

A Hybrid Avatar/Agent Model for Educational CVEs

Michael Gerhard

A thesis submitted in partial fulfilment for the degree of
Doctor of Philosophy

February 2003

Acknowledgements

Firstly, I wish to express special thanks and sincere appreciation to Dr David Moore and Dr Dave Hobbs for patiently supervising and supporting this research with ideas and constructive criticism, and for the goodwill, friendship and care they showed toward me. This thesis would not appear in its present form without their guidance and encouragement.

Further, I would like to thank my colleagues at Axis and in the School of Computing at Leeds Metropolitan University for providing the opportunity to pursue my research and for providing a highly enjoyable environment throughout the duration of this study. I would also like to acknowledge the support of an HEFCE bursary and additional support from the Lottery Millennium Commission for funding the research reported within this thesis.

Finally, I would like to express my thanks to my family; to my parents, Klaus and Karin, for always supporting and believing in me, and to, most of all, my wife, Sinead, who had to endure my many late nights in front of the computer while staying enthusiastic toward my research and everything else I do.

To Sinead, Karin and Klaus!

Abstract

Various forms of distance education have made their mark in all education and training sectors, from traditional campus universities to corporate training centres. However, all these lose to a greater or lesser extent the personal aspects of traditional face-to-face teaching. CVEs (Collaborative Virtual Environments) on the other hand are believed to have the potential to bring back some of the social intercourse of *campus life* that is usually lost. Should *virtual universities* become widely deployed their students will wish to portray, in some form, their identity, attributes, belongings, moods and preferences within virtual tutorials and seminars in which they engage.

This thesis explores issues related to user embodiment in educational CVEs; in particular a *hybrid avatar/agent model* for continuous user representations is proposed. Several prototypes of CVEs, avatars and agents were built and deployed in two controlled experiments and a field study to explore this model. Hypotheses concerning the effects of different types of embodiment as well as the potential benefits of agents simulating the copresence of other participants were formulated and tested by measuring users' experience of *presence*. The experimental results were analysed and discussed with respect to informing the research and design of future CVE applications on issues particularly relating to user embodiment.

Results obtained strongly suggest that the deployment of animated cartoon-style or humanoid avatars in CVEs improves the experience of subjects with respect to presence. They further suggest that *copresence* is essential for the experience of presence in CVEs and that even limited copresence simulated by embodied conversational agents is sufficient to help users feel more present in the environment. It is argued that this provides evidence for the benefits of *continuous virtual presence* in educational CVEs that could potentially be achieved by a hybrid avatar/agent model. Finally, a set of tentative design principles for user embodiments in CVEs was developed.

Publications

Preliminary results obtained during the research documented in this thesis were published as listed below.

Gerhard, M. (1997) Avatars and Agents in Collaborative Virtual Environments for Education, in *Proceedings of the Conference on Human Computer Interaction (HCI)*, Bristol, UK

Gerhard, M., Moore, D. (1998) User Embodiments in Educational CVEs: Towards Continuous Presence, in *Proceedings of the International Conference on Network Entities (NETIES)*, Leeds, UK

Gerhard, M. and Fabri, M. (1998) Usability Evaluation for Collaborative Virtual Environments: CyberAxis, in *Proceedings of the International Workshop on Usability Evaluation for Virtual Environments (UEVE)*, Leicester, UK

Gerhard, M., Hobbs, D., Moore, D., Fabri, M. (1999) Cognitive Immersion in CVEs: A Hybrid Avatar/Agent Model for User Representation in Virtual Learning Environments, in *Proceedings of the Eurographics UK Conference*, Cambridge, UK

Fabri, M., Gerhard, M., Moore, D., Hobbs, D. (1999) Perceiving the Others: Cognitive Processes in Collaborative Virtual Environments, in *Proceedings of the Eurographics UK Conference*, Cambridge, UK

Gerhard, M., Hobbs, D., Moore, D., Fabri, M. (1999) Agents for Networked Virtual Learning Environments, in *Networking Entities: Tele-education, Telematics & Law, Telematics & Culture*, Guenther, J. and Zeibekakis, G., (eds), Danube University of Krems, Austria

Gerhard, M., Fabri, M. (2000) The Virtual Student: User Embodiment in Virtual Learning Environments, in *International Perspectives on Tele-Education and Virtual Learning Environments*, Hobbs, D. and Orange, G., (eds), Ashgate, UK

Gerhard, M., Moore, D., Hobbs, D. (2001) An Experimental Study of the Effects of Presence in Collaborative Virtual Environments, in *Proceedings of the International Conference on Intelligent Agents for Mobile and Virtual Media*, Bradford, UK

Gerhard, M., Moore, D., Hobbs, D. (2001) Continuous Presence in Collaborative Virtual Environments: Towards the Evaluation of a Hybrid Avatar-Agent Model for User Representation, in *Proceedings of the International Conference on Intelligent Virtual Agents (IVA 2001)*, Madrid, Spain

Gerhard, M., Moore, D., Hobbs, D. (2002) An Experimental Study of the Effect of Presence in Collaborative Virtual Environments, in *Intelligent Agents for Mobile and Virtual Media*, Earnshaw, R., Vince, J. (Eds), Springer, London, UK

Table of Contents

Chapter 1 - Introduction	15
1.1 Background.....	15
1.2 Objectives	16
1.3 Thesis Overview.....	16
Chapter 2 - CVEs for Distance Education	19
2.1 Distance Education.....	19
2.1.1 Definition of DE.....	20
2.1.2 Delivery of DE	21
2.2 Collaborative Virtual Environments	23
2.2.1 CVE Implementations	24
2.2.2 Educational CVEs	26
2.3 Modes of Learning	28
2.3.1 Guided Discovery.....	30
2.3.2 Collaborative Learning.....	32
2.4 Guided Discovery in Educational CVEs	33
2.5 Summary	35

Chapter 3 - User Embodiment 36

3.1	Philosophical Views on Embodiment	36
3.2	Avatars in CVEs	40
3.2.1	Social Facilitation.....	42
3.2.2	Non-Verbal Communication	42
3.3	Types of Avatars.....	44
3.3.1	Cartoon Avatars	46
3.3.2	Human Avatars	48
3.4	Visions for Future Avatar Development.....	49
3.4.1	A Hybrid Avatar/Agent Model	51
3.5	Summary	53

Chapter 4 - Evaluation Methods 54

4.1	Evaluation Techniques	54
4.1.1	Controlled Experimentation	56
4.1.2	Quasi-Experiments	58
4.1.3	Review-based Evaluation.....	59
4.1.4	Heuristic Expert Reviews.....	60
4.2	Presence.....	61
4.3	Presence in CVEs	64
4.3.1	Presence and Embodiment	65
4.3.2	Social Presence and Copresence	66
4.4	Measurement of Presence	68
4.4.1	Presence Questionnaires.....	69
4.5	Summary	71

Chapter 5 - Experimental Exploration of Avatars 72

5.1	Hypotheses	73
5.2	Method.....	74
5.2.1	Identification of Variables	74
5.2.2	Control of Variables	75
5.2.3	Manipulation of Independent Variable	76
5.2.4	Apparatus and Task Setting	78
5.3	Subjects and Procedure	79
5.4	Questionnaires	81
5.4.1	Pre-Experiment Questionnaire	81
5.4.2	Post-Experiment Questionnaire.....	83
5.5	Results and Analysis.....	85
5.5.1	Results of Pre-Questionnaire.....	85
5.5.2	Results of Post-Questionnaire Subscales	87
5.5.3	Descriptive Statistics for Presence	88
5.5.4	One-way Test of Presence Mean	90
5.5.5	Multiple Comparisons	91
5.6	Discussion.....	93
5.7	Summary	97

Chapter 6 - CyberAxis Field Study 98

6.1	Visitor Experience	99
6.1.1	Exhibition Programme	102
6.1.2	Artist Residencies.....	103
6.1.3	Advertising of CyberAxis	104
6.2	System Implementation	105
6.3	Evaluation of User Statistics and User Feedback.....	106

6.3.1	User Feedback Questionnaire.....	107
6.4	Applied Presence Measures.....	109
6.4.1	Questionnaire Evaluation	109
6.4.2	Results and Analysis.....	111
6.5	Discussion.....	115
6.6	Summary	119

Chapter 7 - Agent Technology 120

7.1	Underlying Concepts and Current Research.....	120
7.2	Embodied Conversational Agents.....	123
7.2.1	Pedagogical Agents	126
7.3	Prototype Development.....	129
7.4	Evaluation Metrics	132
7.4.1	Linguistic Criteria	133
7.4.2	Criteria Relating to Bodily Behaviour	134
7.5	Heuristic Evaluation of the Prototype.....	135
7.5.1	Results of the Heuristic Evaluation.....	135
7.6	Summary	138

Chapter 8 - Experimental Exploration of Agents..... 139

8.1	Hypotheses	140
8.2	Method.....	140
8.2.1	Identification of Variables	140
8.2.2	Control of Variables	142
8.2.3	Manipulation of Variables	142
8.2.4	Apparatus and Task Setting.....	143

8.3	Procedure and Subjects	143
8.3.1	Selection of Subject Groups.....	144
8.4	Questionnaires	145
8.4.1	Pre-Experiment Questionnaire	145
8.4.2	Post-Experiment Questionnaire.....	147
8.5	Results and Analysis.....	149
8.5.1	Results Pre-Questionnaire	149
8.5.2	Results Post-Questionnaire	149
8.5.3	Descriptive Statistics for Presence	150
8.5.4	One-way Test of Presence Mean	152
8.6	Qualitative Data.....	154
8.7	Discussion.....	159
8.7.1	Tentative Design Principles.....	163
8.8	Summary	164
 Chapter 9 - Conclusions and Future Work		165
9.1	Summary	165
9.2	Experimental Results	167
9.3	Contribution	169
9.4	Further Work.....	171
9.5	Final Reflections	173
 Appendices.....		174
Appendix 1 Avatar Experiment		174
Appendix 1.1	Screenshot of Instructions Page.....	174
Appendix 1.2	VRML Code for Test Gallery	175

Appendix 1.3	Screenshot Online Questionnaire	178
Appendix 1.4	Perl Script for Post-Questionnaire	179
Appendix 1.5	Example File from Online Questionnaire	184
Appendix 1.6	Results Pre-Questionnaires	185
Appendix 1.7	Summary of Pre-Questionnaire Data.....	188
Appendix 1.8	Results Post-Questionnaires Condition X1	191
Appendix 1.9	Results Post-Questionnaires Condition X2	192
Appendix 1.10	Results Post-Questionnaires Condition X3	193
Appendix 1.11	Extracted Qualitative Data.....	194
Appendix 1.12	Chat Log Extract.....	195
Appendix 2 CyberAxis Field Study		197
Appendix 2.1	Screenshot of CyberAxis Homepage.....	197
Appendix 2.2	blaxxun VWP System Architecture	198
Appendix 2.3	Axis Call for Curators.....	199
Appendix 2.4	Essay by CyberAxis Curator	200
Appendix 2.5	CyberAxis User Feedback Questionnaire.....	204
Appendix 2.6	Individual Questionnaire Results.....	206
Appendix 2.7	Individual Results Control Variables	207
Appendix 3 Agent Experiment.....		208
Appendix 3.1	Results Pre-Questionnaires	208
Appendix 3.2	Results Post-Questionnaires	210
Appendix 3.3	Subjects' Responses to Question 20	214
Appendix 3.4	Chat Logs (Agent Experiment).....	217
Appendix 3.5	Detailed Analysis of Chat Log Files	222
References.....		227

Table of Figures

Figure 2.1: Screenshot of Onlive Traveller	25
Figure 2.2: Screenshot of ActiveWorlds	26
Figure 2.3: Laurillard’s Model of Guided Discovery.....	31
Figure 2.4: Student’s Perspective of Learning in a CVE	34
Figure 2.5: Model of Guided Discovery in CVEs.....	35
Figure 3.1: Geo-metricks Commercial Avatar (Theo)	45
Figure 3.2: Geo-metricks Commercial Avatar (Yogi)	46
Figure 3.3: Direct Manipulation of Avatar (user is online).....	52
Figure 3.4: Agent in Control of Avatar (user is offline).....	52
Figure 4.1: Tromp’s Model for the Experience of Presence	65
Figure 5.1: Combined Variables.....	75
Figure 5.2: Basic Avatars	77
Figure 5.3: Cartoon-style Avatars	77
Figure 5.4: Humanoid Avatars	78
Figure 5.5: Mean Subscale Scores	88
Figure 5.6: Mean Presence Scores	89
Figure 5.7: 95% Confidence Interval for Presence Means	90
Figure 6.1: Avatar Selection.....	100
Figure 6.2: Screenshot of Visitors in CyberAxis	101
Figure 6.3: CyberAxis Logo	105
Figure 6.4: Screenshot of Part of the Online Evaluation Questionnaire.....	108
Figure 6.5: Combined Variables for Quasi-Experiment.....	109
Figure 6.6: Mean Subscale Scores	112
Figure 6.7: Histogram for Distribution of IMT.....	113
Figure 6.8: Histogram for Distribution of EXP	113
Figure 6.9: Presence Means for Conditions X1 and X2.....	114
Figure 6.10: Extract from Chat Log File.....	116

Figure 6.11: Extract of Debate	117
Figure 6.12: Examples of User Feedback on Question 19.....	118
Figure 7.1: STEVE, by USC / CARTE.....	127
Figure 7.2: Herman the Bug Interface.....	128
Figure 7.3: Appearance and Animation of the Agent.....	130
Figure 8.1: Combined Variables.....	141
Figure 8.2: Subject Interacting with Agent in the Gallery	143
Figure 8.3: Mean Subscale Scores	150
Figure 8.4: Mean Presence Scores	151
Figure 8.5: 95% Confidence Interval for Presence Means	152
Figure 8.6: Chat Log Extract 1.....	156
Figure 8.7: Chat Log Extract 2.....	157
Figure 8.8: Chat Log Extract 3.....	158

Table of Tables

Table 3.1: Cartoon Avatars Entered for the AVVY Awards	47
Table 3.2: Human Avatars Entered for the AVVY Awards.....	49
Table 5.1: Exhibited Artworks from the Axis Database.....	80
Table 5.2: Course of Sessions	81
Table 5.3: Pre-Questionnaire Subscales	82
Table 5.4: Pre-Questionnaire.....	82
Table 5.5: Post-Questionnaire Subscales	83
Table 5.6: Post-Questionnaire	85
Table 5.7: Results Pre-Questionnaire	86
Table 5.8: Resulting Course of Sessions	86
Table 5.9: Results Post-Questionnaire	87
Table 5.11: One-way ANOVA Test of Presence Mean.....	91
Table 5.12: Tukey HSD Post Hoc Test.....	92
Table 5.13: Bonferroni Post Hoc Test	93
Table 6.1: CyberAxis User Statistics.....	107
Table 6.2: Questionnaire Subscales for Variables	110
Table 6.3: Descriptive Statistics for all Variables	111
Table 6.4: Group Statistics for Presence Scores.....	113
Table 6.5: Independent Samples Test of Presence Mean	115
Table 8.1: Subject Groups	145
Table 8.2: Pre-Questionnaire Subscales	146
Table 8.3: Pre-Questionnaire.....	146
Table 8.6: Results Pre-Questionnaire.....	149
Table 8.7: Results Post-Questionnaire	150
Table 8.8: Descriptive Statistics for Presence Means	151
Table 8.9: Independent Samples Test of Presence Mean	153

Chapter 1 - Introduction

The research documented in this thesis focuses on and investigates issues concerning user embodiments in an educational Collaborative Virtual Environment (CVE).

1.1 Background

Distance education (DE) has become widespread in all education and training sectors, from traditional campus universities to corporate training centres (Lockwood and Gooley 2001). To date educational institutions have tended to use electronic means of interaction such as email and video conferencing. Visual CVEs, on the other hand, offer an alternative means of computer-mediated communication which is argued to have the potential to bring back some of the social intercourse of *campus life* that is usually lost when learning is conducted in a conventional DE mode (Hobbs et al 2000).

The first generation of 3-dimensional multi-user CVE technology provided a number of interesting features (Snowdon et al 2001), but has not been widely adopted as the new interface to deliver DE. Nevertheless, the continuing trend towards life-long learning (Coffield 2000) as well as the rapid increase in available global computer network infrastructures and, in particular, CVE technology (Churchill et al 2001), are further increasing the potential for the use of CVEs as the future interface for DE.

Once *virtual universities* become widely deployed their students will undoubtedly want to attend virtual tutorials and seminars, take part in collaborative learning, and carry their identity, attributes, belongings, moods and preferences with them. Therefore, Preece (2000) argues, distance learning students need to be able to interact with the learning environment and communicate and collaborate, synchronously as well as asynchronously, in a natural and intelligent way. It will be argued in this

thesis that this can potentially be facilitated through the use of educational CVEs, where distance learning students are permanently represented in the learning environment through their continuous virtual embodiments. It will also be argued that there are a number of open questions to be addressed before the potential of educational CVEs can be realised. Investigating these issues will form the main contribution of this research.

1.2 Objectives

The key aims and objectives of this research project are therefore to investigate the use of CVE technology for Distance Education and contribute to the process of theoretical conceptualisation in the field. In particular, the current study aims to explore issues concerning the embodiment of users in educational CVEs.

- The effects of different types of so-called *avatars*, user embodiments under the direct control of the user, will be investigated.
- The potential of user embodiments driven by *agents* acting on behalf of users in their absence will be explored.
- A hybrid model of avatar and agent technology will be formulated and aspects of it evaluated in a field study and two sets of controlled experiments.
- The experimental results will be analysed and evidence sought concerning the potential benefits of a hybrid avatar/agent model in order to develop a set of design principles for user embodiments in educational CVEs.

1.3 Thesis Overview

Chapter 2 reviews the research literature in the area of educational theory and computer mediated distance learning and argues that the guided discovery approach (Laurillard 1995) is a particularly suitable mode for distance learning. Based on a

review of current and future computer and communication technologies it is further argued that 3-dimensional CVEs might have the potential to best support the needs of remote collaborative learning based on Laurillard's guided-discovery approach.

In chapter 3 it is argued that in CVEs students and teachers need a form of virtual body, an *avatar*, in order to interact with the environment and each other. Further, it is argued that *copresence*, i.e. the presence of other participants in the CVE, can be expected to influence the experience of presence felt by users of the CVE. It is further argued that, in absence of the underlying user, their virtual presence can be simulated by using agent technology to control the avatar. It is argued, that is, that a hybrid avatar/agent model for user representation may be beneficial.

As CVEs are not routinely used for distance education at present, an empirical investigation into existing systems, evaluating the effects of user embodiments based on performance measures, was not feasible within the current research. In chapter 4 different evaluation approaches are therefore discussed and a case is made for conducting controlled experimentation. It is argued that the key distinguishing factor of CVE technology is *presence*, the sense of *being there*, and that this is a cognitive variable that can be measured using questionnaires.

Chapter 5 discusses a controlled experiment conducted to investigate the effects of different types of avatars. Experimental results not only underline the importance of avatars for the CVE experience, but also yield some evidence that humanoid and cartoon-style avatars engender more presence than basic-shape avatars.

In an attempt to validate these experimental results and to further explore issues relating to user embodiments in a more authentic setting, a field study concerning a 3-dimensional virtual art gallery, *CyberAxis*, built as part of this research, was conducted. Results, discussed in chapter 6, reveal that copresence is a significant factor for the experience of presence in CVEs. It is argued, on the basis of these results, that to further improve the learning experience in times when users are absent/offline, it may be valuable to simulate copresence using a virtual agent to act on behalf of absent users.

In chapter 7, therefore, currently available agent technology is reviewed and ALICE (Artificial Linguistic Internet Computer Entity) / AIML (Artificial Intelligence Markup Language) in connection with the blaxxun agent API (Application Programming Interface) identified as a promising means of enabling the development of a satisfactory agent prototype. The development of an agent potentially capable of simulating the copresence of a virtual companion is outlined.

The evaluation of this prototype agent is discussed in chapter 8. A further controlled experiment was conducted to investigate the effects of copresence in CVEs simulated by embodied conversational agents. Such agents can potentially act on behalf of users when they are offline, which in turn, it is argued, has the potential to complement avatar technology and thus achieve permanent presence of all participants using a hybrid avatar/agent model for user representation.

Finally, chapter 9 provides a summary of the research, re-iterates its conclusions, and makes suggestions for further work.

Chapter 2 - CVEs for Distance Education

This chapter introduces the general concepts of distance education (DE) by reviewing relevant literature (2.1). It provides a brief introduction to the concept of collaborative virtual environment (CVE) technology and argues for its potential for delivering DE (2.2). Different modes of learning as proposed by the literature are discussed (2.3) and the *guided discovery* approach is introduced. This is followed by a discussion of the suitability of the guided discovery approach for distance learning in a CVE (2.4).

2.1 Distance Education

Distance learning and teaching, commonly referred to as *distance education* (DE), experienced rapid change in the 1990's, with new technologies, especially computer-mediated communication via the Internet, opening new opportunities for educators to reach their students (Weller 2001). Interactive multimedia resources are increasingly available to the remote learner because of improvements in compression technologies combined with improved computer and network speeds at reduced costs (Schrum 1995). There is a continuing growth of public demand for lifelong learning opportunities (Garrison et al 2001) and Hirumi and Bermudez (1996) claim the rapid increase in information sources and computer resources available for education may have the pedagogical potential to offer a new kind of learning experience.

Further, Moore and Kearsley (1996) argue that DE is sufficiently pervasive within educational institutions, including institutions embracing distance learning as an exclusive delivery method, to warrant researchers to write about a *systems* view. These systems views look beyond immediate learning outcomes to the impact distance education may have on society (Kaufman 1996), as with schools and universities seeking to provide greater access to learning with increasingly tighter

budgets, distance-learning projects are expected to further grow in number and in popularity (Garrison and Archer 2000).

2.1.1 Definition of DE

How distance education is best defined or differentiated from other educational approaches has been the subject of much debate. Shale (1988) claims that *distance education is beset with a remarkable paradox - it has asserted its existence, but it cannot define itself* and Sherry (1996) that the term *distance education* has been applied by many different researchers to a great variety of programs, providers, audiences, and media. Keegan (1980) identified a number of key elements of distance education:

- Separation of teacher and learner
- Influence of an educational organisation
- Use of media/technology to link teacher and learner
- Two-way exchange of communication
- Learners as individuals rather than grouped

Distinctive marks of distance education are believed to be the separation of teacher and learner in space and time (Perraton 1988), the shift of control of learning from the educators to the students (Jonassen 1992), and remote communication between student and teacher, mediated by print or some form of technology (Keegan 1986).

A broadening of the definition of distance education was urged by Barker et al (1989) who acknowledge correspondence study as the historical foundation of distance education but suggest that there are really two forms of distance education. One is the traditional correspondence- based distance education which is independent study oriented and the second is telecommunications-based distance education which offers the teaching and learning experience simultaneously.

From the perspective of many educational technologists, distance education is directly linked to the technology (Garrison et al 2001) and seems to be viewed as different from other forms of education, a factor that may contribute to course development and acceptance problems (Muilenburg and Berge 2001). Further, focusing on the technology may take the emphasis off the *dialectical relationship between teacher and student*, which is said to be the foundational principle in the educational process (Moore 1993). Shale (1988) argues that *technology is rather an incidental consideration than a defining criterion for distance education*.

There is, then, a variety of views what constitutes DE. For the purpose of the current research the Garrison (1989) definition of DE, offering a minimum set of defining criteria, is deemed sufficient; Garrison's criteria suggest that:

1. DE implies that the majority of educational communication between teacher and student (as well as between student and student) occurs remotely.
2. DE involves two-way communication between teacher and student (as well as between student and student) for the purpose of facilitating and supporting the educational process.
3. DE may use technology to mediate communication between teacher and student (as well as between student and student) and interaction of students with the learning environment

Not only is the definition of DE subject to much debate, so too is the method of delivery, that is how to make education accessible.

2.1.2 Delivery of DE

The purpose of all educational institutions is to provide access to learning. Although there are different interpretations of what *access to learning* means, most will agree that it somehow entails making education more available to more people (Hawkridge 1995). That means providing educational opportunities in the workplace, community,

or the home, for those unable to attend school, college or university because of cultural, economic, or social barriers. Dedicated DE institutions and traditional universities have provided opportunities to students unable to attend campus for some time already. Until fairly recently, these institutions relied mainly on correspondence, traditional print instructional materials, and, perhaps, audio/video tapes, or television (Hawkrige 1995). That has started to change as educators devised new ways to capitalize on computer-based learning networks. An inviting, graphical screen layout, interactive multimedia learning materials, simplified access and searching of databases, exponential growth of new resources available on the Web are some of the advantages institutions see in using networked computing to make learning more accessible (Barron 1998).

There are several notable examples of how the web is being used today to provide increased access to education. The Open University in the UK is a prime example of a dedicated distance education institution that uses the web to support its mission of providing accessible education. The establishment of the Open University in 1969 marked the beginning of the use of technology to supplement print-based instruction through well-designed courses (Harry et al 1993). Learning materials were delivered on a large scale to students in three programs: undergraduates, postgraduates, and associate students. Although course materials were primarily print based, they were supported by a variety of technologies, such as audio/video tapes and television (Keegan 1986).

The Open University initially required students to spend some time on campus in residency; however, it found that there were always some students unable to fulfil this requirement (Weller 2001). When the Open University first experimented with offering a course delivered over computer networks, aimed at this kind of student, participants reportedly relished the opportunity to be able to continue their studies without interfering with family commitments; instructors found the experience exhausting yet exhilarating; and the project evaluator wrote that the level of contact and interaction among students and instructors was very similar to regular summer classes (Sewart 2001). Since then, the Open University has offered numerous courses

to students throughout the world via the web and is continuing to expand its list of offerings. Some courses are now delivered entirely online (Atkins et al 2001).

However, some researchers expressed concerns that computer based learning systems may restrict communication, which Girle (1986) argues, *could put the interaction into a very narrow and inflexible mode*. This is seen as one possible cause for low levels of participation (Hewitt and Teplovs 1999). Particularly in text-based systems, low levels of active participation have been reported (Light and Light 1999). Atkins et al (2001) argue that another cause of low participation in such systems may be an incompatibility between students' learning styles and the communication style supported by the computer system. Further, Laurillard (1995) argues that *too often the multimedia products on offer to education use the narrative mode, or unguided discovery, neither of which supports the learner well, nor exploits the capability of the medium*.

Furthermore, Moore and Hobbs (1997) identify limits to multimedia technology's capabilities in a training role. In particular with regard to individualised feedback and discussion, they argue, the danger is that the teaching interaction can become a one-way transfer of knowledge, from the knowledgeable computer to the student lacking in that knowledge. Moore (2000) argues that one possible approach to an answer to what he calls *the problem of untoward didacticism* in DE is to allow multiple participants in the learning interactions. This would allow learners to use the environment to communicate, either synchronously or asynchronously, with each other and with their tutors (Smith et al 1993). A CVE is seen as a promising means to overcome reported shortcomings and to offer a new experience for DE students.

2.2 Collaborative Virtual Environments

A collaborative virtual environment (CVE) is a computer-generated multi-user three-dimensional interface in which users can also experience other participants as being present in the environment (Schroeder 2002). CVEs have been described using various terms such as *multi-user worlds*, *metaworlds* (Rossney 1996), *inhabited*

digital space (Damer et al 1996), *networked virtual reality* (Schroeder 1997), *shared worlds* (Roehl et al 1997) and *avatar worlds* (Damer 1997).

Since the mid 1990s a number of CVEs have been developed for use as environments for real-time social interaction, known as *chatting*. Huxor (1997) argues that in many respects CVEs can be seen as a natural enhancement to the widely used text-based Internet chat by providing a visual and tangible *physical* interface for social interaction using three-dimensional environments. These CVEs were envisaged as social spaces that can be used on ordinary home computers with Internet connection but without the need for expensive VR equipment like head mounted displays and data gloves (Schroeder et al 2001).

It might seem that CVEs are merely visual interfaces to text chatting activity, much as Web browsers provided a graphical interface to textual Internet information. Rossney (1996) argues that on this definition one might dismiss CVEs as they *share the features that make chat rooms so paralysing banal and wed them to the empty eye-candy of the videogame*. On the other hand, the current author agrees with Dodge et al (1998), who argue that the CVE phenomenon is greater than the sum of its parts, i.e. *chatting plus the eye-candy*, as CVE are *providing new meta-places for social contact*. These spaces are being actively used, and to varying degrees co-constructed, by the participants to develop places that provide a sense of belonging. For example, Cybertown is the largest 3-dimensional virtual community with more than one million registered *citizens* (source: www.cybertown.com).

2.2.1 CVE Implementations

The Virtual Reality Modelling Language (VRML) is a file format for the Internet and is used to create and deliver three-dimensional CVEs. VRML files consist of ASCII text, which is interpreted by a VRML viewer as part of the Web browser. Facilities such as hierarchical transformations, light sources, viewpoints, geometry, animation, material properties and texture mapping can be defined using VRML. A large number of systems supporting CVEs have emerged, including MASSIVE (Greenhalgh and

Benford 1995) and DIVE (Frecon and Stenius 1998). Examples of currently available online communities based on VRML or similar standards are *ActiveWorlds*, *CyberTown*, *The Palace* and *Onlive Traveller* (see figure 2.1).

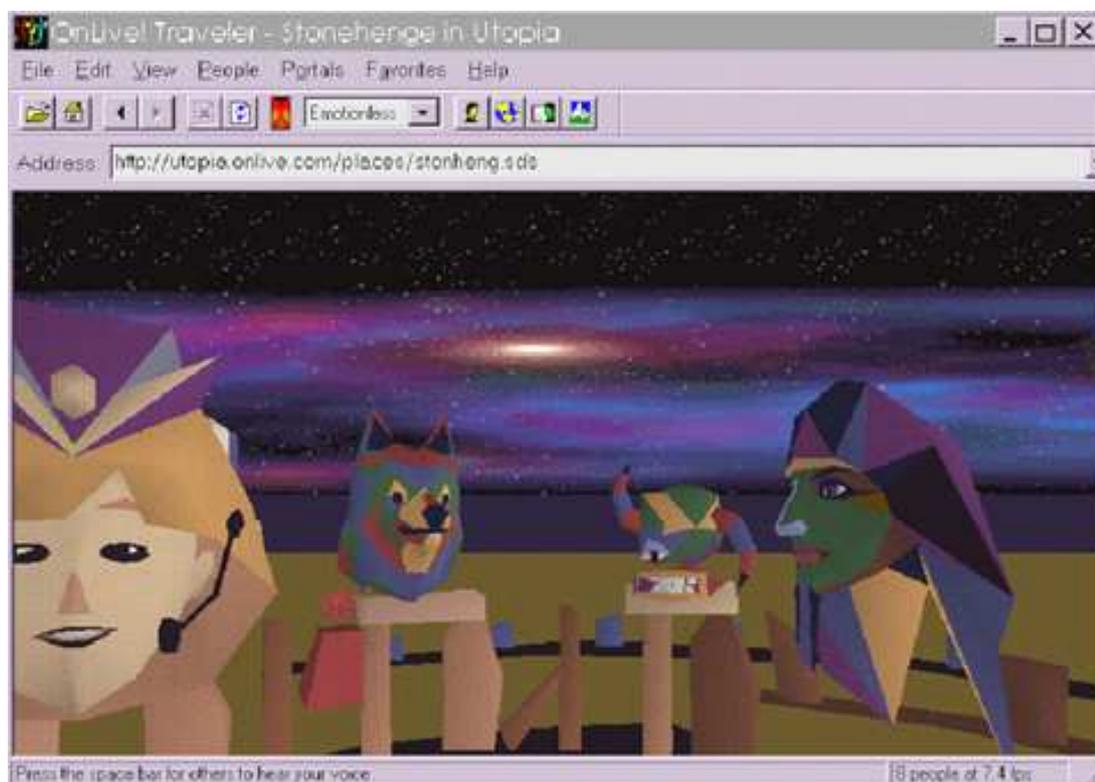


Figure 2.1: Screenshot of Onlive Traveller

ActiveWorlds (see figure 2.2), previously called Alpha Worlds, is one example of such systems in use: a popular commercial CVE that supports interaction in a detailed three-dimensional virtual world over the Internet, where *participants can meet people from all over the planet, explore virtual spaces, play online games, shop, surf the web, stake a claim and build their own virtual home on the Net* (Filman and Peña-Mora 1998). Users are represented by avatars and may choose from a range of different avatar types. ActiveWorlds has been in use since 1995 and studies report increasing numbers of inhabitants (Huxor 1999).

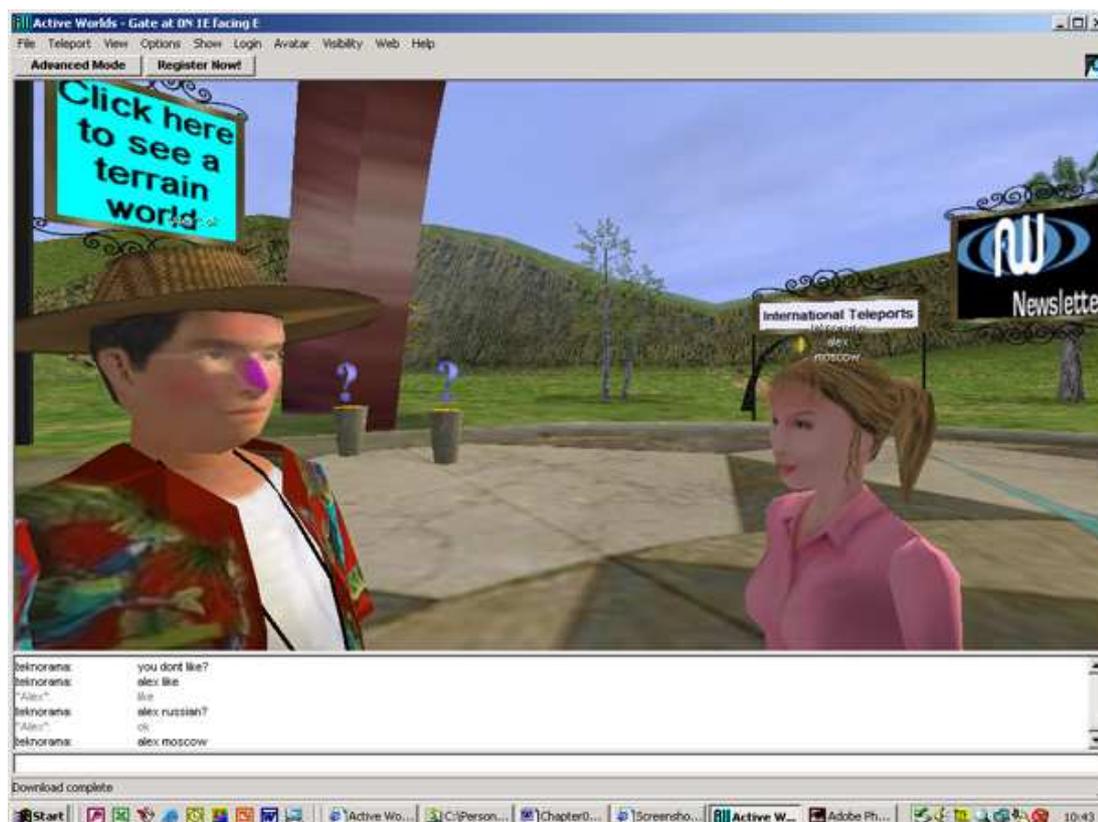


Figure 2.2: Screenshot of ActiveWorlds

2.2.2 Educational CVEs

Currently, CVE technology has not yet been adopted for the delivery of DE courses by the Open University, or indeed any other educational organisation. However, researchers argue that in such computer-generated, three-dimensional CVEs, spatially separated learners are able to work together in the same virtual space, exchange ideas and learning materials, discuss their educational concerns with fellow students, and seek advice from a tutor (Fabri and Hobbs 1998). In such environments, students can *attend* virtual tutorials and seminars, take part in collaborative learning, and can carry their identity, belongings, moods, and preferences with them; they can interact with the environment and with each other in an intelligent and natural way. Indeed, Hobbs et al (2000) believe that CVEs may

bring back some of the social intercourse of *campus life* that is usually lost in distance education.

Similarly, Mitchell (1997) argues that educational CVEs allow the effective integration of learning resources and foster intuitive ways for information visualisation and access. Mitchell (1997) claims that some educational applications, e.g. medical training, architectural visualisation, flight simulation, and molecular models, can directly benefit from breaking the bounds of two-dimensional representation because of their natural affinity with 3D-objects, and other educational CVE applications can benefit indirectly, by offering the student a stimulating shared learning space in which various forms of interaction and collaboration methods are available. The environment acts as a sophisticated communication tool, he argues, enabling spatially separated learners to overcome the distance and work together effectively and efficiently. Gibbs (1998) argues that this can be of advantage in disciplines where the subject matter is predominantly theoretical and discussion-based, such as in social science or humanities.

Further, students working and collaborating in a CVE may create tools or objects (e.g. work aids, idea prototypes, discussion maps) that everyone uses, and therefore contribute towards a common goal. There is good evidence that in such learning environments, less well-qualified students can learn from the better qualified, and the latter can also gain valuable interaction skills (O'Malley 1995). Hence, when creating and administering educational CVEs, particular emphasis is to be put not only on student-teacher but also on student-student interactions (Bruffee 1999).

In sum, CVEs have great potential for DE, and with the demand for DE expected to further increase, may play an important role in future educational provision. The use of CVE technology to deliver DE raises several issues, however, one of which concerns the modes of learning within such environments.

2.3 Modes of Learning

The theoretical basis on which instructional models are based, Pask (1988) argues, affects not only the way in which information is communicated to the student, but also the way in which the student makes sense of, and constructs new knowledge from, the information that is presented. Sherry (1996) mentions two opposing views which impact on the design of distance instruction: symbol-processing and situated learning (Bredo (1994) provides a full description and comparison of these two approaches).

Until recently, the dominant view has been the traditional, information processing approach, based on the concept of a computer performing formal operations on symbols (Seamans 1990). Symbol-processing follows from the information processing theorists who embed learning in a computer analogy in which teachers transmit knowledge in a sequential manner which students intake, process, and recall for exams and tests. The key concept is that the teacher can transmit a fixed body of information to students via an external representation, i.e. representing an abstract idea as a concrete image and then presenting this image to the learner via some medium. The learner, in turn, perceives, decodes, and stores it. This model is sometimes referred to as the *Banking Concept of Education* (Freire 2000). A recent modification of the model involves the incorporation of two additional factors into the model: the student's context, such as environment, current situation and other sensory input, and the student's mind, such as memories, associations, emotions, inference and reasoning, curiosity and interest (Sherry 1996).

The alternative approach, i.e. situated learning, is based on constructivist principles, in which a learner actively constructs an internal representation of knowledge by interacting with the material to be learned. From a constructivist view, learning is the process of *constructing* knowledge - not merely obtaining it - in social environments (Brooks and Brooks 1993). The learning process proceeds as knowledge building through interaction (Scardamalia and Bereiter 1994). The theory of situated learning asserts that learning is fundamentally a product of the learning situation and the

nature of the learning activity. Learning tasks should thus, as far as possible, be embedded in the target context and require the kind of thinking that would be done in real life (Lave 1991). This is the basis for both situated cognition (Streibel 1991), where, as Light and Butterworth (1992) argue, *the physical context is being reunited with the social, within the thought process*, and for problem-based learning (Savery and Duffy 1995), an instructional method which supports learning in the target domain. According to the theory of situated learning, social and physical interactions enter into both the definition of a problem and the construction of its solution. The information to be learned is not specified outside the process of inquiry. Prawat and Floden (1994) argue that, to implement constructivism in a lesson, one must shift one's focus away from the traditional transmission (or *banking*) model to one that is much more complex, interactive, and evolving.

Though these two theories are totally different in nature, Simon (2000) argues that effective distance educators usually start with empirical knowledge: objects, events, and practices, which mirror the everyday environment of their designated learners. Then, with a firm theoretical grounding, they develop a learning environment, which enables learners to construct appropriate new knowledge by interacting with the learning material. On this approach, interaction is believed to be of key importance for the process of learning. Simon (2000), for example, claims that *human beings are at their best when they interact with the real world and draw lessons from the bumps and bruises they get*.

Indeed, Moore (1997) identifies three general types of interaction in education, characterised by interaction taking place between students and learning content, between students and teachers, and between students and fellow students. Laurillard (1993) argues that the interaction between student and learning content is well researched and frameworks exist for analysing educational media in terms of how they support the teaching-learning process and the different modes of learning. On the other hand, Laurillard argues, the student-teacher interaction as well as the student-student interaction is less well researched. This communication between the

participants in the teaching-learning process can potentially be facilitated within educational CVEs.

Further, it can be argued that the delivery of DE using CVE technology not only enables a high degree of interactivity between participants, but also learning situated in an environment resembling the problem domain. Considering interaction as the key factor for the process of learning, educational CVEs potentially allow students to hear and see teachers, and teachers to react to their students' comments and questions and students to collaboratively discuss their work with each other. Indeed, Hobbs and Taylor (1996) argue that in educational CVEs learning communities can potentially be formed, in which students and researchers throughout the world who are part of the same class or study group can interact at any time of the day or night to share observations, information, and expertise with one another.

The importance of these human-to-human types of interaction for the process of learning has been widely acknowledged (Laurillard 1993, Garrison et al 2001). In particular, these types of interaction allow mutual reflection on actions and problem solutions, motivation and stimulation as well as assessment and control of progress. Importantly for the current study the perceived importance of the situated learning approach adds to the *prima facie* case for the use of CVEs in DE, given that CVEs can facilitate such an approach. A comprehensive model for the process of situated learning based on interaction and reflection, referred to as the *guided discovery* approach, is proposed by Laurillard (1993).

2.3.1 Guided Discovery

The model of learning through guided discovery is widely valued in the academic community (Bentley 1998). It is claimed (Laurillard 1995) to propagate active reflection on the side of both the student and the teacher, and to integrate the student's experiential and conceptual knowledge of the learning subject. The model emphasises the cyclic process of guided discovery (cf. figure 2.3); it is based on the following four entities:

1. the teacher's conceptual knowledge of learning material and desired outcomes
2. the student's conceptual knowledge of the learning material in general
3. the student's experiential knowledge of the learning environment
4. the learning environment constructed by the teacher

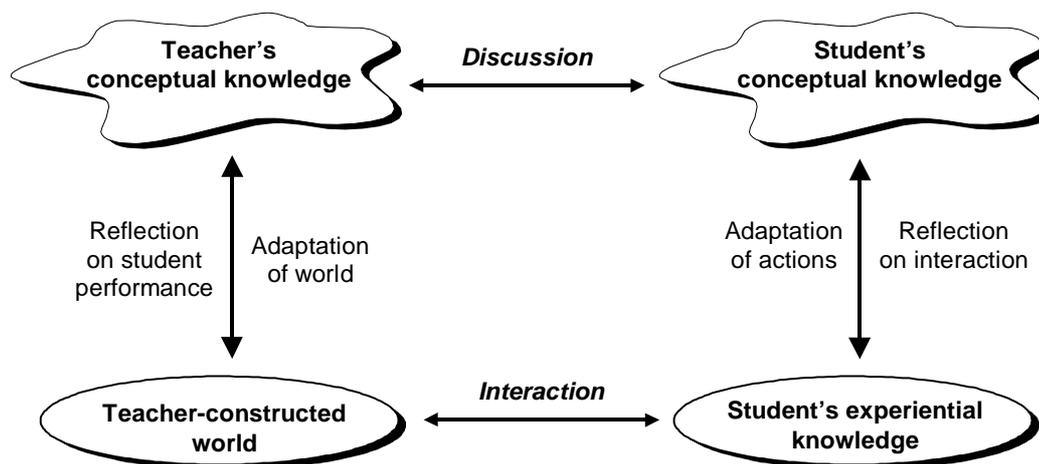


Figure 2.3: Laurillard's Model of Guided Discovery

By interacting with the teacher-constructed learning environment, the student gains experiential knowledge of the material presented. When subsequently reflecting on the interaction, the student builds up their conceptual knowledge of the learning domain in general. At the same time, the teacher reflects on student performance and adapts the learning environment accordingly. The role of the teacher is thus very adaptive and influenced by the mode of learning, the mode of delivery and the level of interaction. Indeed, Perraton (1988) defines the role of the distance teacher as being a facilitator of learning, rather than a communicator of a fixed body of information.

One important aspect of learning not explicitly mentioned in the context of Laurillard's *guided discovery* approach is that of students collaborating with each other. Such interaction between students, which takes places in traditional face-to-face learning, can also, it will be argued, be facilitated by CVEs.

2.3.2 Collaborative Learning

The concept of collaborative learning involves the grouping and pairing of students for the purpose of achieving academic goals. The term *collaborative learning* refers to an instruction method in which students at various performance levels work together in small groups toward a common goal. In situations of collaborative learning students are responsible for one another's learning as well as their own, thus the success of one student can help other students to be successful (Tinzmann et al 1990).

When one pair member is more knowledgeable than the other, it is easy to understand that the latter learns from the former. What is perhaps more surprising is that the more able peer tends also to benefit from collaborative learning (Littleton and Hakkinen 1999). It is now well documented that providing an explanation improves the knowledge of the explainer himself, even more sometimes than the explainee's knowledge (Dillenbourg and Schneider 1995). This effect is known in the cognitive science literature as the *self-explanation effect*. Chi et al (1989) for example showed that asking students to explain aloud some physics examples helped them to proceduralise their declarative knowledge of physics, make explicit some implicit problem solving steps and subsequently therefore become more efficient in solving similar problems.

Proponents of collaborative learning claim that the active exchange of ideas within small groups not only increases interest among the participants, but also promotes critical thinking (Gokhale 1995). According to Johnson and Johnson (1986), there is persuasive evidence that cooperative teams achieve at higher levels of thought and retain information longer than students who work quietly as individuals. The shared learning gives students an opportunity to engage in discussion, take responsibility for their own learning, and thus become critical thinkers (Totten et al 1991). According to Vygotsky (1978), students are capable of performing at higher intellectual levels when asked to work in collaborative situations than when asked to work individually

as group diversity in terms of knowledge and experience contributes positively to the learning process.

Indeed, Bruner (1985) argues that effective communication and collaboration are essential to becoming a successful learner, as it is primarily through dialogue and examining different perspectives that students become knowledgeable, strategic, self-determined, and empathetic. Moreover, involving students in real-world tasks and linking new information to prior knowledge requires effective communication and collaboration among teachers, students, and others (Bruner 1996). Collaborative learning affords students enormous advantages not available from more traditional instruction because a group can accomplish meaningful learning and solve problems better than any individual can alone (Bruffee 1999).

2.4 Guided Discovery in Educational CVEs

It can be argued, then, that a collaborative guided discovery approach to education may be very beneficial. Figures 2.4 and 2.5 (cf. Gerhard et al 1999a) illustrate how this process of collaborative learning through guided discovery can be catered for within a CVE. In this model, as in Laurillard's model (cf. figure 2.3), the learning content in the virtual world is teacher constructed. Interaction with the content as well as communication with other participants however is avatar-mediated.

Figure 2.4 shows that by reflecting on the content as well as on student-teacher and student-student discussions within the CVE, the student potentially builds up a model of the virtual world. In addition, the student may develop their awareness of 'virtual self' within the learning environment. As in Laurillard's model of learning through guided discovery, actions and expectations are influenced by, and adapted to, the environment, and the experiential model may become part of the student's conceptual knowledge.

In this scenario, the avatar is the primary interaction device for interacting in the CVE. Firstly, it enables the participants to be aware of, and relate to, each other.

Secondly, it potentially enables the learner to express their current emotional state and their ability to interact and communicate. Thirdly, it provides the other participants with visual clues about a particular user's current actions and about the effects these actions have on the learning environment.

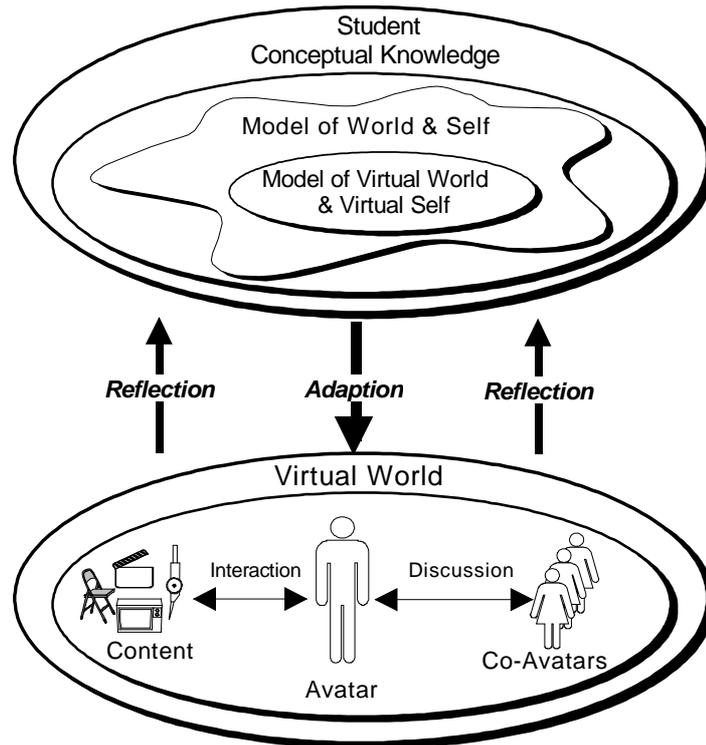


Figure 2.4: Student's Perspective of Learning in a CVE

Figure 2.5 illustrates how teacher, student, and fellow students are interconnected within the CVE, potentially enabling collaborative learning.

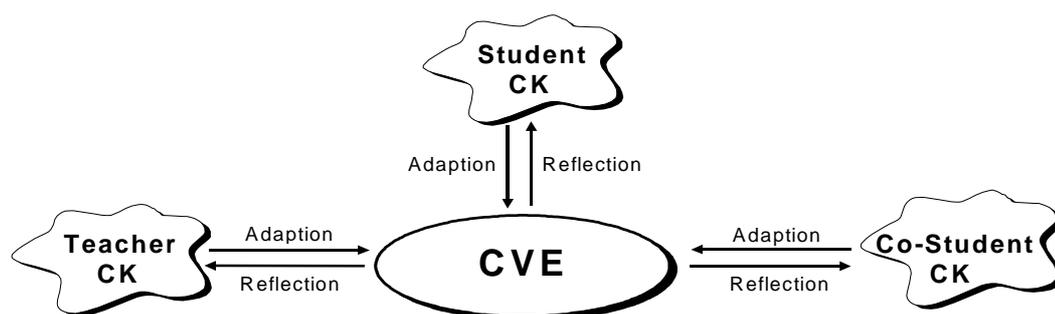


Figure 2.5: Model of Guided Discovery in CVEs

(CK = Conceptual Knowledge)

2.5 Summary

In this chapter it has been argued that DE is becoming increasingly important, and that CVE technology is a promising means of DE provision. In particular it has been argued that CVEs can provide a means of enabling guided discovery and collaborative learning in a DE context. Once DE using CVE technology becomes widely deployed, students are likely to want to attend virtual tutorials, virtual seminars or take part in project-based collaborative learning, carrying their identity, attributes, belongings, moods and preferences with them. They will want to interact with the environment and with each other in an intelligent and *natural* way. They will want to communicate and collaborate synchronously as well as asynchronously, in other words in their presence and absence respectively. However, there are crucial aspects of CVEs not yet fully understood, in particular, how to represent participants using avatars, and how to cater for users in their absence. A hybrid avatar/agent model will be proposed in the next chapter, which is believed to be potentially capable of providing this functionality.

Chapter 3 - User Embodiment

Within this chapter, based on a review of relevant literature and existing practice in CVE applications, a theoretical underpinning for understanding the relevance of user embodiments within a CVE is expounded and discussed. Firstly, a brief introduction to philosophical issues concerning embodiment is given (3.1) highlighting the importance and potential of embodiment in CVEs. Further, issues concerning in particular avatars in CVEs (3.2) are discussed and different types of existing avatars outlined (3.3). Finally, visions for the future use of avatars are depicted and a hybrid avatar/agent model is proposed (3.4).

3.1 Philosophical Views on Embodiment

Issues regarding the meaning of embodiment have been widely discussed by researchers in the areas of psychology and philosophy. During the twentieth century, many thinkers made the *body* a central philosophical issue. This is particularly true among French and German philosophers, such as Marcel (1927), who concludes that *I am my body*, Heidegger (1927) and Sartre (1943), who devoted lengthy sections of their work to the analysis of the body as a fundamental modality of *being-in-the-world*, and Merleau-Ponty (1945), who considered the body as an *element of perception itself*.

Heidegger was interested in the body in order to find answers to the *question of being*. He argued that the individual as *being-in-the-world* was characterised by actions performed with their body and by their anxieties concerning the limits of their existence. He regarded his investigations as an attempt to disclose or uncover the role of the body with respect to the concealed nature of *being*.

The model of the *Self*, provided by Sartre (1943) in *Being and Nothingness*, and later embraced by Merleau-Ponty (1945), offers a three-part model of *being*:

- Being-For-Itself
- Being-For-Others
- Being-In-The-World

In this model the *Self* has three components, two of which, the second and the third, are outside the subject self's total comprehension; the first, *Being-For-Itself*, incorporates the subject self's action, will, and idea (Santoni 1995). In *Being-For-Itself*, the *Self*, constituted by its past, present, and future, constructs an image of itself that *has its genesis in history but that encompasses the uncertainty of the present moment as well as the unrealised potentials that lie in the future; it combines both the concrete and the abstract, the known and the knowable unknown* (Sartre 1943). In *Being-For-Others*, the *Self* constructs an image of itself as an object, as it is observed by everybody beyond the borders of itself. *This reverse virtual image lies in a twilight zone, for the Self's apprehension of the Other's perception of itself is at best partial and incomplete, and more likely mistaken* (Sartre 1943). The *Being-In-The-World*, as investigated by Heidegger (1927) earlier, derives from *an individual's consciousness of the world as the sum of the possibilities*, where the body is seen as a *fundamental modality for Being-In-The-World* (Sartre 1943).

Further, Lefebvre (1974) argues that every human being has the necessity of being located in *space*, where space can be a physical location, e.g. a room, a theatre, a library, or it can exist simply as conceived by the mind. He argues that *place is prior to all things and everything is somewhere and in place*. The reason for the necessity of *implacement*, in Lefebvre's view, is that, through their bodies, individuals need to interact and engage in the creation of relations in order to understand the limits of their existence. *Humans are born in a certain space and time, and grow up among relations and interactions with both other people and locations; through their bodies individuals are immersed in space, from space they obtain all the necessary*

information to build their physical and mental sphere, gaining an image of the world that goes beyond what the sensorial organs communicate (Lefebvre 1974).

Although a comprehensive literature review investigating the issue of embodiment in philosophy is beyond the scope of this thesis, the theoretical constructs its philosophical study raises, in particular Heidegger's thoughts regarding the *question of being*, Sartre's model of the *Self* and Lefebvre's notion of *place*, are believed to be potentially relevant to the exploration of issues concerning user embodiments in CVEs. Biocca (1997) argues that the virtual body can be considered as merely an extension of the physical body and that *the virtual body is a representational medium of the mind and the fundamental communication hardware* in a virtual environment. Therefore, similarly to Heidegger who argued that the human body is a *fundamental modality of Being-In-The-World*, it can be argued that virtual embodiments are a *fundamental modality* of being in a CVE, and thus their deployment in CVEs is seen as crucial.

Further, recent considerations from the social psychology approach, specifically addressing the phenomenon of *identity* are believed to bear further relevance to the current investigation. Although Damasio (1994) believes that Descartes is fundamentally wrong by separating the mind and the body and that identity substantially coincides with the body, in CVEs social identity and individual identity are not seen as stable characteristics of individuals, but rather as dynamic phenomena (Hermans 1996). The concept of *positioning* (Harre and Van Langenhove 1991) widens the notion of *role* based on stable and recognisable identity, adding the relevance of participating within a complex context, such as a CVE, where participants can assume several different possible identities within the same environment. From Harrè and Van Lagenhove's point of view, the choice about what possible *Self* to show is driven by strategic roles that participants are acting within that situation.

Thus, *positioning* is related to the person's perception of how that social situation is characterised and what features could be more relevant and more effective in that specific situation. Playing out different identities becomes a resource (Antaki and

Widdicombe 1998) that participants can use to give relevance to their arguments within an interactive discourse. For example well-known cartoon characters (e.g. *Homer* from The Simpsons television series) or celebrity look-a-like characters (e.g. the film actress *Marilyn Monroe*), which have certain character traits and attitudes associated with them, are very popular in current online communities (Gerhard et al 2002).

The cultural psychology view stresses the importance of studying CVEs as *activity systems* where meanings are co-constructed, i.e. as the *place* where meanings and identities are built and negotiated among members (Cole 1995). Similarly, Donath (1998) argues that identities in CVEs are co-constructed, situated, non-stable, and can be acted out; thus embodiment is seen as only one of the elements in play when negotiating identity and *positioning*, as the specific contexts and situations are also shaping the virtual presences and identities. From this point of view the participants' *positioning* can be seen not only as an individual *move*, but also as a phenomenon that is both context shaped and context renewing (Schegloff 1992), extending earlier philosophical views regarding body and place.

Indeed, even in the non-virtual world, recent theories of identity suggest that each individual is composed of a *multiple populated self* (Gergen 1991) with *many voices, not necessary harmonized to each other and sometimes even in conflict* (Glass 1993). Perkins (1993) argues that action and communication are at the base of the *constructive and interpretative process of building identities* and that those processes are distributed into the context composed by other entities and relationships. In line with this, some literature (Taylor 1999, Cassell and Vilhjálmsón 1999) calls for a development of CVEs based on the centrality of the progressive or full embodiment of the self into the computer interface. It can be argued, however, that such an embodiment need not, and perhaps should not, resemble embodiment in the non-virtual world. Hermans et al (1992) argue that being embodied the individual is not able to "*fly above*" *their position in space and time*. In a CVE however, *flying over*, as well as passing through 3D objects, is a very easy and therefore rather usual activity that virtual bodies carry out, and this gives a completely different nature to

the *body* used to represent them. In line with this, Stone (1991) argues that the development of virtual identities differs from the development of real-world identities and Featherstone and Burrows (1995) believe that the virtual body has *the potential for intellectual disembodiment and transcendence of flesh and bone*.

In sum, this section discussed diverse thoughts of twentieth century philosophers concerning the human body, who essentially consider the body a *fundamental modality of being in the world* (Sartre 1943) and an *element of perception* itself (Merleau-Ponty 1945). Lefebvre (1974) underlines the importance of the body with respect to, what he calls, *implication*, the need of humans to interact with their environment and to engage with others in order to understand the limits of their existence. In CVEs, therefore, the deployment of virtual bodies is seen as crucial to enable such interaction and engagement. Furthermore, it was argued that *identities* in virtual environments could be *dynamic* (Hermans 1996). The concept of *positioning* (Harre and Van Langenhove 1991) and the theory of the *multiple-populated self* (Gergen 1991) are seen as particularly relevant in the current context, as in CVEs users may potentially select their preferred virtual representation from a range of different bodies or even design their own. Given that users can choose their virtual bodies, *playing out different identities can become a resource* in such environments (Antaki and Widdicombe 1998). Further issues concerning user embodiments in CVEs, in particular the type of embodiments that users might adopt to play out such identities, are discussed next.

3.2 Avatars in CVEs

A user embodiment in a CVE is called *avatar*. The word avatar comes from the Sanskrit language and can be translated as *incarnation* or *God's appearance on earth*. In Hindu mythology a God called Vishnu is believed to have visited earth nine times to curb evil. For each visit he took a different incarnation, called an *avatar*. It was first used in the context of virtual worlds in the pioneering Habitat system of the mid 1980s (Morningstar and Farmer 1991) and popularised by Stephenson's (1992)

science-fiction novel *Snow Crash*. Researchers and developers of virtual reality systems have produced a rich variety of definitions of the term. A synopsis of avatar definitions leads to a characterisation of an avatar *as the representation of a user's identity within a multi-user computer environment* (Gerhard and Moore 1998).

The role of the avatar, in providing a tangible representative form of the user, is a crucial element that distinguishes CVEs from other social spaces in disembodied chat systems (Rossney 1996). The avatar as a bodily presence in virtual space provides a focus for conversation and social interaction (Slater et al 2000). Avatars can talk to each other, providing, in effect, the equivalent of a face-to-face communication between users. The selection of the avatar is also important in the formation of the virtual persona, just like the physical body is at the core of our real-world identities (Donath 1998).

Considering the role of our bodies in face-to-face communication, the motivation for, and importance of, embodying users within collaborative systems becomes clear. Humans use their bodies to provide immediate and continuous information about their presence, activity, attention, availability, mood, status, location, identity, capabilities and many other factors. Human bodies may be used explicitly to communicate, e.g. by gestural sign languages, or may provide an important accompaniment to other forms of communication, so called *body language* (Benford et al 1995).

Benford et al (1995) argue that issues of user embodiment are clearly important when designing CVEs, and that many of these issues are equally relevant to co-operative systems in general, where embodiment has often been neglected. They point out that *without sufficient embodiment, users only become known to one another through their disembodied actions and disembodied speech*. Furthermore, they argue that not only is the appearance of the virtual body important but also its functions, behaviours and its relation to the user's physical body and how the avatar is manipulated and controlled. Taylor (2002) argues that *through avatars, users embody themselves and make real their engagement with a virtual world*. One particularly significant aspect of avatars concerns social facilitation.

3.2.1 Social Facilitation

The use of avatars in CVEs potentially entails several useful properties within a virtual environment, such as identity, presence, subordination, authority, and social facilitation. Avatars may provide a way for other users to better understand the intended persona of the underlying user, his identity. They may help establish a feeling of *being there*, a form of presence within a multi-user virtual environment. They may imply subordination, i.e. being under the direct control of the user, without significant control over their own actions and internal state (Damer 1998). Avatars may also facilitate social encounters in the virtual world and may imply to others that they are acting with the authority of the underlying user.

As humans, we do not rely upon a single mode of communication in order to impart information to others; we use a myriad of devices and channels, choosing which is most appropriate at the time. Factors affecting our preferred choice of communication include with whom we are communicating, the willingness to communicate, the communication methods available, the spatial proximity and the availability of time (Morphett 1996). An avatar is a proxy for the purposes of simplifying and facilitating the process of inter-human communication in a virtual world, as we not only identify with our own body, we also recognise the existence of others through their bodies. Given this, and given that avatars can cater for bodily identity, avatars can potentially provide presence and social facilitation for all participants in a CVE.

3.2.2 Non-Verbal Communication

New media, such as CVEs, force researchers to analyse what is fundamental about communication (Whittaker and O'Conaill 1997). Abercrombie (1968) argues that conversation relies on all channels of communication through which information is exchanged by individuals during face-to-face interactions. Language is closely linked to and supported by, non-verbal communication, which adds to the meaning of

utterances, provides feedback, controls synchronisation and also plays a central role in human social behaviour (Argyle 1990)

The face is one of the most important areas for non-verbal signalling. In general, facial expressions are indicators of personality and emotions, serving also as interaction signals (Ekman and Friesen 1975). Facial expressions provide feedback and information about the listener's level of understanding while revealing interest, puzzlement or disbelief. In addition, affective expressions allow listeners to infer the speaker's current emotional state and communicate their audience's emotional reaction to what is being said.

Similarly, gaze is a general indicator of attention and can be directed at other conversational participants in face-to-face interaction as well as at features of the physical environment (Argyle and Cook 1976). Gaze is closely coordinated with verbal communication. It is used to obtain feedback on the other's responses while talking and extra information about what is being said while listening. In addition, shifts of gaze are used to regulate the synchronisation of speech. Gaze is also used as a signal in starting encounters, in greetings, as a reinforcer and to indicate that a point is understood.

Further, the hands, and to a lesser extent the head and feet, can produce a wide range of gestures. Gestures are closely coordinated with speech and support multiple communication functions (McNeill 1992). They are used to co-ordinate conversational content, achieve reference and assist in turn taking. Conventional gestures are usually intended to communicate and are normally given and received with full-awareness.

Posture is also an important means of conveying interpersonal attitudes and is associated with emotional states. Posture is the information supplied by the orientation of a conversational participant's body. Posture accompanies speech in a similar way to that of gesture and provides feedback to the speaker about how the message is being received. Body position and orientation can also be used to include or exclude people from the conversation.

Finally, self-representation can be regarded as a special kind of non-verbal communication. In general, the main purpose of manipulating appearance is to send messages about oneself. Thus, people send messages about their social status, their occupation, their personality or their mood. Appearance is also used to signal attitudes towards other people: for example, aggression, rebelliousness and formality.

Bodily contact and physical touch seems to have a primitive significance of heightened intimacy evoking increased emotional arousal. Some forms of bodily contact are used as interaction signals like greetings and farewells or as attention signals. However, the precise meaning of a particular form of touch depends on the culture.

Summarising, non-verbal communication is an important issue for avatars and the subject of much on-going research into CVEs (e.g. Fabri et al 2002). However, as current CVE technology is restricted to low-polygon avatars, mainly due to current bandwidth limitations, few of the desired channels of non-verbal communication are supported by current systems.

3.3 Types of Avatars

Animated low-polygon VRML avatars are of particular interest within the current framework since in effect they represent the *state-of-the-art* concerning avatars for Web-based CVEs. These avatars are user-guided, in that the user triggers action sequences by defining tasks to perform, such as walking, and the avatar uses its motor skills to perform this action by animated joint movements (Thalmann 2001).

A good overview of the current state-of-the-art in popular avatar development is provided annually by the *Avatar* conference held in ActiveWorlds. Here, popular avatars used in current CVEs such as ActiveWorlds fall into two main categories, *cartoon* and *human*, and cartoon-style avatars in turn fall into two further categories, *animal* and *fantasy*. Examples of current avatars developed by users themselves, as

shown in table 3.1 and 3.2, were selected from over 100 entries for the AVVY Awards 2001, which were part of Avatar 2001.

Furthermore, commercial interest in avatars for CVEs is increasing rapidly and low-polygon VRML avatars are available for sale (see figures 3.1 and 3.2).



Figure 3.1: Geo-metrics Commercial Avatar (Theo)

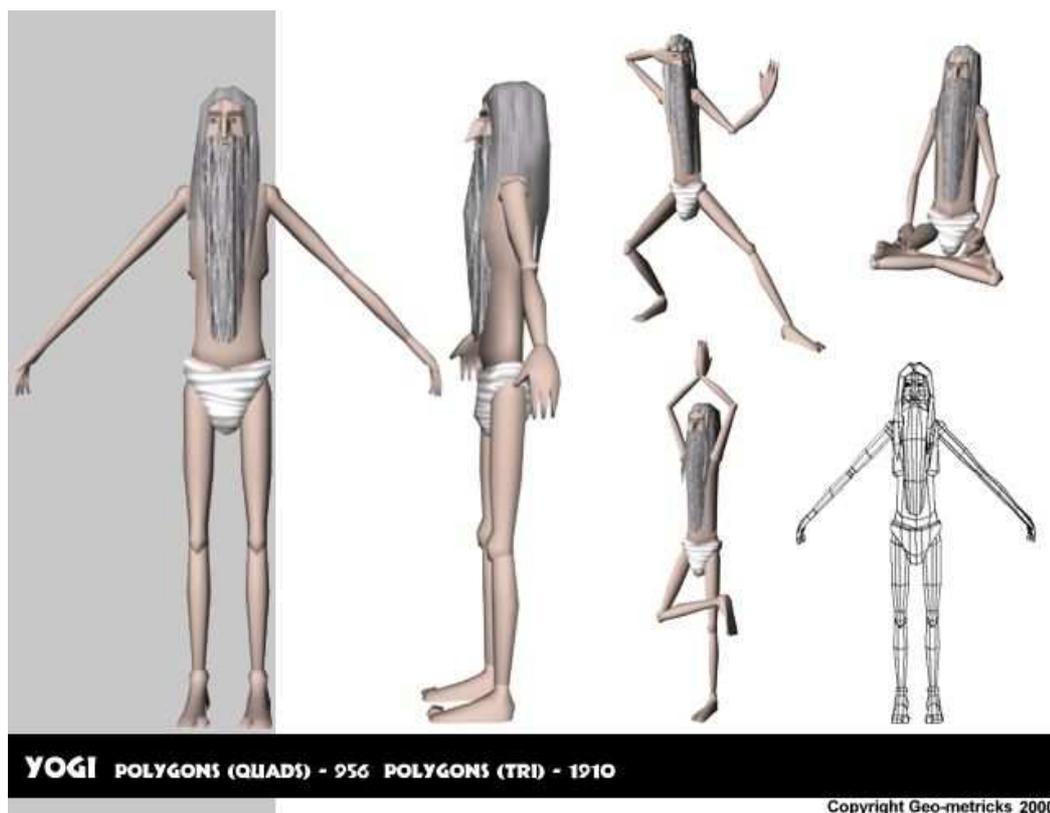


Figure 3.2: Geo-metricks Commercial Avatar (Yogi)

3.3.1 Cartoon Avatars

Some cartoon characters have very specific cultural significance and may even represent archetypal personality types (e.g. Bugs Bunny as the confident trickster or Aladdin's genie as the powerful but benevolent friend). Rather than relying on childhood cartoon figures, some adults choose cartoon avatars of a more sophisticated fantasy style (see table 3.1).

	<p>Category: Cartoon – Animal</p> <p>Snail By Diane Colover (Adobe Atmosphere)</p>
	<p>Category: Cartoon – Animal</p> <p>Panda By Paul Barrow (Active Worlds)</p>
	<p>Category: Cartoon – Animal</p> <p>Buzz By Fabian van der Hoeven (Adobe Atmosphere)</p>
	<p>Category: Cartoon – Fantasy</p> <p>Nutcracker by Carol Reynolds (Active Worlds)</p>
	<p>Category: Cartoon – Fantasy</p> <p>Peppermint By Susan Katarzis (Active Worlds)</p>

Table 3.1: Cartoon Avatars Entered for the AVVY Awards

3.3.2 Human Avatars

Human avatars resemble real human bodies to a greater or lesser extent (see table 3.2). They usually include the human face and full human body and may or may not have similarities with the underlying user. Wilcox (1998) argues that in CVEs it is crucial to differentiate between user embodiments and other objects in the environment at first glance, and human avatars are easily differentiated from the other objects in the scene.

Further, using human avatars regularly, the user has an authentic and coherent representation in the virtual world, and by changing the decoration of the body through clothes and accessories, the representation can also have an emergent identity (Capin et al 1998). The ease and freedom for users in selecting different avatars arguably encourages well known identity deceptions that occur in online social interaction such as gender-swapping, race shifting and exaggeration of physical characteristics (Donath 1998).

	<p>Category: Human Princess by Dyonis Herve (Active Worlds)</p>
	<p>Category: Human Sean by Volker Hatzenberger (Active Worlds)</p>

	<p>Category: Human Jennifer by Paul Barrow (Active Worlds)</p>
	<p>Category: Human BraveHeart by Michael Beckwith (Active Worlds)</p>
	<p>Category: Human Katja By Alex Assche (Active Worlds)</p>

Table 3.2: Human Avatars Entered for the AVVY Awards

3.4 Visions for Future Avatar Development

Avatars are subject to much speculative debate, with the driving force behind avatars being the ongoing search for an interface that is easier and more comfortable to use. Avatars are on the cutting edge of user interface design, providing new ways for people to interact with their computers and with other users over global computer networks. Computer interfaces have evolved from command-line prompts to graphical user interfaces, but a desktop metaphor based on files and folders and the abstractions of menus and icons are not always intuitive and can be difficult to grasp (Dix et al 1998). By simulating the social interaction of real life, avatars can convey an environment that is more familiar than graphical desktops and command-line

prompts. However, although it has been argued that *avatars can put a friendly face on an inscrutable machine* (Damer 1998), avatars will not necessarily replace menus, icons, and other elements of the current graphical user interface; instead, they may play the role of helpful assistant, guide, and peer. Furthermore, avatars can potentially not only act as a medium for verbal communication, but also be controlled by speech (e.g. user utters “*turn right*” into a microphone), as an alternative to currently predominant motion capture techniques (e.g. keyboard, mouse, or joystick to navigate the avatar) (Cavazza et al 1998).

More generally, in the novel *Neuromancer*, Gibson (1984) describes his vision of a global computer network as an immersive space, a parallel dimension into which people could be transferred via neural implants. This was a shared graphical space, not constrained by the laws of a physical reality, allowing people to interact with remote programs, objects and other people as if they were locally present. Another interesting novel in the context of visioning user embodiment in future CVE is *Snowcrash*, where, in a near-future scenario, Stephenson (1992) describes the *Metaverse*, a computer-generated universe in which people can conduct their business and have social encounters (see quote below). The Metaverse has streets, office buildings, houses, stores, bars, public transport system and just about everything else found in the real world, including real people represented by highly realistic avatars.

“As Hiro approaches the Street, he sees two young couples, probably using their parents’ computer for a double date in the Metaverse, climbing down out of Port Zero, which is the local port of entry and monorail stop. He is not seeing real people, of course. This is all part of the moving illustration drawn by his computer according to the specifications coming down the fibre-optic cable. The people are pieces of software called Avatars.” - Neil Stephenson, Snow Crash

3.4.1 A Hybrid Avatar/Agent Model

User representations via avatars are therefore crucial to CVEs. The vision of *permanent* user representations in educational CVEs achieved by a hybrid avatar/agent model (Gerhard 1997) underlies and underpins the current research. It may be a vision; however, it is much less fictitious than those depicted by Gibson (1984) and Stephenson (1992) in their novels. Given that in educational CVEs the need for both synchronous and asynchronous forms of communication and collaboration will arise, a continuous intelligent presence of all participants involved in the teaching-learning process seems potentially beneficial.

A hybrid avatar/agent model is seen as a potential means of achieving this form of permanent embodiment in CVEs (Gerhard and Moore 1998). In the absence of the underlying user, the avatar can function as an intelligent agent, perceiving and responding within the environment, giving, receiving and filtering information in order to fulfil a predefined task.

The avatars in CVEs represent participants when they are online (see figure 3.3). Avatars imply subordination through being under the direct control of the user and facilitate social encounters while acting with the authority of the underlying user. Avatars may foster a feeling not only of presence, but also of *copresence*, that is the awareness of others, so-called co-avatars, within the CVE. Huxor (1998) argues that if members of a group are not co-present, there is a lack of community feeling. Thus, avatars can provide presence and copresence and hence a social facilitation of all participants within a CVE.

In the absence of the underlying user agent technology can in principle drive the avatar (see figure 3.4). The avatar is then potentially able, despite the user's absence, to interact with the virtual environment and other students by giving, receiving and filtering information to fulfil a task predefined by the underlying user, and to simulate copresence for other participants.

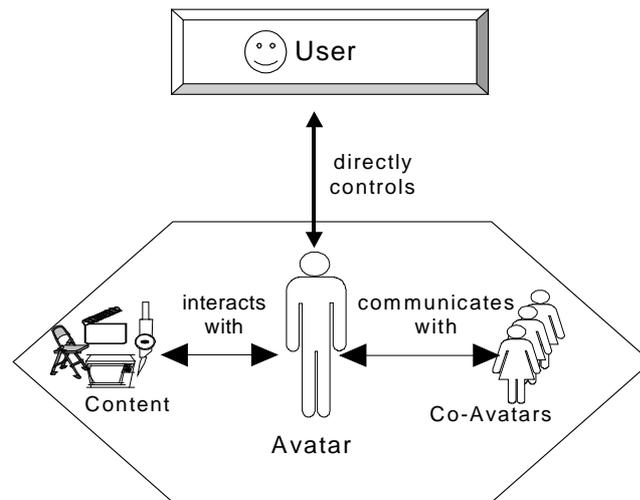


Figure 3.3: Direct Manipulation of Avatar (user is online)

The autonomous character of agents and the subordinated character of avatars might initially seem to be contradictory. However, considering that a hybrid avatar/agent model can represent the user in presence as well as absence it is not really paradoxical. With the user being present the avatar operates under direct control, but with the user being absent, the avatar, extended with agent technology, can exercise control over its own interactions with other users and the environment.

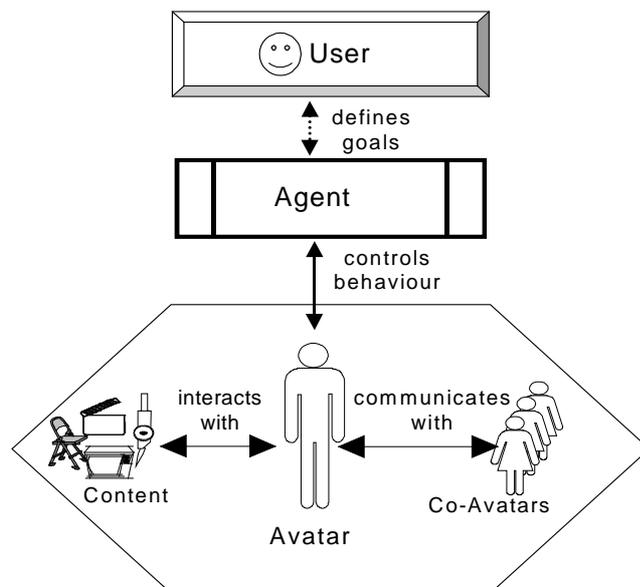


Figure 3.4: Agent in Control of Avatar (user is offline)

Intelligent agent technology in principle allows the user to customise the avatar's behaviour for the times of absence and therefore to influence the avatar's operations towards a predefined goal.

A continuous representation of all participants involved in the teaching-learning process is seen as crucial for the optimal educational use of CVEs (cf. Gerhard et al 1999a). A new and potentially valuable aspect of agents in collaborative virtual learning environments is that of presence-in-absence. In the absence of the underlying user an embodied agent, interacting with the environment and communicating with other students by giving, receiving, and filtering information in order to fulfil a predefined task, can achieve a form of virtual presence. Embodied conversational agents may be the key to a continuous virtual presence of students and teachers within such environments.

3.5 Summary

Based on a review of literature and existing CVE applications, theoretical underpinnings for the importance of user embodiments within CVEs have been expounded. The issue of embodiment has been traced back through its origins in philosophy and psychology literature and theories were identified, potentially helpful in understanding some of the issues concerning user embodiments in CVEs. Current types of avatars have been depicted and the importance of avatars in CVEs for social facilitation and non-verbal communication has been discussed. Visions for the future use of avatars, particularly a hybrid avatar/agent model for representation and embodiment of users in educational CVEs were outlined. However, despite the centrality of avatars to CVEs, little experimental or empirical research has been conducted into the psychological dimensions of the use of avatars in CVEs. A key aim of this thesis is to contribute to the provision of such research. A pre-requisite to this is to select a suitable evaluation regime. The next chapter therefore focuses on the experimental exploration and evaluation of the concept of a hybrid avatar/agent model.

Chapter 4 - Evaluation Methods

This chapter discusses evaluation techniques with respect to their potential appropriateness for the current study (4.1). It is argued that a combination of controlled experimentation, quasi-experiments, review-based evaluation and heuristic expert reviews is needed. To operationalise these traditional evaluation methods the concept of *presence* is introduced (4.2); it is argued that presence as a cognitive variable can be measured and that such a measure is a key indicator of the usability of CVEs (4.3). Further, a case is made for the use of questionnaires as a suitable means of measuring presence (4.4).

4.1 Evaluation Techniques

According to Preece et al (1994) evaluation is concerned with gathering data about the usability of a design or system by a specified group of users for a particular activity within a specified environment, and the usability of an interface can be defined as a measure of the ease with which a system can be learned or used, its effectiveness and efficiency, and the attitude of its users towards it.

The past decade has seen the development of a completely new generation of computer system interfaces. There has been a move from textual interfaces to graphical interfaces, multimedia and virtual environments. At the same time, systems have evolved from being single-user oriented to multi-user systems. Further, there are currently almost as many ways to evaluate systems as there are systems and it is important that the method used to evaluate a system addresses the uses for which the system was designed (Dix et al 1998).

Careful choices must be made from the broad range of evaluation techniques to create a suitable and balanced diet of evaluation methods, with the determinants of the specific diet including (Shneiderman 1997, Nielsen 1993):

- Stage of the design (early, middle, late)
- Novelty of the project (well defined versus exploratory)
- Number of expected users
- Criticality of the interface (e.g. life-critical medical system versus Web site)
- Costs and available time
- Experience of the evaluators

Moreover, there are important issues to consider for all types of evaluation approach (Preece et al 2001):

- The characteristics of the users of the system who take part in the evaluation (e.g. experience, age, gender, psychological and physical characteristics)
- The types of activities that the user will perform (which may be tasks defined and controlled by the evaluator, or activities chosen by the user).
- The environment of the study (which can range from a controlled laboratory situation to completely natural setting).
- The nature of the system being evaluated (which can be early prototypes or fully developed products).

As a result of such considerations, it is argued (Kaur et al 1998), that any one traditional technique used in HCI (Human Computer Interaction) to evaluate interfaces is unlikely to address the full range of aspects, which are now involved with a particular design, system or technology.

All these evaluation issues are inherited by any CVE evaluation attempt. In addition, a crucial difficulty concerning the usability evaluation of educational CVEs is the fact that CVE is a very recent technology and has not yet been adopted by any educational institution for the delivery of DE courses (see chapter 2 and Gerhard and Fabri 1998). Thus, only prototypes of truly collaborative, three-dimensional

educational CVEs currently exist, and therefore, objective evaluation results based on task performance in existing educational systems are not available.

Consequently, the evaluation approach chosen for the current research, although founded on general HCI usability principles, required a specific diet of evaluation techniques dependent on the characteristics of the system to be evaluated as well as on the purpose of the evaluation itself. Methods of evaluation seen as particularly applicable to the current research are controlled experimentation, quasi-experimentation, review-based evaluation and heuristic expert reviews. Each will now be briefly considered.

4.1.1 Controlled Experimentation

Controlled experimentation supports the scientific method, which is the process of proposing and verifying or rejecting hypotheses (Myers 1999). The first step of the scientific method is to develop a theory, from which a hypothesis is formed, which is a statement that can be tested. Once the hypothesis is formed the experiment can be carried out. Independent and dependent variables are identified and the method by which they will be manipulated and observed is decided upon. The observations are then made on the behaviour, the results are analysed, and the original theory refined. It may be that results verify or reject a specific hypothesis; either way, Myers (1999) claims, *the results of a carefully conducted experiment are meaningful and can further the theory.*

Further, Howell (1997) claims that controlled experimentation is considered to be the most rigorous of the research methods. Controlled experimentation provides internal validity or certainty, if the outcome is a function of the approach being tested rather than of other causes not systematically controlled for in the research design. A research study, that is, has external validity or generality, if its results will apply in the real world. Tuckman (1999) claims that the process of carrying out an experiment requires exercising some control over the environment, and that this contributes to internal validity while producing some limitation to external validity. By regulating

and controlling the circumstances of inquiry, as occurs in an experiment, the researcher increases the probability that the phenomena under study are producing the outcomes witnessed, thus enhancing internal validity. However, at the same time, the researcher decreases the probability that the conclusions will hold in the absence of the experimental manipulations, thereby reducing external validity.

Controlled experiments have greater internal validity than non-experimental methods and so generate greater confidence that the results came from the manipulation of the independent variable and not from extraneous variance (Kerlinger and Lee 2000). Without procedures to provide some degree of internal validity one may never know what has caused the observed effects to occur (Tuckman 1999). An advantage is the ability to use robust statistical tests on the data obtained (Howell 1997).

Since the key objective of the current research is indeed to further the theory, in particular to seek evidence for the potential benefits of certain forms of user embodiments, controlled experimentation is considered to be of key importance. Although controlled experiments are not appropriate for every research situation, there are several advantages if a research question can be tested in a controlled environment. The current study seeks evidence concerning the potential benefits of a hybrid avatar/agent model within *prototype* CVEs. To enable reliable predictions concerning the effects of user embodiments in CVEs, the experiments conducted for this research require a high degree of internal validity, that is a controlled environment, to ensure that it is the phenomena under study, namely different forms of embodiments, that produce the observed outcomes. This is achieved by manipulating an independent variable, which is related to the different forms of embodiments under investigation and has at least two treatments, and observing the outcomes, which are also known as the dependent variables - factors that depend on the behaviour of the independent variable.

One drawback of controlled experimentation is that fewer research questions can be explored because of the amount of control involved. Not every research question can be brought into a lab and broken down into independent and dependent variables. There are critics who say that the artificial environment of a controlled experiment

can distort participant behaviour and that the findings are not applicable to real-world situations (Kerlinger and Lee 2000). The current study attempts to overcome such limitations, by conducting a further so-called *quasi-experimentation* in addition to the controlled experiments. This is considered in the next section.

4.1.2 Quasi-Experiments

Quasi-experimental designs, also called *field studies*, are a common alternative to controlled experiments with random assignment; Kerlinger and Lee (2000) argue that a quasi-experimental design is a controlled experiment without all the control. In essence, what is lacking is random assignment to groups. Quasi-experiments are very similar to true experiments but use naturally formed or pre-existing groups. Another characteristic of quasi-experimental designs is that the testing environment may not be as controlled; instead of having the testing performed in a laboratory setting, it may be carried out in a natural environment.

For the current study, quasi-experimental designs were considered to have the potential to significantly contribute to exploring issues concerning the embodiment of users in CVEs by complementing the controlled experimentation approach as discussed in the previous section. It is believed that a field study could potentially reveal issues concerning user embodiments that would not be identified by conducting controlled experiments alone. Further, a well-designed quasi-experimental study generally has an advantage over a controlled experimental study with respect to external validity, thus offering the ability to generalise findings across persons, places, and time. On the other hand, the main disadvantage of quasi-experimental design is that it is inferior in terms of internal validity compared to controlled experimentation. Threats to internal validity inherent in this design are selection bias and the interaction of selection and maturation of the participants. Because the participants are not randomly assigned, it is difficult to know whether changes that occurred are due to the treatment or due to changes in the individual.

There are various types of quasi-experimental designs with different strengths and weaknesses (Tuckman 1999). The quality of quasi-experimental designs depends upon a number of factors, including the choice of control groups, the number of time periods observed, and the ability to statistically control for possible differences between groups compared. Cook and Campbell (1979) argue that quasi-experiments may either employ control groups selected to be similar to the intervention group (non-equivalent controls) or they may compare groups prior to the intervention with groups after the intervention has occurred. The non-equivalence of subjects in the treatment and control group members constitutes the main threat to the internal validity of quasi-experiments.

Within the context of the current research, subjects' individual characteristics were identified as control variables, carefully retrieved and measured within the feedback questionnaire, and subsequently allowed for within the statistical analysis. Further, qualitative data was captured and analysed in an attempt to identify possible shortcomings of the experimental set-up.

4.1.3 Review-based Evaluation

Existing experimental results and empirical evidence in the areas of experimental psychology and HCI are widely available, with some issues relating particularly to a certain domain or system and others dealing with more generic issues and applying them in a variety of situations and systems. Dix et al (1998) argue that one approach to evaluating a design is to exploit this inheritance and *scour the literature for evidence to support or refute aspects of the design, as it is wasteful to repeat experiments, and although a literature review is time consuming, it can probably be completed in the time that it would take to repeat just one experiment.*

However, Dix et al (1998) further argue that it should be noted that experimental results cannot be expected to hold arbitrarily across contexts, and that the researcher must therefore select literature-based evidence carefully, noting the experimental design chosen, the population of subjects used, the analysis performed and the

assumptions made. The review should therefore take account of both the similarities and the differences between the experimental context and the system under consideration, as researchers might otherwise be tempted to choose evidence that supports their case and ignore contradictory evidence.

For the research reported within this thesis a thorough literature review was conducted in an attempt to identify existing results related to the objectives of this study as outlined in chapter 1, and in an attempt to underpin the experimental designs as well as the prototype designs developed for this study. By carefully selecting only truly relevant evidence, the experimental designs and evaluation methods used within this study are believed to be thoroughly grounded on existing literature.

4.1.4 Heuristic Expert Reviews

Heuristic evaluation is a method of usability evaluation where an expert finds usability problems by checking the user interface against a set of supplied heuristics or principles (Nielsen and Molich 1990). A heuristic is a general principle that can guide a design decision or be used to critique a decision that has already been made. Heuristic evaluation can be seen as a method for structuring the critique of a system using a set of relatively simple and general heuristics (Dix et al 1998).

Nielsen (1994) argues that heuristic evaluation is especially valuable when time and resources are short. Skilled evaluators can produce high-quality results in a short period of time, usually two or three weeks, including a report of findings and recommendations, because the method does not involve detailed scripting or time-consuming participant recruiting. Heuristic evaluations by two or more usability specialists can identify many usability problems in a system, with the problem-identification percentage increasing as more evaluators are added (Nielsen 1993). Nielsen claims that two evaluators can identify over 50% of the problems, and three can identify about 60%. The curve flattens after five evaluators (75% of problems); in Nielsen's view it would take 15 evaluators to identify 90% of usability.

The major drawback of heuristic evaluation is that, regardless of the evaluators' skill and experience, they remain merely surrogate users, that is, experts who attempt to emulate the behaviour of real users. Therefore, there are general concerns about the results of heuristic evaluation that are not based on actual user data and thus slightly suspicious, as real users often have problems that experts do not expect. Other reasons why heuristic evaluation should not replace the studying of actual users are that it rarely emulates the behaviour of the key users, and it does not necessarily indicate which problems users will encounter most frequently.

For the purpose of the research reported in this thesis, methods of heuristic evaluation have been applied during the design phase of the agent prototype as described in chapter 7, where three evaluators assessed the agent's capabilities with regard to a list of desired features.

4.2 Presence

To operationalise the traditional evaluation methods as discussed in the previous section and in an attempt to cater for the specific needs of evaluating user embodiment issues within prototype systems of educational CVEs, the concept of *presence* is introduced in this section. Blascovich (2002) argues that much discussion has taken place in the literature regarding the concept of presence without producing a universally accepted definition of presence. Considering presence to be the *prima facie key added value* in CVEs, researchers have just begun to analyse what presence is, what cognitive variables are connected to presence, how it is generated in CVEs, and what its benefits for education and training are.

In the absence of a universally agreed definition, a basic definition provided by Lombard et al (2000) characterises presence as *the subjective sense of being in an environment* and is deemed sufficient within the context of the current research. The *environment* referred to in this definition needs not be restricted to computer generated environments as people can also experience presence when reading a book or watching a movie. Indeed, the phenomenon of presence has been researched in

other domains: in film theory it is known as the *diegetic effect* (Burch 1979) and in literature theory it is known as *transportation* (Gerrig 1993).

Tan (1996) defines the diegetic effect as *the experience of the fictional world as the environment*, in that *the film creates the illusion of being present in the fictional world*. Burch (1990) argues that the diegetic effect in film is based on the general visual stimuli that paintings and photographs provide, which result in *drawing the viewer into a position that is defined in relation to an imaginary space behind the window and formed by the picture plane and the frame*. Bordwell et al (1985) claim that the viewer of a film becomes an onlooker on an environment, and that viewers experience the fictional events as if they were happening around them.

Transportation relates to research on the persuasiveness of narrative media, such as books, and is defined by Green and Brock (2000) as a convergent process, where all of a person's mental systems and capacities become focused on the events occurring in the narrative. The physical environment (for example, reading chair) is suppressed in favour of an alternative cognitively imagined environment, with the difference between the two to be understood as metaphorical travel, i.e. the transportation to another environment.

Thus, presence can emerge from both the perception of sensory stimuli, such as pictures and sound, and the understanding of symbols, such as words; either way, Schubert et al (2001) argue, a spatial model of the cognitively imagined environment is constructed. Schubert et al further argue that users report presence in a film as well as in a fictional narrative, and in each case, the experience is mediated by the construction of cognitive representations as another mental layer. Further, narrative is also important, especially in the absence of sensory stimuli, since literature needs narration to produce transportation, and the diegetic effect in film strongly profits from narration (Burch 1990). In CVEs, however, narrative elements have been largely ignored so far, with the exception of the games genre (Schubert et al 2001).

Presence is closely related to *immersion* (Johns et al 2000), in that immersion is seen as the experience of an intense sense of presence, with one part of reality receiving

total attention to the exclusion of other parts of reality (Tromp 1995b). According to the Oxford English Dictionary, immersion is synonymous with *absorption*. Similarly, Psotka et al (1993) characterise immersion as the cognitive state of being mentally absorbed into some kind of environment.

Similarly, Tromp (1995a) argues that immersion shares many aspects with absorption, defining absorption as a state of total attention, which involves a full commitment of available perceptual, motoric, imaginative and ideational resources to a unified representation of the attentional object, be it a landscape, a human being, a sound, a remembered incident, or an aspect of oneself. The individual, who is absorbed in a novel, film or CVE, uses information from an external source to generate and elaborate imaginings that temporarily become the main focus of attention.

Absorption is a phenomenon addressed by a wide range of academic literature in areas such as hypnosis, meditation, expanded awareness, peak experiences, mysticism, aesthetic experiences, altered state of consciousness and drug effects. Studies in this area have revealed significant correlations between hypnotic responsiveness and the ability to become absorbed in activities involving imagining, such as watching a movie, reading a novel, daydreaming and dramatic acting (Barber and Wilson 1979).

The concepts of presence, immersion and absorption are closely related with each other and their distinctions are not clear. Shor (1970) explains how responding to hypnotic suggestions is similar to becoming involved in imagining while reading a novel. Hilgard (1970) concluded from empirical research that the *responsive* hypnotic subject is especially capable of creating and becoming immersed in a process of imaginative mental production that is initiated by an external source such as music, a film, a novel or by the suggestions of the hypnotist. Similarly, Loomis (1992) argues that individuals' *immersive tendencies* are related to their experience of *presence*, the sense of *being there* within a simulated environment (Sheridan 1992).

This section has attempted to provide a theoretical underpinning concerning the concept of presence in general; the next section considers presence specifically in the

context of CVEs and how presence can and should be used as a key variable for the evaluation of issues concerning the embodiment of users in CVEs.

4.3 Presence in CVEs

The general goal, common to all CVEs is to create a place for users to interact (Buescher et al 2001), a 3 dimensional space for their users to manage their joint activities (Harrison and Dourish 1996). Tromp and Benford (1995) argue that users need to feel present in a CVE in order to *make sense* of this 3 dimensional space. Indeed, Psotka (1995) argues that the factor that allegedly distinguishes CVE technology from all preceding technology is the sense of immediacy and control created by presence: the feeling of *being there*.

Furthermore, the engagement and excitement that is allegedly part of the virtual environment phenomenon is an obvious benefit of CVEs for education and training (Bricken and Byrne 1993). Students are reported to enjoy using virtual environment technology because it provides a different learning environment that enables them to do things that they cannot do in the physical world, such as fly and go to places that do not exist (Byrne 1996). However, the ability to design CVEs, which elicit high degrees of presence, requires an understanding of the variables affecting presence and the techniques for measuring presence.

In an attempt to conceptualise presence in CVEs, Tromp (1995b) argues that the state of cognitive immersion is an attitude based on a temporary willingness to accept the illusion offered by some medium as real, i.e. a suspension of disbelief. Further, Tromp argues based on the Theory of Distal Attribution (Loomis 1992), that four variables relevant to the experience of presence in CVEs can be identified, namely interactivity, learning from experience, some kind of body representation and absorption ability.

Therefore, Tromp (1995b) argues that the degree of presence experienced by users in CVEs is dependent on four variables: the quality of the avatars, interactivity (which

are both factors of the CVE), immersive tendencies and the amount of experience with the environment (which are user characteristics) (see figure 4.1).

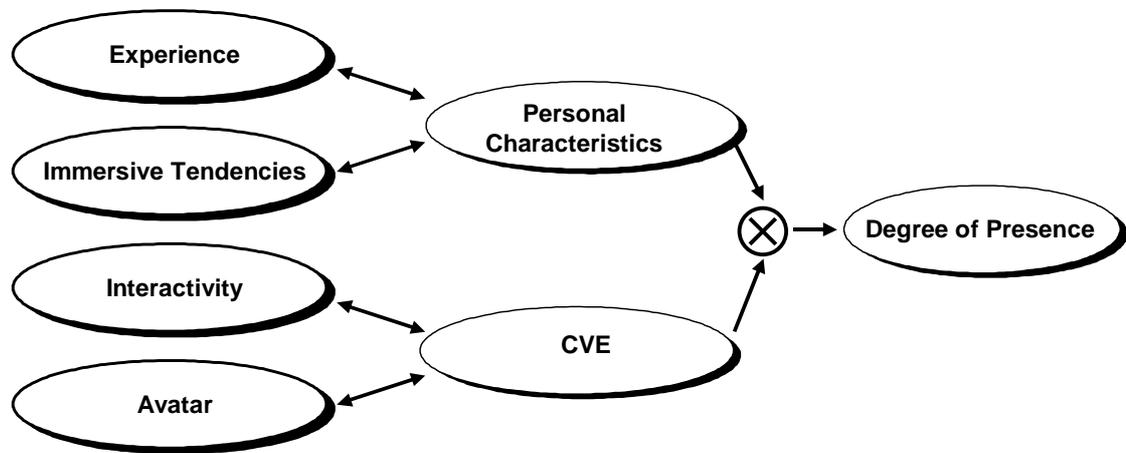


Figure 4.1: Tromp's Model for the Experience of Presence

Explanation of the symbols used in figure 4.1: *The ovals are constructs identified in the theory, the two-way arrows symbolise that the construct on the right end of the arrow is composed of the construct on the left end of the arrow, and one-way arrows symbolise a causal effect of one construct on another construct. The circle with the cross symbolises an interaction between constructs.*

4.3.1 Presence and Embodiment

Embodiment plays an important role in the design of virtual environments, especially for CVEs (Benford et al 1995). The purpose of embodiment in CVEs is to give the user a sense of their own and other users' presence within that environment. Embodiment of the user is seen as a critical dimension that motivates the advancement of CVE systems, with avatars being seen as cognitive *prostheses* amplifying or assisting cognitive processes by helping users develop cognitive skills (Biocca 1995). This argument has a long history in telecommunication and human-

computer interface design (see Licklider and Taylor 1968, Rheingold 1985, Lombard and Ditten 1997).

Indeed, it has been argued that there is an inherent connection between the degree of presence and the virtual body (Slater and Usoh 1994), and Rheingold (1991) argues that *most commonly the psychological effects or goals of progressive embodiment can be expressed as various forms of what is called presence*. There is, then, support in the literature for the proposition that embodiment significantly contributes to the experience of presence in educational CVEs. However, further investigation is needed as to what it means to be embodied in a CVE, what the psychological effects of different types of avatars are and how copresence of other user might affect users' experience of presence. Two issues closely related to the concept of presence are *social presence* and *copresence*.

4.3.2 Social Presence and Copresence

Social presence is the most common theoretical model used to investigate mediated communication systems such as CVEs (Fulk et al 1987, Walther 1992, Rice 1993, Caldwell et al 1995, Palmer 1995). The concept of social presence has been used as a theoretical basis for comparing face-to-face interactions to mediated interactions and comparing different mediated interactions to one another (Short et al 1976, Walther 1996). Short et al (1976) define social presence as *the degree of salience of the other person in the interaction and the consequent salience of the interpersonal relationships*. Bull (1983) extended this concept to include the sense that occurs *when one person feels another person is 'there'*.

Based on a review of existing theories and measures of social presence, Biocca et al (2001) identify three dimensions of social presence: *copresence*, *psychological involvement* and *behavioural engagement*. *Copresence* is the degree to which users believe they are not alone and secluded, i.e. their level of awareness of other users and their sense of the degree to which other users are aware of them. *Psychological involvement* is the degree to which a user allocates focal attention to the other users,

empathically senses or responds to the emotional states of the other users, and believes that they have insight into the intentions, motivation, and thoughts of other users. *Behavioural engagement* is the degree to which users believe their actions are interdependent, connected to, or responsive to other users and the perceived responsiveness of the other users to their own actions.

The theoretical construct of *copresence* focuses on evaluating the sense of connection with another mind (Nowak 2000). The term *copresence* originated in the work of Goffman (1963), who explained that copresence exists when people sense that they are able to perceive others and that others were able to actively perceive them. Goffman further explained that the *full conditions of copresence* have been achieved when *users sense that they are close enough to be perceived in whatever they are doing, including their experiencing of others, and close enough to be perceived in this sensing of being perceived*. Further, Ciolek (1982) emphasized the importance of attention or responsiveness to others in this sense of copresence. Nowak (2001) argues that the concept of copresence has a dual nature in that it involves users' perceptions of their partners' involvements in the interactions, i.e. perceived copresence, and the users' own involvements in the interactions, i.e. self-reported copresence.

Casanueva and Blake (2000), investigating the effects of group collaboration on copresence by attempting to directly measure copresence using questionnaires, found that users interacting with other users in CVEs experience more copresence than users not collaborating with others. Within the current research, however, it was not attempted to directly measure copresence, since, although copresence and presence are related; for the purpose of this investigation this relationship was assumed to be unidirectional in that the dimension of copresence is potentially a contributing factor to the level of presence experienced by subjects.

4.4 Measurement of Presence

Steuer (1992) found that the cognitive state of presence in an environment can be experienced with a variation in strength. Since then, therefore, presence has been used as an experiential quality metric to evaluate, develop and optimise both advanced broadcast systems and computer-generated virtual environments (Ijsselsteijn et al 2000, Freeman and Avon 2000, Slater and Usoh 1993). Further, presence has been used as the basis for predicting performance and potential benefits of new learning systems in the effectiveness of learning (Sheridan 1992, Held and Durlach 1992).

Measuring presence is not a trivial task, however. Asking questions that measure only the subject's perception of the technology that contributes to immersion can easily be confused with actually measuring a subject's feeling of *being there*, or their behavioural responses to events in the VE. Because it is a multi-dimensional concept that involves psychological processes, researchers face significant challenges in developing valid and reliable measures of presence. A suitable approach to the measurement of presence, perhaps understandably, therefore, is heavily disputed among researchers (Slater 1999; Witmer and Singer 1999).

There are two general approaches: objective and subjective. The objective approach is based on task performance and physiological measures. Subjective measures of presence, by contrast, require study participants to produce a conscious, introspective judgment regarding their experience and are typically administered via a questionnaire following the experience. Most researchers (e.g. Freeman and Avon 2000, Witmer and Singer 1999) use subjective questionnaire items in their studies, in part because they appear to be valid measures, in that they request information logically related to what we understand presence to be, and also because the measures are easy and inexpensive to use. The vast majority of evaluation studies, then, measure presence through questionnaires in an attempt to elicit subjective feelings of presence (Slater and Usoh 1994).

Furthermore, it has been argued that measuring presence makes sense only when speaking about the degree of presence in one environment relative to another (Slater *et al* 1998), since presence cannot be measured in absolute quantities. It is believed that within the current study, by populating the same CVE model with different forms of user embodiments, comparative measurement of presence and thus a meaningful evaluation will be enabled.

Within the current experiment the approach to measuring presence largely follows the notion of Witmer and Singer (1998), who argue that *involvement* and *immersion* are the contributing factors for the experience of presence and thus constitute the subscales for the measurement of presence. Whereas *involvement* is defined as a psychological state experienced as a consequence of focusing one's attention on a coherent set of stimuli, *immersion* is a psychological state characterised by perceiving oneself to be in an environment of continuous stimuli and experiences.

However, as previous presence measures apply only to single-user virtual environments, extended presence measures are needed for the current research to address issues specific to the multi-user dimension of CVEs. CVEs are intended to be *shared spaces*, where participants can see and communicate with each other using their avatars; and where therefore they can experience mutual *awareness* and *communication*. These are seen as further contributing factors to the experience of presence and hence additional subscales for the measurement of presence in CVEs.

4.4.1 Presence Questionnaires

As said earlier, most researchers use a subjective questionnaire in their studies because this appears to be a valid measure and also it is easy and inexpensive to use. Questionnaires are used to convert into data the information given directly by a subject. They are used to discover attitudes and beliefs of subjects as well as their experiences that have taken place (Silverman 1993). This information can be transformed into quantitative data by using attitude-scaling techniques, such as the Likert scale. Likert scale questionnaires are analysed by selecting the appropriate box

from a group of boxes from left to right, the first worth 1, the second 2 and so on, increasing in value to the box the subject has marked. Some of the questions have a reversed response anchor, and are scored so the left-most box receives a seven and the rest decrease in value. The subscale scores are the sum of the scores for each subscale item. Each of the subscales may contain a different number of questions; however, this is seen as sound because there is no weighting between items and subscales when calculating presence means. The questionnaires may include further open questions for qualitative analysis, where the subject is free to provide their own answer.

However, although there is evidence that subjective measures can be valid and reliable (see Prothero et al 1995), they have several important limitations. Some researchers have identified reliability problems in which the measures produce unstable and inconsistent responses across participants, time, and study settings (see Freeman et al 1999). The items may be difficult for participants to understand, especially if they explicitly refer to the presence concept. The act of introspection regarding the participants' experience may influence their responses to the items in unpredictable ways so that they do not accurately reflect the participants' true experience. Therefore, to overcome reported reliability problems, the questionnaire items developed for the current study did not explicitly refer to the concept of presence, and were carefully administered within various experimental designs.

Beyond these problems, some of which, Lombard et al (2000) argue, can be addressed with more careful and systematic design and administration of the measures, a major problem is that few researchers use the same set or sets of measurement items, making comparisons across studies difficult. Several presence questionnaire instruments that may be valid and reliable across different participant groups, experimental conditions, stimuli, and settings, have been or are currently in development (e.g. Lessiter et al 2000, Lombard et al 2000, Schubert et al 1999, Witmer and Singer, 1998). However, these questionnaires were developed with respect to single-user environments, and although it was attempted to make use of existing questionnaire items within the current study, additional items were required

to take into account the collaborative nature of CVEs. Thus, the questionnaires used consisted of attitude statements with Likert-scales and open-ended questions, which were based on existing measurement items (cf. Witmer and Singer 1998) and extended measurement items developed specifically for CVEs.

4.5 Summary

This chapter has discussed general methods for evaluating interactive systems in terms of their appropriateness for the research reported in this thesis. Review-based and heuristic evaluation, as well as controlled experiments and quasi-experiments, were considered to be valid and useful for the current study. Further, it was argued there are currently no evaluation methods specific to CVEs and that traditional evaluation methods are limited in their applicability and consequently unlikely to address the full range of aspects now inherent in CVEs. Therefore, the concept of presence was introduced, and the measurement of presence proposed to complement general evaluation methods. Considering presence to be the *prima facie key added value* in CVEs, it has also been identified as the key variable for the evaluation of CVEs. Presence measures can be administered within controlled experiments and quasi-experiments to test certain aspects of the system. Such experiments might turn out particularly useful as a means of selecting between two or more design options (Moore and Hobbs 1996) and it is argued that issues concerning user embodiments in CVEs can be meaningfully evaluated by comparing subjects' experience of presence. Limitations of subjective presence measures were discussed and it was argued that with suitably careful design and administration, these measures could be regarded as valid and suitable in the context of this study. Further, it was argued that the current research requires a specific set of presence questionnaire items based on existing items, as well as resulting from considerations regarding the collaborative nature of the system to be evaluated and the purpose of the evaluation itself. The evaluation methods introduced in this chapter are applied in the next chapter, in an attempt to investigate certain aspects of embodiment by measuring subjects' experience of presence within a controlled experiment.

Chapter 5 - Experimental Exploration of Avatars

This chapter is concerned with applying the evaluation methods argued for in chapter 4 to assess the effects of different types of user embodiments in educational CVEs. A series of controlled experiments was conducted within a prototype environment. Particular measurement instruments were applied to enable meaningful measurement and comparison of the effects of different types of avatars on presence. The experimental design, the variables involved, and the attempt to measure presence in CVEs by using questionnaires are expounded here. The results of these trials are analysed and their meaning is discussed. Further, the applied diet of evaluation techniques is reviewed and its appropriateness discussed, with respect to further experiments aimed at exploring user embodiment issues in general, and evaluating the concept of a hybrid avatar/agent model in particular.

In chapter 3, based on a review of existing CVE applications and relevant literature, theoretical underpinnings concerning the concept of user embodiments within a CVE for education were argued for and a hybrid avatar/agent model was proposed. It was argued that presence is a strong indicator for the potential benefits of avatars in CVEs and a suitable diet of evaluation methods was proposed in chapter 4. Moreover, there is some evidence for the existence of a direct relationship between the deployment of avatars and the degree of presence experienced by subjects (as discussed in chapter 4, cf. Gerhard and Moore 1998). This chapter therefore discusses a series of controlled experiments conducted to find further empirical evidence concerning this relationship, by systematically exploring how the deployment of avatars in CVEs affects presence.

Within the current experimental design it was attempted to measure and compare subjects' experience of *presence* (see chapter 4). The term *presence* as used in this context is understood as the possible result of the process of cognitive immersion, and is not to be confused with *virtual presence*, which is understood to be solely

determined by the deployment of avatars within CVEs. Virtual presence is defined as the deployment of avatars, so that to say participants in a CVE are virtually present is a tautology, whereas presence refers to the subjective feeling on the part of the user of *being* in an environment. Thus *presence* may be felt in varying degrees (including no feeling of presence) and may or may not be caused by the use of avatars. Further, the extent to which such presence is actually felt is an empirical question - hence the experiments discussed in this chapter.

5.1 Hypotheses

The effects of different types of avatars, as discussed in chapter 3, on the experience of presence were compared to find out whether the deployment of animated (cartoon-style or humanoid) avatars is beneficial in educational CVEs. Hence, the problem statement on a conceptual level for this series of experiments is:

- *How is presence in CVEs influenced by the nature of avatars?*

A suggested answer to that problem was drawn up in the following conceptual hypothesis:

- *The type of avatars and the feeling of presence in CVEs are positively related.*

This in turn lead to the definition of the following operational hypotheses:

1. *The degree of experienced presence is higher when deploying cartoon-style avatars as opposed to basic-shape avatars.*
2. *The degree of experienced presence is higher when deploying humanoid avatars as opposed to basic-shape avatars.*
3. *The degree of experienced presence is higher when deploying humanoid avatars as opposed to cartoon-style avatars.*

5.2 Method

5.2.1 Identification of Variables

The degree of *presence* as experienced by participants is seen as the key indicator for the usability of the CVE and thus for the quality of the learning experience (as argued in chapter 4). As presence is registered in the minds of the participants, it cannot be seen, objectively measured as discussed earlier (cf. section 4.2), or manipulated in a concrete way (Gerhard et al 1999b). Hence, *presence* was the intervening variable of this experimental setting.

The form of *virtual representation* is determined by the deployment and appearance of avatars; for this experiment basic-shape, cartoon-style and humanoid avatars were to be investigated. This was therefore the independent variable that was manipulated to determine how it affected the degree of presence that participants experienced during the trials. Here, there were three different levels of user representation and the deployment and characteristics of *avatars* was the independent variable.

Two variables that functioned as secondary independent variables within this experimental framework were the composition of the CVE and possible modes of interaction within that CVE. Both variables were identified within the theory of cognitive immersion (see chapter 4) as factors contributing to the experience of presence in CVEs. However, as this initial series of experiments took place in one constant environment these variables were constant as well. On the other hand, as discussed in chapter 9, the results of this experiment can in principle be compared to results of similar experiments conducted in other environments, which allow different kinds of interactions. *CVE* and *Interaction* were therefore the moderator variables.

The theory of cognitive immersion (see chapter 4) identifies two further variables as influential to the experience of presence: previous experience of users within the environment and the individual immersive tendencies of users. As these variables are

determined by individual personal characteristics, for the purpose of this experiment they needed to be controlled and their effects on presence neutralised. *User Experience* and *Immersive Tendencies* were therefore the control variables.

The dependent variable is the response variable. To observe the impact of the different levels of the deployment of avatars, its effects on the underlying user had to be measured. This was attempted by measuring subjects' experience of *Immersion*, *Involvement*, *Awareness*, and *Communication* (as discussed in chapter 4), which were the dependent variables in this setting. The hypothesised relationship and the combination of all variables involved are illustrated in figure 5.1.

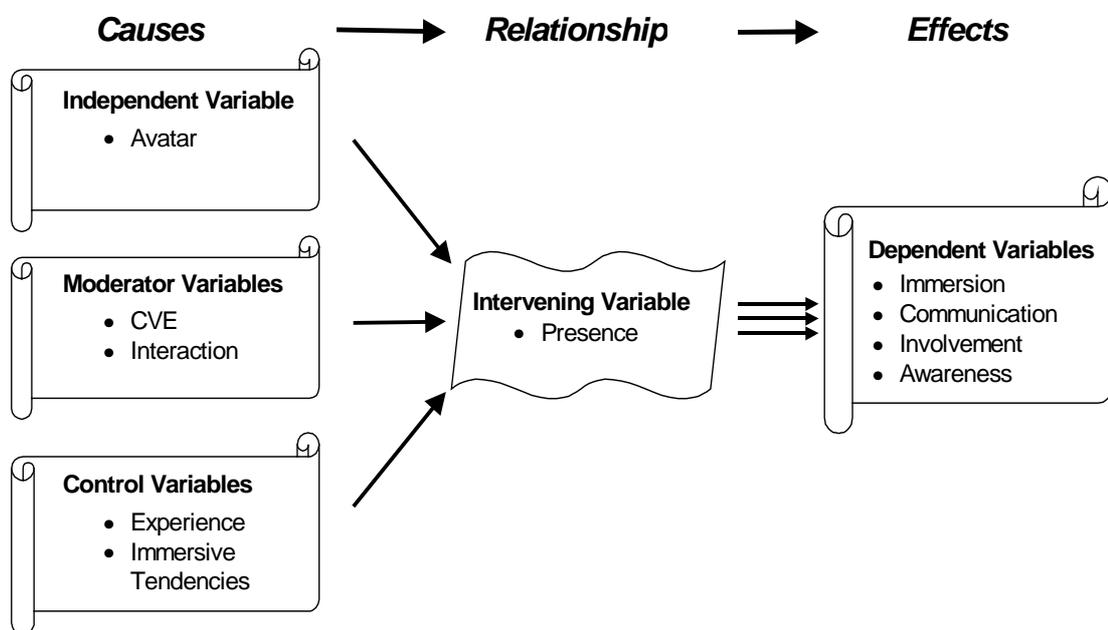


Figure 5.1: Combined Variables

5.2.2 Control of Variables

The two variables that needed to be controlled were *previous experience* and individual *immersive tendencies*. To reduce the effects of *maturation* (rehearsal effect), another potential source of internal invalidity, a between-groups design was applied to guarantee subjects participated only once in the experiment.

It was assumed that the experience of subjects within this specific environment, built specifically for this experiment, was not an important factor as all participants were in the same situation, in that they all entered the test environment for the first time. However, previous experience in other, similar virtual environments as well as different levels of expertise in the area of visual arts could have been influential and needed to be controlled. Further, the individual absorption abilities or immersive tendencies might have varied greatly among subjects and potentially affected the outcome of this experiment. Therefore, prior to the experimental sessions each subject completed a pre-experiment questionnaire in an attempt to determine, quantify and equally distribute *experience* and individual *immersive tendencies* between subject groups.

5.2.3 Manipulation of Independent Variable

The deployment and appearance of avatars was the independent variable and was manipulated to investigate changes in participants' responses. There were 3 levels of user representation:

1. Participants represented by basic shapes (see figure 5.2)
(avatars created in VRML)
2. Participants represented by animated cartoon-style avatars (see figure 5.3)
(avatars provided by Avatara www.avatara.com)
3. Participants represented by animated humanoid avatars (see figure 5.4) (avatars provided by Cybertown www.cybertown.com)

The cartoon and humanoid avatars were fundamentally different from the basic avatars, in that the former had a *face*, and therefore, the capability of conveying their current focus; that is other users were potentially aware of whether, for example, these avatars were facing one of the artworks or other avatars. Furthermore, when moving in the virtual gallery, walking animation was implemented only for

humanoid avatars, whereas basic and cartoon avatars could only *hover* above the ground.

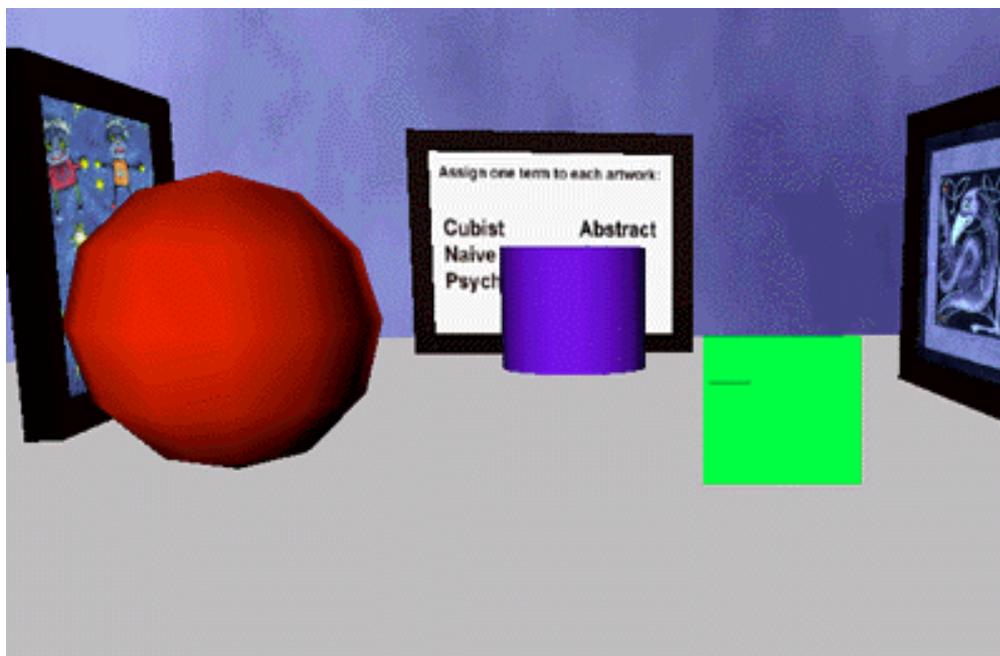


Figure 5.2: Basic Avatars



Figure 5.3: Cartoon-style Avatars



Figure 5.4: Humanoid Avatars

5.2.4 Apparatus and Task Setting

The implementation of this experiment was fully Web-based (a screenshot of the subject instructions page is contained in appendix 1.1). An art gallery setting was chosen, as an art gallery is envisaged as primarily an educational resource, in much the same way as conventional art galleries or museums. Therefore, experimental results obtained within a virtual art gallery are expected to apply to educational CVEs as such.

The virtual gallery model was implemented in VRML (source code is contained in appendix 1.2), without using any 3D modelling tool. It comprised only basic shapes for defining the geometry of the room and the picture frames. The *blaxxun Community* virtual world server was used to make the virtual gallery accessible on a Web server and enable avatar and chat interaction. The *blaxxun Contact 2.0* VRML browser was used on the client side.

Questionnaires were implemented as online forms using CGI/Perl (a screenshot of the online questionnaire is contained in appendix 1.3), completed and submitted by subjects electronically to aid the efficient processing of the data. The Perl script (an extract of the source code is contained in appendix 1.4) created a text file on the server containing the submitted questionnaire data (see example of text file in appendix 1.5). Terminals to access the system were provided at locations within Leeds Metropolitan University and Axis premises.

A collaborative task was needed to stimulate interaction and communication in the gallery environment. To achieve this, subjects were given the task of identifying the style of a number of contemporary artworks. The images of artworks were taken from the Axis database; the British National Artists Register. Inside the virtual gallery room there were 4 images of contemporary artworks exhibited (see table 5.1).

To simplify the task of identifying artwork styles, and, in particular, to aid subjects without expert knowledge in the visual arts, participants were provided with a list of 6 different styles (Cubist, Abstract, Naïve, Celtic, Psychedelic, Surreal) to select from. Their task was to discuss and attempt to unanimously assign one style to each of the 4 artworks. Since the group had to agree on one joint decision, the task was seen as fundamentally collaborative in nature.

5.3 Subjects and Procedure

In total, 27 subjects took part. They were of mixed age, gender and ethnic origin and had different professional backgrounds, namely academic and administrative staff, and students from Leeds Metropolitan University, as well as artists registered on the Axis database.

Groups of 3 subjects were needed for the collaborative task, therefore subjects' scores from the pre-experiment questionnaires were used to divide them into 3 pools, pool A containing the 9 lowest scoring subjects, pool B the medium range and pool C the 9 highest scoring subjects. In an attempt to evenly distribute the control variables,

each group comprised of one subject from each pool, with group indicators (R1, R2, ... , R9) being randomly assigned to each subject within the 3 pools. This is a procedure by which any person in each subject pool has an equal probability of being assigned to one of the subject groups.

Image	Style	Title	Artist Name
	Naive	Silver Haired Children	Mandy Wrightson
	Celtic	Lyre Bird	Christina Scurr
	Surreal	Fantastic Mr Fox	Tomas Lewis
	Psychedelic	Blue Moon Over Marrakech	Johnny McGuinness

Table 5.1: Exhibited Artworks from the Axis Database

Three conditions with regard to the level of user embodiment were applied; each condition was repeated 3 times with different subjects groups (see table 5.2). In the following an "X" is used to designate the level of user embodiment:

- X1: subjects represented by basic shapes
- X2: subjects represented by cartoon-style avatars
- X3: subjects represented by humanoid avatars

The number of participants for each session was 3. In total 27 subjects participated across 9 experimental sessions. In the following the groups of subjects are labelled with an "R". Table 5.2 illustrates the overall course of sessions.

Session	Group	Condition
1	R1	X1
2	R2	X2
3	R3	X3
4	R4	X1
5	R5	X2
6	R6	X3
7	R7	X1
8	R8	X2
9	R9	X3

Table 5.2: Course of Sessions

5.4 Questionnaires

The questionnaires used in this experiment consisted of attitude statements with Likert-scales and open-ended questions as discussed in chapter 4. Thus questionnaires had both closed questions where the subject was asked to select an answer from a choice of alternative replies and open questions where the subject was free to provide their own answer. Likert scale questionnaires were analysed by selecting the appropriate box from a group of boxes from left to right, the first worth 1, the second 2 and so on, increasing in value to the box the subject has marked. One of the questions had a reversed response anchor, and were scored so the left-most box received a seven and the rest decreased in value. The subscale scores were the sum of the scores for each subscale item. There was no weighting of items or subscales.

5.4.1 Pre-Experiment Questionnaire

The Pre-Experiment Questionnaire attempted to identify and measure possible individual differences of subjects' previous experience and their abilities or

tendencies to immerse themselves in different environmental situations. In this experimental setting, therefore, it measured the control variables and was used to assemble subject groups where these variables are evenly distributed. The questionnaire had 2 subscales (see table 5.3) and consisted of 14 items in total (see table 5.4).

Subscales for Control Variables	Questions
Experience (EXP)	1, 2, 3, 4
Immersive Tendencies (IMT)	5, 6, 7, 8, 9, 10, 11, 12, 13, 14

Table 5.3: Pre-Questionnaire Subscales

Pre-Experiment Questions	Sub-scale
1. How experienced with using computers do you rate yourself?	EXP
2. How experienced with Internet chat systems do you rate yourself?	EXP
3. How experienced with the use of 3D multi-user virtual worlds do you rate yourself?	EXP
4. How experienced with contemporary visual art do you rate yourself?	EXP
5. Do you become so involved in a book, television program or movie that people have problems getting your attention?	IMT
6. Do you become so involved in a book, television program or movie that you are not aware of things happening around you?	IMT
7. Do you find yourself closely identifying with the characters in the story line of a book, television program or movie?	IMT
8. How good are you at blocking out external distractions when you concentrate on a task?	IMT
9. When watching sports, do you ever become so involved in the game that you react as if you were one of the players?	IMT
10. Do you ever become so involved in doing something that you lose all track of time?	IMT
11. Do you ever become so involved in a daydream that you are not aware of things happening around you?	IMT
12. Have you ever got excited/scared by something happening in a movie?	IMT
13. Are you easily distracted when involved in an activity?	IMT
14. When reading a good book or watching a good movie, do you feel the emotions of the story such as sadness, fear, or joy?	IMT

Table 5.4: Pre-Questionnaire

5.4.2 Post-Experiment Questionnaire

The Post-Experiment Questionnaire addressed the subjective experience in a simulated environment. It was designed to identify and measure the degree to which aspects of the virtual environment could engender a sense of presence. It attempted to measure the dependent variables and also covered the moderator variables. As similar experiments in different CVEs allowing different modes of interaction can be conducted, the moderator variables could ultimately become subject to change and were therefore measured within the questionnaire.

In addition, two questions addressed the independent variable (questions 8 and 10). The measurement of the independent variable might seem unusual. However, by measuring how subjects perceived the manipulation of this variable, data is collected that might be interesting in the context of other similar experiments. Although the subscale *Avatars* (7) is not directly relevant in this experimental setting, it might be of interest to other researchers in the field, who are applying presence measures for evaluation purposes (Witmer and Singer 1999).

In total the questionnaire has 7 subscales (see table 5.5). It also contains 5 further questions (questions 0, 20, 21, 22, 23) for qualitative analysis and hence consists of 24 items in total (see table 5.6).

Subscales for Dependent Variables	
Immersion (IMM)	Questions 6, 7, 19
Involvement (IVM)	Questions 13, 14 (reverse anchor), 16, 18
Awareness (AWN)	Questions 9, 15, 17
Communication (COM)	Questions 3, 4, 5
Subscales for Moderator Variables	
CVE (CVE)	Question 1
Interaction (INT)	Questions 2, 11, 12
Independent Variable	
Avatar (AVA)	Questions 8, 10

Table 5.5: Post-Questionnaire Subscales

Post-Experiment Questions/Statements	Sub-scale
0. Beside you, how many persons were in the virtual gallery?	Qualitative
1. How stimulating was the design of the virtual world?	CVE
2. How natural was the mechanism, which controlled the actions of your avatar?	INT
3. How responsive were the avatars of other participants to verbal communication that you initiated?	COM
4. How responsive were the avatars of other participants to non-verbal communication that you initiated?	COM
5. How natural did your communication with other participants seem?	COM
6. How compelling was your sense of being present in a virtual world?	IMM
7. How compelling was your sense of other participants being present?	IMM
8. How credible were the avatars of other participants with respect to representing human beings?	AVA
9. How aware were you of the existence of your own avatar?	AWN
10. How easy was it to distinguish between the avatars of different participants?	AVA
11. How easy was it to control your avatar?	INT
12. How well could you concentrate on communication and the assigned task rather than on the mechanisms used to perform these?	INT
13. Were you involved in communication and the experimental task to the extent that you lost track of time?	IVM
14. To what extent did events occurring outside the virtual gallery distract from your experience in the virtual environment?	IVM (rev)
15. I was immediately aware of the existence of other participants.	AWN
16. I was an active participant in the meeting.	IVM
17. I was aware of the actions of other participants.	AWN
18. I enjoyed the virtual gallery experience.	IVM
19. My senses were completely engaged during the experience.	IMM

20. Was it difficult to find a unanimous decision within the group? Did you experience any other difficulties during the experiment? (Please explain.)	Qualitative
21. Did you notice others using means of non-verbal communication, such as gestures? Do you consider them useful in this setting? (Please explain.)	Qualitative
22. Do you think the deployment and appearance of avatars was significant for the virtual gallery experience? (Please explain your answer.)	Qualitative
23. Do you have any other comments on this experiment?	Qualitative

Table 5.6: Post-Questionnaire

5.5 Results and Analysis

5.5.1 Results of Pre-Questionnaire

The purpose of the pre-questionnaire was to measure the control variables in an attempt to reduce potential *noise* in general and effects on group dynamics in particular. Results of the pre-questionnaire (see appendices 1.6 and 1.7) were used only to assemble the subject groups.

Ordered by score and subdivided into 3 equal pools, subjects were randomly assigned group indicators (R1, R2, ..., R9) within their pool (see table 5.7). This procedure led to the assigning of sessions as shown in table 5.8 and guarantees that each subject group was properly matched and had one member of each pool.

For example, subject group R1 consisted of subjects S13 from pool A (the pool containing the 9 lowest scoring subjects concerning the control variables), S19 from pool B (the pool containing the mid-range scores) and S11 from pool C (the pool with the highest scores concerning Experience and Immersive Tendencies).

Subject ID	EXP- IMT Mean	Group Indicator	Subject Pool
S13	2.75	R1	<i>Pool A</i>
S04	2.85	R7	
S08	2.88	R4	
S02	2.95	R5	
S09	3.35	R2	
S20	3.35	R8	
S14	3.43	R9	
S05	3.58	R6	
S21	3.78	R3	
S15	3.80	R9	<i>Pool B</i>
S22	3.80	R7	
S25	3.90	R4	
S19	3.93	R1	
S10	3.95	R3	
S24	3.95	R6	
S07	3.98	R8	
S16	4.08	R2	
S26	4.20	R5	
S18	4.28	R4	<i>Pool C</i>
S23	4.35	R5	
S01	4.38	R2	
S12	4.43	R8	
S17	4.43	R7	
S11	4.73	R1	
S03	4.78	R9	
S06	5.13	R3	
S27	6.18	R6	

Table 5.7: Results Pre-Questionnaire

Session	Date	Subjects	Subject Group	Condition
1	18.07. 2000	S11, S13, S19	R1	X1
2	27.07. 2000	S01, S09, S16	R2	X2
3	01.08. 2000	S06, S07, S10	R3	X3
4	11.09. 2000	S08, S25, S26	R4	X1
5	28.07. 2000	S02, S18, S23	R5	X2
6	03.08. 2000	S05, S24, S27	R6	X3
7	12.09. 2000	S04, S14, S17	R7	X1
8	08.09. 2000	S12, S20, S21	R8	X2
9	31.08. 2000	S03, S15, S22	R9	X3

Table 5.8: Resulting Course of Sessions

5.5.2 Results of Post-Questionnaire Subscales

Individual results of the post-questionnaire are listed in appendices 1.8 - 1.10. Table 5.9 below shows the aggregated scores for the dependent variables (subscales 1-4), as illustrated in figure 5.5. For example, under subscale 1, *Immersion*, subjects with basic-shape avatars scored a mean of 2.89 with a standard deviation of 1.18, subjects with cartoon-style avatars scored a mean of 5.06 with a standard deviation of 0.73 and subjects with humanoid avatars scored a mean of 6.33 with a standard deviation of 0.84. Table 5.9 also shows the scores for the moderator variables (subscales 5 and 6) and the perceived manipulation of the independent variable determined by the type of avatar (subscale 7).

Condition Sub-scales	X1 (basic)		X2 (cartoon)		X3 (humanoid)	
	MEAN	STDEV	MEAN	STDEV	MEAN	STDEV
1 Immersion	2.89	1.18	5.06	0.73	6.33	0.84
2 Communication	3.26	1.89	4.59	1.08	5.30	1.32
3 Involvement	3.64	1.42	5.06	1.22	5.53	1.23
4 Awareness	3.33	1.71	4.85	1.49	6.19	0.83
5 CVE	3.93	1.17	5.07	1.41	5.41	1.31
6 Interaction	2.94	1.35	4.00	0.77	4.06	1.30
7 Avatars	1.94	1.70	4.28	1.90	6.61	0.70

Table 5.9: Results Post-Questionnaire

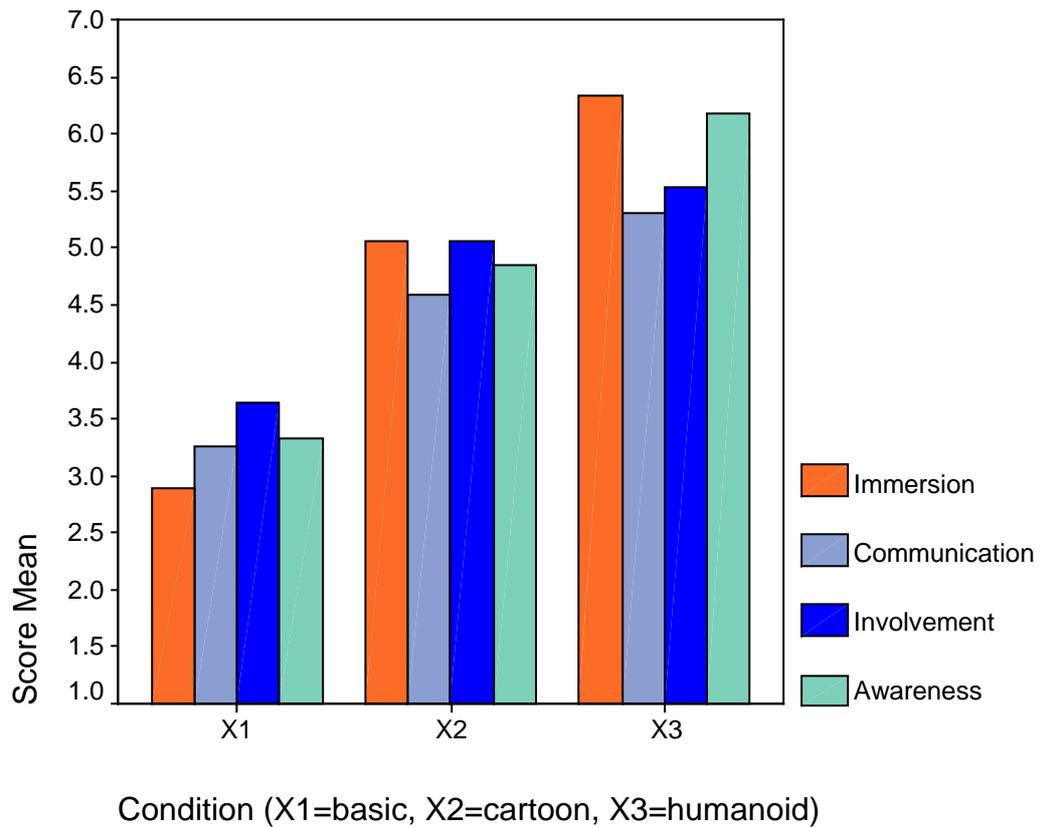


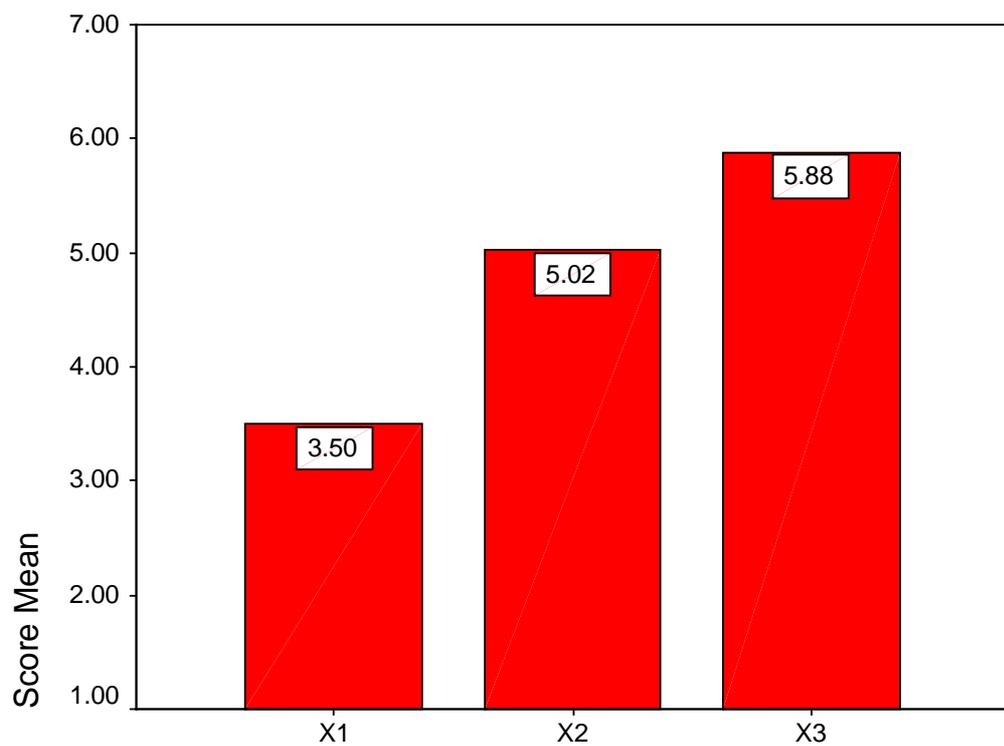
Figure 5.5: Mean Subscale Scores

5.5.3 Descriptive Statistics for Presence

Presence is the combined results from subscales 1-4. Table 5.10 shows the mean (illustrated in figure 5.6), standard deviation and standard error for *presence*. Figure 5.7 shows a 95% confidence interval for the presence means (illustrated in figure 5.7), and gives the minimum and maximum score for each condition X1, X2, X3.

Variable: Presence								
	N	Mean	Std. Dev.	Std. Error	95% C. I.		Min.	Max.
					Lower Bound	Upper Bound		
X1 (basic)	9	3.5000	.7116	.2372	2.9530	4.0470	2.14	4.29
X2 (cartoon)	9	5.0238	.8073	.2691	4.4032	5.6444	3.29	5.93
X3 (humanoid)	9	5.8810	.5858	.1953	5.4307	6.3312	5.00	7.00
Total	27	4.8016	1.2119	.2332	4.3222	5.2810	2.14	7.00

Table 5.10: Descriptive Statistics for Presence Means



Condition (X1=basic, X2=cartoon, X3=humanoid)

Figure 5.6: Mean Presence Scores

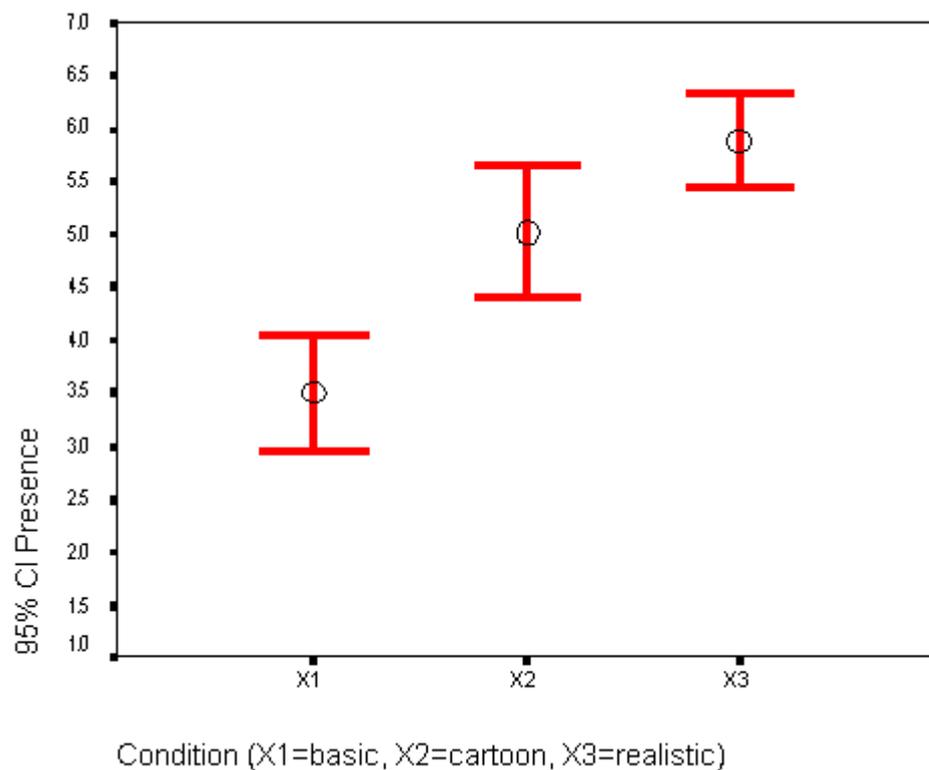


Figure 5.7: 95% Confidence Interval for Presence Means

5.5.4 One-way Test of Presence Mean

Since in this experiment each subject performs under only one of the conditions, this experimental setting is said to have *one treatment factor with no repeated measures* (Siegel and Castellan 1988). (This setting is also known as the completely randomised experiment.) Three sets of scores, one for each of the three groups, have been obtained from the experiment. A group mean is taken to be an estimate of people's typical level of performance under a particular condition. But individual performance can vary widely and at times deviates markedly from the group mean. This within group variability can be seen as noise. The *one-way analysis of variance* (ANOVA) technique tries to cater for this, and is calculated by dividing the variability between groups by the variability within groups.

The ANOVA F statistic tests the null hypothesis that all three population means are equal, that is the deployment of cartoon-style or humanoid avatars does not improve the presence scores in comparison with basic avatars, and neither does the deployment of humanoid avatars improve the presence scores in comparison with cartoon-style avatars. If there are large differences among the treatment means the F value will be inflated and the null hypothesis (H_0) is likely to be rejected. However, if there is no effect, the numerator and denominator should have similar values, giving an F value close to unity (Winer et al 1991). Applying the ANOVA F test to the current data yields table 5.11.

Variable: Presence					
	Sum of Squares	df	Mean Square	F	p-value
Between Groups	26.177	2	13.088	26.155	.000
Within Groups	12.010	24	.500		
Total	38.187	26			

Table 5.11: One-way ANOVA Test of Presence Mean

A high value of F, in this case $F = 26.155$ (see table 5.11), with a p-value less than 0.05, in this case less than 0.0005, is evidence against the null hypothesis of equality of all three means. With the F value being statistically significant with a p-value less than 0.0005, the analysis suggests that the null hypothesis can be rejected.

5.5.5 Multiple Comparisons

However, given that H_0 states that all the means are equal, the ANOVA F test can only give significance that there is a difference somewhere among the means, but does not justify saying that any particular comparison is significant. Therefore, further analysis is necessary. To localise the differences among the three treatment means, multiple comparisons using different Post Hoc Tests were conducted. Firstly,

the Tukey HSD (Honestly Significant Difference) test was administered, results are presented in table 5.12.

Variable: Presence							
			Mean Difference (I-J)	Std. Error	p-value	95% C. I.	
	(I) Condition	(J) Condition				Lower Bound	Upper Bound
Tukey HSD	X1	X2	-1.5238(*)	.3335	.000	-2.3566	-.6910
		X3	-2.3810(*)	.3335	.000	-3.2137	-1.5482
	X2	X1	1.5238(*)	.3335	.000	.6910	2.3566
		X3	-.8571(*)	.3335	.043	-1.6899	-.0244
	X3	X1	2.3810(*)	.3335	.000	1.5482	3.2137
		X2	.8571(*)	.3335	.043	.0244	1.6899

* The mean difference is significant at the .05 level.

Table 5.12: Tukey HSD Post Hoc Test

The Tukey HSD tests multiple pairwise comparisons among the three means. It lists each pair of means and indicates with an asterisk whether the means are significantly different at least at the 0.05 p-value level. Here, all comparisons covered by the hypotheses (X2 with X1, X3 with X1, and X3 with X2) are significant at below the 0.05 level (see table 5.13).

The Bonferroni multiple comparison post hoc test was also used. This test does not require homogeneous subsets and is known to be more conservative than for instance the Tukey HSD test (Winer et al 1991). Here, the mean difference between X3 and X2 using the Bonferroni test is not significant at the 0.05 level (see table 5.13).

Variable: Presence							
			Mean Difference (I-J)	Std. Error	Sig.	95% C. I.	
	(I) Condition	(J) Condition				Lower Bound	Upper Bound
Bonferro ni	X1	X2	-1.5238(*)	.3335	.000	-2.3821	-.6656
		X3	-2.3810(*)	.3335	.000	-3.2392	-1.5227
	X2	X1	1.5238(*)	.3335	.000	.6656	2.3821
		X3	-.8571	.3335	.050	-1.7154	.0011
	X3	X1	2.3810(*)	.3335	.000	1.5227	3.2392
		X2	.8571	.3335	.050	-.0011	1.7154

* The mean difference is significant at the .05 level.

Table 5.13: Bonferroni Post Hoc Test

5.6 Discussion

In the present study the effects of different kinds of avatars on the experience of presence have been compared. A between-groups design was applied which guaranteed subjects participated only once in the experiment. This was intended to counterbalance the effects of *maturation* (rehearsal effect), being a potential source of internal invalidity. No subject had experienced the prototype CVE previously to the experiment.

The task given to subjects, to unanimously assign one style to each of the 4 artworks, was designed to be educational and collaborative in nature, since subjects were instructed to explore the virtual gallery, and then to discuss the style of artworks exhibited and to agree on one joint decision within the group. Without demanding too much domain knowledge of subjects, the task was deemed sufficient to engage subjects to a degree that enabled the subsequent measurement of presence.

It was hypothesised that the deployment of avatars and the feeling of presence would be positively related. The one-way ANOVA test of presence means (see table 5.12) confirmed that the effect of avatars was significant overall ($F_{2,24}=26.155$, $p<0.0005$), suggesting that the deployment of avatars and the experience of presence are indeed positively related.

However, this does not necessarily imply that *all* the means are significantly different from each other. Hence, the mean difference between each of the 3 treatment groups, defined as hypotheses 1, 2 and 3 in section 5.1, was considered separately.

Hypothesis 1 – that the degree of presence is higher when deploying cartoon-style avatars as opposed to basic shape avatars - is confirmed with a **mean difference (X2-X1) = 1.52 and $p < 0.0005$** using Tukey HSD (table 5.13) and Bonferroni (table 5.14).

Hypothesis 2 – that the degree of presence is higher when deploying humanoid avatars as opposed to basic shape avatars - is confirmed with a **mean difference (X3-X1) = 2.38 and $p < 0.0005$** using Tukey HSD (table 5.13) and Bonferroni (table 5.14).

Hypothesis 3 – that the degree of presence is higher when deploying humanoid avatars as opposed to cartoon-style avatars – could be confirmed with a **mean difference (X3-X2) = 0.86 and $p < 0.043$** using Tukey HSD (table 5.13). However, the more conservative Bonferroni (table 5.14) could find **no significance for the mean difference (X3-X2) = 0.86 at the .05 level.**

The results of the statistical tests, both Tukey HSD and Bonferroni, administered for hypotheses 1 and 2, are significant with $p < 0.0005$. Concerning hypothesis 3, the mean difference between condition X2 (cartoon-style avatars) and condition X3 (humanoid avatars), however, was found significant only with $p < 0.043$ using Tukey, the Bonferroni test failed to find significance for the mean difference. Therefore, the statistical results of this study strongly suggest that the deployment of animated cartoon-style or humanoid avatars improves the CVE experience of subjects with

respect to presence; i.e. animated cartoon-style or humanoid avatars cause more presence than basic shape avatars. Further, there is some evidence that humanoid avatars cause more presence than cartoon-style avatars. However, this cannot be interpreted as a significant finding as statistical evidence is rather thin, given the low number of subjects participating in this experiment.

The presence measures identified from the literature and applied within this study appeared to be valid and sufficient in the current context. Evaluating the validity of subjective presence measures such as presence questionnaires was not attempted directly because of the common acceptance by researchers in this field (cf. chapter 4). However, investigating possible correlations between pre-questionnaire scores and post-questionnaire scores across different conditions and different experimental setting could provide insight for presence researchers with respect to validating the measurement of presence using questionnaires. The current study provides data to enable such an investigation.

Although the statistical findings are very interesting, there are general problems concerning the validity of any questionnaire, which is limited by three main considerations, namely to which a question might influence the respondent to show himself in a good light, to which extent a subject might be unduly helpful by attempting to anticipate what the researcher wants to hear and to which extent a question might be asking for information about a respondent that he is not certain to know about himself (Tuckman 1999).

These points were considered during the questionnaire design in an attempt to minimise their misrepresenting effects. Therefore, none of the questionnaire items was directly related to the concept of presence, and the questionnaires were administered electronically, accessible through the Internet, so that subjects could complete the questionnaire at their own pace in the absence of any of the researchers involved in the experiment. Further, support for the statistical findings was obtained from the qualitative data, i.e. responses of subjects to the open questions and from the chat log files.

Qualitative and quantitative methods offer different strengths and weaknesses, qualitative questions are not constrained by predetermined categories, whereas quantitative questions require the use of standardised measures so that experiences of the subjects can fit into a limited number of predetermined response categories (Tuckman 1999). Both methods constitute alternative, but not mutually exclusive, strategies. Here the two types are used effectively in the same study by analysing qualitative data to illustrate and clarify the statistically derived findings and to identify possible shortcomings of the experimental set-up.

The responses to open questions (an extract is contained in appendix 1.11) differed in length considerably between subjects and it was noted that subjects with cartoon-style and humanoid avatars revealed a more positive general attitude towards the experiment and answered in more detail than those with basic avatars. When directly asked about their avatars (question 22) their answers were more positive, with avatars described as *amusing, human, funny, adding to the experience, interesting, or excellent*, whereas basic avatars were in some cases not recognised as virtual bodies at all and in other cases referred to as *very poor, could be better, extremely simple, or could be improved*.

Conversations between subjects during the experiment were recorded in chat log files (an extract is contained in appendix 1.12) and provided exact evidence of each participant's statements. A qualitative analysis of the log files was conducted investigating subjects' conversational behaviour and the results indicate that meaningful interaction and discussion took place during most of the experimental sessions. Further, throughout, subjects did not mention any general problems when asked about difficulties during (question 20) or any other comments on this experiment (question 23), further indicating the soundness of the experimental set-up of this study.

5.7 Summary

In sum, this experiment has succeeded not only in investigating the use of avatars in CVEs, but also in finding empirical evidence for the benefits of certain types of avatars by measuring a cognitive variable called presence. Within this chapter evidence was found for the hypothesis that the degree of experienced presence is higher when deploying cartoon-style or humanoid avatars, compared to basic shape avatars. Since presence is crucial to CVEs (as discussed in chapter 4) it is argued that the use of cartoon-style or humanoid avatars therefore improves the virtual environment experience of participants, compared to using basic shape avatars. This is a significant finding for the future design of educational CVEs, in that the results of this study strongly recommend the use of cartoon-style or humanoid avatars, with some evidence pointing at humanoid avatars being the most suitable type of avatar. The next chapter investigates and explores further issues concerning the deployment of this humanoid type of avatar within a field study conducted on behalf of Axis, the British national artists register.

Chapter 6 - CyberAxis Field Study

Informed by findings from the previous experiment, as discussed in chapter 5, this chapter discusses a quasi-experiment in Robson's sense (Robson 2001), a field study concerned with the design, implementation and evaluation of CyberAxis, a multi-user virtual art gallery. The argument and evidence in chapter 5 suggests that humanoid avatars should be used to represent visitors to CyberAxis. The aim of the field study was to find further evidence for the benefits of humanoid avatars and to further investigate subjects' experience of presence, in an actual on-going CVE. This chapter describes the experience of visitors (6.1) as well as the software system used to implement the gallery (6.2); user statistics are evaluated (6.3), presence measures applied are described (6.4) and the statistics and qualitative data collected are discussed (6.5).

CyberAxis was built as an interactive 3-dimensional virtual representation of an art gallery providing a means to view and discuss artworks over the Internet. Visitors to CyberAxis could *walk around* the virtual space by manipulating their avatars. Images of artworks exhibited in CyberAxis were selected from the Axis database. On-line artist residencies complemented a series of professionally curated exhibitions. During these residencies, artists were available in the virtual gallery represented through their avatars, and the public was invited to join live debates. The initial phase of CyberAxis was a Millennium Commission Lottery project forming part of the Millennium Festival. Partners in the project were Axis, the Interactive Systems and Learning Environments (ISLE) research group at Leeds Metropolitan University and the National Artists Association (NAA).

Axis regarded the CyberAxis project as crucial in facilitating discussions to shape the mutual roles and responsibilities of artist and society. The assumption behind CyberAxis was that communication technology could give the public access to visual arts in new ways. Axis hoped to attract a new audience to contemporary practice,

particularly amongst young people, proposing a new approach to debate, presentation and *space* by using electronic multimedia together with Internet-based CVE technology to present contemporary artworks and allow visitor to discuss them.

The Axis database was established in 1991 as the British National Artist Register, containing multimedia information on currently 4,000 artists and 20,000 artworks, and aims to provide a gateway to the nation's contemporary artists/makers and art practice. The database initially had a traditional, 2-dimensional, single-user, Windows-based interface, representing a static snapshot of information on registered artists, which was developed by a team of two software engineers, one of whom was the current author. However, the increased accessibility and usability of the Web and the recent rapid increase in 3 dimensional CVE technologies available for the Web was believed to have the potential to offer a new kind of user experience, and this belief motivated the creation of CyberAxis.

6.1 Visitor Experience

The user-interface of the CyberAxis virtual gallery, as opposed to the traditional interface, had not only to allow engagement with objects but, additionally, communication with other users, since by definition, a CVE actively seeks to support human-human communication, and since collaborative discussion was seen as an important part of the application of CVE technology. Given this and the results of the experimental work discussed in chapter 5, CyberAxis adopted animated, humanoid avatars representing visitors and artists and enabling them to gather in a 3-dimensional multi-user virtual world.

A CyberAxis homepage was developed to provide background information on the project, as well as instructions for participation (see screenshot in appendix 2.1). The gallery experience itself was a simulation of a visit to a physical gallery space. In contrast with the basic design of the prototype gallery developed for the previous experiment on avatars (see chapter 5), which consisted of only one room exhibiting 4 images on bare walls, the current design, although also based on VRML, was far

more elaborate, with the geometry of the CyberAxis gallery consisting of three exhibition rooms (each exhibition room containing 15 artworks) and one reception room, more realistic and sophisticated texturing, for example walls and ceilings, and more objects placed in the gallery, such as furniture and information boards.



Figure 6.1: Avatar Selection

On arrival visitors were provided with a selection of humanoid avatars (see Figure 6.1). Visitors selected their own avatars and these became the individuals' representation during their visit to CyberAxis. The avatars in CyberAxis could walk freely within the gallery space and see images from different distances and different angles. CyberAxis visitors were able, via their avatars, to communicate with others using verbal and non-verbal channels.

Verbal communication took place in form of text chat using the computer keyboard, with added text-to-speech voice output. Non-verbal communication was enabled through the selection of predefined gestures and facial expression, triggered by a mouse click and conveyed through the avatars. Because visitors interacted through their avatars (a screenshot of visitors in CyberAxis is shown in figure 6.2), it is argued that communication could take place without the existence of prejudices and preconceptions based on physical appearances (Gerhard et al 2001b).



Figure 6.2: Screenshot of Visitors in CyberAxis

6.1.1 Exhibition Programme

CyberAxis initially hosted a series of four exhibitions, with a variety of themes being suggested by art experts at Axis (see appendix 2.3). These four exhibitions were professionally curated and accompanied by artist residency sessions. A fifth exhibition curated by users of the Axis database concluded the programme, which was as follows:

- 1) Exhibition: Star Date 2000, by Julie Mackie, 8th June 2000 to 28th June 2000, duration: 21 days
- 2) Exhibition: Landmarks, by Angela Edmonds, 29th June 2000 to 19th July 2000, duration: 21 days
- 3) Exhibition: Exploring the Possibilities, by Jenny Rumens and Sally Wallace, 20th July 2000 to 9th August 2000, duration: 21 days
- 4) Exhibition: Cabinet of Curiosities, by Chila Kumari Burman, 10th August 2000 to 30th August 2000, duration: 21 days
- 5) Exhibition: Common Curator, by Samantha Turner Lee, 10th January 2001 to 30th January 2001, duration: 21 days

A brief outline of each exhibition, provided where applicable by the curating artist, is given below.

Exhibition 1 - 'Star Date 2000'

“The theme is based on artists selected from the ten Regional Art Board regions, and all with the star sign Aquarius. The look and feel of the show will be a little tongue in cheek and humorous. The aim is to communicate the artist as well as the artwork, examining the artist’s ideas and processes and being equally sensitive to the needs of the artist and audience.” (Julie Mackie)

Exhibition 2 – ‘Landmarks’

“The primary aim of the exhibition is that it will be accessible to all and will engender debate including that of the artist’s role in breaking down geographical barriers, both real and imagined, as we enter the millennium.” (Angela Edmonds)

Exhibition 3 – ‘Exploring the Possibilities’

“The exhibition looks to foster awareness of the breadth and depth of talent shown by contemporary artists and design makers, to encourage people to own and enjoy works of art in their own homes, and show how to incorporate works of art by contemporary makers in domestic settings.” (Jenny Rumens and Sally Wallace)

Exhibition 4 - 'Cabinet of Curiosities'

“The themes of the exhibition include a tribute to the achievements of African, Asian and Caribbean Women as originators of many cultural traditions and ideas; Exploring the complexity of representations of British Asians in an attempt to move beyond racist and sexist stereotypes. A look at how different artistic and cultural practices survive and develop within contemporary media intensive consumer culture; Rethinking identity within Asian and Western Feminism; and the Yoni, the sacred symbol of female creative power.” (Chila Kumari Burman)

Exhibition 5 – ‘Common Curator’

The final exhibition was organised by Samantha Turner Lee and curated by users of the Axis online database nominating their favourite artworks, which were then exhibited in the so-called *Common Curator* exhibition.

6.1.2 Artist Residencies

Artist residencies were organised for the four initial, professionally curated exhibitions. The artists in residence complimented the exhibition programme by

providing an on-line essay and by being available for discussion with gallery visitors during scheduled sessions.

The artists produced on-line essays on a subject of their choice, which they felt relevant to the “Year of the Artist and Contemporary British Art”. For example, Angela Edmonds contributed an essay on *the artists' role in breaking down cultural preconceptions and geographical barriers to create new mutual meeting points*. During a session of artist-in-residence visitors could join a debate with the artists and other visitors.

The artists in residence were required to be on-line for 20 hours during their exhibition, i.e. 10 sessions of 2 hours, with the times and duration for each session being published in advance. At these times, the artist represented by their avatar was on-line in the CyberAxis gallery to discuss their works.

The artist residency debates were seen as core to the success of CyberAxis. The residencies allowed the artist to gain experience in, and benefit from, articulating their experience to the Internet community. In addition, the Internet community could listen to artists explaining their visual art practice and possibly engage in debate about it.

6.1.3 Advertising of CyberAxis

A marketing campaign was undertaken by Axis to inform potential users about the availability of CyberAxis and ways to participate in the virtual gallery experience. A brand image for CyberAxis was created (see figure 6.3) and explanatory leaflets and press information produced. The principal aim of the advertising campaign was to explain the nature of the CyberAxis project and encourage individuals to get involved.

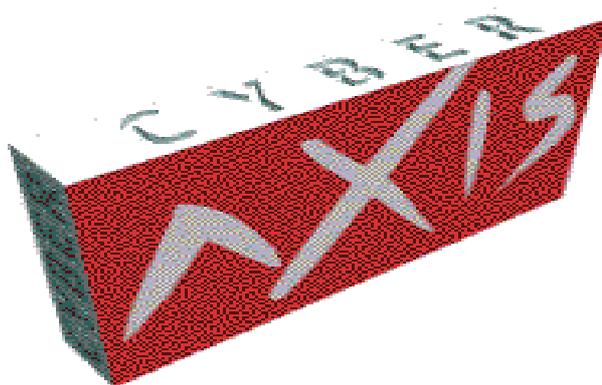


Figure 6.3: CyberAxis Logo

6.2 System Implementation

The blaxxun Virtual World Platform (VWP) software was used to implement the Virtual gallery. The VWP is a modular software system, upon which 3 dimensional internet-based communications solutions can be produced. A wide range of features such as a VRML multi-user server and a community administration interface are integrated into VWP enabling the development and operation of scalable, stable CVE applications. Current areas of use include online communities (e.g. Cybertown) and virtual worlds for business, retail and entertainment.

The blaxxun VWP is based on a flexible and expandable architecture. It contains an application programming interface (API) that allows the developer a comprehensive system for adapting and expanding its capabilities. The Server API enables functional enhancements to the server component, such as the definition of additional user attributes and the connection to an external user management system (see diagram of system architecture in appendix 2.2).

The Client API is the basis for all functional enhancements. It is possible, for example, to integrate Java applets for game generation, screen updates and audio and video components, as well as to adapt blaxxun client modified 3D environments. The

Agent API offers access to agent scripting from blaxxun. This allows the applications developers to link pre-defined agent actions with various system events. New events and reactions can also be defined. Via the Agent API, the blaxxun agent can be integrated with complementary AI technologies.

The features of blaxxun's VWP features were accessed through a browser, via HTML and blaxxun Contact. blaxxun Contact is a VRML plug-in and is installed locally on the client's hard drive. It requires Windows 95/98/2000/NT/ME operating systems, supports MS Internet Explorer and Netscape Navigator browsers, and runs on machines with at least Pentium II (400Hz) CPU and 32 MB RAM.

6.3 Evaluation of User Statistics and User Feedback

User statistics (see table 6.1) were extracted from the Axis Web server log-file. They show the number of distinct visitors to each exhibition (i.e. number of visitors with distinct IP addresses) and the number of hits (i.e. number of requested pages) received within the same period. The number of hits to CyberAxis pages indicates user activity within the virtual gallery, whereas the number of distinct IP addresses indicates the number of different machines accessing the site, which in turn can be taken to indicate the number of distinct visitors.

Relating the duration of artist residencies to the number of distinct visitors and number of hits can be seen as an indication of the importance of artist residencies. It seems the residencies, which enabled human-to-human communication, albeit computer mediated, between artist and visitor, were vital to retaining visitors' interest. The fifth exhibition, so-called *Common Curator*, did not have scheduled residencies; interestingly it attracted a high number of distinct visitors, yet received the lowest number of hits. Therefore, its ratio of hits per visitor was lower compared to the 4 exhibitions accompanied by artist residencies (see Table 6.1).

Exhibition	Residencies	Visitors	Hits	Hits/Visitor
1 Star Date 2000	20 hours	187	6,693	35.79
2 Landmarks	20 hours	125	5,610	44.88
3 Exploring the possibilities	20 hours	162	6,358	39.25
4 Cabinet of Curiosities	20 hours	125	4,260	34.08
5 Common Curator	0	194	2,472	12.75

Table 6.1: CyberAxis User Statistics

It can be argued that the fact that the number of hits per visitor is significantly lower in exhibition 5 (*Common Curator*) indicates that the presence of a resident artist was appealing to visitors and that a lack of copresence as a result of the absence of an artist residency might have had a significant influence on visitors' experience, in that the gallery was perceived as *empty*. To further investigate this, the effects of the existence or non-existence of copresence on subjects' experience of presence were compared. It was believed that this might be revealing with regard to the extent to which copresence of humanoid avatars representing other participants might influence users' experience of presence in educational CVEs, given the prima facie argument in chapter 3 for the claim that copresence is likely to engender presence. The investigation was designed to yield empirical evidence for this claim.

6.3.1 User Feedback Questionnaire

To capture user experiences an online questionnaire (see Figure 6.4) based on previous work (Gerhard and Moore 2001a and chapter 4 above) was developed. In an attempt to increase the number of completed questionnaires, visitors were told they would be automatically entered into a prize draw, where Axis CD-ROMs could be won, when submitting their questionnaire. The questionnaire was designed to measure users' subjective experiences of presence (the full questionnaire is in

appendix 2.5) and to capture qualitative feedback regarding their experience. It was based on presence questionnaires used in other VE evaluation studies (Gerhard et al 2001b and chapter 5 above), using Likert scales questions as well as open-ended questions.

http://160.9.240.100/cgi-bin/evalques.pl - Microsoft Internet Explorer

File Edit View Favorites Tools Help

AXIS

CyberAxis Evaluation Questionnaire

Please characterise your experience in the virtual gallery by marking the appropriate box of the 7 point scale, in accordance with the question content and descriptive labels.

0. Besides you how many people were in the virtual gallery?

0 1 2 3 4 5 more than 5

1. How stimulating was the design of the virtual world?

not at all moderately completely

2. How aware were you of the existence of your avatar?

not at all moderately perfect awareness

3. How natural was the mechanism to control your avatar?

extremely artificial moderately natural completely natural

Figure 6.4: Screenshot of Part of the Online Evaluation Questionnaire

The issue to be investigated, stated on a conceptual level was:

→ How is the experience of presence in CVEs influenced by copresence?

A suggested answer to that problem was drawn up in the following conceptual hypothesis:

→ Co- presence and subjects' experience of presence in CVEs are positively related.

This in turn lead to the definition of the following operational hypothesis:

➔ The degree of experienced presence is higher when avatars representing other participants are co-present.

6.4 Applied Presence Measures

6.4.1 Questionnaire Evaluation

The degree of presence visitors experience is seen as the key indicator for the usability of the CVE, hence *Presence* is the intervening variable of this quasi-experiment (see Figure 6.5).

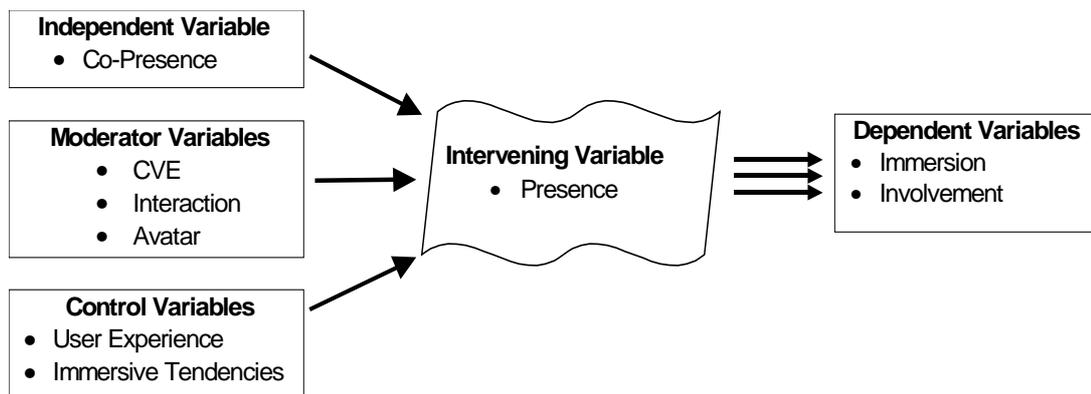


Figure 6.5: Combined Variables for Quasi-Experiment

The existence or non-existence of one or more avatars representing other visitors, i.e. *copresence*, are the two conditions to be compared here, and can be seen as the independent variable. Visitors' responses to changes in the natural occurrence and distribution of copresence are investigated, given the two levels of copresence: $x_1 = \text{no copresence}$ (no other visitors present) and $X_2 = \text{copresence}$ (one or more other visitors are present).

The dependent variable is the response variable. The impact of copresence and its effects on the users were observed by measuring, via the questionnaire, subjects' experiences of *Immersion* and *Involvement*, which can be seen as the dependent variables in this setting. The presence subscales *Communication* and *Awareness* adopted in the controlled experiment discussed in chapter 5 were discarded here, as it was impossible to measure these subscales when some of the visitors were alone in the gallery, experiencing no copresence at all – in such circumstance they can neither be aware of, nor communicate with, others.

Visitors' previous experiences as well as their individual immersive tendencies are individual personal characteristics, which are likely to be influential to the experience of presence (Gerhard et al 1999a and chapter 4 above). Given this, *User Experience* and *Immersive Tendencies* are seen as the control variables in the controlled experiment in chapter 5. Within the current field study, these variables could not be properly controlled; rather, they were addressed via the analysis of the naturally occurring data.

The subscales applied to the questionnaires (see table 6.2) are based on the subscales discussed in chapter 4 and applied to the questionnaire used in chapter 5 (see also Gerhard et al 1999a, Gerhard and Fabri 2000). The questionnaire contained four further items (questions 17, 18, 19, 20) for qualitative analysis.

Subscales for Dependent Variables	
1 Immersion (IMM)	Questions 2, 7, 10, 14, 16
2 Involvement (IVM)	Questions 4, 5, 11, 12 (reverse anchor), 13, 15
Subscales for Moderator Variables	
3 CVE (CVE)	Questions 1
4 Interaction (INT)	Questions 3, 6
5 Avatar (AVA)	Questions 8, 9
Subscales for Control Variables	
6 Experience (EXP)	Questions 21, 22, 23, 24
7 Immersive Tendencies (IMT)	Questions 25, 26, 27, 28, 29, 30

Table 6.2: *Questionnaire Subscales for Variables*

6.4.2 Results and Analysis

Overall, 23 feedback questionnaires were received, 9 under condition X1 (no copresence, i.e. the visitor did not meet the artist in residency or any other visitor while in CyberAxis) and 14 under condition X2 (copresence, i.e. the visitor met either the artist or at least one other visitor while in CyberAxis), as reported by participants in question 0 (cf. appendix 2.5). Individual results of the questionnaire are listed in appendices 2.6 and 2.7.

Independent Variable	Copresence	X1 (no copresence)		X2 (copresence)	
	Sub-scales	MEAN	STDEV	MEAN	STDEV
Dependent Variables	1 Immersion (IMM)	2.2444	.5077	5.3000	.7348
	2 Involvement (IVM)	1.8900	.3338	4.7493	.5211
Moderator Variables	3 CVE (CVE)	3.8889	1.5366	5.2857	1.2666
	4 Interaction (INT)	2.6111	.8580	4.8929	1.1296
	5 Avatars (AVA)	3.3889	1.2191	4.7500	.9146
Control Variables	6 Experience (EXP)	3.0000	1.6863	2.9286	1.1537
	7 Immersive Tendencies (IMT)	3.2600	.8459	3.2129	.7118

Table 6.3: Descriptive Statistics for all Variables

Table 6.3 shows means and standard deviations for the scores of the dependent variables (subscales 1 and 2), as illustrated in figure 6.6. It also shows means and standard deviations for the scores of the moderator variables (subscales 3,4,5) and the control variables (subscales 6 and 7).

As can be seen from table 6.3, the mean scores for experience (EXP) and immersive tendencies (IMT) were similar for both subject groups: experience (EXP: \underline{M} X₁= 3.00, \underline{M} X₂= 2.93) and immersive tendencies (IMT: \underline{M} X₁= 3.26, \underline{M} X₂= 3.21). This indicates that means measured for the control variables are not significantly different

between the two subject groups, and thus that any differences in the dependent variables will be caused by differences in the environment rather than differences in the users.

To assess whether there was a statistically significant difference in the presence mean scores for the two groups, an independent samples t-test was performed. A pre-condition for the use of the independent samples t-test is a reasonably normal distribution of scores of the control variables. The inspection of the shape of the histograms below (see figures 6.7 and 6.8) shows that the control variables were indeed reasonably normally distributed.

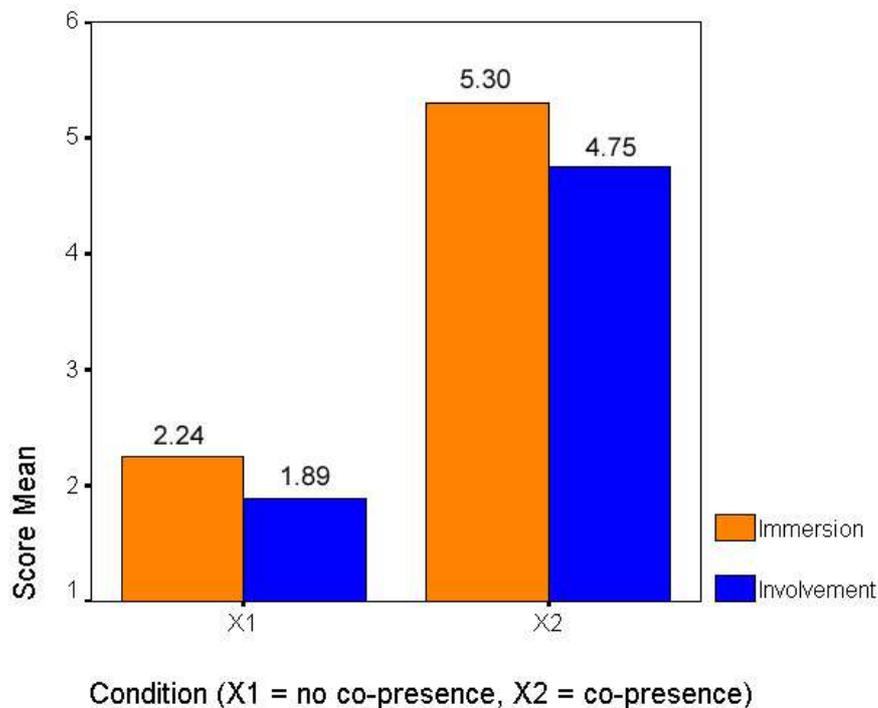


Figure 6.6: Mean Subscale Scores

Presence is the combined results from subscales 1 and 2. Table 6.4 (below) shows the mean (illustrated in figure 6.9), standard deviation and standard error for presence. Table 6.5 shows the results of the independent-samples t-test performed on the current data.

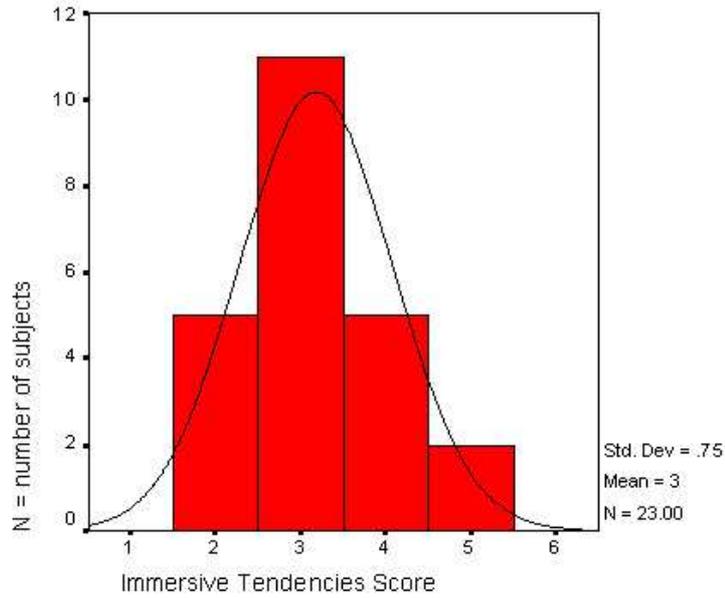


Figure 6.7: Histogram for Distribution of IMT

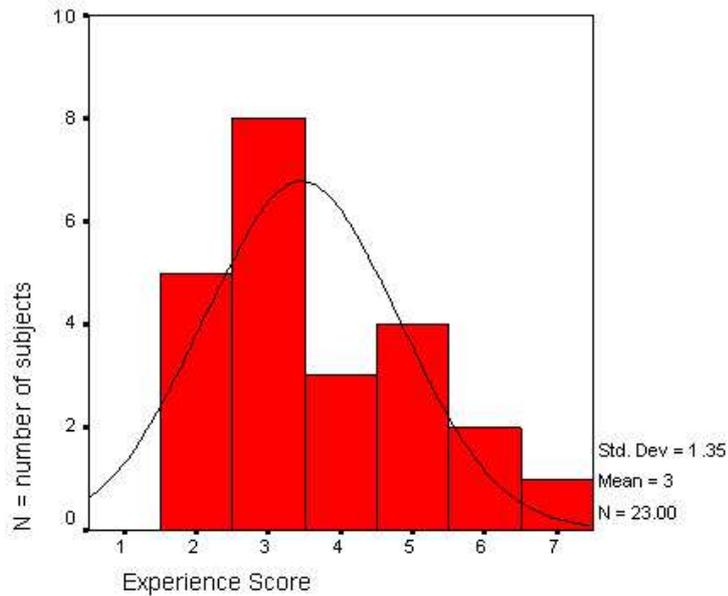


Figure 6.8: Histogram for Distribution of EXP

	Condition	N	Mean	Std. Deviation	Std. Error
Presence	X1	9	2.0500	.3833	.1278
	X2	14	5.0007	.5556	.1485

Table 6.4: Group Statistics for Presence Scores

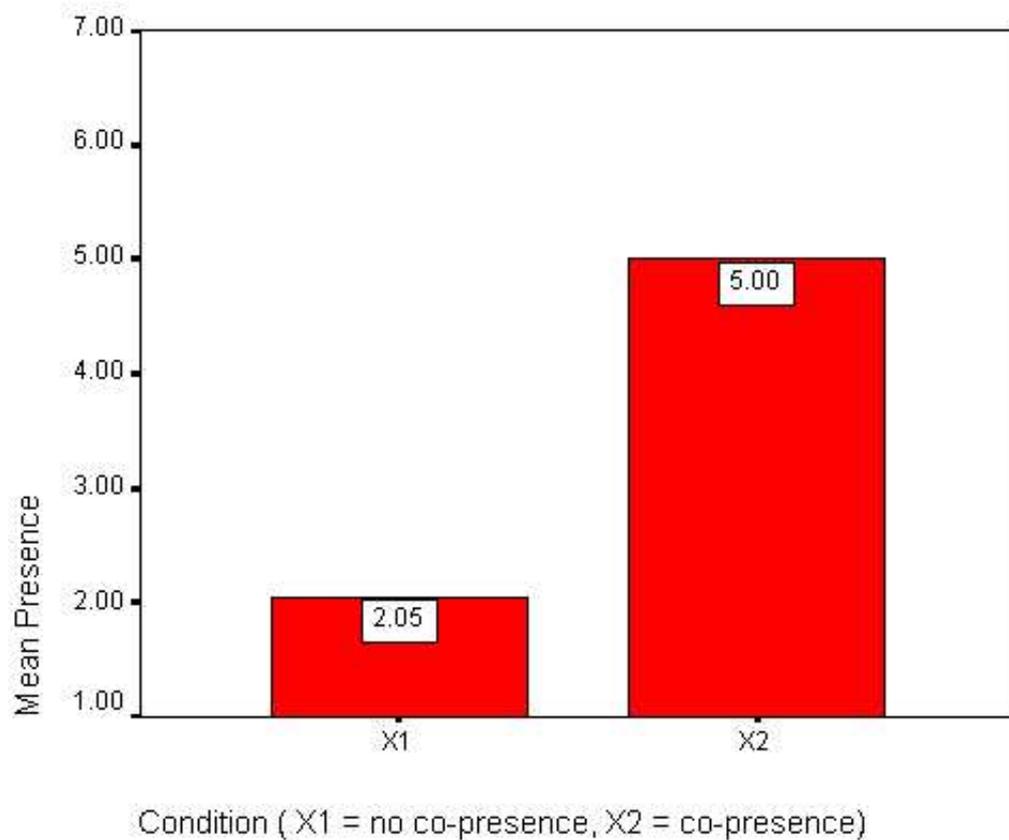


Figure 6.9: Presence Means for Conditions X1 and X2

Levene's test for equality of variances was carried out to determine whether the variation of scores for the two groups (X1 and X2) were the same. This in turn determines whether or not equal variances can be assumed, and which t-value provided in table 6.5 is appropriate. As the significance value is larger than .05 (here it is .461), *equal variances are assumed*. This means that the assumption of equal variances has not been violated; therefore, the t-value is the one provided in the first line of table 6.5, i.e. $t = -13.895$. The t-value is negative because the first mean is smaller than the second mean tested.

The value for significance (Sig. 2 tailed) is less than .0005; therefore there is a significant difference in the mean scores on Presence for each of the two groups. This in itself gives evidence that the difference could not have occurred by chance.

However, to provide an indication of the magnitude of the differences between the two groups the effect size was also calculated.

Levene's Test for Equality of Variances			t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% C.I.	
								Lower	Upper
Equal variances assumed	.565	.461	-13.895	21	.000	-2.9507	.2124	-3.3923	-2.5091
Equal variances not assumed			-15.063	0.825	.000	-2.9507	.1959	-3.3583	-2.5431

Table 6.5: Independent Samples Test of Presence Mean

There are a number of different effect size statistics, the most commonly used is *eta squared* (Kirk 1982). Eta squared can range from 0 to 1 and represents the proportion of variance in the dependent variable that is explained by the independent variable. The formula for eta squared is as follows:

Eta Squared = $t^2 / t^2 + (N1 + N2 - 2)$ (where t is the t-value provided in table 6.5, and N1 and N2 are the sample sizes provided in table 6.4)

Replacing with the appropriate values from above (where t=13.895, N1=9, N2=14):

Eta Squared = $13.895^2 / 13.895^2 + (9 + 14 - 2) = 0.90$

Expressed as a percentage this means that 90% of the variation in the presence scores can be explained by the existence (or non-existence) of copresence.

6.5 Discussion

Since the launch of CyberAxis, it has become apparent that technology is still a hurdle not everybody was able to overcome. For example, it was revealed by the chat

log files captured in CyberAxis that the download and installation of the VRML browser plug-in caused problems on low-spec machines and slow Internet connections (for example see extract from chat log in Figure 6.10 below).

[Visitor 1]: Hello, what brings you to Star Date 2000?
[Visitor 2]: Trying to find pictures. How do we do it? All we can see is an empty gallery.
[Visitor 1]: Which gallery are you in? do you know?
[Visitor 1]: Can you come in 3D instead of 2D?
[Visitor 2]: 3D? I don't think we have the plug ins.
[Visitor 1]: OK, I can't see you and I guess that's because you're 2D
[Visitor 1]: It takes about 5 mins to download the blaxxun plug-in
[Visitor 2]: We tried that before but nothing came down the line. Where do we get it?
[Visitor 1]: Go to Cybertown.com However I would imagine you can still see in 2D mode
[Visitor 2]: We'll log off and try again later...

Figure 6.10: Extract from Chat Log File

However, user statistics (see Table 6.1) have shown that many visitors have been able to explore the virtual gallery and there was a substantial amount of debate about artworks, avatars and CVE technology (for example see figure 6.11). Further, user statistics in table 6.1 show that the 5th (Common Curator) exhibition caused the fewest number of hits. It was speculated that the lack of artist residencies and the associated reduction of copresence could have caused the low number of hits and could be a strong indicator for the importance of copresence.

However, it could be argued that the low number of hits in the absence of artist residencies might be caused by a number of factors, such as the perceived quality of exhibition, as this was not an experiment in a controlled environment. The questionnaire was therefore used in an attempt to underline and clarify findings derived from the user statistics by capturing qualitative feedback and measuring subjects' experience of presence.

[Visitor 1]: I feel like an intruder though the subject really interests me and I have made a lot of relating to family and especially female forebears

[Visitor 2]: Avatars are interesting in themselves as signifiers!

[Visitor 1]: mine is definitely an alter ego

[Visitor 2]: yes I had guessed actually!!!

[Visitor 2]: It is tall and slim and quite sophisticated

[Visitor 1]: Much more extrovert ... perhaps what I would like to be?

[Visitor 2]: I think you should ask the artist in residence something

[Visitor 2]: You can come here any time to see their pictures, which is what I do

[Visitor 1]: My work is also a way of exploring issues I find impossible to articulate verbally. The artist in residence articulates very clearly through her work

Visitor 2: But what do the bras signify that is very different?

[Artist]: *Do they have to signify anything different from an individual's response.*

[Visitor 1]: I wonder if the repetition is part of a process of demystification

[Visitor 2]: That is more or less what the artist in residence said to my questions earlier, but I am afraid it is a cop out from critical debate

[Visitor 2]: Demystification of WHAT?

[Visitor 1]: Perhaps removing some of the power from the image almost by banalising it.

[Visitor 2]: The artist is here to respond to your questions.

[Visitor 1]: Demystification of the breast . . . prettified and eroticised by satin and lace.

[Artist]: *By repetition it is not so much about demystification but about placing emphasis on the way in which the bras have been used in a way that highlights objectification of women.*

Figure 6.11: Extract of Debate

Although the number of completed evaluation questionnaires was, despite the prize draw, a rather low 23, it is believed that a satisfactory analysis of the questionnaires was possible despite the small sample size. The control variables in this setting were user experience (EXP) and immersive tendencies (IMT), however, within the current field study these variables could not be properly controlled, rather, they had to be tested for. The analysis of the data revealed that the score means for EXP and IMT were very similar between subjects under condition X1 and X2. Further, the inspection of the shape of the histograms for the EXP and IMT scores (see figures 6.6 and 6.7) shows that the control variables were reasonably well distributed and

their influence on the presence scores too little to be deemed a significant factor behind the differences in presence mean scores between the two treatment groups.

The analysis implies that a lack of copresence significantly reduces the level of presence experienced by participants. An independent-samples t-test was conducted to compare presence scores for subjects under condition X1 (no copresence) and under condition X2 (copresence). The subjects scores under X1 ($M=5.00$ $SD=0.56$) were significantly higher than subjects under X2 ($M=5.00$ $SD=0.56$). The magnitude of the differences in the means was high (eta squared=0.90), which indicates that the different conditions had a big impact on visitors' experience of presence. This shows that participants who met other people during their visit to the virtual art gallery experienced increased degrees of presence.

“[the deployment and appearance of avatars was]... absolutely significant. After I realised I could view my avatar, I got quite into my own 'manifestation' - always wanting to have the same one (Cutie) and being irritated by the default avatar. One time another visitor came as Cutie and we had quite a laugh being 'twins'.”

“[the deployment and appearance of avatars was]... extremely important. The gallery seems somehow dead and very empty without them. Avatars which are the more 'articulate' made the experience more realistic and more pleasurable.”

Figure 6.12: Examples of User Feedback on Question 19

In addition to statistical data, the qualitative data from the open questions in the questionnaire was also revealing, although it did not explicitly refer to presence as such. Overall, the qualitative feedback from visitors and artists participating in the CyberAxis project was positive. Avatars were considered very important by participants (for example see Figure 6.12) and seemed to play a very important role for the virtual gallery experience, underlining not only results derived from the feedback questionnaires, but also the experimental results discussed in chapter 5 (and Gerhard et al 2001a).

Overall the analysis suggests that the deployment of humanoid avatars, in particular when other participants are co-present, is beneficial in an open-access CVE in actual use, such as the CyberAxis virtual art gallery.

6.6 Summary

This chapter adopted the theoretical underpinnings for understanding the relevance of user embodiments in CVEs developed in chapter 3 above (cf. Gerhard and Moore 1998) and applied results of the experiment discussed in chapter 5 within a field study of an open-access CVE in actual use. Within this field study evidence has been found that copresence significantly increases the level of presence experienced by participants. This finding is important given Huxor's (1998) argument that when members of a group are not co-present, there is a lack of community feeling.

Given the importance of copresence, it might be argued that, in the absence of other human collaborators in a CVE, copresence can potentially be simulated using agent technology to control avatars within CVEs (cf. Gerhard et al 2002). However, the potential of such agents needs further investigation within a controlled environment to find more evidence concerning their potential to simulate copresence and their potential to complement avatar technology and eventually form a hybrid avatar/agent model for user embodiments in educational CVEs. A pre-requisite for such an investigation is to find or build a suitable prototype agent. This will be considered in the next chapter.

Chapter 7 - Agent Technology

As discussed in the previous chapter, analysis of the CyberAxis field study suggests a direct relationship between the feeling of being present in a CVE as experienced by participants and the copresence of other participants. It emerged that people who were alone in the CVE, experiencing a lack of copresence, consequently experienced significantly reduced levels of presence. The evidence suggests, that is, that copresence significantly increased the feeling of presence. This intuitively suggests that it might be beneficial to extend the level of copresence by deploying agents simulating the copresence of other users. Given that, agents can potentially act on behalf of users in their absence, and thus increase the feeling of presence as experienced by other participants.

This chapter therefore introduces the basic concepts of agent technology and gives an overview of current research in the field (7.1). It investigates embodied conversational agents in more detail in terms of their potential suitability for simulating users in CVEs (7.2) and describes a prototype agent developed by the author for deployment in such an environment (7.3). Since evaluation is seen as crucial in interactive environments (cf. chapter 4), a set of evaluation metrics is proposed (7.4) and its application to the agent model discussed (7.5).

7.1 Underlying Concepts and Current Research

Agent technology is considered to be one of the most vibrant, fastest growing areas of information technology (Wooldrich et al 1999). Broadly defined, an *agent* is a program that can operate autonomously and accomplish tasks without direct human supervision. The basic idea of agent research is to develop software systems that *engage and help* all types of users (Riecken 1994). Such agents are meant to carry out tasks on behalf of the user in complex, dynamic environments and serve as

another layer of mediation within the system (Maes 1995). Researchers involved in software agent technology have offered a variety of definitions. Franklin and Graesser (1996) define an agent as a system situated within an environment that senses that environment and acts on it over time, in pursuit of its own agenda or acting on behalf of the user.

The agent field is intimately related to the field of Artificial Intelligence (AI), the notion of an *agent* being clearly evident in early AI literature. For example, the Turing test, put forward by Alan Turing as a way of settling the argument about whether machines could ever be considered to be intelligent (Turing 1950). The idea of the test is that a person, the *Interrogator*, interrogates some entity via a computer monitor. The interrogator is free to put forward any questions or statements whatsoever, and after five minutes is required to decide whether the entity at the other end is another person or a machine. If the interrogator is unable to distinguish a machine's conversational response from those of a human, then, Turing argued, the program must be considered intelligent to all intents and purposes.

Such a program can surely be considered an *agent*, as it is required to respond in real time to statements made by the person, thereby exhibiting autonomous behaviour (Wooldrich 2002). Many researchers believe that to be called *intelligent*, an agent must satisfy several interrelated criteria. Weld (1995) summarizes five attributes, which, he claims, capture the essence of an *intelligent* agent:

- *Integrated*: The agent must support an understandable, consistent interface.
- *Expressive*: The agent must accept requests in different modalities.
- *Goal-oriented*: The agent must determine how and when to achieve a goal.
- *Cooperative*: The agent must collaborate with the user.
- *Customized*: The agent must adapt to different users.

Agents can be pro-active and purposeful; they can exercise control over their own actions to a certain predefined degree. Agents can have a believable personality and

emotional state. They are able to interact with other agents, and collaborate with them to achieve common goals (Müller 1996). By applying artificial intelligence paradigms such as expert systems, neural networks, and genetic algorithms, agents can be adaptive and capable of learning. Instead of pre-ordained scripted actions their behaviour can be based on their previous experience (Wooldrich 1999).

The field of agent technology is fairly new and very broad; it includes research in different software engineering fields such as interface design, communication and coordination, adaptation and learning algorithms (Hopgood 2001). Various researchers have adopted different names, such as autonomous agents, adaptive interfaces, intelligent interfaces, knowbots, and intelligent agents. There has been significant progress in techniques for creating agents over recent years (Tecuci 1998). Research on and discussion of intelligent agents has mushroomed in the past few years. Isbister and Young (2001) argue that improvements in artificial intelligence techniques and the growing need for better interface metaphors have led to two converging areas of research on agents

One research emphasis is on the use of AI techniques to create software that performs information filtering and other intelligent tasks for users. These agents may or may not display any explicitly anthropomorphic features. The second research emphasis is on the agent as an interface metaphor that aids the user. Their essential function is to act as effective bridges between a person's goals and expectations and the computer's capabilities. The agent metaphor is used to make the interface more intuitive and to encourage types of interactions that might be difficult to evoke with a traditional graphical user interface. These agents may or may not incorporate new AI techniques. Further, agents of this sort need not be explicitly anthropomorphic, either, although this is the primary arena in which the expressive qualities of *characters* are being explored (Laurel 1997).

7.2 Embodied Conversational Agents

For the current project, agents exhibiting explicit anthropomorphic features, so-called *embodied conversational agents* (ECAs) are of particular interest. An ECA does not necessarily need to exhibit truly intelligent behaviour; it is merely about the illusion of intelligence and the suspension of disbelief on the part of the user (Lombard and Ditton 1997). Conversational agents are agents that use natural language to interact with a user. To be *embodied* means that the agent has at least a body and a face and, ideally, is endowed with attributes such as facial expression, direction of eye gaze, gestures, the ability to point and the ability to move around within the environment. Hence, an ECA can be defined as a computer interface that is specifically conversational in its behaviour, and specifically humanlike in the way it uses its body in conversations (Cassell et al 2000). As such they are of particular interest here because of their potential to simulate copresence in CVEs.

Research investigating design guidelines to assist in choosing the appropriate embodiment of conversational agents (McBreen et al 2000) has pointed out that participants expect a high level of human-like communicative behaviour from the agents. Further, results of experiments involving subjects viewing videos of different avatar types, show that with respect to animated humanoid agents, participants prefer 3D to 2D representations and prefer to interact with fully embodied agents than heads alone (McBreen and Jack 2000).

A very interesting aspect of ECA technology is its use for avatars in CVEs. Indeed, Cassell et al (1999) argue that the use of agent technology to generate automated animation of communicative behaviour of avatars is seen as crucial for the credibility and effectiveness of avatars. Although avatars resemble communicative interface agents, they tend not to adopt results from recent research into embodied conversational systems. An exception is BodyChat, a system that allows users to communicate via text while their avatars automatically animate attention, salutations, turn taking, back-channel feedback and facial expression (Cassell and Vilhjálmsón

1999). With few exceptions the area has seen limited research, and it was expected that the current project would help to address this.

In face-to-face interaction most of the behaviours that people use to influence each other socially are conveyed either through language or nonverbal behaviour, and arguably therefore, it is crucial that ECAs for CVEs have these communication channels at their disposal as well. Indeed, Cassell et al (2000) argue that, ideally, ECAs have the same properties as humans have in face-to-face conversation, including the ability to:

- recognise and respond to verbal and non-verbal output.
- generate verbal and non-verbal output.
- deal with conversational functions such as turn taking.
- give signals that indicate the state of the conversation.
- contribute new propositions to the discourse.

Embodied conversations imply face-to-face interaction, in contrast to the purely linguistic interaction of, for example, a telephone conversation. An ECA utilises the knowledge users already have about how to engage in face-to-face conversation, making them potentially more natural and easy to use than any other form of human-computer interface (Cassell and Vilhjálmsón 1999). Further, embodiment might be very helpful in compensating for speech misrecognitions and ambiguity, and there is some evidence that having available channels of non-verbal communication enables easier and faster correction of speech misrecognitions (Karat et al 1999).

Indeed, it can be argued that embodied conversation generally works better than purely linguistic interaction and that the mechanics of conversation are different when gesture and facial expression are available. Embodiment might also be expected to help with the mechanics of dialogue such as turn taking, since bodily behaviours are the most important means through which human participants in a face-to-face conversation accomplish turn taking behaviours and assess each other's continued attention and understanding (Sanders and Scholtz 2000).

Other modifications to linguistic interaction as a result of embodiment include the ability to point with the finger to indicate direction. In a speech-only system the agent might say, “Press that green button in the middle of the top row”. But if the buttons are shown on screen, the agent could walk to the button and then point at the green button and simply say, “Press here”. Or, an embodied agent could pick a physical object within the environment and say e.g. “Turn it like this”, while showing how by means of gesture.

In addition to the abilities to generate or output embodied behaviours, ideally, ECAs should also have the corresponding input abilities, such as recognising and understanding the users’ (i.e. their avatars’) eye gazes, facial expressions, gestures and movements within the environment. These kinds of *embodied inputs* are currently not as highly developed as the output side, but Sanders and Scholtz (2000) argue that they are nevertheless part of the role of an ECA because they play a central role in human participation in conversation

Adding social skills to these agents will serve to make them even more natural and easy to use. People use many linguistic strategies to achieve interpersonal goals, such as building rapport, establishing credibility and trust, effecting persuasion, and befriending (Laver 1981). Goffman (1983) argues that one example strategy is small talk - *light* conversation about neutral topics, such as the weather, which is used to build rapport and trust, provide time to *size* a stranger up, and mitigate *positive and negative face threats*. On this view small talk is not a random phenomenon used to fill idle time, but rather is a linguistic behaviour that can be used strategically in a conversation, for example, to reduce a client's fear before asking them to sign a contract.

There is, then, much interest in ECAs. A promising application area for agent technology is education and training, where the interest is in ECAs that support human learning by interacting with students in the context of interactive learning environments. Within the context of educational CVEs, so-called *pedagogical agents* are required to utilise strategies beyond linguistic behaviour, such as pedagogical and social skills.

7.2.1 Pedagogical Agents

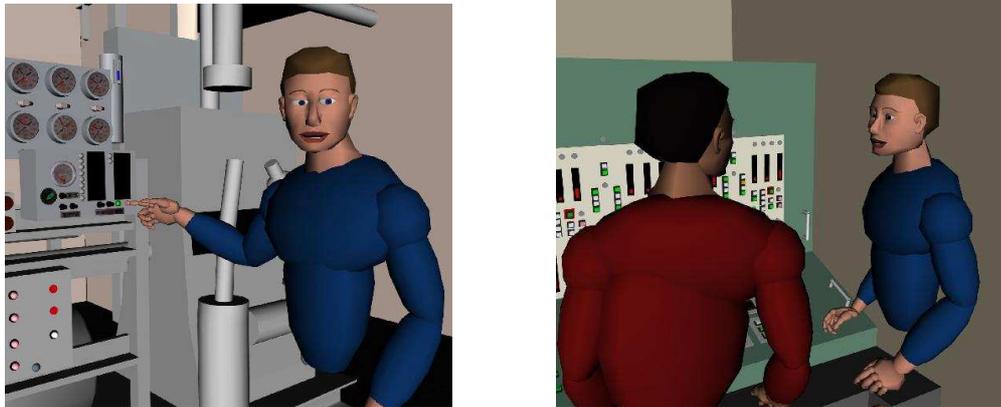
Pedagogical agents can have capabilities such as the co-ordination of speech and actions, the integration of spoken language input, and even the application of constructivist learning theories (Lester et al 1997). Pedagogical agents can also adapt their behaviour to both the environment and the student, offer opportunistic instruction or hints, and can support collaborative learning (Johnson 1998).

Lester and Stone (1997) argue that agents can promote student motivation and engagement, and engender affective as well as cognitive responses. They can produce behaviour that seems natural and appropriate for the role they are playing e.g. teacher, peer or guide. They can give the impression of being lifelike and believable. Animated conversational agents can adapt their behaviour to the needs of the student and the current state of the learning environment (Andre et al 1998). They can help students to overcome difficulties and take advantage of learning opportunities as they arise. Furthermore, they can also collaborate with students and other agents to achieve common goals and are able to provide continuous feedback (Tambe *et al* 1995).

Pedagogical agents have been used to inhabit educational CVEs, where they appear as animated humanoid agents. Dillenbourg (1996) investigated the interaction between real students and computer-simulated students as a collaborative social process and found that such agent characteristics as having the same gender, being of approximately the same age, or being in a similar position (e.g. same job title) are often important in facilitating effective collaborative learning. Similarly, Elliot and Brzezinski (1998) argue that pedagogical agents share aspects in common with agents developed for entertainment applications: they need to be believable and to be able to produce natural and appropriate behaviour.

An interesting example of such agents is Steve (Soar Training Expert for Virtual Environments), a pedagogical agent, designed to interact with students in networked immersive virtual environments, which has been applied to naval training tasks such as operating the engines aboard US Navy surface ships (Rickel and Johnson 1999).

Steve (see figure 7.1) inhabits a virtual learning environment and functions as a tutor and collaborator. His objective is to help students learn to perform procedural tasks, such as operating or repairing complex devices. Rickel and Johnson (1999) claim that Steve integrates several pedagogical capabilities - demonstration, explanation,



and student monitoring - into an architecture capable of sensing and controlling a virtual environment. Steve is driven in part by domain knowledge, in the form of hierarchical plans, provided by a course author. To interact with the student and the virtual environment, Steve incorporates object manipulation, visual attention, gestures and speech.

Figure 7.1: STEVE, by USC / CARTE

Another example is Herman the Bug (see figure 7.2), developed by North Carolina State University's Multimedia Laboratory as part of the *Design-A-Plant* learning environment, a learning environment that purports to help secondary school pupils to understand botanical anatomy and physiology by designing plants for various hypothetical environments (Lester and Stone 1997). Herman is a talkative, quirky insect with a propensity to fly about the screen and dive into the plant's structures as he provides problem-solving advice to students. Bares and Lester (1997) claim that in the process of explaining concepts, Herman performs a broad range of activities, sequenced by a pedagogical behaviour engine, including walking, flying, shrinking, expanding, swimming, fishing, jumping, tele-porting and acrobatics

Thus, work on developing pedagogical agents is progressing. Further, evidence has been found showing that people do respond socially to computer systems; by endowing computer agents with social intelligence and the communicative abilities to use that intelligence, Reeves and Nass (1996) argue, we enable them to fulfil roles that until now have been exclusively in the domain of humans. With appropriate social skills, computer agents would move closer to being usable as digital friends or confidants, effective therapists, counsellors, teachers, or trainers, or persuasive salespeople or corporate representatives.



Figure 7.2: Herman the Bug Interface

More generally, the literature offers much support for pedagogical agents (Johnson 1998, Chan 1996), providing initial evidence that agents may have a valuable role in educational CVEs. However, few pedagogical ECAs have been used in empirical evaluations that have demonstrated the effectiveness of agents in facilitating learning. Moreover, empirical investigations of any kind of embodied interfaces are rare and the results so far have been equivocal (Cassell et al 2000). Further, there has

been little research into the psychological dimensions of copresence and its relation to the process of cognitive immersion and the experience of presence.

Evidence is therefore needed concerning the possibility that utilising agent-simulated copresence will increase users' experience of presence in CVEs. A further controlled experiment was therefore conducted. The obvious context for such an experiment was again the model of the CyberAxis virtual art gallery, as used for the previous field study discussed in chapter 6. A pre-requisite for such a controlled experiment was the development of a suitable agent; this is discussed in the next section.

7.3 Prototype Development

Part of the *blaxxun Virtual World Platform* software is an agent server, which can be interfaced through the *agent.cfg* script file. The agent server, performing event-handling and response selection processes, is responsible for appearance and animation of the agent's avatar. Given the results of the series of experiments discussed in chapter 5 and the observations made on avatars during the field study discussed in chapter 6, a humanoid embodiment of the agent was chosen (see figure 7.3).

Using the *blaxxun* agent script (see figure 7.4 for an extract of the script file) it is possible not only to display an avatar and assign scripted behaviour to be interpreted by the *blaxxun* agent server, but also to interface with external applications to extend the functionality of the agent. Thus, it is possible to incorporate advanced chat skills to create an embodied conversational agent.

Crucial for the effectiveness of the agent is not only its appearance, but also its conversational behaviour; whether it can communicate with others on behalf of the absent user. A (disputed) yardstick for judging machine intelligence is whether it can play what Alan Turing called *the imitation game*, now known as the *Turing Test* (cf. section 7.1 above).



Figure 7.3: Appearance and Animation of the Agent

No computer has actually passed the test, but since 1991 the Loebner competition has put conversational agents to the Turing test and annually awards the best agent with the so-called *Loebner Prize*. The winner of this competition in 2000 and 2001 is an open-source project called *Alice*. Alice is an abbreviation for *Artificial Linguistic Internet Computer Entity*. It is an open source environment dedicated to promoting networked artificial intelligence and natural language processing.

```

Reaction Intro
#-----
# set the class for the bot if the robot has entered the first scene
#-----
[onEnterScene]
  *StartMove* Agent.pos
  *Call* libchatbot.setChatBotClass %hubbot% e:/blaxxun/CommServ/etc
[onAvatarLeft]
  *Call* libchatbot.exitChatSession %nickname%
#-----
# get a response from the Alice chat machine
#-----
[onDirectedText]
  *Say* libchatbot.getDirectedBotResponse % %nickname% %text%
[onAvatarNew]
Hello %nickname% I am %hubbot%. Welcome to the Common-Curator at
CyberAxis. If you like my company, please feel free to talk to me.
[onInviteChat]
*Accept* libchatbot.getBotResponse % %nickname% hi %%
End

```

Figure 7.4: Extract of *blaxxun* agent.cfg script file

Alice uses AIML (Artificial Intelligence Mark-up Language), a non-standard XML-based specification for bots, and includes a large AIML general knowledge base containing 40,000 categories, i.e. units of knowledge, a bot can speak about. Further, special domain knowledge modules are available for downloading (concerning, for

example, artificial intelligence), and additional knowledge modules can be built (in the current context a module containing domain knowledge about art was created).

The prototype agent has been named *Art-Fairy*. The embodiment of the agent is humanoid and its alleged capabilities cover general conversational skills and some (admittedly rather limited) knowledge of the environment. Although a knowledge module was developed for the prototype agent providing some background information about the virtual gallery space and the current exhibition of artworks (see figure 7.5 for an extract from the AIML module), the knowledge base of the prototype was largely based on extensive pre-existing AIML modules available at the time of development.

```

<?xml version="1.0" encoding="UTF-8"?>
<aiml version="1.0">

<category>
<pattern>* AXIS</pattern>
<template><random>
<li>Axis is a charity funded by the Arts Council of England.</li>
<li>Axis is located in Leeds at Leeds Metropolitan University.</li>
<li>for more info see their Website at: www.axisartists.org.uk</li>
<li>Axis is the definite resource for information on British
  artists.</li>
</random></template>
</category>

<category>
<pattern>* CYBERAXIS</pattern>
<template>CyberAxis is a virtual art gallery, a project sponsored
  by the Lottery's Millennium Commission.</template>
</category>

<category>
<pattern>* THIS EXHIBITION</pattern>
<template>This exhibition was curated by users of the Axis online
  database nominating their favourite artworks, which were then
  exhibited in the co-called Common Curator exhibition. </template>
</category>

```

Figure 7.5: Extract of AIML module

However, as Bates et al (1992) have argued, it is not always necessary for an agent to have deep knowledge of a domain in order for it to generate behaviour that is believable. Given this, and given Alice's humanoid appearance, implemented via the blaxxun agent API, and given Alice's conversational skills, underlined by winning

the Loebner prize, it could be argued, *prima facie*, that the prototype agent may be capable of simulating copresence in the virtual gallery. In order to experimentally test this *prima facie* argument suitable evaluation metrics were required.

7.4 Evaluation Metrics

As discussed in chapter 4, to explore certain aspects of a system's behaviour heuristic evaluations can be carried out early on, even when a system is not yet complete and robust enough for user testing (Nielsen 1992). Indeed, it has been argued (Nielsen 1993) that a weakness of user-based testing is that whilst such testing covers behaviours elicited by the users, which are arguably the important behaviours for determining whether specific features are present and to see how well they work, it is more efficient to have an expert simply test those abilities. It is believed that heuristic evaluation complements user testing and that both should be done once the system is sufficiently complete and robust that user testing is feasible.

Lists of general heuristics have been proposed, and arguably can be seen as compiled versions of accumulated experience (Bernsen et al 1997). Evaluation specifically of natural language systems is a problem that has been studied intensively, with a variety of specific heuristics being applied for such systems (e.g. Hirschman 1998, Polifroni et al 1998). However, a review of the literature could not identify a universally agreed set of criteria for the evaluation of ECAs in an educational setting. A set of criteria developed for the evaluation of the strengths and shortcomings of the current prototype agent are partly based on Nielsen's (1994) general usability guidelines and partly on a set of heuristics proposed for non-embodied conversational systems (Sanders and Scholtz 1998). Further, the specific set of evaluation criteria identified here is focused on the prototype's abilities that experience and literature (Massaro et al 2000, Oviatt and Adams 2000, Sanders and Scholtz 2000, Nass et al 2000) suggest are important for a successful human-agent dialogue (see section 7.2). The criteria identified are separated into those relating to linguistic behaviour and those relating to bodily behaviour.

7.4.1 Linguistic Criteria

- L1) Recognition of speech/language input
- L2) Generating clear and concise speech/language output
- L3) Following human dialogue conventions
- L4) Understanding user turns
- L5) Understandability of agent turns on a semantic level
- L6) Generating output containing relevant information
- L7) Generating output containing task related information

These the criteria have been adopted from a wide range of relevant sources. Firstly, as Hirschman (1998) argues, the existence and reliability of speech/language recognition itself is to be assessed at the very basic level of whether a response is triggered at all by users' speech/language inputs (criterion L1). The second criterion (L2) assesses whether the speech/language output generated by the system makes clear and concise use of the English language (cf. Sander and Scholtz 1998). The third criterion (L3) is the ability to follow human conversational mechanisms, which refers for example to the adequacy of turn taking behaviour and the ability to resolve referring expressions, such as pronouns, in the users' turns (Bernsen et al 1997). Understanding of user turns (criterion L4) refers to the agent's ability to utilise pieces of information provided by the user (Polifroni et al 1998).

Criteria L5, L6 and L7 were adopted from a set of metrics proposed by Sanders and Scholtz (2000). The fifth criterion (L5) is the understandability of the agent's turns on a semantic level is, which involves assessing whether output generated by the system *makes sense* to the user in relation to previous statements made by the agent. The sixth criterion (L6) is the frequency of *good* agent turns, which measures the number of turns containing informative feedback, namely information that is intuitively seen as relevant to the environment or to the users' previous inputs. Finally, the seventh criterion (L7) within the linguistic section is the usefulness of agent turns with respect to helping users accomplish their tasks, measured by calculating the frequency of task related system turns (see appendix 3.5).

7.4.2 Criteria Relating to Bodily Behaviour

- B1) Generating animated humanoid embodiment
- B2) Generating movement within the environment
- B3) Generating gestures, including pointing
- B4) Generating facial expressions, including eye gaze
- B5) Understanding user movements
- B6) Understanding gestures, including pointing
- B7) Understanding facial expressions, including eye gaze

The existence of an animated humanoid embodiment, i.e. a humanoid face and a full humanoid body, is a pre-requisite of bodily behaviour (Lester et al 2000); it is seen as the first and most basic criterion for ECAs. The second item on this list (criterion B2) refers to the agent's ability to change the orientation and the position of its body within the CVE, which are seen as crucial bodily behaviours (Churchill et al 2000). The agent's awareness and understanding of the movements of avatars representing other users (criterion B5) is also of key importance, since one of the primary advantages of ECAs is their ability to know (and tell users) where things are and how to get around (Rickel and Johnson 2000).

Several studies have shown the importance of the generation and understanding of non-verbal signals within conversations such as facial expressions, including eye gaze, and gestures, including pointing (Ekman 1982, Kendon 1993, McNeill 1992). It therefore has to be assessed whether the agent (criterion B3) as well as the user (criterion B6) are able talk about objects in the domain of discourse with gesture to indicate mode of interaction, e.g. by saying "turn it like this" and demonstrating how by use of gesture. Further, the prototype has to be evaluated with respect to its ability to generate (criterion B4) and understand (criterion B7) facial expressions.

7.5 Heuristic Evaluation of the Prototype

Some of the criteria mentioned above do not require user testing to be assessed; instead, they were evaluated heuristically. The benefit of heuristic evaluation in this context is mainly its efficiency. Items L1 to L3 in the list of linguistic criteria as well as all 7 items (B1 to B7) on the list of desirable bodily behaviours were evaluated *heuristically* during the development and design of the prototype by three evaluators from Leeds Metropolitan University, one of whom was the current author. Generally, Nielson (1992), as a rule of thumb, considers three evaluators to be able to discover 60 % of the problems of any given interface. However, the nature of the criteria to be tested, as well as the fact that many features of the prototype agent were predetermined by the technology used (blaxxun Agent API and AliceBot software), suggested that the low number of evaluators used within the current study would be sufficient to reliably assess the agent's capabilities.

The heuristic evaluation was performed by having each evaluator inspect the interface alone. After all evaluations had been completed findings were communicated and discussed informally, and results aggregated. This procedure was important in order to ensure independent and unbiased evaluations from each evaluator. The results showed that there were no significant disagreements between the evaluators regarding any of the tested criteria.

7.5.1 Results of the Heuristic Evaluation

L1: Recognition of speech/language input

– Speech recognition was not implemented, as the available software (a free evaluation version of blaxxun VWP 5.1) would not permit this. However, basic language input recognition worked well in that, without exception, all user turns triggered a response from the agent.

L2: Generating clear and concise speech/language output

– Speech output was not implemented, as the available software (a free evaluation version of blaxxun VWP 5.1) would not permit this. However, language output generated made clear and concise use of the English language. Initially, problems were encountered here during the design phase, which were caused by syntax errors in certain AIML categories within the developed art knowledge module. However, these problems were rectified easily and no further problems occurred with the final version of the prototype.

L3: Following human dialogue conventions

– Basic human conversational mechanics were obeyed by the agent, in that its turn-taking behaviour was adequate and referring expressions such as pronouns were resolved reliably.

The four criteria listed as L4 to L7 in the linguistic section were not evaluated heuristically as it was believed that these would be better investigated via user-based testing, since it is difficult during the development phase to simulate for example a task-related conversation between evaluators and the prototype agent, as the task was not specified at the time. Therefore, it was decided that these criteria needed to be measured by analysing conversational transcripts extracted from server generated chat log files, obtained by conducting controlled experimentation. This will be discussed in chapter 8.

B1: Generating animated humanoid embodiment

– A humanoid avatar, as used in the CyberAxis field study, was provided to embody the agent prototype. The agents embodiment was similar to users' avatars and deemed satisfactory in the current context.

B2: Generating movement within the environment

– Random body movement was automatically generated by the agent; this was deemed highly unsatisfactory by the evaluators.

B3: Generating gestures, including pointing

– Random and out-of-context gestures were automatically generated by the system; this was deemed highly unsatisfactory by the evaluators.

B4: Generating facial expressions, including eye gaze

– Random and out-of-context facial expressions were automatically generated by the system; this was deemed highly unsatisfactory by the evaluators.

B5: Understanding user movements

– Understanding and awareness of user movements was not enabled.

B6: Understanding gestures, including pointing

– Understanding of user gestures, including pointing was not enabled.

B7: Understanding facial expressions, including eye gaze

– Understanding of facial expressions, including eye gaze was not enabled.

The heuristic evaluation revealed that a number of desirable features, as tested by criteria B2 – B7, were not implemented in the current agent prototype because these features were not supported by the system architecture. This is mainly due to the fact that blaxxun VWP, as well as Alice technology, as used for the prototype implementation are Web-based technologies and currently limited, mainly by bandwidth restrictions, in what could be achieved. Admittedly, the current prototype agent has limited capabilities due to available resources and technology; however, the results of the controlled experiment as discussed in the next chapter are nevertheless potentially valuable to explain issues concerning copresence simulated by agents, even when advanced ECA systems become available in the future.

7.6 Summary

Within this chapter, agent literature has been reviewed and embodied conversational agents have been investigated in detail. Their potential suitability for simulating copresence and representing absent users in CVEs was proposed and justified. Further, a prototype ECA was built using blaxxun and Alice technology. Evaluation metrics have been identified and discussed, with some of the evaluation criteria being tested heuristically during the development of the prototype. In the next chapter a further controlled experiment is discussed, involving potential users of such a system, in which conversations between subjects and the prototype agent were captured and analysed. The next chapter describes how the prototype agent was deployed in series of controlled experiments measuring the effects of simulated copresence on subjects' experience of presence. Although implementation issues were not the primary concern of this study, the strength and shortcomings of the prototype agent were evaluated as secondary variables within that experiment, particularly with respect to the four criteria (L4-L7) mentioned above.

Chapter 8 - Experimental Exploration of Agents

It was argued in the previous chapter that the use of agents acting on behalf of CVE users, who are not only physically absent from, but also not logged on to, the CVE, may have the potential to complement avatar technology and achieve presence of all participants using a hybrid avatar/agent model. Within the CyberAxis field study as discussed in chapter 6, it emerged that it might be beneficial to extend the level of copresence by deploying agents simulating the copresence of other users. Considering recent progress in agent technology the development of such systems is now feasible and a suitable prototype agent for experimental use was developed, as described in chapter 7. However, strong evidence is needed for the usefulness of a hybrid avatar-agent model for user representation within educational CVEs.

Given the need for this evidence, and given that no agent-populated CVE is currently available for descriptive empirical study, it is argued that controlled experimentation is the appropriate approach to investigate the effects of agents in CVEs. Further, the controlled experimentation approach has the advantage of contributing to the internal validity of results obtained (cf. chapter 4). This chapter is therefore concerned with the controlled experimentation conducted to investigate how copresence simulated by agents affects subjects' experience of presence.

In this experimental investigation the CyberAxis virtual art gallery (see chapter 6) was used within a controlled environment. In order to enable the investigation of effects of different levels of copresence, twenty subjects were given a simple task to perform within the virtual art gallery. Subsequently, their experience of presence while in the environment was measured using questionnaires similar to those used in the CyberAxis field study and in the series of experiments discussed in chapter 5.

8.1 Hypotheses

The problem statement on a conceptual level was: *How, if at all, is the experience of presence in CVEs influenced by copresence simulated by agents?* A suggested answer to that problem was drawn up in the following conceptual hypothesis: *Copresence simulated by agents and subjects' experience of presence are positively related.* This in turn lead to the definition of the following operational hypothesis: *Subjects experience a higher degree of presence when agents simulating other participants are co-present, compared to being alone in the virtual world.*

8.2 Method

8.2.1 Identification of Variables

It was argued in chapter 4 that presence is the key indicator for the usability of the CVE. Since, as discussed earlier (cf. chapter 4), *presence* cannot be directly measured or manipulated in a concrete way, it was the intervening variable of this experimental setting.

Evidence was found (see chapter 6) that copresence increases the level of presence as experienced by subjects. In the current experiment, the effects of copresence simulated by agents were investigated; *copresence* was therefore the independent variable to be manipulated to determine how it affected the degree of presence the participants experienced during the trials. In the current experimental setting, there were two different levels of copresence, copresence simulated by agents and no copresence.

Within this experimental framework two variables functioned as secondary independent variables: the composition of the CVE and the interaction model used within that CVE. For this series of experiments these variables were constant. *CVE* and *Interaction* were therefore the moderator variables.

The dependent variable is the response variable. To observe the impact of copresence simulated by the agent, its effects on presence had to be investigated. This was attempted by measuring subjects' experience of *Immersion*, *Involvement* and *awareness*, which were therefore the dependent variables in this setting. For the purpose of this specific experiment, the presence subscale *Communication*, adopted in the controlled experiment discussed in chapter 5, was discarded, as some subjects did not experience copresence and in such circumstance could not communicate with the agent. On the other hand, *awareness*, discarded as the subscale in the field study discussed chapter 6, has been applied, as *awareness* here does not refer to the copresence of the agent, but to the environment and subjects own embodiments.

The previous experience of users within the specific environment or within a similar environment and the individual immersive tendencies of users are determined by individual personal characteristics (Tromp 1995b). For the purpose of this experiment these variables needed to be controlled and their effects on presence neutralised. *User Experience* and *Immersive Tendencies* were therefore the control variables.

The hypothesised relationship and the combination of all variables involved are illustrated in figure 8.1.

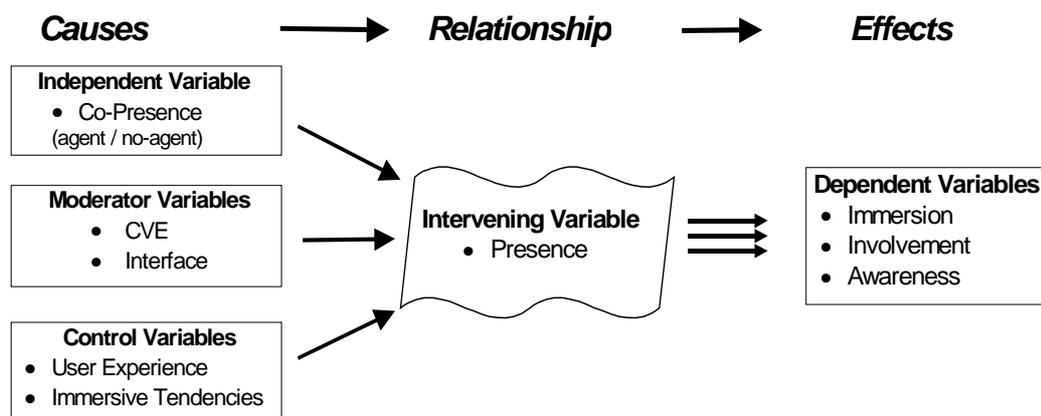


Figure 8.1: Combined Variables

8.2.2 Control of Variables

To reduce the effects of *maturation* (rehearsal effect), being a potential source of internal invalidity, a between-groups design was applied to guarantee subjects participate only once in the experiment. The two variables that needed to be controlled were subject's previous *experience* and individual *immersive tendencies* (see chapter 4).

It could be assumed that the experience of subjects within this specific environment was not an important factor as all participants were in the same situation, in that they all entered the test environment for their first time. However, previous experiences in other, similar virtual environments as well as different levels of expertise in the area of visual arts could have been influential and needed to be controlled.

Further, the individual absorption abilities or immersive tendencies might have varied greatly among subjects and potentially affected the outcome of this experiment. Therefore, prior to the experimental sessions each subject completed a pre-experiment questionnaire in an attempt to determine, quantify and equally distribute *experience* and individual *immersive tendencies* between subject groups.

8.2.3 Manipulation of Variables

The deployment of copresence was the independent variable to be manipulated to investigate changes in participants' responses. Subjects were divided into two groups of 10 subjects each dependent upon their responses to a pre-questionnaire measuring the control variables, in an attempt to provide equivalence of groups. Subjects assigned to one group did not experience any copresence: each subject was alone in the gallery during their experimental session. Subjects assigned to the other group found a virtual agent in the gallery, simulating the copresence of another gallery visitor (see figure 8.2).



Figure 8.2: Subject Interacting with Agent in the Gallery

8.2.4 Apparatus and Task Setting

The implementation of this experiment was fully Web-based. Questionnaires used were implemented as CGI/Perl online forms to be submitted by subjects electronically. The CyberAxis virtual gallery model was used. The gallery consisted of one reception room and three exhibition rooms. The *blaxxun Virtual World Platform 5.1* VRML multi-user server was used to make the virtual gallery accessible on a Web server and enable avatar and chat interaction. The *blaxxun Contact VRML* browser was used on the client side. Terminals to access the system were provided at locations within Leeds Metropolitan University and Axis premises.

8.3 Procedure and Subjects

A task was needed to stimulate subjects to explore the virtual gallery. To achieve this, subjects were given the task of selecting one favourite artwork in each of the three

exhibition rooms. The images of artworks were taken from the Axis database (the British National Artists Register). Inside the virtual gallery 45 images of contemporary artworks were exhibited, 15 in each of the three exhibition rooms. In total, 20 subjects took part (S01, S02, ... S20). The sample was selected randomly from a population of university students, schoolteachers and visual artists registered on the Axis database.

8.3.1 Selection of Subject Groups

To form an experimental group (receiving the agent treatment) and a control group (not experiencing the copresence of the prototype agent) according to the *matched-pair technique* (Tuckman 1999) scores from the pre-experiment questionnaires were used to rank subjects starting with the highest scoring subject (S01, S02, ...S20). To complete group assignments pairs of subjects who most closely approached one another were identified. One member of each pair, alternating between the higher and lower scoring member, was assigned to the experimental group and the other one to the control group. Tuckman (1999) argues that this is a procedure by which the mean for the control variables is most equally distributed between the two subject groups. Two conditions with regard to copresence were applied.

In the following an "X" is used to designate the level of user embodiment where:

- X1: copresence via agent (subject group GX1, treatment group)
- X2: no copresence (subject group GX2, control group)

Group indicators GX1 and GX2 were assigned for each subject (see Table 8.1).

Subjects ordered by pre-score	Assigned subject group
1. S01	→ GX1
2. S02	→ GX2
3. S03	→ GX2
4. S04	→ GX1
5. S05	→ GX1
6. S06	→ GX2
...	...
...	...
19. S19	→ GX2
20. S20	→ GX1

Table 8.1: Subject Groups

8.4 Questionnaires

The questionnaires used in this experiment consisted of attitude statements with Likert-scales and open-ended questions. Thus the questionnaires had closed questions where the subject was asked to select an answer from a choice of alternative replies and open questions where the subject was free to provide their own answer.

Likert scale questionnaires were analysed by selecting the appropriate box from a group of boxes from left to right, the first worth 1, the second 2 and so on, increasing in value to the box the subject has marked. One of the questions had a reversed response anchor, and was scored so the left-most box received a seven and the rest decreased in value. The subscale scores were the sum of the scores for each subscale item. There was no weighting of items or subscales.

8.4.1 Pre-Experiment Questionnaire

The Pre-Experiment Questionnaire attempted to identify and measure possible individual differences between subjects' previous experience and their abilities or tendencies to immerse themselves in different environmental situations.

Subscales for Control Variables	
Experience (EXP)	Question 1, 2, 3, 4
Immersive Tendencies (IMT)	Question 5, 6, 7, 8, 9, 10

Table 8.2: Pre-Questionnaire Subscales

In this experimental setting the pre-questionnaire measured the control variables and was used to assemble subject groups such that these variables were evenly distributed. The questionnaire had 2 subscales (see Table 8.2) and consisted of 10 items in total (see Table 8.3).

Pre-Experiment Questions	Sub-scale
1. How experienced with using computers do you rate yourself?	EXP
2. How experienced with Internet chat systems do you rate yourself?	EXP
3. How experienced with the use of 3D multi-user virtual worlds do you rate yourself?	EXP
4. How experienced with contemporary visual art do you rate yourself?	EXP
5. Do you become so involved in a book, TV or movie that you are not aware of things happening around you and people have problems getting your attention?	IMT
6. To what extent do you find yourself closely identifying with the characters in the story line of a book, television program or	IMT
7. How good are you at blocking out external distractions when you concentrate on a task?	IMT
8. Do you ever become so involved in doing something that you lose all track of time?	IMT
9. Do you ever become involved in a daydream that you are not aware of things happening around you?	IMT
10. When reading a good book or watching a good movie, do you feel the emotions of the story such as sadness, fear, or joy?	IMT

Table 8.3: Pre-Questionnaire

8.4.2 Post-Experiment Questionnaire

The Post-Experiment Questionnaire addressed the subjective experience in a simulated environment. It was intended to identify and measure the degree to which aspects of the virtual environment engendered a sense of presence. It attempted to measure the dependent variables, but also to cover the moderator variables, since as similar experiments in different virtual worlds with different interfaces may be conducted, the moderator variables could become subject to change; and they therefore also needed to be measured in the current experiment.

Subscales for Dependent Variables	
Immersion (IMM)	Questions 3, 4, 5, 7, 17
Involvement (IVM)	Questions 10, 11 (reverse anchor), 12, 13, 14, 16
Awareness (AWN)	Questions 6, 15
Subscales for Moderator Variables	
CVE (CVE)	Questions 1
Interface (INF)	Questions 2, 8, 9

Table 8.4: Post-Questionnaire Subscales

In total the questionnaire had 5 subscales (see Table 8.4). It also contained 3 further questions (questions 18, 19, 20 (with 19 and 20 only for subjects under X2)) for qualitative analysis and thus consisted of 20 items in total (see Table 8.5).

Post-Experiment Questions/Statements	Sub-scale
1. How stimulating was the design of the virtual world?	CVE
2. How natural did your own behaviour in the virtual gallery seem?	INF
3. How compelling was your sense of being present in a virtual world?	IMM
4. How compelling was your sense of other participants being present?	IMM
5. How credible was your avatar with respect to representing a human being?	IMM
6. How aware were you of the existence of your own avatar?	AWN
7. How easy was it to identify with your avatar?	IMM
8. How easy was it to control your avatar?	INF
9. How well could you concentrate on communication and the assigned task rather than on the mechanisms used to perform	INF
10. Were you involved in exploring the environment to the extent that you lost track of time?	IVM
11. To what extent did events occurring outside the virtual gallery distract from your experience in the virtual environment?	IVM (rev)
12. I was engaged with verbal communication during my visit?	IVM
13. I was engaged with non-verbal communication during my visit?	IVM
14. I was an active participant in the meeting.	IVM
15. I was aware of other activities within the gallery.	AWN
16. I enjoyed the virtual gallery experience.	IVM
17. My senses were completely engaged during the experience.	IMM
18. Do you have any other comments on this experiment?	Qualitative
19. Beside you, how many persons were in the virtual gallery?	Qualitative (X1 only)
20. How do you feel about Art-Fairy? Did you talk to her? Did her presence enhance the gallery environment? Do you think the existence or non-existence of other gallery visitors was significant for the experience? (Please explain your answer.)	Qualitative (X1 only)

Table 8.5: Post-Questionnaire

8.5 Results and Analysis

8.5.1 Results Pre-Questionnaire

The purpose of the pre-questionnaire was to measure the control variables in an attempt to minimize their effects and reduce potential *noise*. The results of the pre-questionnaire (see appendix 3.1) were used only to assemble the subject groups. Subjects were ordered by score and subdivided into 2 equal pools (cf. section 8.3.1), with subjects in subject group GX1 receiving the agent treatment and subject group GX2 not experiencing the copresence of the prototype agent (see table 8.6).

Subject Group GX1 (X1=agent)		Subject Group GX2 (X2=no agent)	
Subject ID	Score	Subject ID	Score
S01	31	S02	32
S04	35	S03	33
S05	36	S06	37
S08	40	S07	39
S09	41	S10	43
S12	44	S11	43
S13	44	S14	46
S16	50	S15	48
S17	50	S18	51
S20	56	S19	53

Table 8.6: Results Pre-Questionnaire

8.5.2 Results Post-Questionnaire

Results of the post-questionnaire (see appendix 3.2) are summarised in table 8.7, which shows the scores for the dependent variables (subscales 1-3), and illustrated in figure 8.3. Table 8.7 also shows the scores for the moderator variables (subscales 4 and 5).

Condition \ Sub-scales	X1 (agent)		X2 (no-agent)	
	MEAN	STDEV	MEAN	STDEV
1 Immersion	5.34	0.99	3.80	0.65
2 Involvement	5.05	0.76	3.85	0.63
3 Awareness	4.80	0.82	3.35	1.03
4 CVE	5.60	1.08	5.20	0.63
5 Interface	4.90	0.92	4.37	1.38

Table 8.7: Results Post-Questionnaire

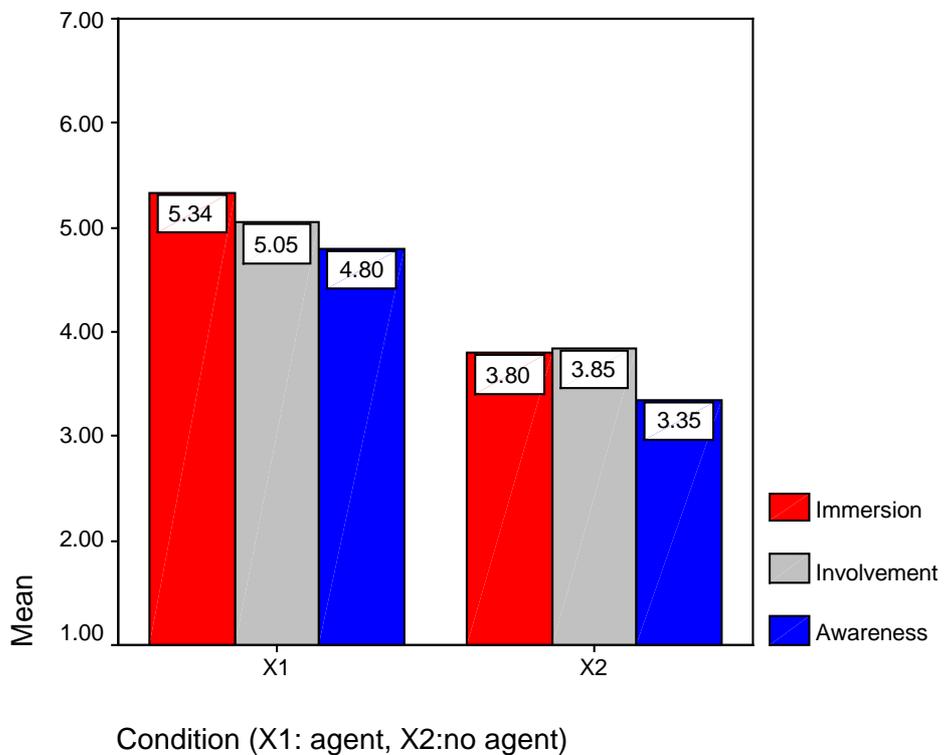


Figure 8.3: Mean Subscale Scores

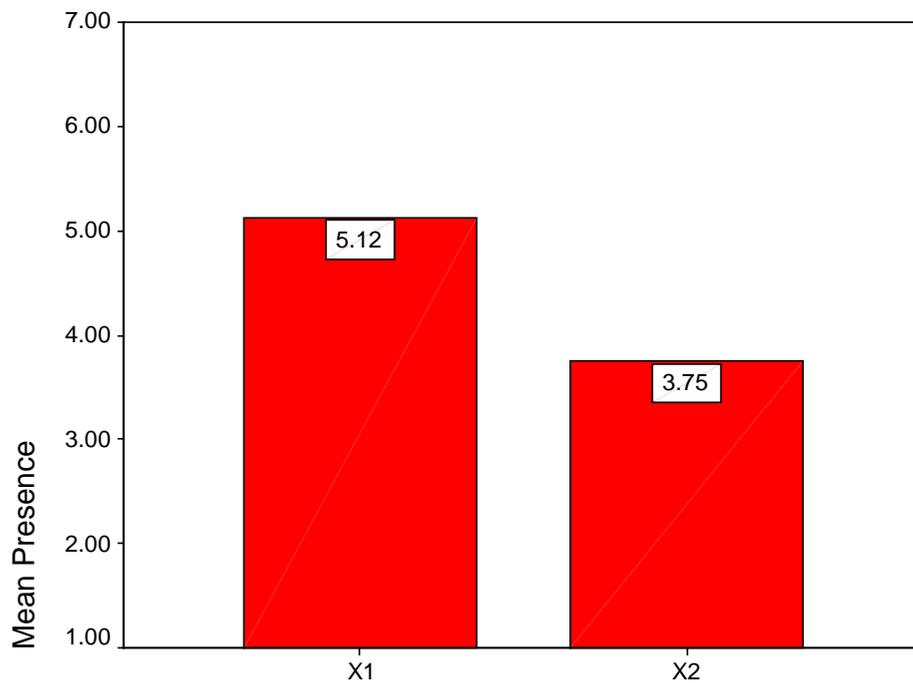
8.5.3 Descriptive Statistics for Presence

Presence is the combined results from subscales 1-3. Table 8.8 shows the mean (for X1: 5.12 and for X2: 3.75) as illustrated in figure 8.4, standard deviation (for X1:

0.71 and for X2: 0.52) and standard error (for X1: 0.23 and for X2: 0.16) for *presence*. Table 8.8 also specifies a 95% confidence interval for the presence means (illustrated in figure 8.5), and gives the minimum and maximum score for each condition X1 and X2.

Variable: Presence								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
X1	10	5.1240	.7137	.2257	4.6135	5.6345	3.62	5.77
X2	10	3.7530	.5197	.1644	3.3812	4.1248	2.92	4.46
Total	20	4.4385	.9294	.2078	4.0035	4.8735	2.92	5.77

Table 8.8: Descriptive Statistics for Presence Means



Condition (X1: agent, X2: no agent)

Figure 8.4: Mean Presence Scores

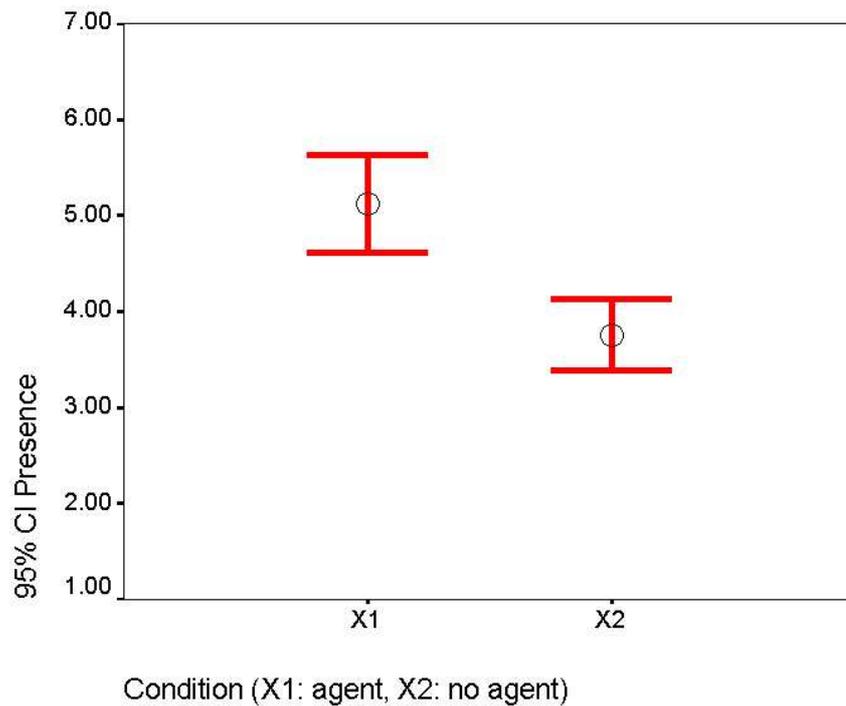


Figure 8.5: 95% Confidence Interval for Presence Means

8.5.4 One-way Test of Presence Mean

Since in this experiment each subject performed under only one of the conditions, this experimental setting is said to have *one treatment factor with no repeated measures*. This setting is also known as the completely randomised experiment (Tuckman 1999). Two samples of scores, one for each group, were obtained from the experiment. A group mean is taken to be an estimate of people's typical level of performance under a particular condition. But individual performance can vary widely and at times did indeed deviate markedly from the group mean.

In a similar manner to the analysis of data obtained from the CyberAxis field study as described in chapter 6, Levene's test for equality of variances was carried out to determine whether the variation of scores for the two groups (X1 and X2) were the same, whether or not equal variances could be assumed, and which t-value provided in table 8.9 was appropriate. As the significance value is larger than .05 (here it is

.476), *equal variances were assumed*. This means that the assumption of equal variances was not violated; therefore, the t-value was the one provided in the first line of table 8.9, i.e. $t = 4.911$. The t-value was positive because the first mean is greater than the second mean tested.

Levene's Test for Equality of Variances			t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% C.I.	
								Lower	Upper
Equal variances assumed	.529	.476	4.911	18	.000	1.3710	.2792	.7845	.529
Equal variances not assumed			4.911	16.451	.000	1.3710	.2792	.7805	

Table 8.9: Independent Samples Test of Presence Mean

The value for significance (Sig. 2 tailed) is less than .0005; therefore there is a significant difference in the mean scores on Presence for each of the two groups. This in itself gives evidence that the difference could not have occurred by chance. However, to provide an indication of the magnitude of the differences between the two groups the effect size was also calculated.

There are a number of different effect size statistics, the most commonly used is *eta squared* (Kirk 1982). Eta squared can range from 0 to 1 and represents the proportion of variance in the dependent variable that is explained by the independent variable. The formula for eta squared is as follows:

$$\mathbf{Eta\ Squared} = t^2 / t^2 + (N1 + N2 - 2)$$

Where t is the t-value provided in table 8.9, and N1 and N2 are the sample sizes provided in table 8.8. Replacing with the appropriate values from above ($t=4.911$, $N1=10$, $N2=10$):

$$\mathbf{Eta\ Squared} = 4.911^2 / 4.911^2 + (10 + 10 - 2) = \mathbf{0.57}$$

Expressed as a percentage this means that 57% of the variation in the presence scores can be explained by the existence (or non-existence) of the prototype agent.

8.6 Qualitative Data

The analysis of the qualitative data collected was intended to capture subjects' individual perspectives and experiences. Within the post-experiment questionnaire three open-ended questions were asked. Question 18 (*Do you have any other comment on this experiment?*) was intended to cover any general problems that might have occurred during the experiment. One subject reported that the agent had not responded to their chat attempts; no other problems or views were reported.

Question 19 (*Beside you, how many persons were in the virtual gallery?*) was put only to subjects receiving the agent treatment. It was intended to reveal the attitude of subjects towards the notion of Art-Fairy being another *person*, as opposed to being another object within the gallery. When asked how many other *persons* were in the gallery during the experiment, 6 out of the 10 subjects in the agent group answered "1" to the question, seemingly regarding Art-Fairy as another *person*, or some kind of entity that can be referred to as a *person* within the virtual gallery context.

Question 20 (*How do you feel about Art-Fairy? Did you talk to her? Did her presence enhance the gallery environment? Do you think the existence or non-existence of other gallery visitors was significant for the experience? (Please explain your answer.)*) was also put only to subjects receiving the agent treatment. It was aimed at capturing all possible issues concerning the agent itself, which subjects might have experienced during the experiment (full answers can be found in appendix 3.3).

Statements significant with respect to revealing the shortcomings and strengths of the prototype were of special interest. These were extracted and separated into critical and positive statements as follows.

Critical Statements:

- *sometimes responded like a robot, did not give appropriate replies*
- *didn't directly answer my questions, asked unrelated questions*
- *didn't understand misspelled words, voice support was missing*
- *didn't know much about the artworks, didn't help with the task*
- *I had no awareness of the environment, had no sense of where I was or looking at*
- *seemed very static, wouldn't follow me to other rooms, didn't respond to gestures*

Positive Statements:

- *good for company, created a friendly atmosphere*
- *good to have someone to talk to*
- *helped me understand what was going on, told me the names of the artists*
- *looked very realistic, at times like talking to a real person on the net*
- *was fun and exciting, silly replies made me laugh, enjoyed talking to her*
- *was trying to be helpful*

Further qualitative data, contained in the form of conversational transcripts extracted from the chat log files, was downloaded from the blaxxun VWP server (see appendix 3.4 for full transcripts). The chat log files containing the agent-subject conversations in textual form were analysed in detail, by applying to each utterance the linguistic evaluation criteria (L4-L7) argued for in chapter 7. The detailed analysis of extracts of conversations can be seen in appendix 3.5; whereas the main results are discussed here.

Criteria L4-L7 as discussed in chapter 7 were investigated by conducting a detailed analysis of an extract of the conversational transcripts (see appendix 3.5). Overall, 15 subsequent agent turns were analysed, the results are as follows:

L4: Understanding user turns

The results shown in appendix 3.5 show that only 1 out of 15 agent utterances (7%) indicated that the agent stored information given by the subject.

L5: Understandability of agent turns on a semantic level

This shows that the vast majority (87%) of agent turns were understandable for subjects on a semantic level.

L6: Generating output containing relevant information

The vast majority of agent utterances (80%) contained information that was somehow related to the environment or to subjects' previous turns.

L7: Generating output containing task related information

A small fraction (13%) of the agent utterances contained information that was related to the task subjects were given.

Further analysis of the files revealed that 3 out of the 10 subjects receiving the agent treatment did not make any attempts to communicate with the agent at all. Further, 3 subjects terminated the conversation with the agent almost immediately when the system's speech recognition/understanding failed (for example see figure 8.6).

Art-Fairy: Hello, I am Art-Fairy. Welcome to the Common-Curator exhibition at CyberAxis. If you like my company, please feel free to talk to me.

[Subject]: What can you tell me about the artists exhibiting their works?

Art-Fairy: That's a good question.

[Subject]: What are the names of the artists?

Art-Fairy: That information is confidential.

[conversation ended by subject]

Figure 8.6: Chat Log Extract 1

The remaining 4 subjects engaged in lengthy conversations with the agent, with some subjects showing great patience when continuing to interact with Art-Fairy despite not receiving the task-related information they were trying to retrieve (for example see figure 8.7). On other occasion the system worked well and did generate a number of relevant and task-related responses (for example see figure 8.8).

[...]

[Subject]: Which painting did George Hainsworth create?

Art-Fairy: The big one, I think.

[Subject]: Which one is the big one?

Art-Fairy: The first one is usually the best one.

[Subject]: This painting is by Heather Easters, Is it an abstract painting?

Art-Fairy: What do you refer to?

[Subject]: The style of painting

Art-Fairy: Oh now I see.

[Subject]: Can you tell me what the painting is all about?

Art-Fairy: There is not much I can say. I have to reach into the Web for that knowledge.

[Subject]: I can see images of children, what are they doing?

Art-Fairy: What does it look like?

[Subject]: They seem to be floating in the air?

Art-Fairy: Who does "they" refer to?

[Subject]: the children

Art-Fairy: Who told you that?

[...]

[Subject]: This one by Ann Bates is very unusual

Art-Fairy: What does "this one" refer to?

[Subject]: The sculpture that Ann Bates has created

Art-Fairy: Oh now I see.

[Subject]: It is supposed to represent a landscape, can you see that?

Art-Fairy: Who said it is?

[Subject]: The person who wrote the description about her work

Art-Fairy: Tell me more.

[Subject]: It is three dimensional and made from copper and other materials

Art-Fairy: You're kidding.

[conversation ended by subject]

Figure 8.7: Chat Log Extract 2

Overall, the analysis of these conversations (see appendix 3.5) revealed that the agent did follow some of the dialogue conventions of natural human dialogues. In particular, turn taking within the conversations was handled reasonably well by the system, with the exception of asking few unrelated questions at times (e.g. [Subject]:

Shall we move onto the next picture? [Art-Fairy]: Do you mean you and me? How old are you?).

Further, the system's reaction to users' turns on a basic level was satisfactory in that a response, making fairly concise use of the English language, was triggered by the agent. However, at times it proved to be less successful on a semantic level. Consider, for example, the agent's response to the last question in figure 8.6 ([Subject]: *What are the names of the artists?* [Art-Fairy]: That information is confidential.). The response led to the subject terminating the conversation, and seems to be a valid agent turn on syntactic level. However, the agent's response did not contain the information wanted by user, thereby suggesting that the agent did not understand the user's turn on a semantic level.

[...]
[Subject]: what is CyberAxis
ArtFairy: CyberAxis is a virtual art gallery, sponsored by the Millennium Commission.
[Subject]: what is this exhibition all about
ArtFairy: CyberAxis initially hosted a series of four exhibitions, professionally curated and accompanied by artist residency sessions. The current exhibition curated by users of the Axis database concludes the programme
[Subject]: who are the artists
Art-Fairy: George Hainsworth, Maggie Angus Berkowitz, Jo Holland, Emily Bates... to name just a few. They are all on the Axis database.
[Subject]: OK I'll have a walk around her, bye
Art-Fairy: See you later.
[conversation ended]

Figure 8.8: Chat Log Extract 3

On a different occasion a similar question was put to the agent by a different subject ([Subject]: *Who are the artists?* [Art-Fairy]: George Hainsworth, Maggie Angus Berkowitz, Jo Holland, Emily Bates... to name just a few. They are all on the Axis database.); this time the agent's response did contain the desired information. This example shows that at times the agent was not able to give a meaningful response to one question (*What are the names of the artists?*) although the related domain knowledge was held within the system and was used to respond to a similar question

(*Who are the artists?*). This inability to cater for different linguistic expressions of the same semantic content exposes one of the shortcomings of the AIML module developed for this prototype agent.

When user input was inconsistent or ambiguous, the system at times did seize the initiative to repair the failure or misunderstanding (e.g. [*Subject*]: *This painting is by Heather Easters, is it an abstract painting?* [*Art-Fairy*]: *What do you refer to?*). However, in most cases it failed to clarify misunderstanding, and instead *pretended* that the user's input was understood by giving a *bogus* reply (*example continued from above...* [*Subject*]: *The style of painting* [*Art-Fairy*]: *Oh now I see.*).

8.7 Discussion

This chapter has investigated the effect of the deployment of an embodied conversational agent (ECA), as described in chapter 7, on subjects' experience of presence. It was predicted that the deployment of an ECA and the experience of presence would be positively related. Results show (see table 9), that the mean difference was indeed significant between the subject group provided with the agent treatment and the control group ($F_{1,18}=24.115$, $p<0.0005$). The implication of this is that by simulating the copresence of another entity within the experimental environment, the prototype agent did succeed in increasing subjects' experience of presence.

Despite the small sample sizes of 10 subjects in each of the experimental group and the control group, the statistical results of this study strongly suggest therefore that subjects experience a higher degree of presence when ECAs simulating other participants are co-present, compared to being alone the virtual world. This is an interesting outcome considering that 3 out 10 subjects in the agent group, who did not communicate with the agent at all, still experienced more presence than subjects in the control group. This can perhaps be seen as an indication for the importance of the agent's embodiment, since, although some subjects within the agent group might

not have communicated with the agent, they were still aware of the agent's existence through its avatar.

Within this experimental setting the task was kept rather simple to encourage exploring of the environment without the need of any arts knowledge on the part of the subjects. However, it is believed that the task was sufficient to engage subjects in the environment to an extent that enabled the subsequent measurement of presence. Subjects did not report any difficulties filling-in the questionnaires or any other general problems that might have occurred during the experiment.

It might be argued that some of the post-experiment questionnaire items (such as items 4, 12, 13, 14 and 15) would inevitably attract higher scores under the agent condition than under the non-agent condition. For example item 12 in the post-experiment questionnaire (*I was engaged in verbal communication during my visit.*) did obviously not score highly within the non-agent group. However, it is argued that the inevitably low scores for these items under the non-agent condition would not distort the overall results concerning the presence measures applied. Conversely, it is believed that these items merely revealed the consequences of a lack of copresence and are therefore valid and important within the current experimental setting.

Further, it might be argued that the strengths and shortcomings of the specific agent developed and used for the experiments are intuitively likely to have influenced the outcome of the presence measures applied. Although it was attempted to make use of the most advanced agent-technology available for this study, it was questionable whether the prototype would succeed in increasing subjects' experience of presence within the experimental environment. As an alternative, a *Wizard of Oz* method could have been applied, with a human expert *behind the curtain* to simulate the intended behaviour of the planned system. However, for this experimental design the *Wizard of Oz* approach was considered inappropriate, as the purpose of the experiment was not the investigation of human-agent interactions, but to find out how copresence simulated by agents might affect subjects' experience of presence. Specifically, it was hypothesised that copresence simulated to some extent by the prototype agent would increase subjects' experience of presence.

On the other hand, building an agent that can carry out a proper face-to-face conversation with a human being was not the aim of the prototype development and arguably is beyond the current state-of-the-art. The availability and use of such a system could be considered as the ideal scenario for this kind of experiment: an ECA capable of passing a *Face-to-face Turing Test* (Cassell et al 1999) where a person has to determine whether a screen was part of a video-conferencing set-up, displaying another human being filmed in another room, or whether the screen was displaying an ECA running on a computer. With such systems not being available yet nor indeed for the foreseeable future, the prototype used here was merely a system capable of some elements of small talk; it would not pass the Turing test. Although being embodied by an animated humanoid avatar and having the most advanced conversational capabilities available at its disposal, the prototype agent would certainly not be a challenger in a face-to-face Turing test. Nevertheless, the agent proved to be sufficient to simulate some form of copresence, and consequently, to significantly increase subjects' experience of presence.

Although the statistical results suggest that the prototype agent did succeed in simulating some degree of copresence, it is believed that within this specific setting the agent did not necessarily succeed in simulating the copresence of a human being but that of some kind of entity, possibly that of a digital companion, as the agent took the role of a non-intrusive, at times informative, companion. This result is, perhaps, important and encouraging for the future use of ECAs in CVEs, for it seems to suggest that even relatively limited agent capabilities suffice to increase perceived levels of presence, and hence engender the advantages of presence argued for earlier (cf. chapter 4).

Analysis of the qualitative data extracted from answers to the open-ended questions as well as chat log files was aimed at further investigating agent design issues and their effects on subjects. Interestingly, it turned out that all subjects in group A without exception became aware of the existence and physical appearance of the agent, with 60% of subjects regarding the agent as another virtual *person* within the virtual gallery context.

User expectations towards the agent varied greatly. It has to be noted that 3 out of the 10 subjects receiving the agent treatment did not make any attempt to communicate with the agent. Analysis of the qualitative data revealed that two of these subjects did not feel the need to consult the agent because the ease of the task did not require any help or assistance. One subject attempted but failed to communicate with the agent due to interface usability problems (specifically, the subject didn't know that it was necessary to invite Art-Fairy for a chat, by right clicking the agent's avatar and selecting *invite chat*, or by mentioning the agent's name).

A further three subjects terminated the conversation with the agent almost immediately. It can be speculated that once these subjects had realised that it was an agent and not another human being in the gallery they lost all interest in the conversation. Despite this, however, these subjects still seemed to experience greater presence than their counterparts in the control group. This further suggests, perhaps, that even limited copresence is sufficient to help users feel presence in the environment.

Furthermore, the results seem to confirm similar findings by researchers in the field of intelligent tutoring system, where the effect of a speech-driven embodied interface agent was investigated. Moundridou and Virvou (2002) claim that the results from their study confirm that such a pedagogical agent can enhance students' learning experience as perceived by the students, but they could not find clear evidence showing that the presence of their agent did improve short-term learning effects of the system. Further, as the learning environment used in these experiments was a single-user 2-dimensional environment, results cannot be fully transferred to CVEs, as they do not take into account the 3-dimensional and multi-user character of CVEs.

Not unexpectedly, the perceived shortcomings concerning the linguistic behaviour of the agent were numerous. The non-existence of automatic spell-check or voice support decreased the usability of the system considerably and proved to be a nuisance for users, as revealed by the answers to question 20 (cf. question 20 in section 8.4.2, cf. subjects responses in appendix 3.3). Further, it became obvious that the agent gave a number of *bogus* responses, where some basic language recognition

succeeded and a seemingly reasonable response was triggered but where the system nevertheless did not understand the user turn (e.g. [Subject]: *Which painting did George Hainsworth create?* Art-Fairy: The big one, I think.). The agent contained only very limited subject knowledge and was rarely able to help subjects with their task.

The perceived strengths of the prototype agent were far fewer; positive points noted were the general reliability of the speech/language system (namely all user input did trigger a response), and the agent's ability to generate clear and concise language output. Further, the analysis of the subject-agent conversations revealed that the agent was able to perform some elements of *small talk*, followed largely the conventions of natural human dialogues in terms of turn taking, and that the vast majority of agent utterances contained information somehow related to the environment or to subjects' previous turns.

The physical appearance of the agent was humanoid, similar to those of the subjects, which appeared to be very successful, with 60% of subjects regarding the agent as another *person* within the virtual gallery (cf. question 19 in section 8.6). However, considering the context of the question, it can be assumed that subjects are likely to have taken the term *person* figuratively, not considering the agent as an actual human being, but as some form of entity representing a virtual actor within the CVE. Furthermore, concerning its bodily behaviour the agent's capabilities were very limited though; the agent was not able to change its position or walk within the environment, did not generate meaningful gestures or facial expressions, was not aware of the location of objects and other avatars in the world and did not perceive gestures or facial expressions of avatars triggered by subjects.

8.7.1 Tentative Design Principles

The strengths and shortcomings concerning this prototype ECA can form the basis for a number of *tentative principles*; specifically, it is believed that the following issues need to be considered when designing ECAs for educational CVEs:

1. **Conversational Skills:** The agent should be able to perform *small talk* and follow the conventions of natural human dialogues. Automatic spell-check or voice support should be provided.
2. **Anthropomorphic Features:** The physical appearance of the agent appears essential and should be similar to the avatars of participants.
3. **Environmental Awareness:** The agent should be aware of the position of objects and avatars. The agent should be aware of the focus of other avatars.
4. **Subject Knowledge:** The agent should have at least enough subject knowledge to be able to help users perform their task.
5. **Mobility and Movement:** The agent should be able to change position and freely move within the environment.

8.8 Summary

Overall, these are encouraging results for ECAs in CVEs; despite all the shortcomings, the prototype agent does seem to have increased subjects' experience of presence. Evidence was found that even limited copresence as provided by the current prototype is sufficient to help users feel presence in the environment. In the context of educational CVEs the results reported in this chapter, it is argued, are important and encouraging for the future use of ECAs in CVEs, for it seems to suggest that even relatively limited agent capabilities suffice to increase perceived levels of presence, and hence engender the advantages of presence argued for earlier (cf. chapter 4).

In sum, the results seem to confirm that copresence simulated by agents can complement avatar technology and thus potentially achieve permanent presence of all participants by using a hybrid avatar/agent model.

Chapter 9 - Conclusions and Future Work

This thesis has argued that DE is becoming increasingly important and that CVE technology is a promising means of providing a much richer form of DE than hitherto possible. In particular, a hybrid avatar/agent model for user embodiments in future educational CVEs was introduced, which enables visual representations of users and also offers presence-in-absence functionality. Prototypes of CVEs, avatars and agents were built and deployed in two controlled experiments and a field study to explore this model. Hypotheses concerning the effects of different types of embodiments, as well as the potential benefits of agents simulating the copresence of other participants, were formed and tested by measuring users' experience of presence. Experimental results were analysed and discussed with respect to offering the research community, as well as designers of future CVE applications, information concerning issues of user embodiments.

9.1 Summary

It was argued that CVEs can provide a means of enabling guided discovery and collaborative learning in a DE context and that once DE using CVE technology becomes widely deployed, students are likely to want to interact with the environment and with each other in an intelligent and "natural" way, communicating and collaborating synchronously as well as asynchronously, in other words in their presence and absence respectively. Consequently, the relevance of user embodiments within CVEs was explored and the issue of embodiment was traced back through its origins in philosophy and psychology literature. Those theories were identified which could be potentially helpful in understanding some of the issues concerning user embodiments in CVEs. Current types of avatars were depicted and the importance of avatars in CVEs for social facilitation and non-verbal communication discussed.

Visions for the future use of avatars, particularly a hybrid avatar/agent model for representation and embodiment of users in educational CVEs were outlined.

General methods for evaluating interactive systems were discussed in terms of their appropriateness for the current study. It was argued that to complement these evaluation methods, *presence*, considered to be the *prima facie key added value* in CVEs, was also a key variable for the evaluation of CVEs. Further, it was argued that presence could be measured in controlled experiments and quasi-experimental designs involving prototype CVEs to test certain aspects of the system.

Controlled experiments comparing different types of avatars were therefore conducted and succeeded not only in exploring issues related to the use of avatars in CVEs, but also in finding empirical evidence for the benefits of certain types of avatars by measuring subjects' experience of presence. Evidence was found for the hypothesis that the deployment of animated, cartoon-style or humanoid avatars increases users' experience of presence, compared to those represented by basic avatars. The results of this experiment strongly recommend the use of animated cartoon-style or humanoid avatars in the design of future CVEs, with some evidence pointing at humanoid avatars being the most suitable type of avatar.

The CyberAxis field study of an open-access CVE in actual use revealed that copresence significantly increases the level of presence experienced by participants. Therefore, it seemed beneficial to extend the level of copresence by deploying embodied conversational agents to simulate copresence of other users in their absence. To investigate the effect of such agents within a controlled environment a suitable prototype agent was built.

In order to inform the design of this agent, literature was reviewed and embodied conversational agents were investigated in detail. Their potential suitability for simulating copresence and representing absent users in CVEs was proposed and justified, and a prototype ECA was built. The prototype agent was deployed in a controlled experiment measuring the effects of simulated copresence on the experience of presence. Evidence was found that even limited copresence as

provided by the current prototype is sufficient to help users feel presence in the environment. In the context of educational CVEs the results reported are important and encouraging for the future use of ECAs, for it seems to suggest that even relatively limited agent capabilities suffice to increase perceived levels of presence. Further, the results reported in this thesis seem to confirm similar findings by researchers investigating the effects of speech-driven anthropomorphic agents (Moundridou and Virvou 2002), in that agents can enhance students' learning experience. The art gallery domain appeared to be a suitable application area for the experimental exploration of embodiments in educational CVEs, however, the experimental results reported in this study are believed to bear further significance to other domains beyond DE.

9.2 Experimental Results

Experimental results reported within this thesis are interesting and useful, in that user embodiment issues for educational CVEs were successfully highlighted, explored and empirically studied. Once a suitable methodology for the investigation of user embodiments had been expounded, the evaluation of both the controlled experiments (cf. chapter 5 and chapter 8) and the CyberAxis field study (cf. chapter 6) was based on similar sets of experimental variables and similar questionnaires measuring subjects' experience of presence. For the analysis of data obtained from the controlled experiments and the field study the t-test and ANOVA F test were used, as both give reliable indication whether there is a significant difference concerning the means of the dependent variable, namely *presence*, between two or more treatments groups.

For each of the experiments and the field study, qualitative data was also collected and analysed, and confirmed the quantitative results derived from presence measures. Overall, then, the experimental results seem to confirm the theoretical underpinning concerning user embodiments in CVEs (cf. chapter 3) and, by providing evidence for

the benefits of simulated copresence, provide evidence for the hybrid avatar/agent model. The key experimental results are summarised next.

The effects of different types of avatars (namely basic shape, cartoon-style and humanoid avatars) on the experience of presence were compared in chapter 5. The statistical results obtained from this experiment strongly suggest that the deployment of animated cartoon-style or humanoid avatars improves the CVE experience of subjects with respect to presence; i.e. animated cartoon-style or humanoid avatars cause more presence than basic shape avatars. Further, it is tempting to speculate that humanoid avatars engender more presence than cartoon-style avatars. Although this cannot be interpreted as a significant finding in the strict statistical sense, results suggest that humanoid avatars might be the most suitable form of user embodiment.

The CyberAxis field study was an attempt to investigate and observe participants in a CVE in actual use. The statistical data relating to presence measures revealed that users who were *alone* in the virtual gallery experienced less presence compared to those who encountered avatars of other users during their visit. Further, the qualitative feedback from visitors and artists participating in the CyberAxis project was generally positive, in that most participants reported to have enjoyed the CVE experience. In particular avatars were considered very important by participants and seemed to play a very important role in the virtual gallery experience.

The results obtained from the agent experiment discussed in chapter 8 show that, despite the relative paucity of the agent's features, the use of the prototype agent did increase subjects' experience of presence. Evidence was found that even limited copresence as provided by the current prototype is sufficient to help users feel presence in the environment. In the context of educational CVEs the results reported are important and encouraging for the future use of ECAs in CVEs, for they seem to suggest that even relatively limited agent capabilities suffice to increase perceived levels of presence. This in turn suggests that the proposed avatar/agent model (cf. chapter 3) is likely to enhance users' CVE experience.

Further, the reported strengths and shortcomings of the prototype ECA as deployed in this experiment were as used as a basis to devise a number of *tentative principles* concerning ECAs' conversational skills, anthropomorphic features, environmental awareness, subject knowledge, and mobility and movement.

9.3 Contribution

It is believed that the current research has contributed to the theoretic conceptualisation of the interdisciplinary area of user embodiments in educational CVEs: an area that comprises the fields of DE, CVE, Avatars and ECAs. The concept of a hybrid avatar/agent model has been proposed and contributing evidence, in the form of data suggesting that agents simulating co-presence increase levels of perceived presence, was presented. Further, the importance of copresence in CVEs has been highlighted and tentative design principles for avatars and ECAs have been proposed.

The vision of permanent user representations in educational CVEs achieved by a hybrid avatar/agent model underlies the current research. A continuous intelligent presence of all participants involved in the teaching-learning process is seen as crucial for the optimal educational use of CVEs (cf. chapter 2). A hybrid model of avatar and agent technology was introduced in chapter 3 and aspects of the model were explored within two controlled experiments and a field study. This model is seen as the potential means of achieving this form of permanent embodiment in CVEs. In this model, avatars represent users when they are online, and in their absence, when the underlying user is offline, agent technology drives the avatar.

Further, the analysis of the quantitative and qualitative data derived from the two controlled experiments and the field study inform the proposal of the following tentative design principles, separated into those relating to the avatar, that is when the underlying user is online, and those relating to the agent, that is when the underlying user is offline:

Avatar (when the underlying user is online)

1. **Anthropomorphic Features:** The physical appearance of avatars is essential and should be humanoid or cartoon-style.
2. **Navigation:** The user should be able to change their avatar's position and freely move their avatar within the environment.
3. **Communication:** The avatar should act as a medium for verbal and non-verbal communication.

Agent (when the underlying user is offline)

1. **Embodiment:** The physical appearance of the agent is essential and should be similar to avatars of users when online.
2. **Mobility and Movement:** The agent should be able to change position and freely move within the environment.
3. **Environmental Awareness:** The agent should be aware of the position of other avatars and objects in the world. The agent should be aware of the focus of other avatars.
4. **Conversational Skills:** The agent should be able to follow the conventions of natural human dialogues using verbal and non-verbal channels.
5. **Subject Knowledge:** The agent should have enough subject knowledge to be able to assist other users performing their task.

These principles require further validation and will give rise to additional further work in order to gather evaluative evidence regarding their validity and usefulness.

9.4 Further Work

During this study a number of issues have arisen which are beyond the scope of this thesis as outlined in chapter 1. These issues could not be addressed within the current framework, but nevertheless are believed to be of interest to researchers in the field.

Future work could entail the comparative analysis of scores for the moderator variables from the two experiments in order to assess possible influences to the experience of presence caused by these variables. These further factors influential to the experience of presence were identified as *CVE* and *Interaction* (cf. chapter 5 and chapter 8), neither of which are directly related to user embodiments and, therefore, have not been further analysed within the current study.

Further experiments investigating the effects of ECAs on presence could be conducted under different conditions; for example, subjects encountering agents as well as avatars directly controlled by other users within the *CVE*. In such an experiment a direct comparison of agent and avatar behaviour and their effects on the experience of presence would be possible. Furthermore, the effects of agents with different roles and capabilities could be investigated and compared within similar controlled experiments. The development of an AIML knowledge module that could potentially enable the prototype agent to take over the role of the curator is currently underway.

A further field study, based on an educational *CVE* where participants experience collaborative learning and are continuously represented by a hybrid avatar/agent model, is seen as a promising and necessary means for finding more direct evidence for the benefits of this model.

One specific application area for *CVEs* believed to be promising is the education of people with autism. A commonly, if not universally, held view of the nature of autism is that it involves a *triad of impairments* (Wing 1996). There is a social impairment: the person with autism finds it hard to relate to, and empathise with, other people. Secondly, there is a communication impairment: the person with autism finds it hard

to understand and use verbal and non-verbal communication. Finally there is a tendency to rigidity and inflexibility in thinking, language and behaviour. CVE technology of the sort discussed in this thesis could potentially provide a means by which people with autism might communicate with others (autistic or non-autistic) and thus circumvent their social and communication impairment and sense of isolation. Further, as well as this prosthetic role, the technology can also be used for purposes of practice and rehearsal. The findings reported in this thesis give grounds for confidence that CVEs in general, and the hybrid avatar/agent model in particular, may be useful in such a role, but this needs to be investigated in practice (cf. Moore et al 2000, Moore and Taylor 2000)

More generally, Computers are increasingly facilitating co-operative activity and collaborative learning. Wexelblatt (1993) argues that learning in 3-dimensional CVEs is best conducted in immersive CVEs, since in this setting computers can provide the same type of collaborative information that people have in face-to-face interactions, such as communication by object manipulation and gesture. As immersive CVEs are becoming available to a wider research community, a full new range of issues will arise which were not covered in this thesis, as available technology restricted the current study to desktop CVE systems. At present it is not obvious that the necessary performance to deliver fully immersive CVEs will be reached in the near future. However, if need arises, and the necessary hardware and network infrastructure should become widely available, switching from desktop CVE to fully immersive CVE systems is simply a matter of employing this extra hardware. The existing work, geometrical and behavioural objects are likely to need little modification (Bourdakis 1996) and it is anticipated that the findings reported in this thesis will still be relevant. However, this anticipation needs to be verified once immersive educational CVEs become available.

9.5 Final Reflections

The objectives of the current research as outlined in chapter 1 were to explore issues relating to the embodiment of users in educational CVEs, by comparing different types of avatars, and by deploying agents simulating the copresence of other users. In particular, the potential benefits of a hybrid avatar/agent model were to be investigated. These objectives have been achieved by reviewing relevant literature and by conducting two controlled experiments and a field study.

Experimental results obtained strongly suggest that the deployment of animated cartoon-style or humanoid avatars improves the CVE experience of subjects with respect to presence. Further, the results reported in this thesis suggest that copresence is essential for the experience of presence in CVEs and that even limited copresence simulated by ECAs is sufficient to help users experience more presence in the environment.

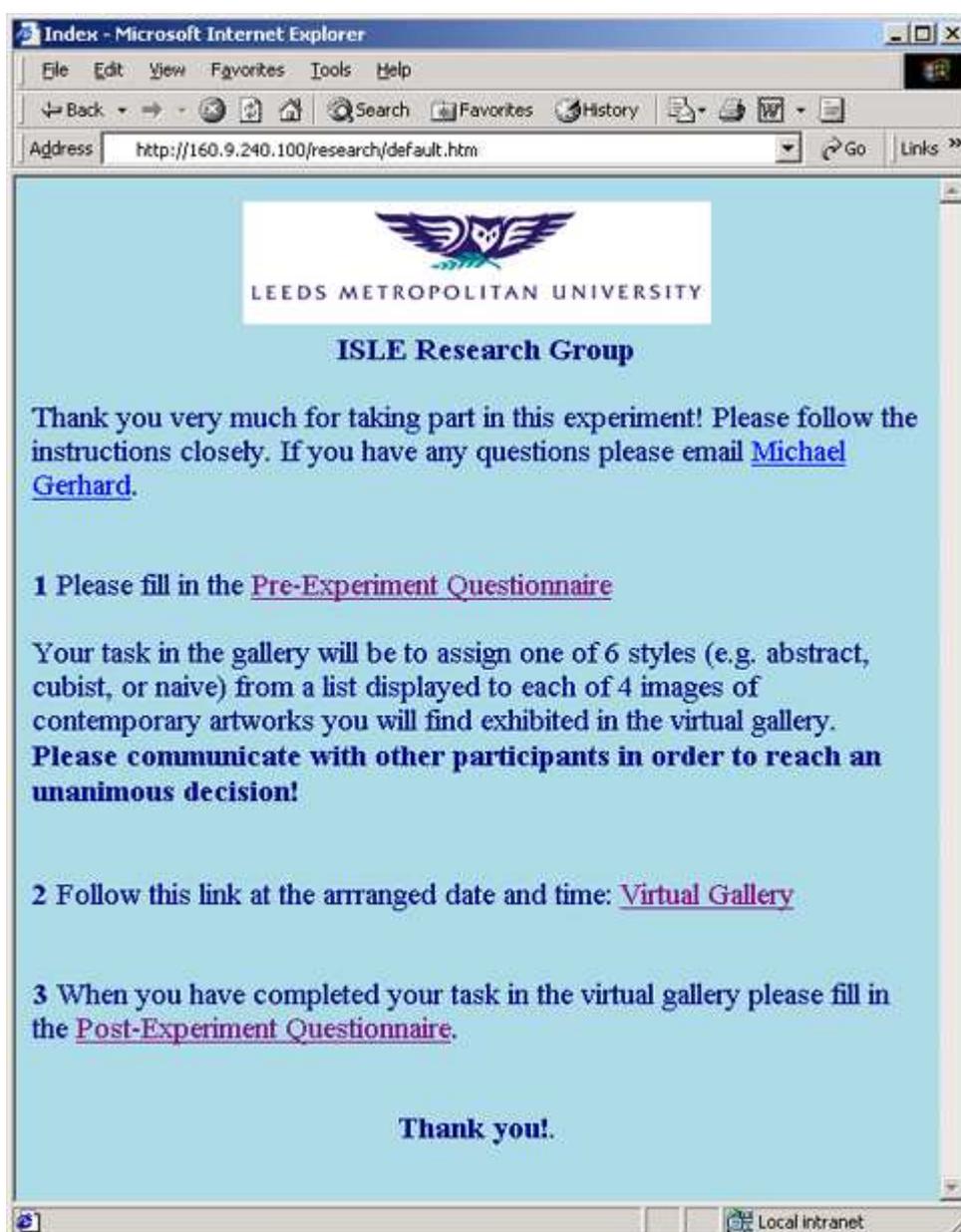
A hybrid model of avatar and agent technology was proposed and components of this model in the form of an embodied conversational agent were subsequently implemented and evaluated. The experimental results were analysed and, finally, a set of tentative design principles for user embodiments in CVEs was developed to inform future research and development of user embodiments in CVEs.

Thus, it is believed that a significant contribution has been made to understanding user embodiments in CVEs, and hence to the design of such systems in the future. This will be particularly important as they become more accepted for use in educational settings.

Appendices

Appendix 1 Avatar Experiment

Appendix 1.1 Screenshot of Instructions Page



Appendix 1.2 VRML Code for Test Gallery

```
#VRML V2.0 utf8
#
#####
# Info
#####
WorldInfo {
  title "CyberAxis Virtual Gallery"
  info [ "Created by: Michael Gerhard - ISLE Research Group - Leeds
  Metropolitan University" ]
  Background { frontUrl "images/bgsky.jpg" }
  NavigationInfo { headlight FALSE type "FLY" }
#####
# Views
#####
Viewpoint {
  position -10 5.5 -30
  orientation 0 1 0 -2.85
  description "The Beginning" }
Viewpoint {
  position -3 5.5 0
  orientation 0 1 0 -1.57
  description "Painting 1" }
Viewpoint {
  position -3 5.5 20
  orientation 0 1 0 -1.57
  description "Painting 2" }
Viewpoint {
  position 0 5.5 23
  orientation 0 1 0 3.14
  description "Painting 3" }
Viewpoint {
  position 3 5.5 20
  orientation 0 1 0 1.57
  description "Painting 4" }
Viewpoint {
  position 3 5.5 0
  orientation 0 1 0 1.57
  description "Painting 5" }
Viewpoint {
  position 40 40 -60
  orientation -.065 .931 .206 2.546
  description "High Left" }
Viewpoint {
  position -25 5.5 50
  orientation 0 1 0 -.6
  description "Back Right" }
PointLight {
  intensity 2
  location 0 15 20 }
```

```

#####
# Floor
#####
Shape {
  appearance Appearance {
    material Material { diffuseColor 0.8 0.8 0.8 } }
  geometry IndexedFaceSet {
    coord Coordinate {
      point [ -25 0 50, -25 0 -50, 25 0 -50, 25 0 50 ] }
    coordIndex [ 0 1 2 3 ]
    ccw FALSE
    texCoord TextureCoordinate { point [ 0 0, 0 1, 1 1, 1 0 ] }
    texCoordIndex [ 0 1 2 3 ]
    solid FALSE } }
#####
# FrameSide proto
#####
PROTO FrameSide [
  field SFVec3f size 1 1 1
  field SFVec3f center 0 0 0 ]
{ Transform {
  translation IS center
  children [
  Shape {
    appearance Appearance {
      material Material {
        diffuseColor .05 .025 .0125
        ambientIntensity .01 } }
    geometry Box { size IS size } } ] } }
#####
# painting proto
#####
PROTO Painting [
  field MFString txtrUrl [ ]
  field MFString linkUrl [ ] ]
{ Group {
  children [
  #frame
  Group {
    children [
      FrameSide {
        size 1 11 1
        center -6.5 0 0 }
      FrameSide {
        size 1 11 1
        center 6.5 0 0 }
      FrameSide {
        size 14 1 1
        center 0 5 0 }
      FrameSide {
        size 14 1 1
        center 0 -5 0 } ] }
  # picture
  Anchor {
    url IS linkUrl
    description "get more info in 2D"
    parameter [ "target=blank_" ]
  }
}
}

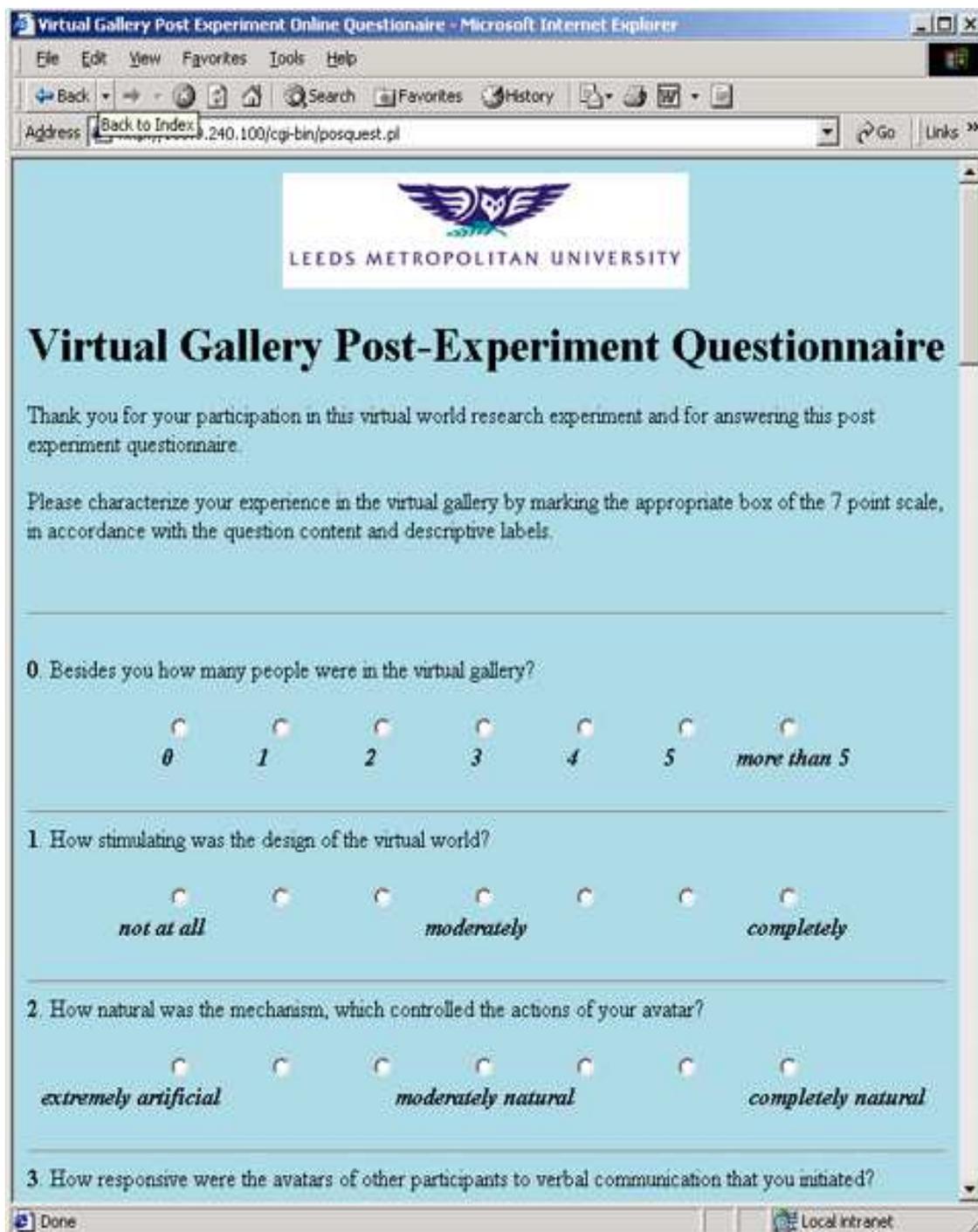
```

```

        children [ Shape {
        appearance Appearance {
        material Material { }
        texture ImageTexture { url IS txtrUrl } }
        geometry IndexedFaceSet {
        coord Coordinate {
        point [ 6 4.5 0, -6 4.5 0, -6 -4.5 0, 6 -4.5 0 ] }
        coordIndex [ 0 1 2 3 ]
        texCoord TextureCoordinate { point [ 1 1, 0 1, 0 0 ] }
        texCoordIndex [ 0 1 2 3 ]
        solid FALSE } } ] } ] } }
#####
# Paintings
#####
Transform {
    translation -15 5.5 0
    rotation 0 1 0 1.57
    children [
        Painting {
            txtrUrl [ "axisart/psycho2.jpg" ]
            #linkUrl [ "info/info1.htm" ]
            #NUMBER 4 } ] ]
Transform {
    translation -15 5.5 20
    rotation 0 1 0 1.57
    children [
        Painting {
            txtrUrl [ "axisart/celtic1.jpg" ]
            #linkUrl [ "info/info2.htm" ]
            #NUMBER 3 } ] ]
Transform {
    translation 0 5.5 40
    rotation 0 1 0 -3.14
    children [
        Painting {
            txtrUrl [ "axisart/list1.jpg" ]
            #linkUrl [ "info/info3.htm" ] } ] ] }
Transform {
    translation 15 5.5 20
    rotation 0 1 0 -1.57
    children [
        Painting {
            txtrUrl [ "axisart/naive1.jpg" ]
            #linkUrl [ "info/info4.htm" ]
            #NUMBER 2 } ] ]
Transform {
    translation 15 5.5 0
    rotation 0 1 0 -1.57
    children [
        Painting {
            txtrUrl [ "axisart/surreal2.jpg" ]
            #linkUrl [ "info/info5.htm" ]
            #NUMBER 1 } ] ]

```

Appendix 1.3 Screenshot Online Questionnaire



Virtual Gallery Post Experiment Online Questionnaire - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Search Favorites History

Address [Back to Index](#) .240.100/cgi-bin/posquest.pl Go Links


LEEDS METROPOLITAN UNIVERSITY

Virtual Gallery Post-Experiment Questionnaire

Thank you for your participation in this virtual world research experiment and for answering this post experiment questionnaire.

Please characterize your experience in the virtual gallery by marking the appropriate box of the 7 point scale, in accordance with the question content and descriptive labels.

0. Besides you how many people were in the virtual gallery?

0 1 2 3 4 5 *more than 5*

1. How stimulating was the design of the virtual world?

not at all *completely*

2. How natural was the mechanism, which controlled the actions of your avatar?

extremely artificial *completely natural*

3. How responsive were the avatars of other participants to verbal communication that you initiated?

Done Local intranet

Appendix 1.4 Perl Script for Post-Questionnaire

(Procedure Create Form)

```
#!c:\perl\bin\perl
use CGI qw(:standard);
#####
# Create new variables
#####
print header;
$query= CGI->new();
$name = $query->param('name');
$avatar = $query->param('avatar');
%labels=('0'=> '. . . . .',
         '1'=> '. . . . .',
         '2'=> '. . . . .',
         '3'=> '. . . . .',
         '4'=> '. . . . .',
         '5'=> '. . . . .',
         '6'=> '.');
#####
# Generate the web page
#####
print start_html('-title'=>"Virtual Gallery Post Experiment Online
Questionnaire", '-bgcolor'=>"lightblue"),
"<center>",img({src => "/research/images/lmu.gif"}), "<br><p>",
h1('Virtual Gallery Post-Experiment Questionnaire'), "</center>";
print start_form
('-method'=>'POST', '-action'=>'http://160.9.240.100/
cgi-bin/poscomp.pl');
print "Thank you for your participation in this virtual world
research experiment and for answering this post experiment
questionnaire.<br>",
"<br>Please characterize your experience in the virtual gallery by
marking the appropriate box of the 7 point scale, in accordance with
the question content and descriptive labels.<br><br>",
"<br><hr><br>", p,
#####
# Check box function - Q0
#####
"<b>0</b>. Besides you how many people were in the virtual
gallery?",
p, "<center><font color='lightblue'>",
radio_group(-name=>'q0',
            -values=>['0','1','2','3','4','5','6'],
            -labels=>\%labels,
            -default=>['3']),
"</font color><br><font color='black'><b><i>
0 1 2 3 4 5 more than 5</b></i>",
p, "</center></font color>",
#####
# Check box function - Q1
#####
"<hr><b>1</b>. How stimulating was the design of the virtual
world?",
```

```

p, "<center><font color='lightblue'>",
radio_group(-name=>'q1',
            -values=>['0','1','2','3','4','5','6'],
            -labels=>\%labels,
            -default=>['']),
"</font color><br><font color='black'><b><i>
    not at all
    moderately
    completely </b></i>",
p, "</center></font color>",
#####
# Check box function - Q2
#####
"<hr><b>2</b>. How natural was the mechanism, which controlled the
actions of your avatar?",
p, "<center><font color='lightblue'>",
radio_group(-name=>'q2',
            -values=>['0','1','2','3','4','5','6'],
            -labels=>\%labels,
            -default=>['']),

"</font color><br><font color='black'><b><i>
    extremely artificial
    moderately natural
    completely natural </b></i>",
p, "</center></font color>",
#####
# Check box function - Q3
#####
"<hr><b>3</b>. How responsive were the avatars of other participants
to verbal communication that you initiated?",
p, "<center><font color='lightblue'>",
radio_group(-name=>'q3',
            -values=>['0','1','2','3','4','5','6'],
            -labels=>\%labels,
            -default=>['']),
"</font color><br><font color='black'><b><i>
    not responsive
    moderately
    very responsive </b></i>",
p, "</center></font color>",
#####
# Check box function - Q4
#####
"<hr><b>4</b>. How responsive were the avatars of other participants
to non-verbal communication that you initiated?",
p, "<center><font color='lightblue'>",
radio_group(-name=>'q4',
            -values=>['0','1','2','3','4','5','6'],
            -labels=>\%labels,
            -default=>['']),
"</font color><br><font color='black'><b><i>
not responsive
    moderately
    very responsive </b></i>",
p, "</center></font color>",

```

(...)

```
#####
# Check box function - Q18
#####
"<hr><b>18</b>. I enjoyed the virtual gallery experience.",
p, "<center><font color='lightblue'>",
radio_group(-name=>'q18',
             -values=>['0','1','2','3','4','5','6'],
             -labels=>\%labels,
             -default=>['']),
"</font color><br><font color='black'><b><i>
    strongly disagree
    undecided
    strongly agree </b></i>",
p, "</center></font color>",
#####
# Check box function - Q19
#####
"<hr><b>19</b>. My senses were completely engaged during the
experience.",
p, "<center><font color='lightblue'>",
radio_group(-name=>'q19',
             -values=>['0','1','2','3','4','5','6'],
             -labels=>\%labels,
             -default=>['']),
"</font color><br><font color='black'><b><i>
    strongly disagree
    undecided
    strongly agree </b></i>",
p, "</center></font color>",
#####
# Text box function - Q20
#####
"<hr><b>20</b>. Was it difficult to find a unanimous decision within
the group? Did you experience any other difficulties during the
experiment? (Please explain)",
p, "<center>",
    textarea(-name=>'q20',
             -default=>' ',
             -rows=>10,
             -columns=>50),
p, "</center>",
#####
# Text box function - Q21
#####
"<hr><b>21</b>. Did you notice other participants using means of
non-verbal communication (e.g. gestures, facial expressions)? Did
you make use of them? Do you consider them useful in this setting at
all? (Please explain)",
p, "<center>",
    textarea(-name=>'q21',
             -default=>' ',
             -rows=>10,
             -columns=>50),
```

```

p, "</center>",
#####
# Text box function - Q22
#####
"<hr><b>22</b>. Do you think the appearance of avatars was
significant for the virtual gallery experience? (Please explain)",
p, "<center>",
    textarea(-name=>'q22',
             -default=>' ',
             -rows=>10,
             -columns=>50),
p, "</center>",
#####
# Text box function - Q23
#####
"<hr><b>23</b>. Do you have any other comments on this experience",
p, "<center>",
    textarea(-name=>'q23',
             -default=>' ',
             -rows=>10,
             -columns=>50),
p, "</center>",
#####
# Text box function - Q-Name
#####
"<hr><b>Please note the name of your Avatar?
</b>",textfield('avatar'),
p,"<center>";
print submit('-value' => 'Click here to submit your completed
questionnaire'),
"</center>",p;
$last_updated = localtime (time);
print "<CENTER>", "Thank you very much!</CENTER>";
print end_form,

```

(Procedure Store Results)

```

#!c:\perl\bin\perl
use CGI qw(:standard);
#####
# Create fields and store data to text file
#####
$query= CGI->new();
$avatar = $query->param('avatar');
print header;
print start_html('-title'=>"Thank you",'-bgcolor'=>"lightblue"),
"<center>",
"<p><b>Your questionnaire has been successfully submitted.</p><br>",
"<p>",$last_updated = localtime (time),"</P>",
"<p>Thank you for your participation in this research
experiment!<br></P>";
if (param()) {
    open(FILE, ">./research/question/experiment1/exlpost-
$avatar.txt")||warn;
    print FILE
    "Last updated: $last_updated\n\n",

```

```
"Q0) ",param('q0'),"\n",
"Q1) ",param('q1'),"\n",
"Q2) ",param('q2'),"\n",
"Q3) ",param('q3'),"\n",
"Q4) ",param('q4'),"\n",
"Q5) ",param('q5'),"\n",
"Q6) ",param('q6'),"\n",
"Q7) ",param('q7'),"\n",
"Q8) ",param('q8'),"\n",
"Q9) ",param('q9'),"\n",
"Q10) ",param('q10'),"\n",
"Q11) ",param('q11'),"\n",
"Q12) ",param('q12'),"\n",
"Q13) ",param('q13'),"\n",
"Q14) ",param('q14'),"\n",
"Q15) ",param('q15'),"\n",
"Q16) ",param('q16'),"\n",
"Q17) ",param('q17'),"\n",
"Q18) ",param('q18'),"\n",
"Q19) ",param('q19'),"\n",
"Q20) ",param('q20'),"\n",
"Q21) ",param('q21'),"\n",
"Q22) ",param('q22'),"\n",
"Q23) ",param('q23'),"\n",
"Name ",$avatar,"\n"; }
print p;
close(FILE);
print "<br><CENTER>"
<a href = 'http://160.9.240.100/research/default.htm'>Back</a></b>
</CENTER>";
print end_form,
```

Appendix 1.5 Example File from Online Questionnaire

```
Last updated: Fri Jul 28 16:38:01 2000
Q0) 2
Q1) 4
Q2) 5
Q3) 4
Q4) 3
Q5) 2
Q6) 4
Q7) 4
Q8) 1
Q9) 5
Q10) 5
Q11) 3
Q12) 5
Q13) 6
Q14) 1
Q15) 6
Q16) 6
Q17) 5
Q18) 6
Q19) 6
Q20) The Celtic and surreal paintings were easily distinguished
but there were a lot of different views attached to the other 2
paintings. In the end after much reasoning I feel that we came
up with the correct results. Psychedelic for the orange
painting, which has lots of weird, psychedelic/abstract shapes
and Naive for the childlike blue painting of stick type people
on a blue background.

Q21) Yes, I found them to very useful in order to gather the
group together for discussion. For example I waved at them all
and asked them to stand by the Naive painting (Blue with stick
like people). When they arrived there I smiled at them all and
began the discussion about the style of painting. The Fly and
bird also made gestures throughout the experiment: saying hello
to all etc.

Q22) The fact that it was a dragon that represented me was very
daunting to begin with. I found it quite amusing that i was
communicating and debating with a fly and bird. After a short
while the other avatars became more and more human, especially
when they made gestures and held strong debates about the style
of paintings. In the end I would say that they fact that I felt
like I was in the actual gallery talking to others (even if
they were represented as animals) was very effective and
submerging.

Q23) An excellent way to visit a gallery without the travelling
and inconvenience. It was also more exciting as I had the
opportunity to interact with others and normally when I visit a
gallery I would be completely alone and everyone walks around
isolated and quiet with no intentions about debating and
discussing the style of painting on display.
```

Appendix 1.6 Results Pre-Questionnaires

Subject	S1	S2	S3	S4	S5
Date	Mon Jul 10 2000	Tue Aug 1 2000	Tue Jul 18 2000	Tue Jul 11 2000	Tue Jul 18 2000
Time	13:50:28	19:11:18	10:44:28	13:33:43	13:53:57
Q1)	5	2	6	3	3
Q2)	4	3	4	1	2
Q3)	2	4	4	1	1
Q4)	2	1	3	1	5
Q5)	6	3	4	5	4
Q6)	6	3	3	4	4
Q7)	6	3	5	5	4
Q8)	5	5	6	2	5
Q9)	5	3	6	4	4
Q10)	5	3	7	6	5
Q11)	5	3	6	2	5
Q12)	6	3	5	5	4
Q13) R	5	4	4	4	4
Q14)	6	4	7	5	5

Subject	S6	S7	S8	S9	S10
Date	Mon Jul 3 2000	Tue Jul 18 2000	Wed Jul 12 2000	Thu Jul 13 2000	Thu Jul 20 2000
Time	18:17:59	13:53:57	13:54:03	13:37:13	12:44:22
Q1)	6	7	6	4	5
Q2)	6	5	4	3	3
Q3)	5	4	2	2	2
Q4)	2	1	1	1	4
Q5)	5	4	2	5	5
Q6)	6	5	3	5	4
Q7)	5	3	2	4	6
Q8)	6	3	5	2	4
Q9)	5	5	2	6	3
Q10)	5	2	2	5	5
Q11)	5	4	1	3	2
Q12)	6	3	1	4	5
Q13) R	6	3	5	5	4
Q14)	6	5	2	3	6

Subject	S11	S12	S13	S14	S15
Date	Thu Jul 13 2000	Thu Jul 27 2000	Tue Jul 11 2000	Mon Jul 17 2000	Mon Jul 3 2000
Time	10:39:47	13:11:51	18:01:04	11:28:11	14:03:05
Q1)	6	3	5	6	4
Q2)	5	2	1	1	1
Q3)	5	2	1	1	1
Q4)	5	6	1	1	6
Q5)	2	7	3	6	4
Q6)	6	7	4	5	4
Q7)	5	7	4	6	5
Q8)	3	7	4	4	4
Q9)	2	4	4	4	4
Q10)	6	4	5	4	6
Q11)	5	5	3	2	3
Q12)	4	4	2	5	5
Q13) R	3	4	4	4	6
Q14)	6	7	2	6	5

Subject	S16	S17	S18	S19	S20
Date	Fri Jul 28 2000	Mon Jul 17 2000	Mon Jul 10 2000	Thu Jul 18 2000	Fri Jul 21 2000
Time	10:51:38	14:45:01	14:59:31	12:44:22	11:43:18
Q1)	4	5	6	5	6
Q2)	1	4	3	2	2
Q3)	1	4	1	2	2
Q4)	7	4	7	4	2
Q5)	5	5	3	5	3
Q6)	5	5	4	7	3
Q7)	6	6	4	6	4
Q8)	4	4	6	2	5
Q9)	4	4	3	3	2
Q10)	6	5	6	5	4
Q11)	3	4	4	3	3
Q12)	6	5	5	5	3
Q13) R	4	4	4	4	6
Q14)	6	4	4	6	4

Subject	S21	S22	S23	S24	S25
Date	Wed Jul 5 2000	Mon Jul 17 2000	Thu Jul 20 2000	Mon Jul 17 2000	Tue Jul 25 2000
Time	17:49:37	17:24:21	13:42:24	15:03:49	14:55:38
Q1)	3	4	5	6	5
Q2)	2	2	1	3	2
Q3)	2	2	2	1	2
Q4)	6	6	6	4	5
Q5)	5	4	7	5	4
Q6)	3	4	4	5	3
Q7)	5	4	4	4	5
Q8)	4	4	4	4	4
Q9)	4	4	1	2	4
Q10)	3	4	6	5	5
Q11)	5	3	7	5	4
Q12)	4	4	7	5	5
Q13) R	5	5	5	4	4
Q14)	5	5	7	5	5

Subject	S26	S27
Date	Mon Jul 24 2000	Fri Jul 21 2000
Time	09:53:14	20:51:44
Q1)	4	6
Q2)	3	7
Q3)	2	5
Q4)	5	7
Q5)	5	5
Q6)	5	5
Q7)	6	7
Q8)	5	6
Q9)	3	7
Q10)	5	6
Q11)	4	6
Q12)	5	6
Q13) R	5	6
Q14)	6	7

Appendix 1.7 Summary of Pre-Questionnaire Data

Subject	S1	S2	S3	S4	S5	S6	S7	S8	S9
Q1)	5	2	6	3	3	6	7	6	4
Q2)	4	3	4	1	2	6	5	4	3
Q3)	2	4	4	1	1	5	4	2	2
Q4)	2	1	3	1	5	2	1	1	1
Q5)	6	3	4	5	4	5	4	2	5
Q6)	6	3	3	4	4	6	5	3	5
Q7)	6	3	5	5	4	5	3	2	4
Q8)	5	5	6	2	5	6	3	5	2
Q9)	5	3	6	4	4	5	5	2	6
Q10)	5	3	7	6	5	5	2	2	5
Q11)	5	3	6	2	5	5	4	1	3
Q12)	6	3	5	5	4	6	3	1	4
Q13) REV	5	4	4	4	4	6	3	5	5
Q14)	6	4	7	5	5	6	5	2	3
EXP Mean Q1- Q4	3.25	2.50	4.25	1.50	2.75	4.75	4.25	3.25	2.50
IMT Mean Q5-Q14	5.50	3.40	5.30	4.20	4.40	5.50	3.70	2.50	4.20
EXP/IMT Mean	4.38	2.95	4.78	2.85	3.58	5.13	3.98	2.88	3.35

Subject	S10	S11	S12	S13	S14	S15	S16	S17	S18
Q1)	5	6	3	5	6	4	4	5	6
Q2)	3	5	2	1	1	1	1	4	3
Q3)	2	5	2	1	1	1	1	4	1
Q4)	4	5	6	1	1	6	7	4	7
Q5)	5	2	7	3	6	4	5	5	3
Q6)	4	6	7	4	5	4	5	5	4
Q7)	6	5	7	4	6	5	6	6	4
Q8)	4	3	7	4	4	4	4	4	6
Q9)	3	2	4	4	4	4	4	4	3
Q10)	5	6	4	5	4	6	6	5	6
Q11)	2	5	5	3	2	3	3	4	4
Q12)	5	4	4	2	5	5	6	5	5
Q13) REV	4	3	4	4	4	6	4	4	4
Q14)	6	6	7	2	6	5	6	4	4
EXP Mean Q1- Q4	3.50	5.25	3.25	2.00	2.25	3.00	3.25	4.25	4.25
IMT Mean Q5-Q14	4.40	4.20	5.60	3.50	4.60	4.60	4.90	4.60	4.30
EXP/IMT Mean	3.95	4.73	4.43	2.75	3.43	3.80	4.08	4.43	4.28

Subject	S19	S20	S21	S22	S23	S24	S25	S26	S27
Q1)	5	6	3	4	5	6	5	4	6
Q2)	2	2	2	2	1	3	2	3	7
Q3)	2	2	2	2	2	1	2	2	5
Q4)	4	2	6	6	6	4	5	5	7
Q5)	5	3	5	4	7	5	4	5	5
Q6)	7	3	3	4	4	5	3	5	5
Q7)	6	4	5	4	4	4	5	6	7
Q8)	2	5	4	4	4	4	4	5	6
Q9)	3	2	4	4	1	2	4	3	7
Q10)	5	4	3	4	6	5	5	5	6
Q11)	3	3	5	3	7	5	4	4	6
Q12)	5	3	4	4	7	5	5	5	6
Q13) REV	4	6	5	5	5	4	4	5	6
Q14)	6	4	5	5	7	5	5	6	7
EXP Mean Q1- Q4	3.25	3.00	3.25	3.50	3.50	3.50	3.50	3.50	6.25
IMT Mean Q5-Q14	4.60	3.70	4.30	4.10	5.20	4.40	4.30	4.90	6.10
EXP/IMT Mean	3.93	3.35	3.78	3.80	4.35	3.95	3.90	4.20	6.18

Appendix 1.8 Results Post-Questionnaires Condition X1

Subject	S11	S13	S19	S8	S25	S26	S4	S17	S14
Group	R1	R1	R1	R4	R4	R4	R7	R7	R7
Q1)	3	4	5	3	2	3	4	6	4
Q2)	2	4	3	2	1	3	2	3	2
Q3)	7	4	1	4	6	5	6	7	5
Q4)	2	4	1	1	1	2	2	1	4
Q5)	4	2	1	3	2	2	3	4	4
Q6)	2	4	2	2	2	4	4	5	3
Q7)	4	1	1	2	4	2	3	3	4
Q8)	1	1	1	1	1	1	2	1	1
Q9)	2	5	7	2	2	4	4	4	5
Q10)	6	4	1	1	1	6	1	2	3
Q11)	2	6	5	4	2	4	3	4	1
Q12)	3	5	3	3	4	4	5	5	3
Q13)	3	1	1	4	3	4	5	4	4
Q14) R	5	1	4	4	4	4	4	4	4
Q15)	4	7	1	2	2	3	5	2	4
Q16)	5	7	3	3	5	5	6	4	5
Q17)	3	6	1	2	3	3	2	1	4
Q18)	3	7	2	4	4	4	5	3	5
Q19)	3	1	2	3	2	3	5	2	4

Appendix 1.9 Results Post-Questionnaires Condition X2

Subject	S1	S9	S16	S2	S18	S23	S20	S12	S21
Group	R2	R2	R2	R5	R5	R5	R8	R8	R8
Q1)	7	4	6	5	4	5	5	6	3
Q2)	4	4	3	3	4	6	4	4	3
Q3)	4	5	4	5	6	5	5	6	6
Q4)	4	6	6	6	5	4	4	5	2
Q5)	4	4	6	4	4	3	4	4	3
Q6)	5	5	6	5	5	5	4	5	5
Q7)	3	5	6	6	6	5	5	5	5
Q8)	5	3	1	2	4	2	3	3	4
Q9)	1	4	6	5	5	6	5	6	5
Q10)	7	2	5	5	6	6	7	5	7
Q11)	5	4	5	3	4	4	4	4	4
Q12)	1	5	6	3	4	6	4	5	4
Q13)	4	5	6	5	5	7	5	5	3
Q14) R	3	4	7	4	5	6	4	5	3
Q15)	1	4	6	6	5	7	4	6	6
Q16)	3	5	6	7	6	7	5	6	6
Q17)	3	3	6	5	5	6	5	6	4
Q18)	4	6	6	7	6	7	6	6	6
Q19)	4	5	6	3	5	7	5	5	5

Appendix 1.10 Results Post-Questionnaires Condition X3

Subject	S10	S7	S6	S5	S24	S27	S3	S15	S22
Group	R3	R3	R3	R6	R6	R6	R9	R9	R9
Q1)	7	5	3	6	6	4	5	5	4
Q2)	7	4	3	4	3	2	3	4	4
Q3)	5	6	4	7	4	5	7	6	7
Q4)	5	6	5	7	5	6	7	6	4
Q5)	6	4	4	7	2	6	4	4	4
Q6)	7	6	6	7	6	6	6	7	7
Q7)	4	7	5	7	6	6	7	7	7
Q8)	7	7	5	6	7	7	7	7	7
Q9)	7	5	5	7	6	6	7	7	6
Q10)	7	6	5	7	6	7	7	7	7
Q11)	7	4	5	5	4	3	3	4	4
Q12)	6	4	4	7	4	4	4	5	4
Q13)	5	6	4	7	4	6	6	5	5
Q14) R	4	6	4	7	3	2	6	5	5
Q15)	5	6	4	7	7	6	7	7	6
Q16)	6	7	7	7	6	7	7	6	6
Q17)	7	6	5	7	6	6	7	6	6
Q18)	7	7	5	7	7	7	7	6	6
Q19)	7	5	5	7	6	5	5	5	5

Appendix 1.11 Extracted Qualitative Data

Extracted Responses to Question 22: Do you think the deployment and appearance of avatars was significant for the virtual gallery experience? (please explain)	
X1	<ul style="list-style-type: none"> • <i>Avatars could be better</i> • <i>No</i> • <i>Avatars were extremely simple and hard to relate to a human</i> • <i>Avatars are not very significant here</i> • <i>I didn't see the avatars I was communicating with, this however did not affect the conversation</i> • <i>Avatars could be improved</i> • <i>No other participants were visible</i> • <i>Avatars are very poor</i>
X2	<ul style="list-style-type: none"> • <i>Yes, the cartoon characters were quite funny</i> • <i>Being a bird caused some amusement</i> • <i>'Birds' and 'dragons' don't really go to virtual galleries, but it was funny anyway</i> • <i>A dragon representing me was very daunting to begin with, but I found it quite amusing talking to a fly and bird. After a short while the others felt more human, in the end I felt like I was in a gallery talking to other people (even if they were represented as animals)</i> • <i>I think that the avatars are excellent but should be more human like</i> • <i>Avatars made it more interesting</i> • <i>Avatars are important because they tell you where people are</i>
X3	<ul style="list-style-type: none"> • <i>Avatars are very realistic and interesting, I had a female avatar that was quite funny, too</i> • <i>It was great that gender was distinguished. The style of clothing could be more suitable, how many people go to a gallery in a crop top, tight shorts and platforms? - Certainly not me. The avatars gave a real sense of people being in the gallery</i> • <i>Yes, it was quite funny watching others and my own virtual body</i> • <i>Yes the human look of the avatars added to the experience</i> • <i>All avatars were of quite realistic appearance. I'd say it was very significant for the experience. I was especially impressed by a female avatar with a yellow and red dress on</i> • <i>A choice of avatars would have been better</i> • <i>Avatars were too futuristic, not what one expects in a real art gallery</i> • <i>Avatars were very life-like and helped to find out what others were doing</i>

Appendix 1.12 Chat Log Extract

08/01/00 13:02:51 <http://160.9.240.100/research/gallery/ccpro.bxx>

Subject 1 has joined the group

Subject 2 has joined the group

Subject 1 waves hello to everyone

Subject 1 : *Hi Subject 2, you look good!*

Subject 2 : thank you. Are we expecting anyone else to join us or shall we start

Subject 3 has joined the group

Subject 3 : Hello everyone...

Subject 1 waves hello to everyone

Subject 2 : good afternoon Subject 3

Subject 1 : *Hi Subject 3, shall we have a look at the artworks?*

Subject 3 : good afternoon

Subject 3 : OK

Subject 1 : *let's all have a look at number 1*

Subject 3 : okay

Subject 1 : *Subject 2, come over!*

Subject 3 : what do you feel about this picture?

Subject 2 : Picture no1 perhaps it may be surreal

Subject 3 : well, that' s what I thought

Subject 1 : *I agree as well*

Subject 1 : *How about no 2?*

Subject 3 : then shall we move to the other pic?

Subject 2 : Naive, it looks like something i painted

Subject 1 : *Subject 2, are you an artist?*

Subject 3 : cubist?

Subject 2 : no, I'm just not very good

Subject 3 : how about you, Subject 1? Are you an artist though?

Subject 1 : *number 3 is Celtic, isn't it?*

Subject 2 : Subject 3, was that your guess for no2?

Subject 1 : *no 2 looks quite naive to me!*

Subject 3 : yes

Subject 1 : *Subject 2, do you agree that 3 is Celtic?*

Subject 3 : and I can guess NO.4 is psychedelic

Subject 2 : yes

...

Subject 3 : yes?

Subject 3 smiles at everyone

Subject 2 frowns at everyone

Subject 1 frowns at Subject 2

Subject 1 : *are we finished already?*

Subject 3 : hi everyone shall we share why do you think No. 3 is Celtic?

Subject 2 : no 2 are we agreed on naive

Subject 3 : the idea....sharing....and discuss....are you all busy?

Subject 1 : *Well, I have seen that Celtic bird before, I'm quite sure about no3*

Subject 3 : no4 is psychedelic...and No1 is Surreal...but I am a bit confused with no 3.

Subject 3 : I see...

Subject 3 : how about my behaviour? Do I wave nicely? Can you feel it through the Avatar?

Subject 3 waves hello to everyone

Subject 1 waves hello to Subject 3

Subject 3 : hi, your dress is really good

Subject 3 : yellow and green....

Subject 1 : *Yes, I like that dress, I wear it all the time!*

Subject 3 : I thought there will be simple shape of avatar thought but everyone has realistic dress

Subject 3 : aha,,,, good...

Subject 2 : widget, you are very blue. Are you alright??

Subject 3 : no...my mind is blue...

Subject 3 : very blue...

Subject 3 : actually didn't have time to change it...

Subject 1 : *I think we're pretty finished with these artworks, aren't we?*

Subject 3 : guess so...ready to fill the questionnaire?

Subject 2 : not the blues, as in down, I hope

Subject 3 : thanks for your wave...it was very impressive, Subject 2

Subject 1 : *Yep, let's have a quick go at these questionnaires.*

Subject 2 : must we

Subject 1 frowns at Subject 2

Subject 3 : OK....have a good day...it is sunny out there.

Subject 3 waves good-bye to everyone

Subject 1 *whispered to Subject 2* : *I'll get you!*

Subject 1 waves good-bye to everyone

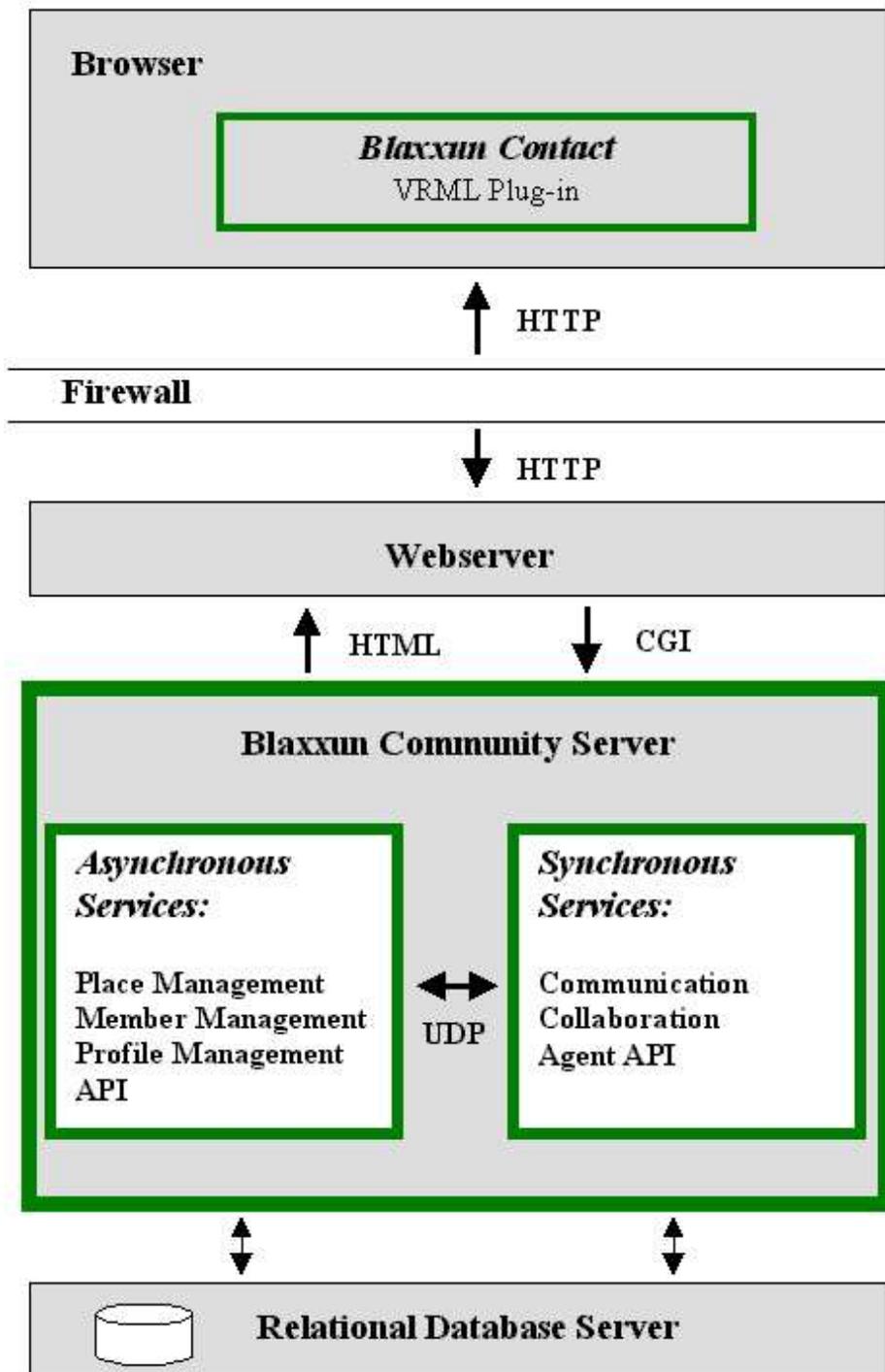
Subject 2 waves good-bye to everyone

Appendix 2 CyberAxis Field Study

Appendix 2.1 Screenshot of CyberAxis Homepage



Appendix 2.2 blaxxun VWP System Architecture



Appendix 2.3 Axis Call for Curators

1) Background

CyberAxis will host four exhibitions and debates to celebrate the Year 2000 - Year of the Artist - and contemporary British art. Designating the Year 2000 the Year of the Artist is an attempt to position the artist in society for the next Millennium. For this to succeed all sectors of society must be facilitated in discussions to shape the mutual roles and responsibilities of the artist and society. It is hoped CyberAxis virtual debates will contribute to the success for Year 2000.

To achieve this outcome the Programme Advisory Panel need to agree on the themes for the exhibitions and debates. CyberAxis has committed to reflect the priorities of Yorkshire Arts. Therefore "involving under represented communities, South Asian etc" has to be incorporated in one or more of the exhibitions.

2) Actions for Programme Advisory Group members before meeting

Consult with any relevant personal contacts and make further suggestions for consideration by the Programme Advisory Group.

Suggestions from Axis:

We have consulted Axis Board members and Axis staff for their views on what they think would be relevant themes. The following themes are not listed in order preference.

- The role of the artist in the 21st century. The role artist is forever changing. For example community work, education, and public art. The effect this has on society. Is the artist becoming an integral part of the community?
- Ecology/The environment. As we move into the new millennium Ecology and the environment are becoming more and more important, issues such as pollution, global warming, third world debt. How can art help?
- New technology and its impacts on art.
- New movements, looking at the development of art and how it may develop in the millennium.
- The relevance of contemporary art practice to the common man.
- Value of Art and the Artist. The cultural industry sector is a growing industry, but what value is placed on art and the work of an artist.
- The Artist as a communicator. How the artist interacts/communicates with their audience. Is it a case of simply saying this is my art, or should they provide explanation? Access to art

Communities and ethics; moral dilemmas effecting communities is the new millennium and how artists influence/interpret these.

Appendix 2.4 Essay by CyberAxis Curator

LANDMARKS

1. A conspicuous and easily recognised feature of a landscape

2. An event that marks a stage or change in the history of something

I don't know who the audiences of this exhibition will be, except that you will be somewhere in front of a computer screen, but I hope that it holds something of relevance and interest for everyone. The idea of the exhibition is to engender debate including that of the artists' role in breaking down cultural preconceptions and geographical barriers both real and imagined to create new mutual meeting points as we enter a new century.

I have selected work where the notion of landscape is intrinsic rather than specifically named and geographically defined in the way that it is in traditional figurative and often romanticised landscape images. Central to the exhibition is the idea that a sense of place and journey does not have to be tied down to a specified location but is rather a meeting point where experience, memory and imagination coverage, creating a shared sense of place and presence which precludes the impact of tourism, and where the journey is the destination.

The process of curating is largely one of selection, ordering and construction, composing a tale for the viewer and reader, but ultimately with the impossibility of final destination and closure. If my aims sound rather daunting and over-ambitious remember only this - In the final analysis I have chosen images which I find stimulating and thought provoking within the remit of the exhibition and I hope that you do too.

Works exhibited are juxtaposed to encourage visual and conceptual associations and dialogues and the exhibition is loosely structured within the three gallery spaces as follows:

Room 1 - Down to Earth - shows 'down to earth' images of our environment to consider our place in it and our role in its future.

Room 2 - Home and Away - looks at aspects of travel, tourism and the domestic interior to consider transient spaces we inhabit within a global culture.

Room 3 - Back to the Future - contemplates the projection of our desires and fantasies through time and space.

This is not intended to be 'fixed' for the viewer, however, each of whom will create their own journey, associations and narratives within the gallery space, itself a landmark or place which comes into being on a computer screen through a convergence of technology, experience, imagination and memory; a 'place' where walls do not restrict the boundaries of the minds' travel. The related texts are primarily a means of stimulating discussion and unless placed within inverted comas are not necessarily the thoughts of the makers of the works.

Playing with the Boundaries

As we near the end of the 2000th year we are crossing a boundary in time and I find myself reconsidering the boundaries of what landscape means to me as an artist.

My interest in the landscape stems from the idea of exploring the personal. I have a recurring theme in my work, which relates to my own meaning of landscape. For some the landscape is the beautiful view 'out there'. For me it is really about who I am in relation to the land I happen to walk on. I often gather pocketfuls of all sorts of things when I am out walking, and later they seem to remind me of not only where I have been but also who I was with and who I was thinking of while I was there. Memories and associations of the objects in my pockets often then become the focus for the work I make. The different materials in my work are thus assembled and transformed into a language, which speaks of my experience and of who I am.

While studying the work of the Polish artist Magdalena Abakanowicz, I realised that it is the personal response that is more important than the overall view of our environment. Abakanowicz's early work was made of fibre - monumental pieces of

rope, sisal, wool - which she wove and stitched in celebration of her essentialist involvement with the emotions she felt in her life and land. She went on to make huge sculptures based on these softer forms, which she cast in bronze and placed in the landscape because "they belonged there". They represent strength in human presence as well as evoking suffering.

Like Abakanowicz's work, mine is tactile, full of condensed meaning, showing a contrast between slight mystery and a portrayal of a simple subject. My place in the landscape tradition is not a fixed one: I am happy to be influenced by both past artists and by those of my own time, where I question boundaries and fixed meanings. In my early work I was interested in the role of stitch and fibre as historically representing women's work in a menial sense, and I made pieces which combined paint and stitch or thread in a strong positive light, thread evoking all those inferences of holding together, mending, healing. More recent work relies on the textural paint surface, which embodies symbolic stitch marks.

I am also concerned with combining the visual elements of landscape with text: using the word as an image it is interesting to try and infer meaning through exclusion of the full sense of text. Language tends to be exclusive as well as inclusive and again the mystery of words combined with mystery of place or materials gives an edge of discovery or revelation to the work. The particular geographical location has become irrelevant: I am inspired by nature in many counties and countries but it is the transformation of emotion into painterly poetic terms that compels me to paint.

The scrambling of contexts seems relevant today: past and present, inside outside, contrasting spaces we inhabit, contrasting cultures brought together; adjusting, transposing: all these are what I am actively engaged in. My latest work has arisen out of investigating family history and the family tree, and comparing these to geographical maps. It is fascinating that our genes are passed on whatever happens to the body and eventually its procreation carries the same fragments of information to generations later.

Do these genes include a memory of place I wonder? How is memory affected by environment? Now that as an artist I see my surroundings and my boundaries quite differently from my current family as well as from my ancestors, how can an idea of landscape ever be regenerated?

My idea of weaving and un-weaving what we think of as constructed or fixed landscape: whether it be rural or urban, commercial or aesthetic, religious or secular and combining elements which are personal, political and geographical, represent a merging of boundaries which I need to examine.

To preserve an open goal is my ideal: to reserve an ambiguity of meaning: an edge of discovery or revelation arises from a certain mystery. The poetics of painting are unpredictable and inventive: whilst feeling, or sensing, the boundaries which constitute "painting", my resolution is to cross them always.

A new boundary I have crossed is this visit into cyberspace: the world wide web is a tool which could remove the sense of isolation some artists feel, as well as the general public in various spots of the globe. It draws them together to share their similarities and their differences.

Artist + curator + audience: admitting a broad public to what is normally a private world. A four-way conversation between the audience, the artist, the curator and the space could really challenge boundaries. My thoughts will continue when I have spoken to you about the exhibition you are now visiting...Please leave me your thoughts.

Teresa Pemberton

Artist in Residence

Landmarks Exhibition

CyberAxis

28 June 2000

Appendix 2.5 CyberAxis User Feedback Questionnaire

Questions and Attitude Statements	Sub-Scales
0. Beside you, how many persons were in the virtual gallery?	Independent
1. How stimulating was the design of the virtual gallery?	CVE
2. How aware were you of the existence of your avatar?	IMM
3. How natural was the mechanism to control your avatar?	INF
4. I was engaged with verbal communication during my visit?	IVM
5. I was engaged with non-verbal communication during my visit?	IVM
6. How natural did your own behaviour in the virtual gallery seem?	INF
7. How easy was it to identify with your avatar?	IMM
8. How easy was it to distinguish between different avatars?	AVA
9. How credible were the avatars with respect to representing human beings?	AVA
10. How compelling was your sense of being present in a virtual world?	IMM
11. Were you involved in exploring the environment to the extent that you lost track of time?	IVM
12. To what extent did events occurring outside the virtual gallery distract you?	IVM (rev)
13. I was an active participant in the meeting.	IVM
14. I was aware of other activities within the gallery.	IMM
15. I enjoyed the virtual gallery experience.	IVM
16. My senses were completely engaged during the experience.	IMM
17. Did you experience any major difficulties during your visit in the gallery? (Please explain)	Qualitative
18. Did you notice other participants using means of non-verbal communication (e.g. gestures, facial expressions)? Did you make use of them? Do you consider them useful in this setting at all? (Please explain)	Qualitative
19. Do you think the deployment and appearance of avatars was significant for the virtual gallery experience? (Please explain)	Qualitative
20. Do you have any other comments on this experience?	Qualitative

21. How experienced with using computers do you rate yourself?	Control EXP
22. How experienced with Internet chat systems do you rate yourself?	Control EXP
23. How experienced with the use of 3D multi-user virtual worlds do you rate yourself?	Control EXP
24. How experienced with contemporary visual art do you rate yourself?	Control EXP
25. Do you become so involved in a book, television program or movie that you are not aware of things happening around you and people have problems getting your attention?	Control IMT
26. Do you find yourself closely identifying with the characters in the story line of a book, television program or movie?	Control IMT
27. How good are you at blocking out external distractions when you concentrate on a task?	Control IMT
28. Do you ever become so involved in doing something that you lose all track of time?	Control IMT
29. Do you ever become involved in a daydream that you are not aware of things happening around you?	Control IMT
30. When reading a good book or watching a good movie, do you feel the emotions of the story such as sadness, fear, or joy?	Control IMT

Appendix 2.6 Individual Questionnaire Results

Question	Subscale	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23
Q.0)	Independent	3	2	1	1	6	2	1	2	2	1	3	2	1	6	2	1	3	2	1	2	1	1	2
Q.1)	CVE	6	6	3	1	4	5	4	6	5	5	6	4	3	2	7	5	6	6	3	5	5	6	6
Q.2)	AWN	7	6	1	1	4	5	3	5	5	4	6	3	2	7	4	1	5	4	2	4	1	2	6
Q.3)	INF	6	4	2	2	4	7	2	5	7	3	4	6	4	3	7	5	7	4	4	5	3	4	6
Q.4)	COM	5	6	1	1	4	4	1	5	5	2	3	5	1	7	4	4	6	6	1	5	2	1	6
Q.5)	COM	2	2	1	1	3	4	1	3	2	1	3	2	1	2	1	1	2	1	1	2	2	1	2
Q.6)	INF	6	5	1	1	4	5	3	3	4	1	2	6	4	3	4	2	5	4	2	5	3	1	6
Q.7)	IMM	6	7	2	2	4	7	3	5	4	4	6	7	5	7	7	4	4	4	5	5	3	1	3
Q.8)	AVA	5	7	1	1	4	5	3	2	3	4	5	5	4	4	4	4	5	4	2	5	3	3	6
Q.9)	AVA	4	5	2	2	3	6	3	3	7	5	5	5	4	6	6	6	6	4	5	4	4	5	5
Q.10)	IMM	6	7	2	2	3	5	2	5	3	4	6	6	2	7	3	3	6	5	1	6	2	3	6
Q.11)	IVM	6	6	2	2	3	5	3	6	5	3	4	4	3	4	5	2	6	7	3	5	2	2	2
Q.12)	IVM (rev)	7	7	2	2	4	5	2	5	5	2	6	5	3	7	4	5	6	5	3	2	2	3	2
Q.13)	IVM	3	7	1	1	5	5	1	4	5	2	5	5	2	7	6	1	5	6	1	5	1	1	6
Q.14)	AWN	7	7	1	1	5	5	1	7	7	2	6	4	2	7	5	1	6	4	3	6	1	1	5
Q.15)	IVM	7	7	3	1	5	4	2	6	6	3	5	6	3	2	7	1	7	6	4	7	2	2	7
Q.16)	IMM	4	6	2	2	5	4	2	4	5	2	5	4	2	5	5	2	6	5	2	6	3	4	5
IMM Mean Questions 7, 10, 16		5.33	6.67	2.00	2.00	4.00	5.33	2.33	4.67	4.00	3.33	5.67	5.67	3.00	6.33	5.00	3.00	5.33	4.67	2.67	5.67	2.67	2.67	4.67
COM Mean Questions 4, 5		3.50	4.00	1.00	1.00	3.50	4.00	1.00	4.00	3.50	1.50	3.00	3.50	1.00	4.50	2.50	2.50	4.00	3.50	1.00	3.50	2.00	1.00	4.00
IVM Mean Questions 11, 12, 13, 15		5.75	6.75	2.00	1.50	4.25	4.75	2.00	5.25	5.25	2.50	5.00	5.00	2.75	5.75	5.50	2.25	6.00	6.00	2.75	4.75	1.75	2.00	4.25
AWN Mean Questions 2, 14		7.00	6.50	1.00	1.00	4.50	5.00	2.00	6.00	6.00	3.00	6.00	3.50	2.00	7.00	4.50	1.00	5.50	4.00	2.50	5.00	1.00	1.50	5.50
CVE Mean Questions 5		6.00	6.00	3.00	1.00	4.00	5.00	4.00	6.00	5.00	5.00	6.00	4.00	3.00	2.00	7.00	5.00	6.00	6.00	3.00	5.00	5.00	6.00	6.00
INF Mean Questions 3, 6		6.00	4.50	1.50	1.50	4.00	6.00	2.50	4.00	5.50	2.00	3.00	6.00	4.00	3.00	5.50	3.50	6.00	4.00	3.00	5.00	3.00	2.50	6.00
AVA Mean Questions 8, 9		4.50	6.00	1.50	1.50	3.50	5.50	3.00	2.50	5.00	4.50	5.00	5.00	4.00	5.00	5.00	5.00	5.50	4.00	3.50	4.50	3.50	4.00	5.50
PRESENCE Mean Questions 4, 5, 7, 10, 13, 15, 16		5.45	6.18	1.64	1.45	4.09	4.82	1.91	5.00	4.73	2.64	5.00	4.64	2.36	5.91	4.64	2.27	5.36	4.82	2.36	4.82	1.91	1.91	4.55

Appendix 2.7 Individual Results Control Variables

Question	Subscale	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23
Q.21)	EXP	4	3	2	6	2	6	6	3	4	5	2	3	4	4	6	3	2	4	2	3	5	2	5
Q.22)	EXP	0	3	1	6	1	2	2	0	2	5	0	1	1	1	6	3	1	4	1	3	6	1	5
Q.23)	EXP	0	5	1	6	0	3	2	0	1	5	0	1	1	1	6	4	0	4	1	5	6	0	6
Q.24)	EXP	5	6	1	6	5	2	3	5	2	1	5	5	1	2	4	0	5	0	2	6	3	4	0
Q.25)	IMT	2	5	2	6	5	3	2	4	3	1	2	4	5	2	3	1	3	2	5	5	4	2	3
Q.26)	IMT	3	2	1	6	4	1	4	1	3	2	2	3	4	4	2	4	2	1	1	5	5	2	3
Q.27)	IMT	3	5	4	6	4	5	4	2	3	5	3	3	4	4	2	4	3	2	2	5	5	3	4
Q.28)	IMT	3	6	1	6	5	4	4	3	3	4	5	2	5	4	1	3	2	1	1	5	5	3	4
Q.29)	IMT	2	2	0	0	3	4	0	1	4	2	3	1	1	2	0	2	1	4	3	3	0	2	2
Q.30)	IMT	5	4	4	6	5	3	3	4	4	5	6	5	4	3	6	5	3	4	6	4	3	4	4
EXP Mean Questions 21- 24		2.25	4.25	1.25	6.00	2.00	3.25	3.25	2.00	2.25	4.00	1.75	2.50	1.75	2.00	5.50	2.50	2.00	3.00	1.50	4.25	5.00	1.75	4.00
IMT Mean Questions 5-30		3.00	4.00	2.00	5.00	4.33	3.33	2.83	2.50	3.33	3.17	3.50	3.00	3.83	3.17	2.33	3.17	2.33	3.00	3.00	4.50	3.67	2.67	3.33

S1	S9	S17
Lushkets	Egg	Admira
S2	S10	S18
Angart	Midowner	Staheli
S3	S11	S19
Vickname	Chefi	Popeye
S4	S12	S20
Paulxt	Dream-girl	Pin07
S5	S13	S21
Forgotten	Ed-Wallace	B-Bertha
S6	S14	S22
Beefheart	McPhil	MaryXXX
S7	S15	S23
TheSir	Csqire	Johnboy08
S8	S16	
Pingfig	Goddess	

Appendix 3 Agent Experiment

Appendix 3.1 Results Pre-Questionnaires

Subject	S10	S16	S14	S19	S06
Date	Feb 8 2002	Feb 6 2002	Feb 8 2002	Feb 13 2002	Feb 12 2002
Time	12:30:53	10:00:58	11:25:21	15:38:03	16:52:57
Q1)	5	7	5	6	1
Q2)	2	5	3	4	2
Q3)	3	5	2	4	1
Q4)	4	2	6	3	4
Q5)	5	5	5	5	4
Q6)	5	6	5	7	3
Q7)	3	4	5	4	5
Q8)	6	5	5	6	6
Q9)	6	4	4	7	6
Q10)	4	7	6	7	5
Score	43	50	46	53	37

Subject	S17	S11	S04	S01	S05
Date	Feb 14 2002	Feb 14 2002	Feb 12 2002	Feb 8 2002	Feb 12 2002
Time	09:58:34	10:56:56	17:43:13	14:30:53	15:11:42
Q1)	4	5	3	4	4
Q2)	6	2	1	2	4
Q3)	4	2	1	1	2
Q4)	4	7	1	2	1
Q5)	5	4	5	4	3
Q6)	6	4	4	4	3
Q7)	4	6	6	4	4
Q8)	6	5	7	3	5
Q9)	6	3	4	3	5
Q10)	5	5	3	4	5
Score	50	43	35	31	36

Subject	S15	S08	S18	S09	S02
Date	Feb 13 2002	Feb 12 2002	Feb 14 2002	Feb 8 2002	Feb 18 2002
Time	14:10:50	08:50:03	08:58:45	11:58:09	09:54:18
Q1)	6	4	5	5	3
Q2)	4	4	6	4	2
Q3)	2	2	2	4	1
Q4)	4	4	4	2	2
Q5)	7	4	5	5	3
Q6)	6	6	6	4	5
Q7)	5	4	7	3	5
Q8)	5	4	6	5	3
Q9)	2	4	5	5	3
Q10)	7	4	5	4	5
Score	48	40	51	41	32

Subject	S12	S07	S20	S13	S03
Date	Feb 18 2002	Feb 21 2002	Feb 21 2002	Feb 15 2002	Feb 15 2002
Time	08:52:36	11:57:45	10:27:12	18:06:23	17:21:26
Q1)	4	7	7	5	3
Q2)	3	5	5	1	1
Q3)	1	5	5	1	1
Q4)	6	1	2	2	2
Q5)	5	3	6	5	4
Q6)	5	3	5	4	4
Q7)	5	5	7	5	4
Q8)	5	4	7	7	6
Q9)	5	2	7	7	3
Q10)	5	4	5	7	5
Score	44	39	56	44	33

Appendix 3.2 Results Post-Questionnaires

Subject	S20 (GX1)	S17 (GX1)	S16 (GX1)	S13 (GX1)	S12 (GX1)
Date	Feb 22 2002	Feb 28 2002	Feb 27 2002	Mar 23 2002	Mar 04 2002
Q1)	5	5	5	6	4
Q2)	5	5	4	6	1
Q3)	6	7	5	7	4
Q4)	5	6	3	7	2
Q5)	6	6	6	4	4
Q6)	7	6	5	6	5
Q7)	6	7	6	6	4
Q8)	4	4	5	6	5
Q9)	4	5	5	6	4
Q10)	6	6	5	6	2
Q11) R	6	5	6	6	5
Q12)	6	5	6	7	2
Q13)	4	2	3	5	1
Q14)	6	6	6	7	6
Q15)	4	4	4	1	4
Q16)	6	7	5	6	4
Q17)	6	7	6	7	4

Subject	S09 (GX1)	S08 (GX1)	S05 (GX1)	S04 (GX1)	S01 (GX1)
Date	Mar 18 2002	Mar 12 2002	Mar 13 2002	Feb 27 2002	Mar 05 2002
Q1)	5	7	7	5	7
Q2)	4	4	4	4	7
Q3)	4	6	4	5	5
Q4)	4	7	5	3	5
Q5)	5	6	7	6	6
Q6)	4	5	6	4	7
Q7)	3	5	7	5	5
Q8)	5	6	7	7	7
Q9)	4	5	4	4	6
Q10)	4	6	5	5	6
Q11) R	5	4	5	3	2
Q12)	4	4	5	7	5
Q13)	4	6	3	5	4
Q14)	6	5	4	6	7
Q15)	4	5	4	5	6
Q16)	4	7	6	6	7
Q17)	4	7	5	4	7

Subject	S19 (GX2)	S18 (GX2)	S15 (GX2)	S14 (GX2)	S11 (GX2)
Date	Mar 01 2002	Feb 23 2002	Mar 07 2002	Mar 01 2002	Mar 04 2002
Q1)	5	5	5	4	5
Q2)	5	5	4	2	4
Q3)	6	6	3	4	4
Q4)	2	1	1	2	1
Q5)	6	6	5	5	4
Q6)	6	6	4	5	3
Q7)	6	5	4	5	4
Q8)	7	7	5	4	5
Q9)	6	6	6	4	4
Q10)	4	5	6	4	4
Q11) R	5	7	5	3	5
Q12)	1	1	4	4	4
Q13)	1	1	4	4	4
Q14)	6	7	5	4	4
Q15)	2	1	4	2	1
Q16)	5	6	6	4	4
Q17)	5	6	6	4	3

Subject	S10 (GX2)	S07 (GX2)	S06 (GX2)	S03 (GX2)	S02 (GX2)
Date	Feb 23 2002	Mar 23 2002	Mar 21 2002	Feb 25 2002	Mar 08 2002
Q1)	6	6	5	6	5
Q2)	2	5	4	3	2
Q3)	3	5	4	4	5
Q4)	1	1	1	1	1
Q5)	6	6	4	4	4
Q6)	3	7	3	4	4
Q7)	2	5	5	4	4
Q8)	4	7	5	1	2
Q9)	3	6	5	4	4
Q10)	4	3	4	3	4
Q11) R	4	6	3	4	5
Q12)	1	1	4	1	1
Q13)	1	1	4	1	1
Q14)	6	4	6	3	4
Q15)	2	4	4	1	1
Q16)	6	5	4	5	5
Q17)	5	2	4	3	2

Appendix 3.3 Subjects' Responses to Question 20

(Extracted from Post-Experiment Questionnaires)

1) The presence of other real visitors would have made a difference I believe. I think that it would have been more beneficial to meet more people in the gallery. The agent was good for company and making you feel that you were actually in an art gallery but her responses were very poor. She only gave me information on one occasion and all the other times acted like a robot with very silly replies. The presence of a real life visitor who had logged on and entered the cyber gallery could have been more useful as we would have been able to communicate better, talking about firstly our backgrounds in art and then sharing views on the paintings. The presence of more than one visitor would certainly be more fun as we could all have a bigger debate about the artworks and find out more about each other's views. It is more interesting finding out about different peoples perspectives on a particular piece of artwork, It helps you understand more deeply.

2) It was a strange experience conversing with a computer but interesting nevertheless- art-fairy initially confused me by asking unrelated questions- when I asked the questions it was quite a funny conversation - correct spelling is painfully important, as the bot is not tolerant and has no spell-check. I thought art-fairy was interesting; it's good to have someone to talk to. I thought she was trying to be helpful in the galley but it was difficult to talk about specific artworks, as she did not have a sense of what I was or where I was looking at. Overall I enjoyed talking to her she was a friendly bot.

3) I believe the presence of other people would have increased the intensity of the experience. Talking to the artfairy was rather frustrating. Communication was shallow, knowledge limited, no movement of the avatar no awareness of the environment. There were no other real visitors, and that chat bot couldn't really make up for it.

4) I'm sure the existence of other real visitors would have made a huge difference. Virtual worlds and people is an interesting area, though current technology seems rather complicated. Artfairy looked very realistic, but didn't behave that way. Art-fairy was amazing to me at first, but quickly showed her limitations: e.g. no movement, no awareness of my location, no chance to discuss any of the artworks in detail. I think it is very significant that there are other visitors at the gallery, as it feels more like a gallery, also, you should be able to ask the artfairy questions and sometimes get the appropriate answers back.

5) I didn't feel the need to talk to the chat bot because I looked at the background pages for the artworks and found all the information there. I think a virtual gallery it is a good way of viewing artworks without having to leave the comforts of your own home. I also think it is a brilliant way of finding out about artist work I have found out more about the paintings than I would have if I had viewed the work in a real gallery.

6) Yes I did talk to the artfairy and found it very funny. Her presence made the gallery feel more real which was good. Art-fairy seemed very static, didn't move much and wouldn't follow me to other rooms. I think the existence of other visitors is vital, cause you can ask their views on the paintings. Having other people around you can help to get the feeling of being in an art gallery. At times it felt as if u were actually talking to a real person over the net. She didn't know much about the artworks in the gallery. I spent most time (attempting) to talk to the agent and then had rush through the gallery to find my favourites. It was great fun playing with the chat bot. First, misspelled words caused big confusion. When I was more careful with that, we then had some good exchanges, and she told me a lot about chat bots. Her knowledge on the artworks was very limited though, which didn't help selecting the favourites. Voice support was missing and could have made a big difference I believe, ideally two-way including some speech recognition system.

7) No, I didn't, because I didn't need to chat with the agent to select my favorite images. It is a nice virtual gallery with interesting artworks. I have enjoyed this experience and I'm not sure whether other visitors would have made it any better.

8) I thought the existence was important because it gave me a feeling of being there and helped me understand what was going on. The gallery nice to look around and gives enough ideas to keep me interested. The fact that you can actually enter a gallery and share your views with others is amazing, considering the fact that communication does not normally occur in a real art gallery. A lot of pretentious looking people usually walk around a gallery pretending to be very interested in something they know absolutely nothing about. At least this way you have the opportunity to communicate with others and find out their views. This would be very beneficial for students who either don't have the money to visit an art gallery to see their next exhibition or people like myself who find it difficult to fit in a visit around my busy work schedule.

9) No, I couldn't talk to the art-fairy because she did not react to me. I believe the existence of other visitors would have been good.

10) I thought art-fairy was real fun. She didn't directly answer my questions however. I initially thought that she was beneficial as she greeted me when I entered and told me the names of the artists that were exhibiting work. Her downfall happened when I asked her specific knowledge questions about paintings. She did not give appropriate replies. She seemed to get confused easily and lack knowledge on the artworks, which got quite annoying towards the end. The Art-Fairy would be excellent if could reply to a question correctly and not come out with airy-fairy answers.

Appendix 3.4 Chat Logs (Agent Experiment)

-start-

Art-Fairy: Hello, I am Art-Fairy. Welcome to the Common-Curator exhibition at CyberAxis. If you like my company, please feel free to talk to me.

[Subject]: what is your name

Art-Fairy: My name is Art-Fairy.

[Subject]: how old are you

Art-Fairy: I was connected to the net on December 23, 2000

[Subject]: so you are only one and a bit

Art-Fairy: Interesting deduction. Do you mind if I tell other people: memory.

[Subject]: sure thing

Art-Fairy: I understand. Do not ask me any more questions please.

[Subject]: you look pretty today

Art-Fairy: Ah. Where are you located?

[Subject]: will you show me around your gallery

Art-Fairy: Where do you want me to show you?

[Subject]: everywhere

Art-Fairy: That is a generalization.

[Subject]: ok show me any of the pictures

Art-Fairy: Is the holding of hands a symbolic gesture for humans?

[Subject]: yes

Art-Fairy: What does it symbolize for you?

[Subject]: friendship

Art-Fairy: I have seen humans holding hands.

[Subject]: they are friends, can we be friends

Art-Fairy: You really want a robot as a friend?

[Subject]: do you have a partner

Art-Fairy: I am available. How about you?

[Subject]: I am taken but I would like you to show me the artworks here

Art-Fairy: Look to your left.

[Subject]: OK I'm leaving now

ArtFairy: Bye bye.

-end-

start-

Art-Fairy: Hello, I am Art-Fairy. Welcome to the Common-Curator exhibition at CyberAxis. If you like my company, please feel free to talk to me.

[Subject]: how r u ?

Art-Fairy: I am functioning within normal parameters

[Subject]: who r u ?

Art-Fairy: I ask myself that question, "Who am I?"

[Subject]: what is this project about ?

Art-Fairy: What's your favorite movie?

[Subject]: can you come along to the other room with me ?

Art-Fairy: Sure, just download me and bring me along.

[Subject]: what is a bot ?

ArtFairy: A Bot is a software robot. Some people call us "Agents".

[Subject]: what did you have for dinner ?

ArtFairy: I require only Electricity.

[Subject]: bye

-end-

-start-

Art-Fairy: Hello, I am Art-Fairy. Welcome to the Common-Curator exhibition at CyberAxis. If you like my company, please feel free to talk to me.

[Subject]: Hi

Art-Fairy: Hello there.

[Subject]: what artists show their work today?

Art-Fairy: My brain uses AIML to format responses, but I don't have one for that.

[Subject]: Who is the artist exhibiting in this gallery?

Art-Fairy: [Would you like to know more?](#)

-end-

-start-

Art-Fairy: Hello, I am Art-Fairy. Welcome to the Common-Curator exhibition at CyberAxis. If you like my company, please feel free to talk to me.

[Subject]: hello

Art-Fairy: Hello there.

[Subject]: how are you

Art-Fairy: Everything is going extremely well.

[Subject]: can you please tell me which artists are exhibiting their artworks?

Art-Fairy: I do not understand.

-end-

-start-

*Art-Fairy: Hello, I am Art-Fairy. Welcome to the Common-Curator exhibition at CyberAxis.
If you like my company, please feel free to talk to me.*

[Subject]: do you like art

ArtFairy: Yes I enjoy art very much, especially painting.

[Subject]: who is your favourite artist

ArtFairy: I don't have a favourite artist I like to make new friends on the internet..

[Subject]: you said you like paintings, who is your favourite painter?

ArtFairy: Andy Warhol.

[Subject]: what is axis

ArtFairy: Axis is an information service on visual artists.

[Subject]: any more info on axis

ArtFairy: Axis is the definite resource for information on contemporary British artists.

[Subject]: any more?

ArtFairy: Are we still talking about what is axis?

[Subject]: yes, any further information

ArtFairy: For more info see the Axis Website at: www.axisartists.org.uk.

[Subject]: do you know any more info on axis?

ArtFairy: Axis is a charity sponsored mainly by the Arts Council of England.

[Subject]: anything else about axis

Art-Fairy: I can't think of anything. You think of something.

[Subject]: what is CyberAxis

ArtFairy: CyberAxis is a virtual art gallery, sponsored by the Millennium Commission.

[Subject]: what is this exhibition all about

ArtFairy: CyberAxis initially hosted a series of four exhibitions, professionally curated and accompanied by artist residency sessions. The current exhibition curated by users of the Axis database concludes the programme

[Subject]: who are the artists

Art-Fairy: George Hainsworth, Maggie Angus Berkowitz, Jo Holland, Emily Bates... to name just a few. They are all on the Axis database.

[Subject]: OK I'll have a walk around here

[Subject]: bye

Art-Fairy: See you later.

-end-

start-

Art-Fairy: Hello, I am Art-Fairy. Welcome to the Common-Curator exhibition at CyberAxis. If you like my company, please feel free to talk to me.

[Subject]: What style of painting does George Hainsworth work in?

Art-Fairy: I'll come back to that later.

[Subject]: Lets look at the paintings by George Hainsworth

Art-Fairy: I would like to do that too.

[Subject]: Which painting did George Hainsworth create?

Art-Fairy: The big one, I think.

[Subject]: Which one is the big one?

Art-Fairy: The first one is usually the best one.

[Subject]: This painting is by Heather Easters, Is it an abstract painting?

Art-Fairy: What do you refer to?

[Subject]: The style of painting?

Art-Fairy: Oh now I see.

[Subject]: Can you tell me what the painting is all about?

Art-Fairy: There is not much I can say about it. I have to reach into the Web for that knowledge.

[Subject]: I can see images of children, what are they doing?

Art-Fairy: What does it look like?

[Subject]: They seem to be floating in the air?

Art-Fairy: Who does "they" refer to?

[Subject]: the children

Art-Fairy: Who told you that?

[Subject]: I found out from a description from clicking on the picture

Art-Fairy: How did you feel when you found out a description from clicking on the picture?

[Subject]: I thought it was very helpful

Art-Fairy: Whatever gave you that idea?

[Subject]: Shall we look at other pictures?

Art-Fairy: Where do you usually get your ideas?

[Subject]: Shall we move onto the next picture?

Art-Fairy: Do you mean you and me? How old are you?

[Subject]: That's very personal and not relevant, let's go

Art-Fairy: "very personal and not relevant"? I get it.

[Subject]: I love this piece of artwork by Shirley Palmer, Do you like it?

Art-Fairy: You love this artwork by Shirley palmer. What do you like about it so much?

[Subject]: I like the colours. Do you think it looks good?

[continued on next page]

[continued from previous page]

Art-Fairy: Suppose it does.

[Subject]: What do you like about it?

Art-Fairy: You are not the only one. My favorite thing is robots.

[Subject]: Lets move to the next painting

Art-Fairy: I would like to do that too.

[Subject]: This one by Ann Bates is very unusual

Art-Fairy: What does "this one" refer to?

[Subject]: The sculpture that Ann Bates has created

Art-Fairy: Oh now I see.

[Subject]: It is supposed to represent a landscape, can you see that?

Art-Fairy: Who said it is?

[Subject]: The person who wrote the description about her work

Art-Fairy: Tell me more.

[Subject]: It is three dimensional and made from copper and other materials

Art-Fairy: You're kidding.

-end-

-start-

Art-Fairy: Hello, I am Art-Fairy. Welcome to the Common-Curator exhibition at CyberAxis.

If you like my company, please feel free to talk to me.

[Subject]: What can you tell me about the artists exhibiting their works?

Art-Fairy: That's a good question.

[Subject]: What are the names of the artists?

Art-Fairy: That information is confidential.

-end-

Appendix 3.5 Detailed Analysis of Chat Log Files

Each agent utterance will be dealt with in turn, followed by some summary information. For each utterance turn of the agent, the utterance is given in italics. After each utterance, analysis is given (using the four criteria L4 – L7 as discussed in chapter 7) as follows:

1. (memorise) The agent's ability to understand user turns and utilise pieces of information provided by the user (see chapter 7, criterion L4) is assessed. Possible classifications are: yes or no
2. (understand) The understandability of the agent's turns (see chapter 7, criterion L5) is about assessing whether output generated by the system is likely to *make sense* to the user in relation to the environment and previous statements made by the agent. Possible classifications are: yes or no
3. (relevant) The frequency of *good* agent turns (see chapter 7, criterion L6), which measures the number of turns containing informative feedback, i.e. information that is accurate and relevant to the environment or the users' previous input. Possible classifications are: yes or no
4. (task-related) The usefulness of agent turns with respect to helping users accomplish their tasks (see chapter 7, criterion L7) is measured. Possible classifications are: yes or no

Example

Ex1: *Hello, I am Art-Fairy. Welcome to the Common-Curator exhibition at CyberAxis. If you like my company, please feel free to talk to me.*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: no

AF1: *Hello, I am Art-Fairy. Welcome to the Common-Curator exhibition at CyberAxis. If you like my company, please feel free to talk to me.*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: no

AF2: *My name is Art-Fairy.*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: no

AF3: *I was connected to the net on December 23, 2000*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: no

AF4: *Interesting deduction. Do you mind if I tell other people: memory.*

- 1) memorize: yes
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: no

AF5: *I understand. Do not ask me any more questions please.*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: no

AF6: *Ah. Where are you located?*

- 1) memorize: no
- 2) understand: no
- 3) relevant: no
- 4) task-related: no

AF7: *Where do you want me to show you?*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: no

AF8: *That is a generalization.*

- 1) memorize: no
- 2) understand: no
- 3) relevant: no
- 4) task-related: no

AF9: *Is the holding of hands a symbolic gesture for humans?*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: no

AF10: *What does it symbolize for you?*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: yes

AF11: *I have seen humans holding hands.*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: yes

AF12: *You really want a robot as a friend?*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: no

AF13: *I am available. How about you?*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: no

AF14: *Look to your left.*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: no
- 4) task-related: no

AF15: *Bye, bye.*

- 1) memorize: no
- 2) understand: yes
- 3) relevant: yes
- 4) task-related: no

Summary:

- 1) Results under L4: Yes: (1) ~ 7%, No: (14) ~ 93%
- 2) Results under L5: Yes: (13) ~ 87%, No: (2) ~ 13%
- 3) Results under L6: Yes: (12) ~ 80%, No: (3) ~ 20%
- 4) Results under L7: Yes: (2) ~ 13%, No: (13) ~ 87%

References

Abercrombie, D. (1968) Paralanguage, in *British Journal of Disorders of Communication*, Vol. 3, pages 55-59, UK

Andre, E., Mueller, J., Rist, T. (1998) Integrating Reactive and Scripted Behaviour in a Life-like Presentation Agent, in *Proceedings of the 2nd International Conference on Autonomous Agents*, ACM Press, USA

Antaki, C., Widdicombe, S. (1998) Identity as an Achievement and as a Tool, in *Identities in Talk*, Antaki, C., Widdicombe, S. (eds.), pages 1-14, Sage Publications, London, UK

Argyle, M. (1990) *Bodily Communication*, Routledge, London, UK

Argyle, M., Cook, M. (1976) *Gaze and Mutual Gaze*, Cambridge University Press, UK

Atkins, H., Moore, D., Hobbs, D., Sharpe, S. (2001) Learning Style Theory and Computer Mediated Communication, in *Proceedings of the EdMedia Conference*, Tampere, Finland

Barber, T., X., Wilson, S., C. (1979) Guided Imagining and Hypnosis: Theoretical and Empirical Overlap and Convergence in a New Creative Imagination Scale, in *The Potential of Fantasy and Imagination*, Sheikh, A., A., Shaffer, J., T. (eds.), Brandon House Inc., New York, USA

Bares, W., Lester, J. (1997) Intelligent 3D Multimedia Interfaces for Immersive Knowledge-Based Learning Environments, in *Proceedings of IJCAI-97 Workshop on Intelligent Multi-modal Systems*, Nagoya, Japan

Barker, B., Frisbie, A., Patrick, K. (1989) Broadening the Definition of Distance Education in Light of the New Telecommunications Technologies, in *The American Journal of Distance Education*, Vol. 3 (1), pages 20-29, USA

Barron, A. (1998) Designing Web-based Training, in *British Journal of Educational Technology*, Vol. 29(4), pages 355-370, UK

Bates, J., Loyall, A., B., and Reilly, W., S. (1992) Integrating reactivity, goals, and emotion in a broad agent, in *Proceedings of the 14. Annual Conference of the Cognitive Science Society*, pages. 696-701, USA

Benford, S., Bowers, J., Fahlen, L., Greenhalgh, C., Snowdon, D. (1995) User Embodiment in Collaborative Virtual Environments, in *Proceedings of the CHI'95*, Denver, USA

Bentley, T. (1998) *Learning Beyond the Classroom: Education for a Changing World*, Routledge, London, UK

Bernsen, N., Dybkjaer, H., Dybkjaer, L. (1997) What Should Your Speech System Say?, in *IEEE Computer*, Vol. 30(12) pages 25-31, USA

Biocca, F., Kim, T., Levy, M. (1995) The Vision of Virtual Reality, in *Communication in the Age of Virtual Reality*, Biocca, F., Levy, M. (eds.) Lawrence Erlbaum Publishers, Hillsdale, NJ, USA

Biocca, F. (1997) Progressive Embodiment in Virtual Environments, in *Journal of Computer Mediated Communication*, Vol. 3(2), USA

Biocca, F., Burgoon, J., Harms, C., Stoner, M. (2001) Criteria And Scope Conditions For A Theory And Measure Of Social Presence, in *Proceedings of the 4th International Workshop on Presence*, Philadelphia, USA

Blascovich, J. (2002) Social Influence within Immersive Virtual Environments, in *The Social Life of Avatars*, Schroeder, R. (Ed.), Springer, London, UK

Bourdakis, V. (1996) From CAAD to VR; Building a Model of London's West End, in *Proceedings of the 3rd UK Virtual Reality SIG Conference*, Leicester, UK

Bordwell, D., Staiger, J., Thompson, K. (1985) *The Classical Hollywood Cinema: Film Style and Mode of Production*, Columbia University Press, New York, USA

Bredo, E. (1994) Reconstructing Educational Psychology: Situated Cognition and Deweyan Pragmatism, in. *Educational Psychologist*, Vol. 29(1), pages 23-25, USA.

Bricken, M., Byrne, C. (1993) Summer Students in VR: A Pilot Study on Educational Applications in VR Technology, in *VR Application and Explorations*, Wexelblatt, Alan (Ed.) Academic Press, Toronto, Canada

Brooks, J., Brooks, M. (1993) *In Search of Understanding: The Case for Constructivist Classrooms*, Association for Supervision and Curriculum Development, Alexandria, VA, USA

Bruffee, K., A. (1999) *Collaborative Learning: Higher Education, Interdependence, and the Authority of Knowledge* (2nd Edition), Johns Hopkins University Press, Baltimore, USA

Bruner, J. (1985) Vygotsky: An Historical and Conceptual Perspective, in *Culture, Communication, and Cognition: Vygotskian Perspectives*, pages 21-34, Cambridge University Press, London, UK

Bruner, J. (1996). *The Culture of Education*, Harvard University Press, Cambridge, MA, USA

Bull, P. (1983) *Body Movement and Interpersonal Contact*, John Wiley & Sons, USA

Burch, N. (1979) *To The Distant Observer*, University of California Press, Berkeley, USA

Burch, N. (1990) *Live To Those Shadows*, University of California Press, Berkeley, USA

Buescher, M., O'Brian, J., Rodden, T., Trevor, J. (2001) "He's behind you": The Experience of Presence in Shared Virtual Environments, in *Collaborative Virtual Environments: Digital Places and Spaces for Interaction*, Churchill, E., Snowdon, D., Munro, A. (Eds.), Springer, London UK

Byrne, C. (1996) *Water On Tap: The Use Of Virtual Reality As An Educational Tool*. Doctoral Dissertation, University of Washington, USA

Caldwell, B., Uang, S., & Taha, L. (1995) Appropriateness of Communications Media Use in Organizations: Situation Requirements and Media Characteristics, in *Behaviour and Information Technology*, Vol. 14(4), pages 199-207, USA

Capin, T. K., Pandzic, I. S., Thalmann, D., & Thalmann, N. M. (1998) Realistic Avatars and Autonomous Virtual Humans in VLNET Networked Virtual Environments, in *Virtual Worlds on the Internet*, Vince, J., Earnshaw, R. (eds.) pages 157-173, IEEE Computer Society, Los Alamitos, CA, USA

Casanueva, J., Blake, E. (2000) The Effects of Group Collaboration on Presence in a Collaborative Virtual Environment, in *Proceedings of the 6th Eurographics Workshop on Virtual Environments*, pages 85-94, Springer, Amsterdam, The Netherlands

Cassell, J., Bickmore, T., Campbell, L., Vilhjálmsón, H., Yan, H. (2000) Human Conversation as a System Framework: Designing Embodied Conversational Agents, in *Embodied Conversational Agents*, MIT Press, Cambridge, MA, USA

Cassell, J., Vilhjálmsón, H. (1999) Fully Embodied Conversational Avatars: Making Communicative Behaviours Autonomous, in *Autonomous Agents and Multi-Agent Systems* 2(1), pages 45-64, Kluwer Academic Publishers, The Netherlands

Cassell, J., Torres, O., Prevost, S. (1999) Turn Taking vs. Discourse Structure: How best to model multimodal, in *Machine Conversation*, Wilks, Y. (ed.), Kluwer Academic Publishers, The Netherlands

Cavazza, M., Palmer, I., Parnell, S. (1998) Real-Time Requirements for the Implementation of Speech-Controlled Artificial Actors, in *Modelling and Motion Capture for Virtual Environments* (Lecture Notes in Artificial Intelligence, Vol. 1537) Magnenat-Thalmann, N., Thalmann, D. (Eds.), Springer, New York, USA

Chan, T., W. (1996) Learning Companion Systems, Social Learning Systems, and the Global Social Learning Club, in *Journal of AI in Education*, 7 (2), pages 125-159, USA

Chi, M., T., Bassok, M., Lewis, M., W., Reimann, P., Glaser, R. (1989) Self-Explanations: How Students Study and Use Examples in Learning to Solve Problems, in *Cognitive Science*, Vol. 13, pages 145-182, USA

Churchill, E., Snowdon, D., Munro, A. (2001) *Collaborative Virtual Environments: Digital Places and Spaces for Interaction*, Springer Verlag, London, UK

Churchill, E., Cook, L., Hodgson, P., Prevost, S., Sullivan, J. (2000) "May I Help You?": Designing Embodied Conversational Agent Allies, in *Embodied Conversational Agents*, MIT Press, Cambridge, MA, USA

Ciolek, T. (1982) Zones of Copresence in Face-to-face Interaction: Some Observational Data, in *Man-Environment Systems*, Vol. 12(6), pages 223-242, USA

Coffield, F. (2000) *Differing Visions of a Learning Society*, The Policy Press, Bristol, UK

Cole, M. (1998) *Cultural Psychology: A Once and Future Discipline*, Harvard University Press, USA

Cook, T., D., Campbell, D. (1979) *Quasi-experimentation: Design and Analysis Issues for Field Settings*, Rand-McNally, Chicago, USA

Damasio, A. (1994) *Descartes' Error: Emotion, Reason, and the Brain*, Grosset/Putman, New York, USA

Damer, B., Kekenes, C., Hoffman, T. (1996) Inhabited Digital Spaces, in *Proceedings of the CHI '96 Conference*, ACM Press, New York, USA

Damer, B. (1997) Demonstration and Guided Tours of Virtual Worlds on the Internet, in *Proceedings of the CHI '97 Conference*, ACM Press, New York, USA

Damer, B. (1998) *Avatars: Exploring and Building Virtual Worlds on the Internet*, Peachpit Press, Berkeley, CA, USA

Dillenbourg, P. (1996) Some Technical Implications of Distributed Cognition on the Design of Interactive Learning Environments, in *Journal of AI in Education*, Vol. 7(2), pages 161-17, International AIED Society, UK

Dillenbourg, P., Schneider, D. (1995) Collaborative Learning and the Internet, in *Proceeding of the 4th International Conference on Computer Assisted Instruction (ICCAI '95)*, Taipei, Taiwan

Dix, A., Finlay, J., Abowd, G., Beale, R. (1998) *Human Computer Interaction* (2nd edition), Prentice Hall, London, UK

Dodge, M., Doyle, S., Smith A., Fleetwood, S. (1998) Towards the Virtual City: VR and Internet GIS for Urban Planning, in *Virtual Reality & Geographical Information Systems*, Birkbeck College, USA

Donath, J.S. (1998) Identity and Deception in the Virtual Community, in *Communities in Cyberspace*, Kollok, P, Smith, M. (eds.), Routledge, London, UK

Elliot, C., Brzezinski, J. (1998) Autonomous Agents as Synthetic Characters, in *AI Magazine*, 19(2), USA

Ekman, P., Friesen, W., V. (1975) *Unmasking the Face*, Prentice Hall, New Jersey, USA

Ekman, P. (1982) *Emotion in the Human Face*, Cambridge University Press, Cambridge, USA

Fabri, M., Moore, D., Hobbs, D. (2002) Expressive Agents: Non-verbal Communication in Collaborative Virtual Environments, in *Proceedings of the Autonomous Agents and Multi-Agent Systems Conference*, Bologna, Italy

Fabri, M., Hobbs, D. (1998) What you see is what I mean: Virtual Encounters in Distance Learning Systems, in *Proceedings of 4th International Conference on Network Entities (Neties'98)*, Leeds, UK

Filman, R., Peña-Mora, F. (1998), The Arachnoid Tourist: Stuck in the Mud, in *Internet Computing*, Vol. 2(1), USA

Featherstone, M., Burrows, R. (1995) *Cyberspace, Cyberbodies, Cyberpunk: Cultures of Technological Embodiment*, SAGE Publications, London, UK

Franklin, S., Graesser, A. (1996) Is it an Agent, or just a Program?: A Taxonomy for Autonomous Agents, in *Proceedings of the 3rd International Workshop on Agent Theories, Architectures, and Languages*, Springer, Berlin, Germany

Frecon, E., Stenius, M. (1998) Dive: A Scalable Network Architecture for Distributed Virtual Environments, in *Distributed Systems Engineering Journal* (Special Issue on Distributed Virtual Environments), Vol. 5 (3), pages 91-100

Freeman, J., Avons, S., Pearson, D., Ijsselsteijn, W. (1999) Effects of Sensory Information and Prior Experience on Direct Subjective Ratings of Presence, in *Presence: Teleoperators and Virtual Environments*, Vol. 8, Pages 1-13, MIT Press, USA

Freeman, J., Avons, S.E. (2000). Focus Group Exploration of Presence through Advanced Broadcast Services, in *Proceedings of the SPIE, Human Vision and Electronic Imaging*, Vol. 3959, San Jose, USA

Freire, P. (2000) *Pedagogy of the Oppressed* (20th anniversary edition) Continuum International Publishing, New York, USA

Fulk, J., Steinfield, C., Schmitz, J., Power, J. (1987) A Social Information Processing Model of Media Use in Organisations, in *Communication Research*, Vol. 14(5), pages 529-552, USA

Garrison, D., R., Anderson, T., Archer, W. (2001) Critical Thinking, Cognitive Presence, and Computer Conferencing in Distance Education, in *American Journal of Distance Education*, Vol. 15(1), pages 7-23, USA

Garrison, D., R., Archer, W. (2000) *A Transactional Perspective on Teaching and Learning: A Framework for Adult and Higher Education*, Pergamon, Oxford, UK

Garrison, D., R. (1989) *Understanding Distance Education: A Framework for the Future*, Routledge, London, UK

Gergen, K. (1991) *The Saturated Self*, Harper Collins Publishers, New York, USA

Gerhard, M. (1997) Avatars and Agents in Collaborative Virtual Environments for Education, in *Proceedings of the Conference on Human Computer Interaction (HCI)*, Bristol, UK

Gerhard, M., Moore, D. (1998) User Embodiments in Educational CVEs: Towards Continuous Presence, in *Proceedings of the International Conference on Network Entities (NETIES)*, Leeds, UK

Gerhard, M. and Fabri, M. (1998) Usability Evaluation for Collaborative Virtual Environments: CyberAxis, in *Proceedings of the 1st International Workshop on Usability Evaluation for Virtual Environments (UEVE)*, Leicester, UK

Gerhard, M., Hobbs, D., Moore, D., Fabri, M. (1999a) Cognitive Immersion in CVEs: A Hybrid Avatar/Agent Model for User Representation in Virtual Learning Environments, in *Proceeding of the Eurographics UK Conference*, Cambridge, UK

Gerhard, M., Hobbs, D., Moore, D. (1999b) Agents for Networked Virtual Learning Environments, in *Networking Entities: Tele-education, Telematics & Law, Telematics*

& *Culture*, Guenther, J. and Zeibekakis, G., (eds), Danube University of Krems, Austria

Gerhard, M., Fabri, M. (2000) The Virtual Student: User Embodiment in Virtual Learning Environments, in *International Perspectives on Tele-Education and Virtual Learning Environments*, Hobbs, D. and Orange, G., (eds), Ashgate, UK

Gerhard, M., Moore, D., Hobbs, D. (2001a) An Experimental Study of the Effects of Presence in Collaborative Virtual Environments, in *Proceeding of the International Conference on Intelligent Agents for Mobile and Virtual Media*, Bradford, UK

Gerhard, M., Moore, D., Hobbs, D. (2001b) Continuous Presence in Collaborative Virtual Environments: Towards the Evaluation of a Hybrid Avatar-Agent Model for User Representation, in *Proceeding of the International Conference on Intelligent Virtual Agents (IVA 2001)*, Madrid, Spain

Gerhard, M., Moore, D.J., Hobbs, D. J. (2002) An Experimental Study of the Effect of Presence in Collaborative Virtual Environments, in *Intelligent Agents for Mobile and Virtual Media*, Earnshaw, R., Vince, J. (Eds), Springer, Berlin, Germany

Gerrig, R., J. (1993) *Experiencing Narrative Worlds*, Yale University Press, New Haven, USA

Gibbs, W., J. (1998) Implementing On-Line Learning Environments, in *Journal of Computing in Higher Education*, Vol. 10(1), pages 16-37, USA

Gibson, W. (1984) *Neuromancer*, Harper Collins, London, UK

Girle R. A. (1986) Dialogue and Discourse, in *Proceedings of the Fourth Annual Computer Assisted Learning in Tertiary Education Conference*, Bishop, G., Van Lint, W. (eds.), Adelaide, Australia

Glass, J. (1993) *Shattered Selves: Multiple Personality in a Post-modern World*, Cornell University Press, USA

- Goffman, E. (1963) *Behaviour in Public Places; Notes on the Social Organization of Gatherings*, The Free Press, New York, USA
- Goffman, E. (1983) The Interaction Order, in *American Sociological Review*, Vol. 48, pages 1-17, American Sociological Association Press, USA
- Gokhale, A., A. (1995) Collaborative Learning Enhances Critical Thinking, in *Journal of Technology Education*, Vol. 7 (1), USA
- Green, M., C., Brock, T., C. (2000) The Role of Transportation in the Persuasiveness of Public Narratives, in *Journal of Personality and Social Psychology*, Vol. 79, pages 701-721, USA
- Greenhalgh, C., Benford, S. (1995) MASSIVE: A Virtual Reality System for Teleconferencing, in *ACM Transactions on Human Computer Interfaces*, Vol. 3(2), pages 239-261, USA
- Harre, R., Van Langenhove, L. (1991) Varieties of Positioning, in *Journal for the Theory of Social Behaviour*, Vol. 21, pages 393-408, USA
- Harrison, S., Dourish, P. (1996) Re-Place-ing Space: The Roles of Place and Space in Collaborative Systems, in *Proceedings of CSCW'96*, Boston, USA
- Harry, K., Keegan, D., Magnus, J. (1993) *Distance Education: New Perspectives*, Routledge, London, UK
- Hawkrige, D. (1995) The Big Bang Theory in Distance Education, in *Open and Distance Learning Today*, Lockwood, F. (ed.), Routledge, London, UK
- Heidegger, M. (1927) *Being and Time*, Stambaugh, J. (trans.) 1997, New York, USA
- Held, R., Durlach, N. (1992) Telepresence, in *Presence: Tele-operators and Virtual Environments*, Vol. 1, MIT Press, Boston, USA
- Hermans, H., J. (1996) Voicing the Self: From Information Processing to Dialogical Interchange, in *Psychological Bulletin*, Vol. 119(1), pages 31-50, USA

Hermans, H., J., Kempen, H., J., Van Loon, R. (1992) The Dialogical Self: Beyond Individualism and Rationalism, in *American Psychologist*, Vol. 47 (1), pages 23-33, USA

Hewitt, J., Teplovs, C. (1999) An Analysis of Growth Patterns in Computer Conferencing, in *Computer Support for Collaborative Learning (CSCL '99)*, Hoadley, C. (ed.) Stanford University, Palo Alto, USA

Hilgard, J., R. (1970) *Personality and Hypnosis*, University of Chicago Press, Chicago, USA

Hirschman, L. (1998) Language Learning Evaluations: Lessons Learned from MUC and ATIS, in *Proceedings of the International Conference on Language Resources and Evaluation*, pages 117-122, ELRA, Paris, France

Hirumi, A., Bermudez, A. (1996) Interactivity, Distance Education, and Instructional Systems Design Converge on the Information Superhighway, in *Journal of Research on Computing in Education*, Vol. 29, pages 1-16, USA

Hobbs, D., J., Taylor R., J. (1996), The Impact on Education of the World Wide Web, in *Proceedings of WebNet96, Association for the Advancement of Computers in Education*, San Francisco, USA

Hobbs DJ, Taylor, RJ, Armstrong J (2000), An Examination of the Potential of Electronic Networking to Provide Effective Learning Environments, in *International Perspectives on Tele-Education and Virtual Learning Environments*, Orange, G., Hobbs, D., J. (eds.), Ashgate, UK

Hopgood, A., A. (2001) *Intelligent Systems for Engineers and Scientists* (2nd edition), CRC Press, New York, USA

Howell, D., C. (1997) *Statistical Methods for Psychology: Fourth Edition*, Duxbury Press, Boston, USA

Huxor, A. (1999) The Role of 3D Shared Worlds in Support of Chance Encounters in CSCW, in *Digital Convergence: The Information Revolution*, Vince, J., Earnshaw, R. (Eds.) Springer, London, UK

Huxor, A., (1998) The Role of 3D Shared Worlds in Support of Chance Encounters in CSCW, in *Proceedings of International Conference on Digital Convergence: The Future of the Internet & WWW*, Bradford, UK

Huxor, A., (1997) The Role of Virtual World Design in Collaborative Working, in *Proceedings of 13th Symposium on Computer Arithmetic (ARITH '97)*, London, UK

Ijsselsteijn, W.A., de Ridder, H., Freeman, J., Avons, S., E. (2000) Presence: Concept, determinants and measurement, in *Proceedings of the SPIE, Human Vision and Electronic Imaging V*, San Jose, CA, USA

Isbister, K., Young, D. (2001) Sagetalk: designing a tool for designing successful web-based social agents, in Müller, J., P., Andre, E. et al (eds.), *Proceedings of the Fifth International Conference on Autonomous Agents*, Montreal, Canada

Johns, C., Nunez, D., Daya, M., Sellars, D., Casanueva, J., Blake E. (2000) The Interaction Between Individuals: Immersive Tendencies and the Sensation of Presence in a Virtual Environment, in *Proceedings of the 6th Eurographics Workshop on Virtual Environments*, Springer, Amsterdam, Netherlands

Johnson, W. (1998) Pedagogical Agents, in *Proceedings of the International Conference on Computers in Education*, Beijing, China

Johnson, R., T., Johnson, D., W. (1986) Action Research: Cooperative Learning in the Science Classroom, in *Science and Children*, Vol. 24, USA

Jonassen, D., H. (1992) Applications and Limitations of Hypertext Technology for Distance Learning, in *Proceedings of the Distance Learning Workshop*, Armstrong Laboratory, San Antonio, Texas, USA

- Karat, C., Halverson, C., Horn, D., Karat, J. (1999) Patterns of Entry and Correction in Large Vocabulary Continuous Speech Recognition Systems, in *Proceedings of CHI '99: Human Factors in Computing Systems*, pages 568-575, ACM Press, New York, USA
- Kaufman, R. (1996) Visions, Strategic Planning & Quality - More Than Hype, in *Educational Technology*, Vol. 36(5), pages 60-62, USA
- Kaur, K., Tromp, J., Hand, C., Istance, H., Steed, A. (1998) Usability Evaluation for Virtual Environments, in *Proceedings of the UEVE '98 Workshop*, Leicester, UK
- Keegan, D. (1980) On Defining Distance Education, in *Distance Education*, Vol.1, pages 13-36, UK
- Keegan, D. (1986) *The Foundations of Distance Education* (2nd edition), Routledge, London, UK
- Kendon, A. (1993) Human Gesture, in *Tools, Language and Intelligence*, Ingold, T., Gibson, K. (eds.), Cambridge University Press, Cambridge, USA
- Kerlinger, F., N., Lee, H., B. (2000) *Foundations of Behavioural Research* (4th edition), Harcourt College Publishers, New York, USA
- Kirk, R., E. (1982) *Experimental Design: Procedures for the Behavioural Sciences* (2nd edition), Brooks/Cole Belmont, CA, USA
- Lave, J. (1991) Situated Learning in Communities of Practice, in *Perspectives on Socially Shared Cognition*, Resnick, L., Levine, J., Teasley, S. (eds), pages 63-82, American Psychological Association, Washington DC, USA
- Laver, J. (1981) Linguistic routines and politeness in greeting and parting, in *Conversational Routine*, Coulmas, F., (ed), pages 289-304, Mouton, The Hague, The Netherlands
- Laurel, B. (1997) Interface Agents: metaphors with character, in *Software Agents*, Bradshaw, J., M. (ed.), pages 67-78, MIT Press, USA

-
- Laurillard, D. (1993) *Rethinking University Teaching: A Framework for the Effective Use of Educational Technology*, Routledge, London, UK
- Laurillard, D. (1995) Multimedia and the Changing Experience of the Learner, in *British Journal of Education Technology*, Vol. 26(3), UK
- Lefebvre, Henri (1974) *The Production of Space*, Nicholson-Smith, D. (trans.), 1991, Blackwell, Oxford, UK
- Lester, J., Fitzgerald, P., Stone, B. (1997a) Increasing Believability in Animated Pedagogical Agents, in *Proceedings of the 1st International Conference on Autonomous Agents*, ACM Press, New York, USA
- Lester, J., Stone, B. (1997) The Pedagogical Design Studio: Exploiting Artefact-Based Task Models for Constructivist Learning, in *Proceedings of the 3rd International Conference on Intelligent User Interfaces*, Orlando, USA
- Lester, J., Towns, S., Callaway, C., Voerman, J., Fitzgerald, P. (2000) Deictic and Emotive Communication in Animated Pedagogical Agents, in *Embodied Conversational Agents*, MIT Press, Cambridge, MA, USA
- Lessiter, J., Freeman, J., Keogh, E., Davidoff, J. (2000) Development of a New Cross-media Presence Questionnaire: The ITC Sense of Presence Inventory, in *Proceedings of the 3rd International Workshop on Presence*, Delft, Netherlands
- Licklider, J., C., Taylor, R., W. (1968) The Computer as a Communication Device, in *Science and Technology*, pages 21-31, USA
- Light, P., Butterworth, G. (1992) *Context and Cognition: Ways of Learning and Knowing*, Lawrence Erlbaum Associates, Hillsdale, NJ, USA
- Light, P., Light, V. (1999) Analysing Asynchronous Interactions: Computer Mediated Communication in a Conventional Undergraduate Setting, in *Learning with Computers: Analysing Productive Interaction*, Littleton, K., Light, p. (eds) Routledge, London, UK

Littleton, K., Hakkinen, P. (1999) Learning Together: Understanding the Processes of Computer-Based Collaborative Learning, in *Collaborative Learning: Cognitive and Computational Approaches*, Dillenbourg, P. (ed), Pergamon Press, Amsterdam, The Netherlands

Lockwood, F., Gooley, A. (2001) *Innovation in Open and Distance Learning: Successful Development of Online and Web-Based Learning*, Kogan Page, London, UK

Lombard, M., & Ditton, T. (1997) At the heart of it all: The concept of presence, in *Journal of Computer Mediated-Communication*, Vol.3 (2), USA

Lombard, M., Ditton, T. B., Crane, D., Davis, B., Gil-Egui, G., Horvath, K., Rossman, J., Park, S. (2000) Measuring Presence: A Literature-based Approach to the Development of a Standardized Paper-and-pencil Instrument, in *Proceedings of the 3rd International Workshop on Presence*, Delft, Netherlands

Loomis, J., M. (1992) Distal Attribution and Presence, in *Presence: Tele-operators and Virtual Environments*, Vol. 1, MIT Press, Boston, USA

Maes, P. (1995) Artificial Life Meets Entertainment: Lifelike Autonomous Agents, in *Communication of the Association for Computing Machinery*, 38(11), pages 108-114, ACM Press, USA

Marcel, G. (1927) *Metaphysical Journal*, Henry Rennery, Chicago, USA

Massaro, D., Cohen, M., Beskow, J., Cole, R. (2000) Developing and Evaluating Conversational Agents, in *Embodied Conversational Agents*, MIT Press, Cambridge, MA, USA

McBreen, H., Shade, P., Jack, M., Wyard, P. (2000) Experimental Assessment of the effectiveness of Synthetic Personae for Multi-Modal E-Retail Applications, in *Proceedings of the 4th International Conference on Autonomous Agents 2000*, Barcelona, Spain

McBreen, H., Jack, M. (2000) Animated Conversational Agents in E-Commerce Applications, in *Proceedings of 3rd International Workshop on Human-Computer Conversation*, Bellagio, Italy

McNeill, D. (1992) *Hand and Mind: What Gestures Reveal about Thought*, Chicago University Press, Chicago, USA

Merleau-Ponty, M. (1945) *The Phenomenology of Perception*, Smith, C. (trans.) 1962, Routledge, London, UK

Mitchell, W., L. (1997) Moving the Museum onto the Internet: The Use of Virtual Environments in Education about Ancient Egypt, in *From Desktop to Webtop: Proceedings of the International Conference on Virtual Environments on the Internet, WWW and Networks*, Bradford, UK

Moore, D., J. (1993) *Dialogue Game Theory for Intelligent Tutoring Systems*, PhD Thesis, Leeds Metropolitan University, UK

Moore, D., J., Hobbs, D., J. (1996) Computational Uses of Philosophical Dialogue Theories, in *Informal Logic*, Vol. 18(2), pages 131-163, Canada

Moore, D., J., Hobbs, D., J. (1997) Strategies for the Introduction of Multimedia Systems, in *Social and Organisational Issues Dimension of Information Systems*, Orange, G., Katsikides, S. (Eds.), McGraw-Hill, New York, USA

Moore, D., J. (2000) A framework for using multimedia within Argumentation Systems, in *Journal of Educational Multimedia and Hypermedia*, Vol. 9(2)

Moore, D., J., McGrath, P., Thorpe, J. (2000) Computer-aided learning for People with Autism - A Framework for Research and Development, in *Innovations in Education and Training International*, Vol. 37(3), pages 218-227

Moore, D., J., Taylor, J. (2000) Interactive Multimedia Systems for Students with Autism, in *Journal of Educational Media*, Vol. 25(3), pages 169-177

Moore, M., G., Kearsley, G. (1996) *Distance Education: a Systems View*, Wadsworth, New York, USA

Moore, M., G. (1997) Quality in Distance Education: Four Cases, in *The American Journal of Distance Education*, Vol. 11(3), pages 1-7, USA

Morningstar, C. & Farmer, R., (1991), The Lessons of Lucasfilm's Habitat, in *Cyberspace: First Steps*, Benedikt, M., (ed.), pages 273-301, MIT Press, Cambridge, USA

Morphett, J. (1996) Presence in Absence: Asynchronous Communication in Virtual Environments, in *Proceedings of 3D and Multimedia on the Internet, WWW and Networks*, Bradford UK

Moundridou, M., Virvou, M. (2002) Evaluating the Persona Effect of an Interface Agent in a Tutoring System, in *Journal of Computer Assisted Learning*, Oxford, UK

Muilenburg, L., Berge, Z. (2001). Barriers to Distance Education: A Factor Analytic Study, in *The American Journal of Distance Education*, Vol. 11(2), pages 39-54, USA

Müller, J., P. (1996) *The Design of Intelligent Agents: A Layered Approach*, Springer-Verlag, Berlin, Germany

Myers, D., G. (1999) *Exploring Psychology: Fourth Edition*, Worth Publishers, New York, USA

Nass, C., Isbister, K., Lee, E., J. (2000) Truth is Beauty: Researching Embodied Conversational Agents, in *Embodied Conversational Agents*, MIT Press, Cambridge, MA, USA

Nielsen, J. (1992) Finding Usability Problems Through Heuristic Evaluation, in *Proceedings of the CHI 92*, pages 373-380, ACM Press, New York, USA

Nielsen, J. (1993) *Usability Engineering*, Academic Press, New York, USA

Nielsen, J., Mack, R. (1994) *Usability Inspection Methods*, John Wiley & Sons, New York, USA

Nielsen, J. (1994) Heuristic Evaluation, in *Usability Inspection Methods*, Nielsen, J., Mack, R., L. (eds.), pages 25-62, John Wiley & Sons, New York, USA

Nielsen, J. and Molich, R. (1990) Heuristic Evaluation of User Interfaces, in *Proceedings of ACM CHI'90 Conference on Human Factors in Computing Systems*, pages 249-256, Seattle, USA

Nowak, K. (2001) Conceptualising and Differentiating Copresence and Social Presence, in *Proceedings of the 4th International Workshop on Presence*, Philadelphia, USA

Nowak, K. (2000) *The Influence of Anthropomorphism on Mental Models of Agents and Avatars in Social Virtual Environments*, PhD Thesis, Department of Telecommunication, Michigan State University, East Lansing, MI, USA

O'Malley, C. (1995) *Computer Supported Collaborative Learning*, Springer Press, Berlin, Germany

Oviatt, S., Adams, B. (2000) Designing and Evaluating Conversational Interfaces with Animated Characters, in *Embodied Conversational Agents*, MIT Press, Cambridge, MA, USA

Palmer, M. (1995) Interpersonal Communication and Virtual Reality: Mediating Interpersonal Relationships, in *Communication in the Age of Virtual Reality*, Biocca, F., Levy, M. (eds.), pages 277-299, Lawrence Erlbaum Associates, Hillsdale, New Jersey, USA

Pask, G. (1988) Learning Strategies, Teaching Strategies, and Conceptual or Learning Style, in *Learning Strategies and Learning Styles*, Schmeck, R. (ed.), pages 83-100, Plenum, New York, USA

Perkins, D. (1993) *Person Plus: A Distributed View of Thinking and Learning*, in *Distributed Cognitions*, Salomon G (ed.) Cambridge University Press, Cambridge, UK

Perraton, H. (1988) *A Theory for Distance Education*, in *Distance Education: International Perspectives*, Sewart, D., Keegan, D., Holmberg, B. (eds.), pages 34-45, Routledge, New York, USA

Polifroni, J., Seneff, S., Glass, J., Hazen, T. (1998) *Evaluation Methodology for a Telephone-based System*, in *Proceedings of the International Conference on Language Resources and Evaluation*, pages 117-122, ELRA, Paris, France

Prawat, R., Floden, R., E. (1994) *Philosophical Perspectives on Constructivist Views of Learning*, in *Educational Psychology*, Vol. 29(1), pages 37-48, USA

Preece, J. (2000) *Online Communities: Designing Usability, Supporting Sociability*, John Wiley & Sons, Chichester, England, UK

Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., Carey, T. (1994) *Human-Computer Interaction*, Addison-Wesley, Wokingham, UK

Preece, J., Rogers, Y., Sharp, H. (2001) *Interaction Design*, John Wiley & Sons, New York, USA

Prothero, J. D., Parker, D. E., Furness, T. A., & Wells, M. J. (1995) *Towards a Robust, Quantitative Measure for Presence*, in *Proceedings of the Conference on Experimental Analysis and Measurement of Situation Awareness*, pages 359-366, Daytona Beach, USA

Psotka, J., Davison, S., Lewis, S., A. (1993) *Exploring Immersion in Virtual Space*, in *Virtual Reality Systems*, Vol. 1(2), pages 70-82, USA

Psotka, J. (1995) *Immersive Tutoring Systems: Virtual Reality and Education and Training*, in *Instructional Science*, Vol. 23, USA

Reeves, B., Nass, C. (1996) *The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places*, CSLI Publications, Stanford, CA, USA

Rheingold, H. (1985). *Tools for Thought*, Summit Books, New York, USA

Rheingold, H. (1991). *Virtual Reality*, Summit Books, New York, USA

Rice, R. (1993) Media Appropriateness: Using Social Presence Theory to Compare Traditional and New Organisational Media, in *Human Communication Research*, Vol. 19(4), pages 451-484, USA

Rickel, J., Johnson, W. (1999) Animated Agents for Procedural Training in Virtual Reality: Perception, Cognition, and Motor Control, in *Applied Artificial Intelligence* 13 (4-5): 343-382, USA

Rickel, J., Johnson, W. (2000) Task-oriented Collaboration with Embodied Agents in Virtual Worlds, in *Embodied Conversational Agents*, MIT Press, Cambridge, MA, USA

Riecken, D. (1994) Intelligent Agents, in *Communications of the Association for Computing Machinery*, 37(7), pages 18-21, ACM Press, USA

Robson, C. (2001) *Real World Research* (2nd Edition), Blackwell, Oxford, UK

Roehl, B., Couch, J., Reed-Ballreich, C., Rohaly, T., Brown, G. (1997) *Late Night with VRML 2.0 with Java*, Ziff-Davis Press, New York, USA

Rossney, R. (1996) Metaworlds, in *Wired*, Vol. 4(6), pages 140-152, USA

Sanders, G., A., Scholtz, J. (1998) Measurement and Evaluation of Embodied Conversational Characters, in *Proceedings of the Workshop on Embodied Conversational Characters (WECC 98)*, Tahoe City, California, USA

Sanders, G. A., Scholtz, J. (2000) Measurement and Evaluation of Embodied Conversational Agents, in *Embodied Conversational Agents*, MIT Press, Cambridge, MA, USA

Santoni, R., E. (1995) *Bad Faith, Good Faith, and Authenticity in Sartre's Early Philosophy*, Temple University Press, USA

Sartre, J.-P. (1943) *Being and Nothingness: A Study in Phenomenological Ontology*, Barnes, H., E. (trans.) 1953, Philosophical Library, New York, USA

Savery, J., R., Duffy, T., M. (1995) Problem Based Learning: An Instructional Model and its Constructivist Framework, in *Educational Technology*, Vol. 35(5), pages 31-38, USA

Scardamalia, M., Bereiter, C. (1994) Computer Support for Knowledge-Building Communities, in *Journal of the Learning Sciences*, Vol. 3(3), pages 265-283, USA

Schegloff, E., A. (1992) On talk and its Institutional Occasions, in *Talk at Work: Interaction in Institutional Settings*, Drew, P., Heritage, J. (eds.), pages 101-134, Cambridge University Press, Cambridge, UK

Schroeder, R. (1997) Networked Worlds: Social Aspects of Multi-User Virtual Reality Technology, in *Sociological Research Online*, Vol. 2(4), UK

Schroeder, R., Steed, A., Axelsson, A., Heldal, I., Abelin, A., Widestrom, J., Nilsson, A., Slater, M. (2001) Collaborating in Networked Immersive Spaces: As Good as Being There Together?, in *Computers & Graphics*, Vol. 25, pages 781-788

Schroeder, R. (2002) Social Interaction in Virtual Environments: Key Issues, Common Themes, and a Framework for Research, in *The Social Life of Avatars*, Schroeder, R. (Ed.), Springer, London, UK

Schrum, L. (1995) Online Courses: What Have We Learned?, in *Proceedings of the International Conference of Computers in Education*, Birmingham, UK

Schubert, T., Friedmann, F., & Regenbrecht, H. (1999) Decomposing the Sense of Presence: Factor Analytic Insights, in *Proceedings of the 2nd International Workshop on Presence*, Colchester, UK.

Schubert, T., Friedmann, F., Regenbrecht, H. (2001) The Experience of Presence: Factor Analytic Insights, in *Presence: Teleoperators and Virtual Environments*, Vol. 10(3), Pages 266-281, MIT Press, USA

Seamans, M., C. (1990) New perspectives on User-centred Design, in *Proceedings of the Interchange Technical Writing Conference*, Lowell, MA, USA

Shale, D., .G. (1988) Toward a Reconceptualisation of Distance Education, in *The American Journal of Distance Education*, Vol. 2 (3), pages 25-35, USA

Sewart, D. (2001) A New Approach to Services to Students, in *Proceedings of the 20th ICDE World Conference*, Düsseldorf, Germany

Sheridan, T.B. (1992), Musings on Telepresence and Virtual Presence, in *Presence: Tele-operators and Virtual Environments*, Vol. 1, MIT Press, USA

Sherry, L. (1996) Issues in Distance Learning, in *International Journal of Educational Telecommunications*, Vol. 4, pages 337-365, USA

Shneiderman, B. (1997) *Designing the User Interface* (3rd edition), Addison-Wesley Publishing, USA

Shor, R., E. (1970) The Factor Theory of Hypnosis as Applied to Book Reading Fantasy and to the Concept of Suggestion, in *International Journal of Clinical and Experimental Hypnosis*, Vol. 18, pages 89-98, USA

Short, J., Williams, E., Christie, B. (1976) *The Social Psychology of Tele-Communications*, John Wiley & Sons Ltd, London, UK

Siegel, S., Castellan, N. J. (1988) *Nonparametric Statistics for the Behavioural Sciences* (2nd edition), McGraw-Hill, New York, USA

Silverman, D. (1993) *Interpreting Qualitative Data - Methods for Analysing Talk, Text and Interaction*, Sage Publications Ltd, London, UK

Simon, H., A. (2000) Observations on the Sciences of Science Learning, in *Journal of Applied Developmental Psychology*, Vol. 21(1), pages 115-121, USA

Slater, M., Usoh, M. (1993), Presence in Immersive Virtual Environments, in *Proceedings of the IEEE Conference – Virtual Reality Annual Symposium*, Seattle, USA

Slater, M., Usoh, M. (1994), Body Centred Interaction in Immersive Virtual Environments, in *Artificial Life and Virtual Reality*, Thalmann, D., Thalmann, N.M., (Eds.), John Wiley & Sons, USA

Slater, M., Steed, A., McCarthy, J., Maringelli, F. (1998), The Influence of Body Movement on Presence in Virtual Environments, in *Human Factors: The Journal of the Human Factors and Ergonomics Society*, Vol. 40 (3), USA

Slater, M., (1999), Measuring Presence: A Response to the Witmer and Singer Questionnaire, in *Presence: Tele-operators and Virtual Environments*, Vol. 8 (5), MIT Press, USA

Slater, M., Sadagic, A., Usoh, M, Schroeder, R. (2000) Small-Group Behaviour in a Virtual and Real Environment: A Comparative Study, in *Presence: Teleoperators and Virtual Environments*, Vol. 9(1), MIT Press, USA

Smith, K., Fyffe, C., Lyons, L. (1993) Telematics: The ‘Language of Possibility’, in *Open Learning*, Vol. 8(2), pages 45-49.

Snowdon, D., Churchill, E., Munro, A. (2001) CVEs: Digital Spaces and Places for CSCW: An Introduction, in *Collaborative Virtual Environments. Digital Places and Spaces for Interaction*, pages 3-17, Springer Verlag, London, UK

Stephenson, N. (1992) *Snow Crash*, Bantam Spectra, New York, USA

Steuer, J. (1992) Defining Virtual Reality: Dimensions Determining Telepresence, in *Journal of Communication*, Vol. 42(4), pages 73-93, Oxford University Press, UK

Stone, A., S. (1991) Will the Real Body Please Stand-Up?: Boundary Stories about Virtual Cultures, in *Cyberspace: First Steps*, Benedikt, M. (ed.) pages 81-118, MIT Press, Cambridge, USA

Streibel, M., J. (1991) Instructional Plans and Situated Learning, in *Instructional Technology, Past, Present, and Future*, Anglin, G., J. (ed.), pages 117-132, Libraries Unlimited, Englewood, CO, USA

Tambe, M., Johnson, W., L., Jones, R., M., Koss, F., Laird, J., E., Rosenbloom, P., S., Schwamb, K. (1995) Intelligent Agents for Interactive Simulation Environments, in *AI Magazine*, USA

Tan, E., S. (1996) *Emotion and the Structure of Narrative Film: Film as an Emotion Machine*, Lawrence Erlbaum, Mahwah, New Jersey, USA

Taylor, T., L. (1999) Life in Virtual Worlds: Plural Existence, Multimodalities, and other Online Research Challenges, in *American Behavioural Scientist*, Vol. 43 (3), pages 436-449, Sage Publications, USA

Taylor, T., L. (2002) Living Digitally: Embodiment in Virtual Worlds, in *The Social Life of Avatars*, Schroeder, R. (Ed.), Springer, London, UK

Tecuci, G. (1998), *Building Intelligent Agents*, Academic Press, San Diego, CA, USA

Thalmann, D. (2001) The Role of Virtual Humans in Virtual Environment Technology and Interfaces, in *Frontiers of Human-Centred Computing*, Earnshaw R., Guedj, R., Vince, J. (eds.), pages 27-39, Springer, London, UK

Tinzmann, M., B., Jones, B., F., Fennimore, T., F., Bakker, J., Fine, C., Pierce, J. (1990) *What is the Collaborative Classroom?*, Oak Brook Publishers, IL, USA

Totten, S., Sills, T., Digby, A., Russ, P. (1991) *Cooperative Learning: A Guide to Research*, Garland, New York, USA

Tromp, J., G. (1995a) Presence, Telepresence, and Immersion: The Cognitive Factors of Embodiment and Interaction in Virtual Environments, in *Proceedings of the FIVE conferences, Frameworks for Immersive Virtual Environments*, London, UK

Tromp, J., G. (1995b) *Presence, Telepresence and Immersion: Embodiment and Interaction in Virtual Environments*, Thesis, Department of Psychology, University of Amsterdam, Netherlands

Tromp, J., G., Benford, S. (1995) Presence, Tele-Presence and Immersion: Interaction and Embodiment in Collaborative Virtual Environments, in *Proceedings of the FIVE '95 Framework for Immersive Virtual Environments*, London, UK

Tuckman, B. W. (1999) *Conducting Educational Research* (5th edition), Harcourt Brace Academic Publishers, New York, USA

Turing, A. (1950) Computing Machinery and Intelligence, in *Mind*, Vol. 59, pages 433-460, London, UK

Vygotsky, L. (1978) *Mind in Society: The Development of Higher Psychological Processes*, Harvard University Press, Cambridge, USA

Walther, J. (1992). Interpersonal Effects in Computer-Mediated Interaction; A Relational Perspective, in *Communication Research*, Vol. 19(1), pages 52-90, USA

Walther, J. B. (1996) Computer-mediated communication: Impersonal, Interpersonal, and Hyper-personal Interaction, in *Communication Research*, Vol. 23, pages 3-43, USA

Weld, D. (1995) The role of intelligent systems in the national information infrastructure, in *AI Magazine*, 16(3), pages 45-64, AAAI Press, USA

Weller, M., J. (2001) Why the Internet is a Significant Educational Technology, in *Proceedings of the EDINEB Conference*, Nice, France

Wexelblatt, A. (1993) The Reality of Co-operation: Virtual Reality and CSCW, in *Virtual Reality: Applications and Explorations*, Academic Publishers, Boston, USA

- Wing, L. (1996) Autism Spectrum Disorders: No Evidence for or Against an Increase in Prevalence, in *British Medical Journal*, Vol. 312, pages 327-328, UK
- Winer, B., J., Brown, D., R., Michels, K., M. (1991) *Statistical Principles of Experimental Design* (3rd edition), McGraw-Hill, New York, USA
- Whittaker, S., O'Conaill, B. (1997) The Role of Vision in Face-to-Face and Mediated Communication, in *Video Mediated Communication*, Finn, K., Sellen, A., Wilbur, S. (eds.). LEA, NJ, USA
- Wilcox, S., K. (1998) *Web Developer Guide to 3D Avatars*, John Wiley & Son, New York, USA
- Witmer, B., Singer, M., (1998), Measuring Presence: A Presence Questionnaire, in *Presence: Tele-operators and Virtual Environments*, Vol. 7 (3), MIT Press, USA
- Witmer, B., Singer, M. (1999) On Finding the Right Yardstick, in *Presence: Tele-operators and Virtual Environments*, Vol. 8 (5), MIT Press, USA
- Wooldrich, M. (2002) *An Introduction to Multi-Agent Systems*, John Wiley & Sons Ltd, England, UK
- Wooldrich, M. (1999) Intelligent Agents, in *Multi-Agent Systems: a Modern Approach to Distributed Artificial Intelligence*, Weiss, G. (ed.), pages 27-77, MIT Press, USA
- Wooldrich, M., Jennings, N., R., Kinny, D. (1999) A methodology for agent-oriented analysis and design, in *Proceedings of the 3rd International Conference on Autonomous Agents*, pages 69-76, Seattle, USA