 16(4), 681-735.
Egeth, H., & Yantis, S. (1997). Visual attention: Control, representation, and time course. Annual Review of Psychology, 48, 269-297.
Erickson, T., Halverson, C., Kellogg, W. A., Laff, M., & Wolf, T. (2002). Social translucence: designing social infrastructures that make collective activity visible. CACM, 45(4), 40 - 44.
Fogarty, J., Hudson, S. E., Atkeson, C. G., Avrahami, D., Forlizzi, J., Kiesler, S., Lee, J. C., & Yang, J. (2005). Predicting human interruptibility with sensors. ACM Transactions on Computer-Human Interaction, 12(1), 119–146.
Fogarty, J., Hudson, S. E., & Lai, J. (2004). Examining the robustness of sensor-based statistical models of human interruptibility. Proceedings Proceedings of the SIGCHI conference on Human factors in computing systems, Vienna, Austria, 207-214.
Fogarty, J., Ko, A. J., Aung, H. H., Golden, E., Tang, K. P., & Hudson, S. E. (2005). Examining task engagement in sensor-based statistical models of human interruptibility. Proceedings Proceedings of the SIGCHI conference on Human factors in computing systems, Portland, Oregon, USA, 331-340.
Fogarty, J., Lai, J., & Christensen, J. (2004). Presence versus availability: The design and evaluation of a context-aware communication client. Internat. Journal of Human-Computer Studies, 61(3), 299-317.
Franke, J. L., Daniels, J. J., & McFarlane, D. C. (2002). Recovering context after interruption. Proceedings 24th Annual Meeting of the Cognitive Science Society (CogSci 2002), 310-315.
Gievska, S., Lindeman, R., & Sibert, J. (2005). Examining the qualitative gains of mediating human interruptions during hci. Proceedings 11th International Conference on Human-Computer Interaction, Las Vegas, Nevada.
Gillie, T., & Broadbent, D. E. (1989). What makes interruptions disruptive? A study of length, similarity and complexity. Psychological Research Policy, 50, 243-250.
Gladwell, M. (2000). The tipping point: How little things can make a big difference. Boston, MA: Little, Brown and Company.
Goldhaber, M. H. (1997). The attention economy and the net. First Monday, 2(4).
Gonzalez, V. M., & Mark, G. (2004). "constant, constant, multi-tasking craziness": Managing multiple working spheres. Proceedings SIGCHI Human factors in computing systems, Vienna, 113-120.

Healey, C. G. (2005, December). Perception in visualization. Retrieved 30 June, 2006, from http://www.csc.ncsu.edu/faculty/healey/PP/

Heylighen, F. (2004). Tackling complexity and information overload: From intelligence amplification and attention economy to the global brain. Technological Forecasting and Social Change, [Submitted](available online at: http://pcp.vub.ac.be/Papers/PapersFH2.html).

Ho, C., Nikolic, M., Waters, M., & Sarter, N. (2004). Not now! Supporting interruption management by indicating the modality and urgency of pending tasks. Human Factors, 46(3), 399-409.

Ho, J., & Intille, S. S. (2005). Using context-aware computing to reduce the perceived burden of interruptions from mobile devices. Proceedings SIGCHI conference on Human factors in computing systems, Portland, Oregon, USA, 909-918.

Horvitz, E., & Apacible, J. (2003). Learning and reasoning about interruption. Proceedings 5th International Conference On Multimodal Interfaces, Vancouver, British Columbia, Canada, 20 - 27.

Horvitz, E., Kadie, C., Paek, T., & Hovel, D. (2003). Models of attention in computing and communication: From principles to applications. Communications of the ACM, 46(3), 52-59.

Horvitz, E., Koch, P., & Apacible, J. (2004, November 2004). Busybody: Creating and fielding personalized models of the cost of interruption. Proceedings Conference on Computer Supported Cooperative Work, Chicago, Illinois.

Horvitz, E., Koch, P., Kadie, C. M., & Jacobs, A. (2002, July 2002). Coordinate: Probabilistic forecasting of presence and availability. Proceedings Eighteenth Conference on Uncertainty and Artificial Intelligence, Edmonton, Alberta, 224-233.

Hudson, J. M., Christensen, J., Kellogg, W. A., & Erickson, T. (2002, April 20-25). "i'd be overwhelmed, but it's just one more thing to do": availability and interruption in research management. Proceedings SIGCHI conference on Human factors in computing systems, Minneapolis, USA, 97 - 104.

Iqbal, S. T., Adamczyk, P. D., Zheng, X. S., & Bailey, B. P. (2005). Towards an index of opportunity: Understanding changes in mental workload during task execution. Proceedings Proceedings of the SIGCHI conference on Human factors in computing systems, Portland, Oregon, USA, 311-320.

Jameson, A., Schafer, R., Weis, T., Berthold, A., & Weyrath, T. (1999). Making systems sensitive to the user's time and working memory constraints. In Proceedings of the 4th international conference on intelligent user interfaces (pp. 79-86). Los Angeles, California, United States: ACM Press.

Kaptelinin, V., & Czerwinski, M. (Eds.). (2007). Beyond the desktop metaphor - designing integrated digital work environments: MIT Press.

Kvavilashvili, L., Messer, D. J., & Ebdon, P. (2001). Prospective memory in children: The effects of age and task interruption. Developmental Psychology, 37(3), 418-430.

Lester, J., Converse, S., Kahler, S., Barlow, T., Stone, B., & Bhogal, R. (1997). The persona effect: Affective impact of animated pedagogical agents. Proceedings CHI '97, 359-366.

Mark, G., Gonzalez, V. M., & Harris, J. (2005). No task left behind? Examining the nature of fragmented work. Proceed. SIGCHI conference on Human factors in computing systems, Portland OR, 321-330.

Marlow, C., Naaman, M., Boyd, D., & Davis, M. (2006). Tagging paper, taxonomy, flickr, academic article, toread. Proceedings Hypertext 2006, New York.

Marsh, R. L., Hicks, J. L., & Bryan, E. S. (1999). The activation of un-related and canceled intentions. Memory & Cognition, 27(2), 320-327.

Maslach, C., Schaufeli, W. B., & Leiter, M. P. (2001). Job burnout. Annual Review of Psychology, 52, 397-422.

McAfee, A. P. (2006). Enterprise 2.0: The dawn of emergent collaboration. Sloan Management Review, 47(3), 21-28.

McCrickard, D. S., Catrambone, R., Chewar, C. M., & Stasko, J. T. (2003). Establishing tradeoffs that leverage attention for utility: Empirically evaluating information display in notification systems. International Journal of Human-Computer Studies, 58(5), 547-582.

McCrickard, D. S., & Chewar, C. M. (2003). Attuning notification design to user goals and attention costs. Communications of the ACM, 46(3), 67-72.

McFarlane, D. C., & Latorella, K. A. (2002). The scope and importance of human interruption in human-computer interaction design. Human-Computer Interaction, 17(1), 1-62.

Meacham, J. A., & Leiman, B. (1982). Remembering to perform future actions. In U. Neisser (Ed.), Memory observed: Remembering in natural contexts (pp. 327-336). San Francisco: Freeman.

Miller, G. (1956). The magical number seven, plus or minus two. Psychological Review, 63, 81-97.

Nabeth, T., & Roda, C. (2006). Les espaces sociaux virtuels: Approches, pratiques émergentes et perspectives. In A. Bounfour (Ed.), Capital immatériel, connaissance et performance (pp. 225-265): L'Harmattan.
Nagata, S. F. (2003). Multitasking and interruptions during mobile web tasks. Proceedings 47th Annual Meeting of the Human Factors and Ergonomics Society, 1341-1345.
Nardi, B., Whittaker, S., & Schwarz, H. (2000). It's not what you know, it's who you know: Work in the information age. First Monday, May 2000.
Nisbett, R. E. (2003). Geography of thought: How asians and westerners think differently, and why. New York: Free Press.
Nonaka, I., & Takeuchi, H. (1995). The knowledge-creating company. Oxford University Press.
O'Conaill, B., & Frohlich, D. (1995). Timespace in the workplace: Dealing with interruptions. Proceedings CHI '95 Conference Companion, Denver, CO, 262-263.
O'Reilly, T. (2005). What is web 2.0 design patterns and business models for the next generation of software. Retrieved 09/30/2005, from http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html
Obermayer, R. W., & Nugent, W. A. (2000). Human-computer interaction for alert warning and attention allocation systems of the multi-modal watchstation. Proceedings SPIE 2000
Picard, R. W. (1997). Affective computing. Cambridge, MA: MIT Press.
Picard, R. W. (2004). Human responses to technology scrutinized. The Washington Post.
Rensink, R. A. (2000). Seeing, sensing, and scrutinizing. Vision Research, 40(10-12), 1469-1487.
Robertson, T. J., Prabhakararao, S., Burnett, M., Cook, C., Ruthruff, J. R., Beckwith, L., & Phalgune, A. (2004). Impact of interruption style on end-user debugging. Proceedings SIGCHI conference on Human factors in computing systems, Vienna, Austria, 287-294.
Roda, C., & Nabeth, T. (2007). Supporting attention in learning environments: Attention support services, and information management. Proceedings Second European Conference on Technology Enhanced Learning (EC-TEL 2007), Crete, Greece, Forthcoming.
Roda, C., Stojanov, G., & Clauzel, D. (2006). Mind-prosthesis metaphor for design of human-computer interfaces that support better attention management. Proceedings AAAI 2006 Fall Symposia on "Interaction and Emergent Phenomena in Societies of Agents", Arlington, Virginia, 52-59.
Roda, C., & Thomas, J. (2006). Attention aware systems: Theories, applications, and research agenda. Computers in Human Behavior, 22(4), 557–587.
Rubinstein, J. S., Meyer, D. E., & Evans, J. (2001). Executive control of cognitive processes in task switching. Journal of Experimental Psychology: Human Perception and Performance, 27(4), 763-797.
Rudman, P., & Zajicek, M. (2006). Autonomous agent as helper – helpful or annoying? Proceedings IAT 2006 - IEEE/WIC/ACM International Conference on Intelligent Agent Technology, Hong Kong
Schroeder, R., & Axelsson, A. (Eds.). Avatars at work and play: Collaboration and interaction in shared virtual environments: Springer-Verlag New York, Inc., Secaucus, NJ, 2.
Sellen, A. J., Louie, G., Harris, J. E., & Wilkins, A. J. (1996). What brings intentions to mind? An in situ study of prospective memory. Memory & Cognition, 5(4), 483-507.
Senge, P. (1994). The fifth discipline: The art and practice of the learning organization. Doubleday.
Sifry, D., Marks, K., Çelik, T., & Hayes, E. (2006). Attention.Xml. Retrieved 30 June, 2006, from http://developers.technorati.com/wiki/attentionxml
Speier, C., Vessey, I., & Valacich, J. S. (2003). The effects of interruptions, task complexity, and information presentation on computer-supported decision-making performance. Decision Sciences, 34(4), 771-797.
Stone, L. (2006). Linda stone's thoughts on attention and specifically, continuous partial attention. Retrieved June 2007, from http://continuouspartialattention.jot.com/WikiHome
Summers, L., & Dahod, S. (2003). You've got the power: Using goal-driven performance management to empower. from http://www.workinfo.com/free/Downloads/141.htm
Toet, A. (2006). Gaze directed displays as an enabling technology for attention aware systems. Computers in Human Behavior, 22(4), 615-647.
Vertegaal, R., Chen, D., Shell, J., & Mamuji, A. (2006). Designing for augmented attention: Towards a framework for attentive user interfaces. Computers in Human Behavior, 22(4), 771-789.
Wolfe, J., Klempen, N., & Dahlen, K. (2000). Postattentive vision. Journal of Experimental Psychology: Human Perception & Performance, 26(2), 693-716.

Wolpers, M., Martin, G., Najjar, J., & Duval, E. (2006, 6-8 September 2006). Attention metadata in knowledge and learning management. Proceedings 6th International Conference on Knowledge Management, Graz, Austria.
Wright, P. M., & Snell, S. A. (1998). Toward a unifying framework for exploring fit and flexibility in strategic human resource management. Academy of Management Review, 23(4), 756-772.
Zijlstra, F. R. H., Roe, R. A., Leonova, A. B., & Krediet, I. (1999). Temporal factors in mental work: Effects of interrupted activities. Journal of Occupational and Organizational Psychology, 72, 163-185.