Extended Abstract

Supporting attention with dynamic user models

Claudia Roda
American University of Paris
147, rue de Grenelle 75007 Paris
croda@aup.edu

Major theme: Robotic and computational models of interaction and cognition

As networked technologies provide users with increasing access to information and people anywhere, anytime, the need for systems that are capable of supporting users in their choices of cognitive resources allocation has been increasingly recognized (McCrickard, Czerwinski, & Bartram, 2003; Roda & Thomas, 2006b; Vertegaal, 2003). The design of systems capable of adapting to the needs of individual users, that are operating in specific context, and under certain constraints is attracting significant interest both in industry and academy. In particular, research work in *attention aware systems*, i.e. systems that support users in their attentional choices (Roda & Thomas, 2006a), promises to address many of the problems related to information overload, cyber collaboration, and mobility, by providing features helping users in coping with attentional limitations. Such features may include intelligent notification and management of interruptions, support to task resumption and multitasking, and awareness mechanisms for collaborative attention allocation. In general attention aware systems may require a complete rethinking of the metaphors underlying interfaces conceptualization (Roda, Stojanov, & Clauzel, 2006) and of the way we design systems as a whole (see for example the ubiquitous computing (Weiser & Brown, 1996) or ambient intelligence (Kunz, October 2001) literature). At the conceptualization level, attention aware systems will require a much better understanding of how human attentional processes work, and how they might be supported.

Just like human beings do, in order to display attention awareness, systems must be capable of: (1) Detecting current user’s attentional state, (2) Determining possible alternative foci, (3) Evaluating cost/benefits of possible user’s attentional shifts, (4) Establishing modalities for interventions best suited to support the user in allocating his/hers attentional resources. All these functionalities will need to deal with the uncertainty intrinsically associated to modeling user's cognition.
The implementation of each of the above capabilities has presented difficulties often related to the system's representation of, and reasoning about, human attentional processes. In particular, several elements of the interaction between the user and the system require a more dynamic representation. For example, it has become obvious that methods based solely on gaze-tracking (Baudisch, DeCarlo, Duchowski, & Geisler, 2003) are not sufficient for acquiring information about users' attention. The phenomena of inattentional blindness and inattentional amnesia (Rensink, 2000) demonstrate that the current task acts as a filter on visual attention. Experimental studies (Triesch, Ballard, Hayhoe, & Sullivan, 2003) have demonstrated that the same gaze pattern may be used in the context of different tasks to acquire different visual information. Therefore, the same gaze pattern may be associated to different attentional foci. Some attempts have been made to contextualize gaze-tracking by using additional sources of information (Horvitz, Kadie, Paek, & Hovel, 2003). In an abstract manner, this contextualization should aim at relating two aspects of the user activity. Information about the current interaction of the user with the system and the environment (e.g. data from gaze-tracking, mouse-tracking, observation of the user through a camera) should be related to the user's past (inter)actions and to hypothesis on how these may guide the user activity (i.e. hypothesis on possible user's goals). Detecting current user’s attentional state therefore requires a user model that dynamically describes the user state as a function of his/her past interactions with the environment. Interactivist models do

exactly this, they relate system's (user's) mental states to sequences of past interactions with the environment, and therefore seem to provide the general framework necessary to create dynamic user models that integrate all different sources of information about the users' (inter)actions allowing an attention aware system to make a better guess at what the user's attentional focus might be.

Another problem often encountered when trying to support the user in allocating more efficiently his/her cognitive resources, is that it is very difficult to modify acquired habits. For example, if a user is accustomed to regularly checking the email notification icon, he/she may look for that icon even if not needed or even if another icon indicates that the user is working off-line. A further example is the fact that if a user has learned to ignore certain links on a web page as not useful, he/she is likely to keep ignoring them even when they become task relevant. Kruschke (2001, 2003) explains these phenomena in terms of *learned attention* (highlighting) and *learned inattention* (conditioned blocking). He suggests that "both attentional shifting and associative learning are driven by the rational goal of rapid error reduction" (Kruschke, 2003, p.171) so that, in order to reduce errors with respect to already learned cues, we learn to attend to certain cues and to ignore others. Within the intertactivist framework, attention may be modeled as the choice necessary to determine which conditions in the environment are relevant for the generation of functional presuppositions. Whenever a functional presupposition results dysfunctional the user may learn that such dysfunction is due to an ill choice of its *relevant conditions*. Given a general functional presupposition FP:

(FP) if the environment satisfies RC then interaction INT is appropriate

If FP results being dysfunctional we have four possible error conditions:
(err1) the implication FP does not hold (it is false)
(err2) RC is not a sufficiently refined *relevant condition*
(err3) something else was erroneously detected instead of RC
(err4) interaction INT was erroneously enacted (somehow failed)
Correspondingly, if FP results being functional, then it can be reinforced at four levels: the implication holds, RC is a relevant condition, RC was appropriately detected, INT was appropriately enacted.
At a first basic level, attention may be related to error condition err2 (or the corresponding reinforcement). This error condition may trigger the *learning* process which, by monitoring ongoing interactive processes, "introduces variation when things are not going well, and stability when they are proceeding according to plan" (Bickhard, 2000) p.7-8. It is through this learning process (possibly recursively applied) that the user may generate strategies allowing selection of relevant conditions. Such *learned strategies about attention allocation* are *motivations* as described in (Bickhard, 2000), and they emerge from a learning process about attention. Some of these motivations can be related to phenomena previously called *chronic concern* (Moskowitz, 2002); other of these motivations, generated with the aim of rapid error reduction, can be related to the phenomena described by Krusche (in passing, note that motivations related to chronic concerns may lead one to question whether the classic differentiation between endogenous and exogenous attention (Arvidson, 2003; Posner, 1980; Yantis, 1998) is actually justified). In order to manage attention in situations of highlighting or conditioned blocking the system must be able to model the fact that the user has actually adopted those strategies to manage current attention allocation. This requires dynamically modeling the possible learning of these strategies with respect to past interactions with the system.
Modeling user attention as a dynamic phenomena involving learning may allow attention aware systems to evaluate situations in which the desired support may be better obtained using motivational strategies such as inducing temporary task failure or switching, rather than through purely sensory (e.g. visual, auditory) interventions.

The interactivist framework provides a structure supporting the representation of attention-related information about users that is dynamically related to their past interactions with the system and the environment, and that takes into account the learning processes continuously underlying attention allocation. It seems therefore important to pursue a detailed analysis of how the interactivist framework may answer some philosophical and operational questions related to the support of human attentional mechanisms by computer systems. Such analysis may open the way to significant improvements in the design of attention aware systems.

References

Arvidson, P. S. (2003). A lexicon of attention: From cognitive science to phenomenology. *Phenomenology and the Cognitive Sciences, 2*(2), 99-132.

Baudisch, P., DeCarlo, Duchowski, A., & Geisler, B. (2003). Focusing on the essential: Considering attention in display design. *Communications of the ACM, 46*(3), 60-66.

Bickhard, M. H. (2000). Motivation and emotion: An interactive process model. In R. D. Ellis & N. Newton (Eds.), *The caldron of consciousness* (pp. 161-178).

: J. Benjamins.

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.

Kruschke, J. K. (2001). Toward a unified model of attention in associative learning. *Journal of Mathematical Psychology, 45*(6), 812-863.

Kruschke, J. K. (2003). Attention in learning. *Current Directions Psychological Science, 12*, 171-175.

Kunz, P. (Ed.). (October 2001). *Ercim news, special issue on ambient intelligence* (Vol. 47): European Research Consortium for Informatics and Mathematics.

McCrickard, D. S., Czerwinski, M., & Bartram, L. (Eds.). (2003). *Notification user interfaces special issue of the international journal of human-computer studies* (Vol. 58(5)): Elsevier.

Moskowitz, G. B. (2002). Preconscious effects of temporary goals on attention. *Journal of Experimental Social Psychology, 38*(4), 397-404.

Posner, M. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25.

Rensink, R. A. (2000). Seeing, sensing, and scrutinizing. *Vision Research, 40*(10-12), 1469-1487.

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. (2006a). Attention aware systems: Theories, applications, and research agenda. *Computers in Human Behavior, 22*(4), 557–587.

Roda, C., & Thomas, J. (Eds.). (2006b). *Attention aware systems. Special issue of the journal computers in human beaviour* (Vol. 22(4)): Elsevier.

Triesch, J., Ballard, D. H., Hayhoe, M. M., & Sullivan, B. T. (2003). What you see is what you need. *Journal of Vision, 3*, 86–94.

Vertegaal, R. (Ed.). (2003). *Attentive user interfaces. Special issue of communications of the acm* (Vol. 46(3)): ACM.

Weiser, M., & Brown, J. S. (1996). The coming of age of calm technology. Retrieved May 2006, from http://www.ubiq.com/hypertext/weiser/acmfuture2endnote.htm

Yantis, S. (1998). Control of visual attention. In H. Pashler (Ed.), *Attention* (pp. 223-256). London, UK: University College London Press.