[**Information Interfaces and Presentation**]: Multimedia Information Systems—*Artificial, augmented and virtual realities*; H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces—*Evaluation / methodology*

General Terms: Human Factors, Experimentation, Design

Additional Key Words and Phrases: Social interaction, virtual reality, CSCW, objects, shared spaces, user interface design, embodiment

1. INTRODUCTION

Recent years have witnessed extraordinary advances in the quality and effectiveness of visualization and VR technologies. Indeed, a wide variety of organizations and institutions are increasingly finding novel and innovative uses for these technologies, uses that encompass and include the fields of design, entertainment, medicine, engineering, and so forth. However, most industrial applications are being used to support high-quality graphical visualizations of real (and imagined) scenes and settings, where individual users navigate around the world(s), whether on their own or with a local audience. However, in future years, these virtual settings and scenes could well become everyday work or meeting places for remote participants—for example, architects discussing possible alterations to a design; or medical experts discussing and planning surgical techniques. Indeed, it is increasingly recognized that changes in the structure of contemporary organizations will place corresponding demands on technology to provide support for such distributed collaborative work [Barnatt 1995]. The trend toward disaggregation, globalization, and dynamic networks of firms suggests that CSCW technologies will play an increasingly important part in supporting cooperation and communication amongst distributed personnel.

To provide adequate support for teamwork "in" (and through) virtual environments, however, basic research is necessary to understand the kinds of resources and support individuals require to undertake seamless collaboration. For example, it is widely recognized that much collaborative work rests upon the sharing and discussion of a whole host of documents, tools, and other artefacts and that supporting such interaction is a general problem for the development of advanced shared workspaces. Although asynchronous text-based systems to support remote work, such as email, Notes, and the World Wide Web, are flourishing within the business community, technologies to support real-time, collaborative work, such as media spaces, have met with less success. These systems have not as yet proved to provide satisfactory domains for collaborative work, and even their precursors, such as video-telephony and video-conferencing, have failed to have the impact that many envisaged. It has been argued that the relative weakness of many systems to support synchronous remote working derives from their inability to assist individuals in working flexibly with a variety of workplace objects (e.g., Heath et al. [1997]). This would seem of

critical importance for the development of virtual environments where remote colleagues would need to discuss virtual objects and scenes as well as collaboratively coordinate their navigation around, and looking within, the world. Thus, we need to draw on our understanding of the kinds of resources people utilize in face-to-face interaction to conduct object-focused work, to explore the problems and difficulties faced by individuals interacting through CVEs.

In this paper we build on workplace studies and media space research to develop and evaluate a Collaborative Virtual Environment (CVE) designed to support real-time collaboration and interaction around objects and artefacts. In particular, we wish to explore the extent to which the system provides participants with the ability to refer to, and discuss, features of the virtual environment. The implications of these observations are then drawn out with regard to the specific development of CVEs to support interaction around objects. We also consider more general issues relevant for the development of sophisticated support for distributed collaborative work.

2. BACKGROUND

In their wide-ranging investigation of organizational conduct, workplace studies have powerfully demonstrated how communication and collaboration are dependent upon the ability of personnel to invoke and refer to features of their immediate environment (e.g., Goodwin and Goodwin [1996], Heath and Hindmarsh [2000], and Heath et al. [1994]). Studies of settings such as offices and control rooms have shown that individuals not only use objects and artefacts, such as screens, documents, plans, diagrams and models, to accomplish their various activities, but also to coordinate those activities, in real time, with the conduct of others. Indeed, it is found that many activities within colocated working environments rely upon the participants talking with each other, and monitoring each others' conduct, whilst looking, both alone or together, at some workplace artefact. An essential part of this process is the individual's ability to refer to particular objects, and have another see in a particular way what they themselves are looking at [Hindmarsh and Heath 2000]. These studies provide insights into the demands that will be placed on technologies that aim to provide flexible and robust support for remote working.

Interestingly, systems to support distributed collaboration are increasingly attempting to meet these needs. Rather than merely presenting face-to-face views, conventional video-conferencing systems are now often provided with a "document camera," and media spaces and similar technologies are increasingly designed to provide participants with access to common digital displays or enhanced access to the others' domain (e.g., Tang et al. [1994], Kuzuoka et al. [1994], Gaver et al. [1993], and Heath et al. [1997]). However, it is not clear that such systems provide adequate support for object-focused collaboration.