Approaches to the Design and Measurement of Social and Information Awareness in Augmented Reality Systems

Frank A. Biocca[1], Jannick Rolland[3], Geraud Plantegenest, [1] Chandan Reddy, [1] Chad Harms[1], Charles B. Owen[2], Weimin Mou[1], Arthur Tang[1].

M.I.N.D. Lab[1], METLAB[2]
Michigan State University
East Lansing, MI USA

ODALab[3]
University of Central Florida
Orlando, Fl USA

Biocca@msu.edu

Abstract
This paper characterizes the problem of managing focal and peripheral awareness of people, objects, and procedures in augmented reality (AR) systems. We suggest interface design strategies that map the problem to properties of human spatial cognition and briefly introduce how the problem is addressed in three collaborative AR projects.

1 Awareness of augmented reality systems

To perform tasks, navigate, and coordinate behaviour in the physical environment, members of work teams or other coordinated groups must continuously be aware of the state of others, objects, and the environment. Humans possess highly evolved mechanisms for monitoring the location of the body, objects, and the environment in space. Entering into this evolutionarily developed pattern are technologies that can mediate interaction between individuals and dramatically extend the range of other people an individual can be aware of. Networked technologies, especially immersive augmented reality (AR) technologies, are grafted onto the evolved system and mediate the natural relationship between the body and the environment (Biocca, 1997). However, no synchronous technology merely subtracts from the environment; rather it adds new elements to monitor, a virtual environment. More critically in this expanded and potentially limitless virtual environment, the objects, states, and people that one must monitor are outside the physical environment and include distant mediated others such as team members, virtual tools, data objects, and the states of various support technologies such as automobile indicators, etc. Augmented reality promises to bring this world of virtual objects, people, and tools together and to merge them with the busy world of physical objects, people, and tools. In the expanded, parallel, and competing realm of objects and people lies the root of the dilemma of awareness management.

Carefully managing the integration of knowledge in distributed augmented reality systems that support collaborative work is key to providing the right level of interaction and engagement in group communication (Alavi & Tiwana, 2002) But, in awareness systems, the focus is on the substance and the real time resource allocation of attention and short-term memory to the people, information objects, and environments at hand. Awareness information is always required to coordinate group activities, whatever the task domain. A key problem in augmented reality systems is that the virtual and physical objects compete for the attentional resources of the individual, people, and additional information.

Part of this problem of awareness in AR can be initially characterized by a simple two dimensional space depicted in Figure 1. We can posit that for any object or person and any specific step in a

task, there is an ideal level of awareness for a tool or person and that this tool or person may inhabit the virtual or physical space or a bit of both, as when real participants are annotated with virtual. This level of awareness can be characterized as a location in this two dimensional space. Focal awareness is defined as the allocation of high levels of attention to and high levels of modelling of the states of physical, virtual, or imaginary people or objects. Focal awareness is likely to use conscious attentional resources. Peripheral awareness is defined as limited consciousness of people or objects, based on largely automatic attentional processes indicating that people or objects are co-present. We will return to the issue of social presence below.

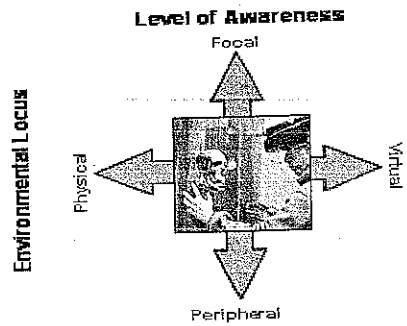

Figure 1: AR awareness continuum

Looking at the design features of awareness systems, most often they have primarily been focused on the awareness of people: their location, behaviour, and states. But in augmented and virtual reality, agency might be attributed to a real physical person mediated by a telecommunication system, an agent representing the system, or tools and environments that may be thought of as having "agency" by the user, for example that a computer system is "aware" of the user's presence. So awareness of others, initially conceived as just awareness of presence and states of office mates or others in a networked environment, might be better conceived as a general awareness of the states of agents, whether they are real people, computer agents, or objects for which a user might attribute some agency. A user may attribute dispositional "agent-like" states in objects such as tools, machines, and data objects. In all cases the key issue that relates people and objects to the user on some common plane is the user's planned, current, or past interaction with the item. A person, tool, or environment might have been, or be the current object of interaction, or is under consideration for interaction in some procedure, be it a conversation, tool manipulation, etc. Thought of this way, similar principles and issues might apply to all information objects and potentially simplify the problem space of awareness management in an augmented reality system.

2 Spatial organization of awareness

A project called Mobile Infospaces works with a fundamental psychological and design property of AR, ***spatial representation***. The project examines the psychological properties of space and its relation to the design of interfaces that manage objects, tools, and people in AR space (for theoretical basis and model see Biocca, Mou, Tang, & Owen, 2003; Mou, Biocca, Tang, & Owen, submitted). The fundamental variable that ties awareness and the augmented reality systems is the use of spatial organization and sensory cues to organize object and social awareness along the continuum of focal to peripheral awareness. As much as half of the brain is dedicated to processing visual-spatial information and guiding spatial movements (Kanwisher, 2001). In our current projects we are exploring various ways in which so-called spatial natural mappings activate primitive or highly learned cognitive responses based on perceptual or motor affordances of objects or agents around the user's body. Many information systems such as graphs and visualizations make extensive use of perceptual and spatial cues. Mapping information organization to the human brain's prodigious capacity for spatial cognition may offer a potential route for managing awareness in mobile, AR interfaces.

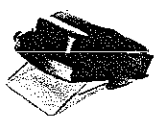

Figure 2: Prototype AR Projective HMD

Figure 3: Teleportal ARC Room

Figure 4: Cylindrical volumetric screen with virtual object.

The Teleportal system is a room-based augmented reality system. It uses a projective, head mounted displays (HMD) (Biocca & Rolland, Pending; Rolland et al., submitted). The projective augmented reality HMDs (see Figure 2) projects a set head tracked, stereo images to a strategically retroreflective fabric in the physical environment (See Figure 3) or molded for any surface including curved ones (See Figure 4). The user has the illusion of a 3D object floating in front or behind the surface plane (Figure 4). See Hua et al, 2000; Hua et al., 2003)

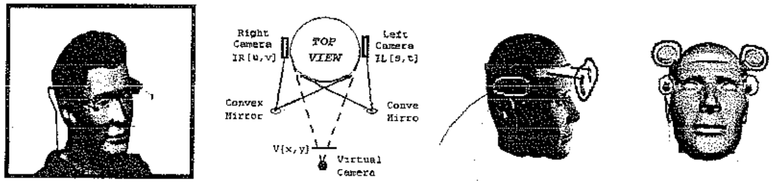

Figure 5: Teleportal Face-to-face capture: (a) concept, (b) schematic, (c, d) current implementation.

In networked teamwork situations others must sometimes move from the peripheral-to-focal awareness. The movement from one to the other is vividly suggested by two English phrases that use spatial metaphors to represent the extremes of the continuum between peripheral and focal: one suggesting peripheral awareness, "he's hardly on my radar"; to one suggesting high focal, almost excessive, awareness and social presence, "this person is in my face." With the 3D face-to-face capture system we are attempting to develop a technology that can use spatial mapping to manage social awareness from the very high focal awareness and high social presence, "he's in my face," to peripheral awareness of the other. The 3D face-to-face system is designed to capture a full 3D image of the face (See Figure 5). It uses head-worn stereo cameras with a set of small convex mirrors. This affords a highly detailed record of the facial expression of the remote user no matter where the individual is looking. We used Structured light mechanism for generating a 2D frontal view of the face and Water's model for generating facial animation. The realism in the 3D face model is dramatically improved by texture mapping. Used as input for an augmented reality system and coupled to data from a head tracker, the technique will allow us to position the 3D head of the remote user in the exact location within the matched networked Teleportal rooms (see Reddy, Stockman, & Biocca, 2003 for details).. This affords (a) awareness of spatially accurate visual 3D head-model of the attention of the remote other in the matched networked Teleportal room, (b) record of non-verbal cues of emotional states (c) high-focal awareness in cases where

the other must be "in your face," (d) and allow the computer to be "aware" of facial expressions of the user.

3 Social Presence Measures for Awareness

How does one measure awareness other than within a simple continuum of "aware" or "unaware"? How can we get at the characteristics or qualities of that awareness of others? Finally, how can the general notion of social awareness be extended to not only awareness of the states of mediated others, but to the states of agents and computer tools who take on properties of agents, for example virtual animal assistants? Therefore, in the study of awareness a key issue is the measurement of ***social presence***, especially as mediated agents, virtual agents, and tools with apparent agency move within the continuum between focal and peripheral awareness.

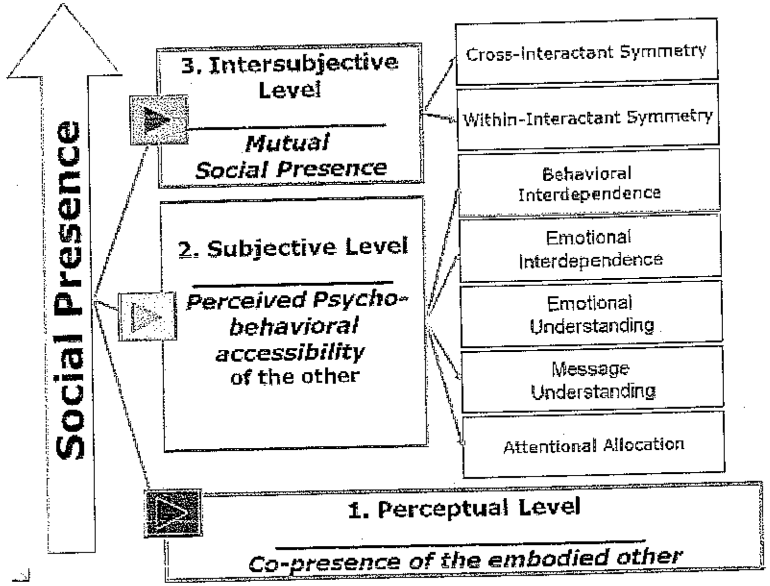

Figure 6: Mutual awareness may be measured using the dimensions of the Networked Minds Measure of Social Presence (http://www.mindlab.org/)

The Networked Minds Social Presence Inventory is a self-report measure that yields eight dimensions. The lowest dimension, co-presence, measures the movement from non-awareness to peripheral awareness of the other. The other dimensions of social presence capture qualities of the sense of accessibility of the other as the other moves from peripheral to more focal awareness, and the qualities of that awareness. The measure includes sets of paired items that assess the degree to which interactants assess themselves, how much they feel socially present, and how much they perceive the other to be socially present. This allows us to derive two other indices:

- **Within-interactant social presence symmetry**: This is an index of the degree to which an individual perceives their sense of social presence to be equal or symmetrical to the other interactants.
- **Cross-interactant social presence symmetry**: This index reports the degree to which each of two or more individuals perceive the other's level of social presence as matching the other's own self-assessed social presence.

These two indices can be used to assess the effects of different interfaces and social interactions on the degree of mutual awareness, measured as the degree to which the others are socially present. The measure might be useful to individuals who study awareness and can be downloaded from http://www.mindlab.org/.

3.1 Summary and conclusion

Awareness issues may be critical to the design of augmented reality systems. We have suggested the use of spatial organization strategy for interface designs. These may assist the user in managing the allocation of focal and peripheral awareness to people, tools, and other objects. A persistent issue is likely to be the competition of the virtual and physical environment for attentional resources, especially when the physical and the virtual are poorly integrated. When poorly integrated, physical presence in one environment may compete with the sense of physical presence in the other. Finally, we have briefly introduced how some of these issues are addressed in the design of a room based and mobile augmented reality systems.

4 References

Alavi, M., & Tiwana, M. (2002). Knowledge integration in virtual teams: The potential role of KMS. Journal of the American Society for Information Science and Technology, 53(12), 1029-1037.

Biocca, F. (1997). The cyborg's dilemma: progressive embodiment in virtual environments. Journal of Computer-Mediated Communication, 3(2), http://www.ascusc.org/jcmc/vol3/issue2/biocca2.html.

Biocca, F., Mou, W., Tang, A., & Owen, C. (2003). Mobile infospaces: A working model of spatial information organization in virtual and augmented reality environments. East Lansing: Media Interface and Network Design Lab (www.mindlab.org).

Biocca, F., & Rolland, J. (Pending). Teleportal Face-to-Face system: Teleconferencing and tele-work augmented reality system, Patent Application: 6550-00048; MSU 99-029, Dec. 22, 2000. United States: Michigan State University & University of Central Florida.

Kanwisher, N. (2001). Faces and places: of central (and peripheral) Interest. Nature Neuroscience, 4, 455-456.

Hua, H., A. Girardot, C. Gao, and J. P. Rolland, "Engineering of head-mounted projective displays, Applied Optics 39(22), 3814-3824 (2000).

Hua, H, Y. Ha, and J.P. Rolland, "Design of an ultra-light and compact projection lens," Applied Optics 42(1), 97-107 (2003).

Mou, W., Biocca, F., Tang, A., & Own, C. (submitted). Spatial cognition and mobile augmented reality systems. Behavior & Information Technology..

Reddy, C., Stockman, G., & Biocca, F. (2003). Face model construction and transmission for telecollaboration. East Lansing: M.I.N.D. Lab.

Rolland, J., Biocca, F., Gao, C., Hua, H., Ha, Y., Harrysson, O., et al. (submitted). Design and prototyping of a teleportal ultralight-weight large field of view head-mounted display. International Journal of Advanced Manufacturing Technology.