Contextual grounding in CVE design

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Abstract

A proper respect for eventual context of use is crucially important for the success of virtual environments destined for real-world organisations, yet is frequently absent from accounts of the design of such applications. We describe how contextual requirements have influenced the design of a CVE to support the delivery of safety-critical training, and illustrate the use of techniques to elicit, consolidate and refine such requirements.

1 Introduction

The development of collaborative virtual environments has now reached a stage of maturity where the technology can be deployed in real-world organisations. This paper considers the factors beyond functionality and usability which have to be taken into account in designing for everyday use in the work environment. We briefly review how researchers and practitioners in other domains have addressed contextual matters, and discuss such issues and techniques for handling them in a case study of the development of a CVE for safety-critical training.

It is now commonplace in thoughtful design for mainstream interactive applications that issues pertaining to context of use assume equal importance with usability considerations and effective functionality. Such work has been supported by a battery of techniques and approaches which have been developed in recent years by human computer interaction and information systems researchers and practitioners. Among the more prominent of these are the (originally) Scandinavian school of participatory or cooperative design (e.g. Greenbaum and Kyng, 1991, Bødker, Grønbæk, and Kyng, 1993); Soft Systems Methodology (Checkland 1981; Checkland and Scholes, 1990, 1999 and numerous case studies), and approaches informed by ethnography (particularly common in the domain of computer supported cooperative work (CSCW), e.g. Heath and Luff, 1992, to cite a classic example).

While most of these approaches have devised tools peculiar to themselves, they also have much common ground. They typically involve a strong emphasis, not only on working with users, but in carrying out much of this activity in the workplace of the target user community. Users and other stakeholders are commonly actively involved as co-analysts/designers/evaluators of actual or projected systems, prototypes and projected usage scenarios. Rich data from periods of observation of the workplace is frequently collected, as are samples of artefacts used in the workplace. And invariably, any projected technical system is considered in its wider social setting. Many of these techniques, although not necessarily their underlying philosophy, have been integrated and adapted for practical application in commercial settings in Holtzblatt and Beyer's 'Contextual Design' (Holtzblatt and Beyer, 1998).

In the design of virtual environments, and CVEs in particular, however, to date attention has concentrated primarily on the technical challenges of representing complex spaces, actors, movement and communication (e.g. DIVE – Carlsson and Hagsand, 1993; Massive – Greenhalgh and Benford, 1995), supplemented by a growing body of work focussing on the usability of the environment for individuals or collaborating groups (e.g. Kalawsky, 1999; Stanney, Mourant and Kennedy, 1998; Deol Kaur, Sutcliffe and Maiden, 1999). With rare exceptions such as Mitchell and Economou (2000) who discuss the influence of context of use in a short account of the design of an educational VE, explicit consideration of contextual issues is largely absent from accounts of design, and even where it is evident that attention has been paid to context, little is said about the techniques employed. In the case of CVEs, this lacuna is particularly significant, since as ample evidence from the CSCW community attests, the nature of cooperation, its genres, mores and variations is even more culturally sensitive than single user-machine interaction. Accordingly, this paper discusses in some detail the work we undertook in defining contextually grounded requirements for a collaborative virtual reality desktop training environment, describes the techniques we employed and illustrates the outcomes for the emerging design.

The CVE is a key deliverable of the DISCOVER project, whose consortium comprises four marine and offshore training organisations, virtual reality technology specialists, training standards bodies, a number of interested employers and ourselves as requirements and evaluation consultants. The objectives of DISCOVER are to design, develop, and validate CVE based simulations and associated training scenarios for training and assessing individuals and teams of personnel operating in the maritime and offshore exploration and production sectors. In the remainder of this paper, we provide some background to the project, describe how issues of context have been handled in the requirements and early design stages of the project and conclude with some overall observations and outstanding issues.

1.1 Background to DISCOVER

Effective safety-critical training in the maritime and offshore domains is crucially important. Disasters such as that which overtook the Piper Alpha oil platform in the North Sea in the 1980s, the loss of the Estonia during a Baltic crossing and most recently the sinking of a Greek ferry Express Samina all highlight the need for team-based training in such high-level skills as situational awareness, decision making and leadership. Such training is also the subject of much interest in military settings, as recent publications such as Cannon-Bowers and Salas (1998) and Annett, Cunningham and Mathias-Jones (2000) demonstrate. Whatever the domain, the undertaking is often almost prohibitively expensive, since trainees are co-located at a specialist training sites for several days at a time, or in the case of the offshore industry, hugely complex disaster simulations which are created *in situ* involving the coordination of large numbers of personnel and multiple agencies. DISCOVER will provide a virtual reality based series of collaborative training simulations which could dramatically reduce the need for senior mariners and oil rig workers to have to attend courses or run quite so many expensive exercises. It is envisaged that while the system will be made available at existing training centres, it will also be used offshore or on board ships more frequently and in, perhaps, an *ad hoc* manner.

It will be appreciated that these latter possibilities are a considerable departure from current training provision. Such a situation means that for acceptance by the training community to be a realistic possibility, the technology must be grounded in current policy and practice, have real utility for those involved and that stakeholders play a significant part in the design of the system.

(There is a large body of Information Systems literature pertaining to influences affecting technology uptake: see Adam Mahmood *et al* (2000), for a recent meta-review which confirms the significance of the factors just mentioned in many case studies relating to end-user satisfaction, and in particular, user participation.) Finally, there is the non-trivial consideration that industry institutions validating training provision will review the CVE in its place within a complete course, not in isolation. For all these reasons, a contextually informed requirements and design process was particularly important for DISCOVER.

2 An approach to uncovering contextual issues

The identification of contextual issues entails the identification of stakeholder groups (the complete list here is a long one, including passengers on any form of maritime transport) and working through the impact for each group of adopting virtual simulations as part of training regimes. In this paper we focus on just one facet of this work, that concerning maritime training organisations. Our initial approach, drawn from techniques well-established in the participatory design, customer-centred design and CSCW communities included:

- scoping interviews with key personnel to define the system boundaries and identify initial perceived potential;
- observational sessions and further interviews;
- consolidation into an overall ‘viewpoints’ requirements analysis;
- review of an early prototype application;
- a participatory workshop to consolidate generic models and derive detailed requirements.

Throughout, we have taken a holistic, user-driven approach, being concerned not just with what the CVE must do but how it should fit with organisational and individual praxis and industry wide conventions, expectations, norms and rules.

The remainder of section 2 describes our work in establishing context of use data and the initial set of contextual requirements for one maritime user organisation[1]. Section 3 then discusses the treatment of further considerations which arise on integrating the needs of all three maritime training organisations into a detailed requirements specification.

2.1 Initial steps in defining context of use

Among the first steps undertaken was a scoping enquiry with key stakeholders (employers, trainers, their managers and training validating bodies). Most were face-to-face interviews, but employers were contacted via email. This established a certain amount of common ground in that it was agreed that role-playing of disaster scenarios was a central element in safety-critical training, and that a CVE could be a useful extra resource for supporting this. However, there were also potentially conflicting high level perspectives. To take just one example, training organisations, employers and trainees were delighted at the prospect of being able to access or deliver simulation resources at the workplace, or indeed the home, and of having these resources available to fit with the demanding patterns of work. At the same time, the same stakeholders, together with validating bodies, were concerned that the quality of experience afforded by the virtual reality simulator must be just as effective as current methods, when personnel are

[1] CVEs for maritime and offshore environments were developed separately.

immersed in a series of simulation exercises of a period of several days. As will be seen, the need to support the former possibility while maintaining the degree of engagement afforded by current practice had a significant influence on requirements on the CVE. The next stage in the work gathered data to enable a detailed appreciation of current practice necessary to inform a contextually grounded design.

2.1.1 Training practice observed

Two extended periods of observation of safety critical training sessions were undertaken at the Warsash Maritime Centre (WMC). Both sessions were videotaped, transcribed and analysed. Senior mariners undertaking training and trainers were also debriefed after practice sessions. These activities focused particularly on issues identified by the early scoping work, for example how a sense of realism was engendered and maintained, areas where current training practice did not fit well with the needs of trainees, trainers or employers, perceptions of the scope for technology such as the DISCOVER CVE and so forth. We should point out here that although this paper is concerned with contextual issues, the elicitation work with user organisations also fulfilled the purpose of collecting data pertaining to functional matters, for example the objects used in training which would need to be replicated in the CVE; or to usability, for example the background technology skills of trainees.

WMC provides short courses in the team-based management of emergencies at sea for professional mariners. The courses are validated, well-respected in the industry and staffed by tutors who are both experienced trainers and master mariners. Training is scenario-centric, allowing trainees to play different roles in emergency situations derived closely from real-life incidents and supplemented by debriefing sessions and theory modules. The training scenarios follow a generic pattern of an incident occurring which becomes steadily more serious and complex, the exact plot being adapted dynamically by the trainers depending on the actions and reactions of the ‘crew’. The action is played out in a room adapted from a conventional lecture room, where the ‘bridge’ of the ship is to be found behind a screen in one corner and contains the blueprints laid out on a table, alarm and control panels, communication devices, reference manuals and a crew list. The other piece of simulation equipment is in the main body of the room. This comprises a set of four shelves rather resembling a large tea-trolley each bearing the relevant blueprint plan for a four-deck section through the ship. Both these plans and those on the ‘bridge’ can be annotated with schematic depictions of hazard such as smoke, and are populated by models of crew members who can be moved, knocked over to simulate injury or death and so on. The simulation is completed by an ‘engine room’, located in an office down the corridor from the lecture room, and simply equipped with a pair of walkie-talkies and more blueprints.

A typical scenario concerns a badly maintained ship carrying a hazardous cargo which catches fire. A team is sent to investigate, and the situation is exacerbated by crew members being overcome by smoke, power failures, engine stoppages and sundry other hazards. Trainees form teams of the bridge party, the on-scene party dealing with the incident at first hand (working around the ‘trolley’) and the engine room and communicate using cell phones and walkie-talkies. Other trainees act as non-participant observers. Tutor-trainee interaction is intense, relating both to the plot of the scenario and the team’s handling of it – tutors move around the rooms, pointing out aspects which the team might have overlooked, hint at possible actions and generally keep the action running smoothly. As problems escalate, the teams become very evidently engaged in the ‘emergency’. The trainer moves the plot along, for example by knocking some of the miniature figures representing the remainder of the crew into the casualty position, a development which will be reported back to the bridge by the incident team leader. Once the action has run its course, a full debriefing takes place, comprising discussion and feedback about the teams' actions, what actually happened in the real-world original of the scenario, and alternative approaches. Tutors take pains to ensure this is trainee led, and discussions are amplified by the tutor's recall of particular incidents together with the incidents noted by observers. For these courses, learning outcomes relate to communication, team leading and decision making skills, and are assessed by the tutors, drawing upon their observations during the sessions.

Staff at WMC held varying models of how a CVE might support their work. From the organisational point of view, it was hoped that the system will enable training to be delivered in a more flexible and economical manner, allowing skills to be acquired, practised and even assessed without the need for mariners to attend in person. This model requires an environment which is self-contained, supports all the different types of interaction described above, runs over the internet, and has the added value of simulating some conditions more realistically than current methods. Tutors would need the facility to modify events in the environment as in current practice. In this view of the world, trainees interact with the environment, each other and any other role players inside the CVE, with the possible addition of video-conferencing for discussions, debriefing and tutor–trainee interaction. Another view expressed was that the CVE would be a more-or-less direct substitute for the 'tea trolley' embodying the section through the ship, with the advantages of increased realism. Here trainees would remain physically co-located at the centre, and most interpersonal interaction would be outside the environment. Finally, the concept of remote delivery was seen as an interesting development with added potential for an enhanced degree of realism, the acquisition of new skills for themselves and additional business.

2.1.2 From observation to contextual requirements

The next step was to distil the observational and interview data into an initial set of high level requirements, which would be revised and detailed once a prototype was available. (An early prototype would have been useful in support of the first stage of the requirements process, but time and organisational constraints within the DISCOVER project precluded this.) In addition to numerous requirements driven *mainly* by either (i) the functionality pertaining to direct interaction with the environment by trainees or tutors and to communication among participants or (ii) the usability constraints on such functionality, data from WMC gave rise to a number of high level contextual requirements.

Examples included

- A convincing degree of realism – not only a matter of creating engagement, or of facilitating skill transfer, where the evidence for the importance of realism is somewhat mixed, but required to engender sufficient face validity to convince the industry that CVE-mediated training could be effective.)
- Support for group discussion and de-briefing, making reference to parts of sessions in the CVE
- Support for performance appraisal, including self assessment, evaluation of participants against each other, team evaluation and detailed description of every participant, and documented by extracts from CVE sessions.

- The keeping of records of each trainee's participation in CVE sessions
- Validation of trainee identity throughout training
- Self-paced instruction offering just-in-time and just-enough training
- Provide a more satisfying professional role for trainers than classroom teaching.
- Support the acquisition of new skills by trainers, thereby enhancing job security.

Given the complex nature of the DISCOVER project, we adopted an informal viewpoints approach (Sommerville and Sawyer, 1997a, 1997b) to organising and presenting the aggregated requirements from WMC and the other training organisations. The approach is increasingly accepted as a means for separating concerns in software development in accordance with a variety of criteria, such as the interests and perspectives of users, the development strategies and methods, the notations employed, or the services provided by the system to various parties (motivated by related work in the area of databases). As well as proving a useful overall framework, this proved invaluable in according contextual elements the same prominence allotted to requirements deriving from more familiar perspectives. Context was also documented by usage scenarios (as distinct from the training scenarios described above), essentially short stories encapsulating how a system is, or will be, used. The technique has been extensively deployed by the human-computer interaction and requirements communities as an aid to describing, envisaging and evaluating human-computer systems. (See Carroll, 1995, for a full discussion.) The usage scenario set out below is an example illustrating how the CVE might be used as part of training which combines low technology and virtual simulations.

> A group of experienced first mates are being trained and assessed as part of their company's programme to fast-track their promotion to captain. They have been sent on a three day assessment course at a training centre which has integrated the DISCOVER CVE into training and assessment provision. Since this is the first time any has used software of this type, they undertake small familiarisation exercises, at first individually and then with the other two team members. In this way they become accustomed to moving their avatars around the ship, interacting with objects and communicating via virtual walkie-talkies and telephones. Once this has been achieved, the training scenario commences. We start with acting captain Pike and his bridge staff, first mate Kidd and helmsman Drake (who has an inactive part in this extract, but also acts as an observer) as Captain Pike, a man of 10 years experience, takes the merchant ship Reliant into Europort. At this point all are located on the 'bridge' in the training room. Offstage, the tutor in charge of the starts a fire in one of the holds of the virtual ship. The action proceeds thus…
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>> Chief engineer Scott (played by the tutor offstage) via walkie-talkie to captain Pike, "One of the ABs has reported that there's smoke coming from number 3 hold." Captain to Scott , "Get a man along there to have a look and report back". Chief engineer to captain, "Roger that". The chief engineer reports back "There's a lot of smoke here and the surrounding walls are hot." He is instructed by Captain Pike to send a fire team. The tutor duly sends a virtual fire team, controlling the avatars himself. Chief engineer to captain, "Fire confirmed in number 3 hold. I've got the team leader with a couple of the ABs cooling the walls with a hose. I think you had better take a look". The captain then instructs first mate Kidd to enter the CVE and to assess the situation. Kidd leaves the 'bridge' and then engages with the CVE. He 'walks' to number 3 hold, observes the state of the fire and containment action and using virtual communications asks the team leader for a report. Kidd then reports to the captain, "The fire is burning out of control. Suggest you release the CO2 and contact shore for additional help" … Behind the scenes the tutor has been listening in to both the real and virtual communications from the control room and adjusts events in the virtual ship accordingly.
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> The action continues, divided between physical and virtual simulators, until the ship is on the point of sinking, or has been brought safely to port, or the tutor judges that another suitable endpoint has been reached. After the session is concluded, the three trainees and the tutor discuss events with the aid of replays of selected sections of the action.

To illustrate the direct effects on systems design, among the requirements which arise from this usage scenario is the need for a close degree of realism since trainees are being assessed as if their performance had taken place on a real ship. And as we have noted earlier, a high degree of perceived realism and sense of presence is required for the CVE to win credibility in the industry as a whole. This contrasts with many other collaborative virtual environments, where the overall aim is one of collaboration to achieve a particular goal within the environment, for example agreeing the layout of furniture, as in Hindmarsh *et al* (1998). In other cases, the activity within the CVE is part of a larger collaborative process, but the way collaboration works within the CVE need not exactly replicate real world interaction. The perceived need for realism presents constraints on the design of DISCOVER: ideally, interaction and collaboration must not be artificially *harder* than in the real world, but neither must they be artificially *easier*. Therefore much useful research which has addressed the problems of the limitations of CVEs so as to ensure that the users of such environments are aware of their surroundings and of other users (e.g. Benford *et al*, 1993; Fuchs *et al*, 1995; Bellotti *et al*, 1993 among others) cannot be directly employed. For example, for trainees, DISCOVER cannot exploit ‘magical’ devices such as birds’ eye views of the state of environment, *Star Trek*-like transporting, or visible rubber banding between an avatar and its current focus of attention, although all these features might be both useful and acceptable to tutors.

2.2 Consolidation to detailed requirements

In parallel with the requirements process, the software developers had produced a prototype CVE, embodying the basic functionality for CVE embodiment of a ship and its bridge and drawing heavily on the COVEN literature (e.g. Normand *et al*, 1997) for guidance in the implementation of features to support collaboration and communication. In the prototype environment, avatars representing ship’s officers could be moved by trainees around a bridge and adjacent areas, communicate with each other via virtual walkie-talkies and telephones and undertake simple interactions with objects such as fire extinguishers. Tutors could observe the avatars in the CVE, obtain a bird’s eye view of the ‘ship’ trigger events such as fires and communicate with trainees. Figures 1 and 2 show some aspects of this. Contextual issues, and of course, the desired functionality and adequacy of usability, could now be considered more

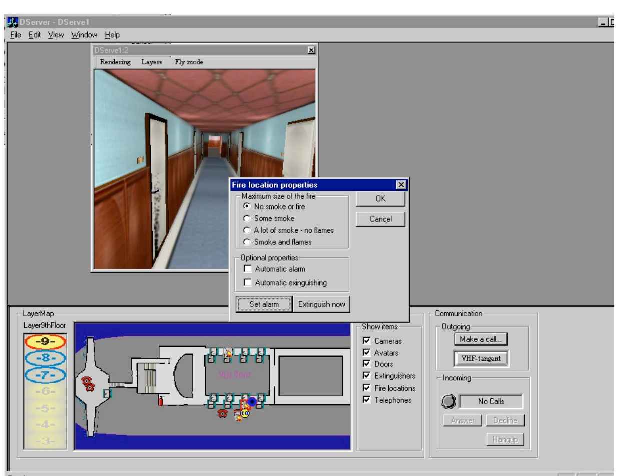

Figure 1

directly. Reaction from trainers and trainees to demonstrations and simple hands-on tasks (followed by interviews and questionnaires) in WMC and the two other maritime training organisations confirmed much previous information as to usage intentions and underlying purposes, but also revealed some divergence between the training organisations as to how the CVE would be used and triggered much debate about the detailed design features which would be necessary to support differing practice. In particular, overall reaction to the prototype emphasised that since most of the skills to be learnt related to communication and decision making, this aspect of the CVE (rather than the manipulation, of, for example, fire extinguishers) needed to be optimised for effectiveness and ease of use. Now that the potential and limitations of the environment could be assessed more realistically by stakeholders, it was necessary to revisit the existing high level requirements, and derive a consolidated, detailed, concrete design specification for developers which would nonetheless support each intended context of use. This was achieved by means of a workshop.

Before moving on to this next step, however, we should briefly introduce the other two maritime training organisations – the Danish Maritime Institute (DMI) and the Institute of Ship Operation, sea Transport and Simulation (ISSUS). DMI and ISSUS, just as WMC, provide validated and highly respected maritime training courses. Both undertake training featuring crisis management scenarios, but here emergencies such as fires or the loss of a man overboard typically intervene as hazards complicating the simulated navigation of a ship into port rather than forming the main focus of training. The sessions take place within highly sophisticated physical bridge simulators, whose complexity requires several operators alongside tutors and assessors. Staff at DMI in particular stressed that that their current simulators provided as near realistic an experience as it is possible to have without being on board ship. DMI had been heavily involved in the earlier phase of the requirements process in a similar way to DMI. ISSUS, because of project resource constraints, became directly involved only at the prototype review stage.

2.3 The workshop

The workshop was the final phase of the requirements elicitation. At this two day event, trainers from the three organisations met with the representatives from one of the software developer organisations and two facilitators from the requirements team.

ıre 3

Figure 2

The agenda was very simple: (i) to agree the detailed functionality of the maritime simulator and how it was expected to be used in conjunction with existing training and (ii) to agree a consolidated training scenario. We adapted elements of Contextual Design (Holtzblatt and Beyer, 1998) to facilitate these processes, principally a variant of the affinity diagram technique, which supports the identification of common themes from a mass of contextual data.

We began by asking each training organisation to revisit what they wanted of DISCOVER in terms of the ‘w’ words (familiar to user-centred design practitioners), i.e. why, when, who, where and, of course, how. As each organisation described their needs we recorded each issue or explicit requirement on a Post-IT™ Note. At the end of the process we had gathered over 400 Post-Its of which approximately 10% were subsequently discarded as duplicates or irrelevant on closer inspection.

The trainers were then invited to create an affinity model which required them to sort the requirements/issues into logical groups (as illustrated opposite): emerging groupings included the layout and configuration of the virtual ship, the appearance and functionality of the avatars and the context of use of the completed system. Throughout this process the software designer helped ground the requirements in reality. At the end of the first day we had been able to build on the affinity model to construct a communications model and an artefact/physical model of the environment to be recreated.

The objectives of the second day were to agree a consolidated training scenario and to be cross-checked against a co-constructed series of storyboards. A very small section of a command and control scenario is as follows:

0200 (start time)	Fire reported, alarm raised on bridge
	Muster - 3 missing : 1 Motorman from the Engine room and 2 seamen
+05 minutes	Smoke reported in Engine Room,
	Stewards report fire along their alleyway (report via On Scene Commander)
+15 minutes	Smoke detector alarm activated for No. 4 cargo hold.
	Engine Room reports blistering of paint and scorching behind heat exchange unit in Engine Room.
	Assistance required in engine room.

At each stage a variety of competences are expected to exhibited by the trainees such as "maintain effective communications", "controlling response to emergencies" and "controlling personnel during emergency situations" and these in turn are assessed by the trainers. At each step in the scenario we co-constructed a storyboard of who was where, communicating with whom and cross-checked it with the statement of requirements we had elicited on the first day. This detailed reasoning and checking entailed in this process continued to surface a number of residual design challenges related to context of use. The most significant of these concerns how the CVE will be used alongside other systems, views on this having changed somewhat since the project's inception in the light of a growing appreciation of both the potential and constraints of a collaborative virtual environment. For DMI and ISSUS, currently envisaged use is as an adjunct to the physical bridge simulator, so that fire hazards and similar events can be introduced more realistically to a simulated navigation. Although this requires a degree of realism similar to that of the physical simulator, the events practised within emergency scenarios and possible responses are relatively constrained and predictable. WMC, however, maintain ambitions to replace part or all of their current simulations. Paradoxically, the very low fidelity of these means that almost any variant of action anywhere within the ship is possible, given imaginative trainees and resourceful and quick-thinking tutors. Given these quite fundamental differences, one design solution will be to provide a basic CVE representing a small section of the ship for use in conjunction with a physical simulator, with an option to expand coverage to other parts of the vessel for more holistic scenarios. For the future, but not within this project, intelligent avatars may be a promising direction.

3 Discussion

The paper demonstrates how DISCOVER and other CVEs intended for real-world exploitation add to the challenges encountered in development by the need to take into account the constraints imposed by differing contexts of use. Indeed, of the overall requirements set for the project, around one-third related to contextual issues. We would contend that a strong end-user focus such as that we have adopted is vital to the identification of these matters, and would commend the techniques we have used in working with contextual issues. In this way it has been possible to address two of the major factors identified in the meta-review of technology uptake by Adam Mahmood *et al.* (2000) - compatibility with expectations and utility - and the process itself has necessarily contributed to the most important factor cited, user participation.

As will be appreciated, engaging with these requirements have necessitated a considerable amount of work beyond the construction of a veridical, usable collaborative environment embodying the salient features of a ship (in itself a far from simple task). However, we are confident that the process has avoided some of the pitfalls which would otherwise only have become evident once the final system was implemented and introduced into training centres. Moreover, although some design and development work has had to await the results of contextual investigations, in a number of respects the resulting challenges have been simplified by the narrowing of design space.

However, issues remain to be addressed. Many contextual requirements translate directly into design features. Others, however, will demand close liaison with the industries concerned – trainers, trainees, employers and standards bodies – to engender the sense of confidence necessary if DISCOVER is to take its place as a trusted item of training technology. Finally, looking to the later phases of the work, we raise the issue of contextually meaningful evaluation and validation. We have elicited a comprehensive, grounded set of requirements against which to review system, and are thus optimistic that evaluation can produce results that are meaningful in respect of the intended context of use. However, the real-life emergencies to be trained for are thankfully rare, and certainly not susceptible to structured evaluation, and full-scale emergency exercises on board real ships or rig are infeasible for reasons of cost and practicality. There are also ethical problem with the running of trials: it is important that the environment is trialled with real trainees, yet such people cannot readily be spared from their normal work simply to experiment with a new system. This means that the trials have to take the place of normal sessions, a factor which removes the issues discussed above from being merely of academic interest: lives may depend on getting the solution right. We are aware from recent communications with the designers of VR based training for other industries that this is a very current subject of concern and debate.

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