Attention Management in Virtual Community Environments*

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

1 Introduction

The advent of modern Information and Communication Technologies (ICT) has radically changed our ability to access information and to communicate. Whilst once information was a scarce, and hard to access resource, nowadays *human attention* has become the scarce resource and information (of all types and qualities) abounds.
This state of things directly impacts processes of knowledge creation which demand a careful management of individual and collective attentional resources (Belmondo, 2006).
It has become obvious that we need new methodologies and tools for managing the wide range of data, knowledge, and opportunities that have become available. 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, facilitating human attentional processes, may represent a critical factor in fostering innovation.

Shared virtual environments support increasingly complex interactions (Nabeth & Roda, 2006; Schroeder & Axelsson) and enable new interruption channels which have become an almost constant factor in many working and learning environments. Although interruptions may bring to one's attention information possibly useful for the primary (current) task, or even, in the case of simple primary tasks, facilitate task performance (Speier, Vessey, & Valacich, 2003); it has been widely reported that 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) especially when the user is working on handheld devices in mobile environments (Nagata, 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. 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 to the community for access and management of knowledge, ICT tools themselves represent an important mean to support people 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 its is critical to organization's 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 an individual and at an organizational level (Davenport & Beck, 2001). For the individual, the attention of knowledge workers corresponds generally to the activity in which they are currently engaged (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 that are part of 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. Different

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researches have been conducted and systems have been proposed to address the alignment of the individual goal and the company 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). Finally, 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 customer 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.

2 Reaching the limits of human bounded cognitive abilities

The advent of the knowledge-based economy has radically transformed the nature of work and business in organizations. Employees, who once used to fulfil only 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 environment 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 whilst playing a leading role in a multitude of dynamic virtual communities. 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 reinvent 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 increase of collaboration often based on digital interaction. 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) research shows that it is important to be aware of cultural differences), and from different organisations. These interactions increasingly include less formal forms of communication (for instance Nardi, B., Whittaker, S, Schwarz, H. (2000) indicate that social networks have become a key source of labour and information in the information age), for which the filtering strategies are more fuzzily defined.

Yet, humans have not radically changed: people have still very limited capacities for manipulating more than a few concepts at a given time (Miller (1956) work on the short term or working memory indicates that human being have a maximum capacity to manipulate 7 +- 2 chunks of information) and for doing several things at the same 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). At the organizational level, increased competition and pressure to augment shareholders value has conducted more frequently to downsizing rather than to expanding man-power: people are asked to do more in less time.

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 mental performance?

We propose in the next section that better support to the attentional processes of users of digital environments, and virtual community environments in particular, may be provided by designing attention aware systems (Roda & Thomas, 2006). We briefly indicate the work already done in this direction or under development. We take both the perspective of the virtual community users, and that one of their managers.

3 Supporting attention in virtual community environments

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. Furthermore, some of our actions may require a varying degree of cognitive effort depending on how easily we can focus on the activity. This implies that at **operational level** the environment in which action takes place determines how easily we can attend to a given focus. Finally, we are able, as we are doing here, to reason about our own strategies for allocating attention. At the **meta-cognitive level** one may elaborate and evaluate strategies for attention allocation that are, or will be, implemented at the cognitive level. Following these principles, we propose that attention should be supported in digital environments at four levels:

- At the perceptual level by, for example, facilitating access to relevant information or presenting interruptions at the appropriate level of conspicuity.
- At the deliberative level by, for example, supplying tools for the control of task priorities, or by motivating users who are loosing focus.
- At operational level users may be supported by simplifying some attention related operations such as restoring the context of interrupted tasks, or by filtering incoming messages.
- Finally, at the meta-cognitive level the users can be supported in their reflection about how they allocate attention by, for example, providing self-diagnostic tools.

3.1 Supporting attention at the perceptual level

Supporting perception means increasing both the ability to notice relevant information and to discard irrelevant one. 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 conspicuity[1].

Information selection in virtual communities 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 and they 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. The latter 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 to facilitate information comprehension in virtual communities, and therefore reducing 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

[1] Conspicuious: obvious to the eye or mind. The Merriam-Webster Online Dictionary

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. 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.
This concept of supplying meta-data information is similar to the concept of magic lens that has been introduced by Bier and al. (Bier, Stone, Pier, Buxton, & DeRose, 1993, p.73) 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, 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. In order to enable users to appropriately allocate attention in situations such as the ones exemplified, attention aware systems may support 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*.

Presenting interruptions at the correct level of conspicuity may significantly reduce load at the perceptive level. 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 user (for instance the user can be busy and should not be disturbed) or the context (the user is in communication mode and consulting his/her mailbox). 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, and (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, p. 515) 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 a community member'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 user:

- 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 community member what he/she was doing, in other cases it will be necessary to supply some help in order to encourage him/her to continue the activity.

<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 work and learning 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 (e.g. turning off the stove when the water boils). 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 to supply reminder services where the system issues a reminder at a specified time or at the occurrence of a given event. These reminders may be particularly useful in helping users 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)).

Resuming a task, however, 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 user. 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 the user to easily re-establishing the task context (see next section).

Since, not in all situations it is 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 creating 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 imposes 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 community members in the allocation of attention to the most urgent task; 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 the user to limit the number of tasks executed concurrently, and reducing the need for the users to think about a particular task until it is necessary. On the basis of the contents of the agenda, the system may automatically send notifications about tasks due soon, relieving the community members from remembering about these events. Task agendas may also include information about prerequisites for actions execution helping the user to allocate attention only to those actions whose prerequisites are fulfilled, or notifying the user when prerequisites for task execution become 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. These types of time-allocation evaluations are often disregarded in complex multitasking environment.

Support to group level attention

In collaborative environments, the role of the community manager is often that of a moderator capable of identifying information and tasks that are relevant and beneficial for the whole group. In attention aware systems this can be reflected in at least three different types of actions.

First, if the system is aware about task dependencies between tasks performed by different group members, it may be 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, by tracking access to, and actions on documents, the system may be able to inform group members about those tasks that are receiving the most attention from other group members. 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)).

Third, in collaborative, multi-user environments 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 in which the activity of other members of the group depends on the prompt notification and consequent response). 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

As indicated previously, people are very ineffective at working on too many things at the same time, because of the limited human multitasking capabilities (as indicated by Rubinstein, Meyer, and Evans (2001), switching from one task to another is costly). 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 community members 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. We consider situations in which the user:

- 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 information 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" (Czerwinski, Horvitz, & Wilhite, 2004, 178 - 179). A system capable of saving the context of interrupted tasks and restoring this context on demand may significantly reduce such load and minimise the 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; 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 collecting data from 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), in the more general case interruptions may generate stress (Bailey, Konstan, & Carlis, 2001; Zijlstra, Roe, Leonova, & Krediet, 1999) and hinder the performance of the primary task (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). Adamczyk, and Bailey (Adamczyk & Bailey, 2004, 2005; Bailey, Adamczyk, Chang, & Chilson, 2006) propose task models that would allow for such finer-grained temporal reasoning.

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 users 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. Two prototypes have been developed: one supplying instructions for car repair (Jameson, Schafer, Weis, Berthold, & Weyrath, 1999), and one for making a phone call in an airport (Bohnenberger, Brandherm, Grossmann-Hutter, Heckmann, & Wittig, 2002). These prototypes serve to explore methodologies for assessing users' resource limitation on the basis of their speech, and consequently bundling instructions in appropriately long sequences. Dynamic Bayesian networks and influence diagrams are used ''for modelling the user's resource limitations and making decisions about the system's behaviour'' (Jameson, Schafer, Weis, Berthold, & Weyrath, 1999) (, p. 81). Although, as the authors indicate, these prototypes are still experimental, they are a good demonstration of how notification content may be adapted to the user's attentional state.

Systems supporting task delegation reduce the cognitive effort required of the learner 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 users 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, in a virtual learning community, the community organizer may create a message to be sent to the community; in this situation, he/she may be allowed to also 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's and group's 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 users in observing their current attention related practices.

A first mechanism that can be used consists in displaying a statistical visualization of how the users are allocating their attention. For instance users may be presented with a graphical representation including information such as the different activities in which users are involved, the time allocated to each activity, the distribution of the user's effort over time (e.g. are users allocating long periods or short periods of time?), etc. Another graph may visualize statistics reflecting the number and nature of interruptions. Finally, other tools may help to visualize particular behavioural practices, such as the time between the reception of a message, and the processing of this message by the user.

Some of this information may be private for the individual user, other may be presented to the community at large.

A second series of mechanisms consists in diagnostic tools helping to assess the communication or working practice of the user, and in particular to measure the level of effectiveness. One of the simplest mechanisms may consist in the comparison of the user's practices with others. 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. For instance an artificial agent (or a real person) may intervene to suggest to the user to change a practice that is not very effective for this user or for others.

Other mechanisms that can be used to provide meta-cognitive support consist in the implementation of agendas, in which the user can explicitly specify his/her learning objectives, and receive assistance about how to achieve them. This assistance can consist in a tool helping learners to assess the effort and the means to employ to achieve a particular objective, and later to help monitoring the progresses and identify drops of attention.

4 Conclusions

Collaboration and interaction in virtual community environments 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 inducing frequent interruptions, and situations of extreme multi-tasking. In this paper we argue that virtual communities environments should have in-built support for appropriate attention allocation both at the level of the individual and of the community. We analyse such support at four different levels: perceptual, deliberative, operational, and meta-cognitive and we discuss how virtual communities have been, or could be enhanced by attention-related services at these four levels.

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