Chapter 1 Introduction

"An interface is **humane** if it is responsive to human needs and considerate of human frailties. If you want to create a humane interface, you must have an understanding of the relevant information on how humans and machines operate. In addition, you must cultivate in yourself a sensitivity to the difficulties that people experience. That is not necessarily a simple undertaking. We become accustomed to the way that products work to the extent that we come to accept their methods as a given, even when their interfaces are unnecessarily complex, confusing, wasteful, and provocative of human error."

Jef Raskin, (2000).

Chapter 1: Introduction

Collaborative Virtual Environments (CVEs) are computer generated graphical, three dimensional, multi-user spaces in which geographically remote people can interact with each other and the virtual environment in real-time, with the ultimate aim of supporting users to collaborate on shared tasks. During 1995 – 1999, the Communications Research Group (CRG) in the department of Computer Science at the University of Nottingham was (amongst other things) involved in a large scale CVE research and development project funded by the European Community (CORDIS RTD-PROJECT ACTS AC040). This 5-year project was entitled: "Collaborative Virtual Environments" (COVEN) of which the author was one of the principal usability engineers. This thesis is based on work performed by the author on CVE specific design advice and usability evaluation issues studied during the COVEN project.

1.1 Definition of the Problem

Collaborative virtual environments are a novel application area of computing technology, demanding an understanding of human-computer interaction (HCI) and computer mediated human interaction in virtual spaces. Standard usability engineering and HCI evaluation techniques do not directly address the usability problems introduced by these new applications. The technology on which CVEs are built is in its early stages, with in particular the human factors impact of its specific features still poorly explored (Durlach and Mavor, 1995), illustrated by the fact that significant usability problems with single user VEs have been found (Kaur, Maiden and Sutcliffe, 1999). To address this lack of CVE specific usability tools,

comprehensive guidelines for the design and evaluation of CVEs have to be developed. Therefore, investigating the human behavioural aspects that affect performance and satisfaction in CVEs, is a prerequisite of developing tools for VE usability-design and evaluation. It requires focused exploratory studies of the unique aspects and phenomena of CVEs, embedded in a general framework of scientific inquiry (Groot, 1969), which provides a means to systematic, incremental, refinement of our understanding of new concepts, such as CVEs. This thesis is an exploration of the usability problems introduced by desktop CVE technology. To be more precise, the COVEN project had a three-pronged approach and the work presented in this thesis is a further analysis of these strands (see Figure 1.1).

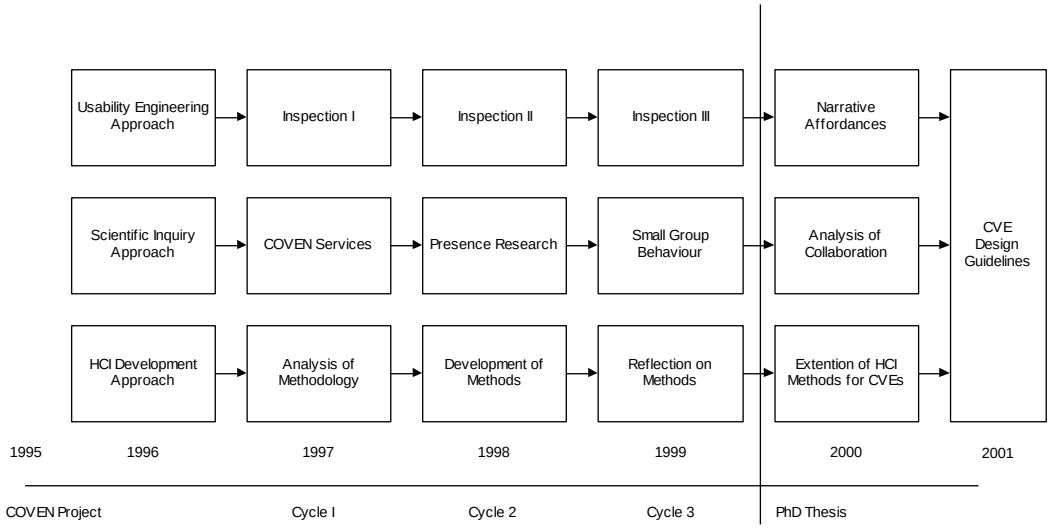


Figure 1.1: COVEN and thesis research in framework.

1.2 Research Aims and Objectives

Considering the current lack of understanding of CVE specific usability problems the main aim of the research presented in this thesis is as follows:

To investigate the use of Collaborative Virtual Environments in order to improve the usability and the process of their design, development and evaluation.

This aim will be achieved by meeting the following objectives:

1) Critically reviewing the capabilities and limitations of current CVE systems in terms of their impact on usability;
2) Examining existing theories and methodologies for designing and evaluating artifacts (hardware and software) which may have a possible bearing on theories and methods for the design and evaluation of CVE applications;
3) Identifying and describing the collaboration activities humans perform in real and virtual environments;
4) Carrying out experiments using representative CVE user task scenarios, and analyse and describe observations of the actions of collaborating users;
5) Developing a structured framework in which to propose and support CVE usability requirements;
6) Providing recommendations for the future of CVE design and evaluation.

There are many aspects of usability that come to light through an analysis of the introduction and use of CVEs in the workplace. However, the focus of this thesis is on the investigation of the central claim of CVE technology: the facilitation and support of collaboration, rather than the broader aspects of usability for CVE technology. It may come as no surprise that the broader usability aspects of CVE use also emerge

through the analysis of the collaboration process in CVEs. All aspects of CVE usability that are discovered through this analysis are incorporated in this thesis.

1.3 Contribution of this Research to the Academic Community

This research addresses the capabilities and limitations of CVE systems for the support of collaboration, with particular consideration for the needs of CVE users and designers. It reviews state-of-the-art CVE technologies, and the existing theories and methodologies for CVE design and evaluation, in view of contributing to the design of usable computer generated, 3D, multi-user, real-time, collaborative virtual environments. It then provides an insight into the actual user behaviour through experimental work. And finally, it discusses future research directions, providing three methods to aid usability design and evaluation for CVEs:

- An observation method, generally applicable to the analysis of CVE user behaviour (Chapter 5, 8, and 10).
- A design method, generally applicable to the design of CVEs for usability (Appendix F).
- An Inspection method, generally applicable to the evaluation of CVE designs (Appendix G).

In summary, this research is intended to further previous studies in CVE development and evaluation by concentrating on the immediate needs of users and designers in collaborative tasks mediated by CVE technology, by providing a precise methodology to identify usability problems, and how to derive usability recommendations from them in a systematic scientific fashion, and by offering two complementary methods

for CVE design and evaluation respectively, embedded in traditional usability engineering techniques, and the cognitive psychology tradition.

1.4 Contribution of this Research to Industry

This research has relevance to many CVE development companies. It is focused on the atomic collaborative tasks that CVEs need to support in order to achieve satisfactory usability scores. Furthermore, it takes into account the limitations posed on CVE design by the computational demands of distributed multi user virtual environments. Based on these considerations, this thesis presents CVE usability guidelines. Many of these guidelines were used to support usability improvements to DIVE, and to some extent in dVS.

In summary, this research identifies some of the immediate CVE usability issues (Chapter 10), which need to be addressed in order to make viable commercial products based on CVE technology and to this end the thesis provides some pertinent guidelines for CVE design (Appendix F) and evaluation (Appendix G); from prototype to end-product, identifying the least-pervasive and most cost-effective processes where possible.

1.5 Contributions of COVEN Project to this Research

This thesis is based on the information and experimental data, which the author collected during her employment on the European Commission funded COVEN Project. The author's position in the project was as usability researcher and she stood in direct collaboration with all individuals in the project who were involved in the

network trials. The author was also privileged to attend meetings as a COVEN representative. Finally, the author publicized several papers that would not have come together without the collaboration of her COVEN colleagues (discussed in Chapter 9).

Throughout this thesis explicit commentary will distinguish the authors own work from that carried out in cooperation with others and that, which took place elsewhere in the COVEN Project.

1.6 Background to this Research

The main aims of the COVEN project were: creation of support for collaboration within virtual environments (including reciprocal awareness, communication, group interaction, etc.); corresponding requirements at network and runtime services level (involving concern for scalability and continuous media support); increasing understanding of CVE usability; and contribution to current standardisation efforts (DIS, VRML, MPEG4), in order to further the development of future collaborative (tele)work and communication systems, both for professional and home users. The project incorporated three cycles of evaluation and development, conducting 40+ international networked trials with the COVEN application to establish the networking requirements of this new technology and to uncover critical human factors issues. The work has been disseminated through papers, public reports and videos, a workshop and demonstrations (http://coven.lancs.ac.uk). Design advice from the usability evaluations were integrated in the application, and the final application has been made commercially available. The COVEN project and the author's role in the project are discussed in more detail in Chapter 4.

1.7 Research Methodology

In order to address the objectives stated in the previous section a number of different methods were used in line with an overall systematic scientific approach common to behavioural research. The methods employed aim to:

- make explicit the consequences of a design for the user, given an understanding of what tasks the user tends to perform, through the application of empirical research techniques.
- promote empirical observation of how people perform their work, presented through informal language and a more formal task analysis, in order to better understand the users' tasks, and the associated problems that arise between them and the mediating technology.

This thesis uses interviews, task analysis, observation, inspection reports, usability reports, questionnaires, and design reflection reports, to come to usability evaluation and design guidelines for CVEs specifically. These methods are introduced in more detail in the chapters to follow.

1.7.1 Literature Reviews and Information Gathering

Literature research took place throughout this study through the University of Nottingham's library, the Communications Research Group's private library, the VIRART private library, and the USINACTS, RESPECT and other research projects publications, pertinent to the research topic. Further information was gained via the internet resources through various web-sites and newsgroups including: sci-virtual worlds newsgroup, UKVRSIG mailing list, CVE mailing list, and personal emails. Additionally, a local Virtual Reality special interest group (University of Nottingham

VR-SIG "Universe"), a well-attended first CVE Conference, a special interest group discussion and a workshop, all regarding Virtual Environment design and evaluation were organised (all instigated and co-organised by the author).

1.7.2 Field Research among CVE Designers

A number of leading research groups and companies in the area of CVE development were contacted or visited and both formal and informal interviews were carried out (Chapter 6). These groups include: SICS, DIVISION, LIG, University of Geneva, University of Lancaster, University College London, City University, Philips Research, TNO-FEL, KPN, IIS, Berlin, SID-Chain Brussels, University of Loughborough, de Montfort University, University of Lancaster, University of Manchester, University of Nottingham.

1.7.3 Hierarchical Task Analysis of Collaboration

A hierarchical task analysis (HTA) of CVE collaboration is created, based on the researched literature in line with the methodological approach as outlined by Diaper (1989). The HTA identifies and defines the actions of collaborating CVE users, and decomposes the high-level collaboration tasks into their constituent subtasks and operations. The HTA (Chapter 7), is presented as a bridging structure between theories of collaboration (Chapter 3), and the observations of CVE collaboration (Chapter 8).

1.7.4 Spatial and Temporal Interaction Analysis Method

A method was developed to analyse small group interaction in CVEs (described in Chapter 5). The behaviours are categorised according to predefined categories, and

scored along a time axis. This method enabled the author to make quantifiable behavioural observations from long video recordings of user interactions in a given CVE task.

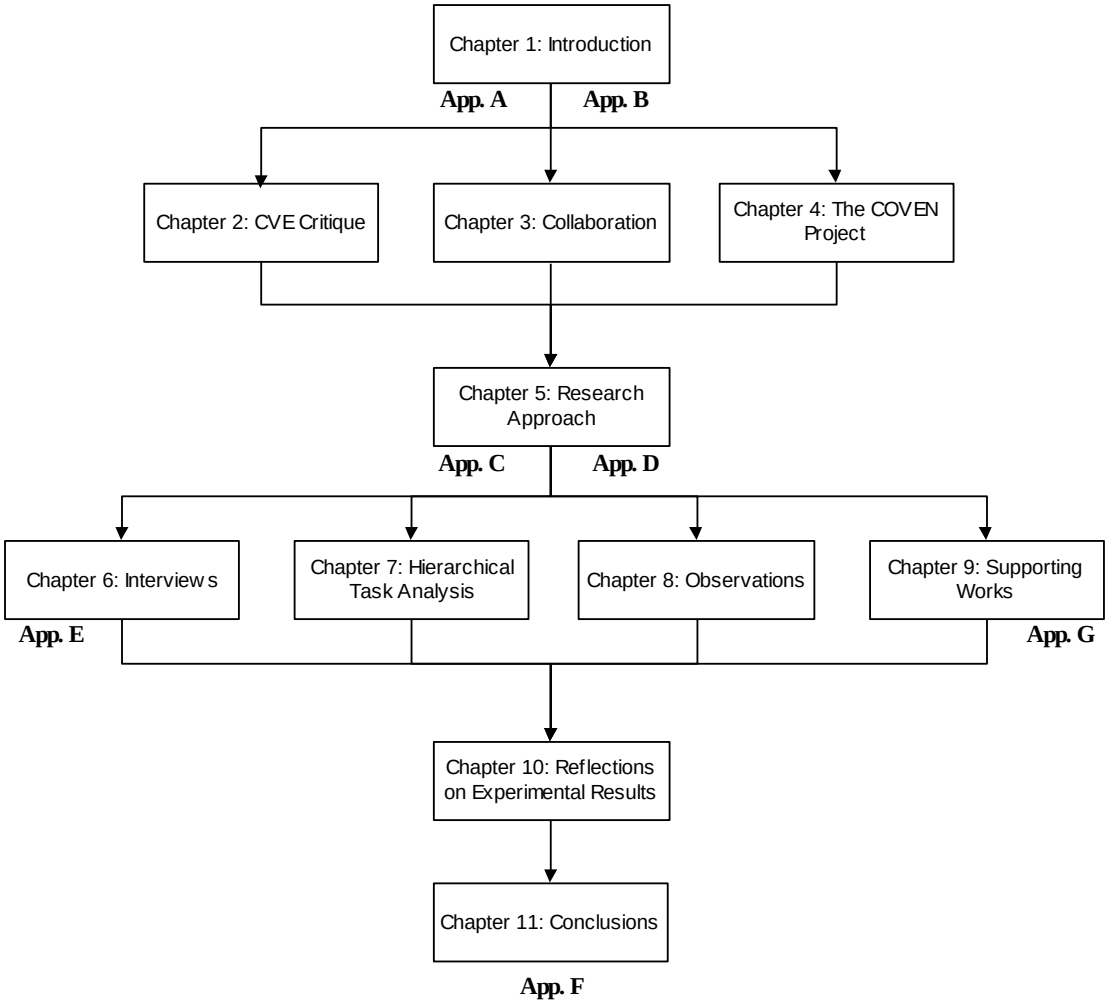
1.7.5 Experimental Research

Given the outcomes of the information gathered from the literature, the HTA of collaboration, and the fieldwork, a methodological framework was produced to guide the design of the experimental research conducted. Three sets of experiments were analysed to explore aspects of collaboration in CVEs in detail (Chapter 8).

1.8 Structure of Thesis

The structure of this thesis is illustrated in Figure 1.2. Chapter one provides the background information for this thesis. Chapter two reviews the state-of-the-art limitations of research and development of collaborative software. Chapter three provides information about the project from which the data analysis presented in this thesis has been derived. Chapter four presents collaboration information gathered through literature, archives and field research. Chapter five describes the research approach chosen for this thesis. Chapter six presents the results of interviews with CVE designers about their work practise and problems. Chapter seven presents a hierarchical task analysis of collaboration. Chapter eight describes the experiments analysed in this thesis as part of the author's work in full detail. Chapter nine presents other works performed by the author and colleagues during the COVEN Project and the exact contributions of the author's work. Chapters ten consist of the author's analysis and discussion of the research findings of this thesis, a discussion as to whether the objectives that were stated at the beginning of this thesis were reached,

and recommendations for future research. Appendix A presents a list of COVEN and author documents. Appendix B presents a glossary for all technical terms used in this thesis. Appendix C presents an example data sheets from the observational analysis described in chapters five, nine, and ten. Appendix D presents the questions from a questionnaire and interviews with CVE users. Appendix E presents the questions from a questionnaire and interviews with CVE designers. Appendix F presents the usability guidelines for designing CVEs that have been derived from the findings of the research presented in this thesis. Appendix G presents the COVEN Inspection method.



Appendix A: List of papers
Appendix B: Glossary
Appendix C: Example data sheets
Appendix D: CVE User Questionnaires and Interviews
Appendix E: CVE Designer Questionnaires and Interviews
Appendix F: CVE Design Guidelines
Appendix G: COVEN Inspection Method

Figure 1.2: Structure of thesis.

In terms of content the chapters of this thesis can be defined as follows:

Chapter 2 consists of four distinct sections. Section one reviews CVE technology, section two reviews CVE design practise, section three reviews CVE usability practise, and section four reviews a number of existing CVEs.

Chapter 3 consists of a review of key features of human-human communication and collaboration.

Chapter 4 consists of a description of the COVEN Project and the author's role within the project.

Chapter 5 consists of four distinct sections. Section one describes the research approach used in this thesis. Section two is a description of the method used for the observations presented in Chapter 8. Section three is a description of the experiments that are analysed using the observational method. Section four is a description of the type of data collected during the experiments.

Chapter 6 consists of an interpretation of five interviews with CVE designers about their design practise, and the results of a feedback questionnaire on a COVEN evaluation report as reported by the COVEN designers.

Chapter 7 consists of an hierarchical task analysis of CVE collaboration, providing a detailed analysis of the tasks and subtasks CVE users have to perform in order to achieve collaboration on a shared task as mediated by CVE technology.

Chapter 8 consists of three distinct sections. Section one is a description of match between the predicted categories of collaborative behaviours and the observed behaviours. Section two is an analysis of the observed behaviours. And section three

is a description of the analysis and comparison between statistically predicted and observed behaviours.

Chapter 9 reviews and discussed relevant material from COVEN deliverables and papers the author of this thesis published during the time this thesis was written, in order to support the wider interpretation of the results of the experiments presented in this thesis.

Chapter 10 reviews and compares the results from the experiments with key-issues from the review of collaborative activities (Chapter 3), the key-problems for CVE usability as derived from the HTA of collaboration (Chapter 7), and the key-issues about CVE usability as identified in the supporting works (Chapter 9).

Chapter 11 reviews and compares the results from the research presented in this thesis with the original research aims as formulated at the outset (Chapter 1).

Appendix A presents a list of COVEN and author documents.

Appendix B presents a glossary of all technical terms used in this thesis.

Appendix C presents example data sheets of the data collection described in Chapter 5 and 8.

Appendix D presents the interview questions and transcripts from the interviews with CVE users.

Appendix E presents the interview questions and transcripts from the interviews with CVE designers.

Appendix F presents the usability guidelines method that the author created during the COVEN Project.

Appendix G presents the COVEN Inspection Method that the author created during the COVEN Project together with colleagues.