



PERGAMON

Safety Science 41 (2003) 111–129

SAFETY SCIENCE

www.elsevier.com/locate/ssci

Crew Resource Management training for offshore oil production teams

Paul O'Connor, Rhona Flin*

*Department of Psychology, University of Aberdeen, Industrial Psychology Group,
King's College, Old Aberdeen AB24 2UB, UK*

Abstract

This paper describes a project to adapt a form of human factors training designed to improve safety called Crew Resource Management (CRM), which is widely used in aviation, to the training of offshore oil platform teams. The aim of the project was to design, deliver, and evaluate an offshore CRM training course. A total of 77 offshore workers from three different North Sea production platforms attended the courses. Their feedback was generally positive indicating that CRM training can be adapted for this industrial sector. There was some evidence of a change in attitudes towards decision making and personal limitations. However, there is a need to develop sensitive evaluation measures to be able to draw more conclusive evidence of the effects of CRM training on safety performance.

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Keywords: Crew Resource Management; Human factors; Training; Training evaluation; Offshore

1. Introduction

This paper describes a project to develop Crew Resource Management (CRM) training for the offshore oil industry and extends previous human factors research with the offshore oil industry carried out by Mearns et al. (1997).

The aviation industry recognised the significance of human error in accidents almost 20 years ago, and has been instrumental in the development of training programmes designed to reduce error and increase the effectiveness of flight crews known as Crew Resource Management (CRM; Wiener et al., 1993). CRM can be defined as “using all the available resources—information, equipment, and people—to achieve safe and efficient flight operations” (Lauber, 1984, p. 20).

* Corresponding author. Tel.: +44-1224-272341; fax: +44-1224-273211.

E-mail address: r.flin@abdn.ac.uk (R. Flin).

CRM training is used by virtually all the international airlines and is recommended by the major civil aviation regulators (e.g. FAA, 1998; JAA, 2001). In the UK, human factors training and examination are mandatory for a Flight Crew Licence, and the CAA requires that CRM training be carried out annually by commercial pilots (CAA, 1998). There is no standardised methodology for developing CRM training (Salas et al., 1999a), and aviation companies have been able to develop their own tailored courses. The content of CRM training has been identified from accident analysis and aviation psychology research. The topics covered, “are designed to target knowledge, skills, and abilities as well as mental attitudes and motives related to cognitive processes and interpersonal relationships” (Gregorich and Wilhelm, 1993, p. 173).

An introductory CRM course generally takes place in a classroom over two or three days. Teaching methods include lectures, practical exercises, role play, case studies, and video films of accident re-enactments. A course typically covers six core topics: team work, leadership, situational awareness, decision making, communication, and personal limitations (Flin and Martin, 2001). Refresher training is also advised, normally a half or whole day course focusing on a specific CRM topic. The training is reinforced during Line Oriented Flight Training (LOFT) in which the pilots are assessed both on their technical and CRM skills while flying a normal flight in the simulator or in real-life. To facilitate the valid assessment of CRM skills in aviation, the European Community Directorate for Transport and the Environment sponsored the development and validation of a behavioural marker system called NOTECHS (see Avermaete and Krujsen, 1998; O'Connor et al., 2002). Behavioural markers are a prescribed set of behaviours which have been identified as indicative of some aspects of skilled human performance (Flin and Martin, 2001). They are becoming increasingly widespread in aviation to enable instructors to make reliable assessment of the CRM skills of pilots.

Due to the success of CRM in aviation it has been adopted in a number of other high-reliability industries including aviation maintenance, medicine, air traffic control, and the maritime industry (see Flin et al., in press for a review). Miles and O'Connor (2000) stated that CRM training would also be beneficial in the offshore oil and gas production industry. It is postulated that CRM training is relevant to this industry due to the extensive use of teamworking in an industry characterised by hazardous conditions and a strong emphasis on safety. Mearns et al. (1997) also recommended that

training programmes are developed for teaching human factors skills. . . Crew Resource Management (CRM) provides a framework for such training because it essentially teaches skills such as leadership, teamworking, decision making, assertiveness and communication with the aim of reducing error (pp. 138–139).

The CRM research package was a component of a larger 2-year HSE joint industry project sponsored by: Agip UK Ltd.; AMEC Process and Energy Ltd; BP; Coflexip Stena Offshore Ltd. Conoco UK Ltd.; Elf Exploration UK; Halliburton Brown and Root; Health and Safety Executive (OSD) Kerr-McGee North Sea Ltd.;

Salamis/SGB Ltd.; Transocean Sedco Forex; Shell Expro UK Ltd.; Texaco North Sea UK Ltd; Total Fina.

2. A methodology to design and deliver CRM training to offshore oil and gas production teams

The objectives of this study were to design, implement, and evaluate a CRM training programme for offshore oil production teams. Table 1 provides an overview of the methodology recommended by Salas et al., (1999b) and Oser et al., (2001) for delivering effective CRM training. It is based on research conducted to develop CRM training for US naval aviators and guidelines from the literature (Oser et al., 2001). This framework was used to design and deliver CRM training to offshore personnel.

3. Determine training requirements

3.1. Steps 1 and 2: identify operational requirements and assessment of training needs

Studies offshore have shown that human errors are a frequent cause of accidents (Mearns et al., 1997). Data collected by the Mineral Management Service in the USA indicate that a high proportion of accidents and incidents are due to human error, accounting for approximately a third of accidents and incidents in the offshore oil industry in the US (Outer Continental Shelf) between 1995 and 1996 (Mineral Management Service, 1997). This is similar to the proportion of human factors errors found in an examination of a representative selection of 1997 incident reports for a UK offshore operating company in which 28% of accidents were attributed to human error (Bryden et al., 1998).

Table 1

A methodology to design and deliver CRM training (adapted from Salas et al., 1999b, pp. 168–169)

Stages	Steps
Determine training requirements	<ol style="list-style-type: none"> 1. Identify operational requirements. 2. Assess team training needs. 3. Identify teamwork competencies. 4. Determine team training objectives.
Design training method and materials	<ol style="list-style-type: none"> 5. Determine instructional delivery method. 6. Design scenarios and create opportunities for practice.
Training evaluation	<ol style="list-style-type: none"> 7. Design assessment measures. 8. Design and tailor tools for feedback. 9. Evaluate the effectiveness of the training.

Members of the workforce also recognise the consequence of human factors in accident causation. In a survey of the workforce on six UK offshore platforms ($n=622$), 70% of the workers agree that “most accidents are due to human failure” (Flin et al., 1996). In addition, over a third of the respondents cited “lack of care and attention” as the most common cause of accidents (p. 75). Mearns et al. (1997) also found that the most effective supervisors, in terms of safety performance, utilise interpersonal skills more often than less effective supervisors. By way of illustration, the effective supervisors value their subordinates more, visit the work site more frequently, and encourage participation in decision making.

Unfortunately detailed studies of the contribution of human factors to accidents have not been carried out. Also, companies have not traditionally coded these types of accidents consistently (Gordon, 1998). However, data collected by Mearns et al. (1997) allow a closer examination of human error offshore. They examined databases that showed human factors causes in accidents from seven offshore companies. The data were extracted over a two year period from 1994 to 1996 with the exception of one company that only had data for an 18-month period. A total of 1268 incidents were recorded (lost time incidents, minor, or near-miss). These incidents were then coded using 55 human factors categories according to their underlying causes based on the International Safety Rating System (ISRS) of coding. The incidents produced 1123 codes, with some incidents containing no human factors codes, and others having multiple codes. The codes were examined to establish how many of them would fit within the topics for a CRM course (teamwork, leadership, situation awareness, decision making, communication, and personal limitations). From Table 2, it can be seen that 46% of the 1123 human factors codes fell within one of the broad CRM topics.

The most cited code was personal limitations which relates to stress and fatigue. Parkes (1992) found offshore workers had higher levels of general psychological distress when contrasted with a comparable group of onshore workers. Further, fatigue may also be a factor in accidents offshore due to the long periods of work (14–21 days). Miles (1999) describes research carried out of offshore accident rates by Connolly (1997) in which the incidence of serious injury in comparison to all injuries was found to increase with increasing tour time.

Table 2
Incidence of ‘CRM topic’ errors

CRM topic	Percentage of codes
Team work	6
Leadership	2
Situation awareness	9
Decision making	11
Communication	5
Personal limitations	13
Total	46

Thus, it has been demonstrated that human error occurs on offshore installations, and a proportion of incidents appear to be due to the six core CRM skills: teamwork, leadership, situational awareness, decision making, communication, and awareness of personal limitations.

3.2. Step 3: identify teamwork competencies

The human factors research described earlier and discussions with offshore personnel were integrated to develop the offshore non-technical skills framework which

Table 3
Offshore operations non-technical skills framework

Categories	Skills
Situation Awareness	Plant status awareness Environmental awareness Anticipation Concentration/avoiding distraction Shared mental models
Decision Making	Problem definition/diagnosis Risk and time assessment Recognition Primed Decision Making ^a /Procedures/Analytical Option generation/choice Outcome review
Communication	Assertiveness/speaking up Asking questions Listening Giving appropriate feedback Attending to non-verbal signals
Team Working	Maintaining team focus Considering others Supporting others Team decision making Conflict solving
Supervision/Leadership	Use of authority/assertiveness Maintaining standards Planning and co-ordination Workload management
Personal Resources	Identifying and managing stress Reducing/coping with fatigue Physical and mental fitness

^a Recognition Primed Decision Making (RPD) is a style of decision making in which experience is used to identify a workable course of action as the first one considered (Klein, 1997). This is often used by experts to make rapid decisions during periods of time pressure.

formed the basis of the skills to be trained in the CRM course (see Table 3). This was partly based on a framework developed for the aviation industry called NOTECHS (see O'Connor et al., 2002 for details).

3.3. Step 4: determine team training objectives

The objectives of the training programme were:

1. To raise crew awareness and enhance knowledge of human factors that can cause or exacerbate incidents related to safety or production.
2. To develop non-technical skills and attitudes which, when applied, can prevent or mitigate the effects of error whether instigated by human or technical failings.
3. To integrate CRM knowledge, skills, and attitudes into current work practices.

4. Designing training methods and materials

4.1. Step 5: determining the instructional delivery method

To aid in the development of the course an examination was made of the topics and content of CRM courses in aviation (e.g. *British Airways, Bristow Helicopters Ltd*), aviation maintenance (e.g. Taylor, 1998), a course designed by a UK nuclear power company for control room personnel (Belton, 2001), and the experience of one of the authors in designing CRM training for offshore emergency response personnel (Flin, 1995). However, it was important the course was tailored specifically for offshore personnel. One of the main criticisms from participants of the early aviation CRM courses was that they were not sufficiently relevant to aviation (Helmreich et al., 1999).

I am not suggesting the mindless import of existing programmes; rather, aviation experience should be used as a template for developing data driven actions reflecting the unique situation of each organisation (p. 784).

One of the companies involved in the larger project agreed to take part in this CRM evaluation study. The course was designed to be delivered onshore over two days at the sponsoring company's training facility. It was delivered by two industrial psychologists (authors)—this is not standard CRM practice as the training should be delivered by experienced personnel from the worksite, but it was not possible to train any offshore personnel to carry out the training. The course consisted of an introduction to CRM and six workpackages. The content of the course is outlined in detail later. Each module has a set of objectives that the training aimed to address.

5. Day one

The course opened with a short introduction from an Asset Manager (an onshore senior manager responsible for a field of platforms) to illustrate that the course had the support of management and to outline the reason why this type of training was deemed relevant.

Introduction. The aim of this module was to provide the participants with an understanding of human error, the origins of CRM, and its relevance offshore.

- History of CRM, and its roots in the aviation industry.
- Aims of CRM and standard topics.
- CRM training beyond the cockpit.
- Definition of human error.
- The rationale for CRM training for offshore teams.

Work package 1: Situation Awareness. The aim of this work package was to give the participants an understanding of the concept of situation awareness, and the factors that can influence it.

- Definition of situation awareness.
- Situation awareness model.
- The causes and symptoms of loss of situation awareness.
- The concept of mental models and the importance of a shared mental model within a team.

Work package 2: Decision making. This work package concentrated on individual decision making. It aimed to provide participants with an understanding of different types of decision making, and outlined the situations to which each type is applicable and some of the factors which have a detrimental effect on decision making.

- Factors that hinder effective decision making.
- The standard management decision making (analytic, option comparison).
- Rule based decisions (e.g. procedures).
- Intuitive/recognition primed decisions.
- The limitations of human memory and the effect of working memory capacity on decision making.
- Optimising decision making.

Work package 3: Communication. This module aimed to stress the critical role of communication in any team working environment. Participants should gain an understanding of how to communicate more effectively.

- The advantages and disadvantages of one and two way communication.
- The importance of feedback.
- Barriers to communication.
- Requirements of good communication.
- Assertiveness, and how it can be achieved in communication.
- Maintaining effective listening skills.

6. Day two

Work package 4: Team co-ordination. Participants should gain an understanding of some of the difficulties associated with teamworking in an offshore environment.

- Team working.
- Barriers to effective team co-ordination.
- Optimising team co-ordination.
- Team roles.

Work package 5: Fatigue and shiftwork. Designed to enhance understanding of how fatigue and its effects on performance.

- Fatigue as a cause of accidents.
- Acute and chronic fatigue.
- Five phases of sleep.
- Circadian rhythm.
- The effects of fatigue on performance.
- Methods of avoiding fatigue.

Work package 6: Stress. This workpackage aimed to provide participants with an understanding of stress and how it affects performance.

- Definition of stress and why it is relevant offshore.
- Basic models of stress.
- Causes of stress.
- Stress and personality.
- The human performance curve.
- Symptoms of stress.
- Stress management and coping techniques

6.1. Step 6: design scenarios to create opportunities for practice

The method of training included lectures, group exercises, group discussions, questionnaires, and videos. Practice-based methods are arguably the most potentially effective method of team training (Salas and Cannon-Bowers, 2000). It was not possible to use a simulator as part of this training course, however other examples of practice-based methods used were small syndicate exercises. Seven case studies were collected for use in the training. Three were collected by company personnel with a background in human factors, and four were obtained from interviews with an HSE offshore safety inspector regarding accident investigations in which he had been involved (two of these incidents were used to evaluate knowledge as a result of the training, see the next section).

7. Training evaluation

The fundamental question of whether CRM training can fulfil its purpose of increasing safety and efficiency does not have a simple answer (Helmreich et al.,

1999). Although research has been devoted to the ongoing development of CRM training courses only a small proportion of this has been devoted to evaluation (Holt et al., 2001). Therefore, it was necessary to develop measures specifically for the offshore CRM training.

7.1. Step 7: design assessment measures

The course was evaluated at the first two levels of Kirkpatrick's (1976, 1998) training evaluation hierarchy (reactions and learning). An analysis was not carried out of the effects of the training on behaviour as it was outwith the scope of the project to develop a reliable and valid set of behavioural markers for examining the participants at the workplace, and no opportunities were available to collect observational data. However, this is something that could be developed, particularly for control room personnel who undertake exercises in simulators during which their behaviour could be observed.

Several measures of the effect of the training on the organisation were reviewed. Productivity information, the number of platform trips (unplanned plant shut-downs), and accident and near-miss data were considered for their utility as potential metrics, however, were discounted. Many factors influence the productivity of an offshore platform such as location or age. This makes it very difficult to use this metric as a reliable measure of the effectiveness of CRM training, especially when the entire crew was not being trained. The accident and near-miss data were also deemed not to be useful. The accident rate offshore is so low that it does not provide a robust test for the effectiveness of CRM programmes. Therefore, three alternative methods of evaluation were used.

7.1.1. Reactions

A course feedback questionnaire was designed for the offshore CRM course that contained statements about the delivery of the course. This questionnaire was administered after the course had been completed and consisted of closed statements in which the participants could respond on a five-point Likert scale, and with open-ended questions allowing the participants to write their comments.

7.1.2. Attitudes

In order to measure any changes in attitudes to CRM skills, a questionnaire was designed. The Offshore Attitude Questionnaire (OAQ) consisted of 30 items designed to elicit attitudes regarding decision making, situation awareness, communication, and personal limitations. It was based on the Cockpit Management Attitude Questionnaire (CMAQ) designed by Gregorich et al. (1990). The CMAQ questionnaire has been widely used in aviation to assess the attitudes to topics covered in CRM training (see O'Connor et al., 2001). However, it was also necessary to write eight items specifically for the OAQ to address the specific topics that were taught on the offshore CRM course. The questionnaire was tested on a sample of company personnel with offshore experience to ensure that the items could be understood.

7.1.3. Knowledge

The use of knowledge assessment to evaluate CRM training has not been widely reported in the literature. In a review of 48 studies in which CRM training had been evaluated, only six included a knowledge assessment (O'Connor et al., 2001). For the offshore CRM course it was decided that rather than have an explicit test of participants' knowledge of the curriculum, it would be assessed by presenting them with two written accident vignettes. Kerlinger (1996) considers vignettes to be a type of unobtrusive measure. He defines them as "... brief concrete descriptions of realistic situations so constructed that responses to them will yield measures of variables" (p. 475) (see also Gliner et al., 1997, for use of vignettes in evaluation).

The offshore scenarios used were based on real incidents that indicated a range of human factors causes. The first was presented at the beginning of the course, and the second at the end of the course (the order of the scenarios was counter-balanced for each course). The participants were asked to identify the human factors causes of the accident. The vignettes were piloted on the first three CRM courses. It was found that it was necessary to prompt the participants with a number of headings on the answer sheet to aid in the generation of causes. Thus, a list of six possible headings were provided: planning, communication, team working, supervision, personal limitations (e.g. stress or fatigue), and other contributory factors.

7.2. Step 8: designing tools for feedback

Feedback or knowledge of results is critical for both learning and motivation (Wexley and Latham, 1991). The Asset Manager was provided with a report for each of the three platforms regarding the feedback from the reaction, learning, and attitudes measures. In addition, a more general report was written in which the responses from the shifts were compared. The platform specific reports were also distributed to the Offshore Installation Managers (OIMs; the most senior member of staff on the installation) on each platform with the intention that they address any issues that may have been raised.

7.3. Pilot courses

Although not included as a step in Salas et al. (1999b) methodology for designing CRM training, two pilot courses were run. A total of 10 participants attended the first course, and 11 attended the second. A number of changes were made to the training course on the basis of the extensive feedback obtained.

7.3.1. Participants

It had initially been decided to run the courses without the OIMs present, on the basis that the presence of the site manager might inhibit the discussion of critical human factors problems. This proved to be a mistake and the feedback from the participants on the pilot courses indicated strongly that the crews wanted their OIM to be present to discuss key issues openly with him.

The pilot courses were both run with a mix of crews from two platforms (one installation was significantly older than the other). The feedback from these groups was that they would prefer to take the course only with their own platform shift in order to discuss issues and events relevant to them.

7.3.2. Course content

The length of time spent on the introduction was reduced, the amount of theory reduced, and greater efforts were made to tailor the topics to the offshore environment. This was done by obtaining, and using, real-life offshore scenarios for discussion, and reducing the number of aviation accident videos shown.

7.3.3. Course evaluation

It was decided that a knowledge-based assessment should also be designed (see earlier).

7.4. Hypotheses

It was possible to propose a number of hypotheses about the effects of the CRM training:

H1. The training will lead to an increase in positive attitudes to the CRM concepts covered in the training.

In aviation it has been found that immediately after CRM training there is a significant positive shift in attitudes to the concepts addressed by CRM training. Data from a number of airlines obtained using the CMAQ have shown that attitudes about flightdeck management change in the desired direction as a result of CRM training (e.g. Salas et al., 1999a; Helmreich and Merritt, 1998; Helmreich and Wilhelm, 1991).

H2. The training will result in an increase in the human factors knowledge of the participants.

As generally found in the small number of studies which have examined the effect of CRM training on knowledge (O'Connor et al., 2001), it was expected that there would be an increase in the knowledge of participants after the training.

H3. There will be differences in the responses to the training between the operating company personnel and the contracting staff.

The majority of personnel offshore are contracting staff, and do not work for the company that actually operates the oil platform. In fact, contractors make up 80% of the offshore workforce, and the operating companies generally only providing the key personnel on the platform such as the OIM, supervisors, and control room

personnel. Thus, there may be a number of cultures operating on an installation (Boyd, 1996; Mearns et al., 1998), and different responses to the training.

8. Sample

Six courses were run with participants ($n=77$) attending from both shifts from three North Sea production platforms operated by a major offshore oil and gas company. A total of 43% of participants were from production, 21% maintenance, 33% were 'other' (drilling, deck crew, etc.) and 4% gave no response. Further, 43% were employed by the company which operated the oil platform, and 54% were contractor personnel employed by a service company. The course sizes ranged from 10 to 21 participants.

9. Results

9.1. Step 9a: evaluate the effectiveness of training (course feedback questionnaire)

Participants were given questionnaire after each work package with a number of items to which they could answer on a scale ranging from 1 'very poor' to 5 'excellent'. The questions were designed to establish whether the workpackage was interesting, informative and relevant to their job. Table 4 shows the mean and standard deviation of the responses to the six or seven questions in each category.

Table 4 shows that the majority of participants rated the course as satisfactory or better. The overall mean scores for the questions relating to each work package were examined to assess whether there were any significant differences in the feedback from participants from the operating or contracting companies. An independent sample *t*-test did not reveal any significant differences between the responses of operating company personnel and contractors.

Participants were asked if they thought that any of the sections required more or less time. Stress and teamwork were the most frequent topics that the participants would have liked to have spent more time on, with some participants indicating that

Table 4

Mean and standard deviation (in parentheses) of operator and contractor responses

Work package	Operators	Contractors
Background to CRM	3.5 (0.3)	3.7 (0.3)
Situation awareness	3.7 (0.4)	3.7 (0.4)
Decision making	3.8 (0.4)	3.8 (0.4)
Communication	3.8 (0.4)	3.8 (0.5)
Team working	4.0 (0.3)	4.0 (0.4)
Fatigue	3.8 (0.5)	3.8 (0.5)
Stress	4.0 (0.4)	4.0 (0.4)

less time could have been spent on the background on CRM. Only 3% of participants indicated that they would not use any of the skills they had learned on the course. Finally, participants were also given the opportunity to write comments about the course. In general, the additional comments were favourable, with some individuals writing lengthy summaries of their thoughts.

Thus, the results from the course feedback questionnaire suggest that the majority of participants were generally positive about the course. The work package concerned with stress was recognised as being particularly relevant for the offshore environment. It was suggested that the course could be improved with more offshore case studies, more time devoted to learning the skills outlined in the training, and support to help the platforms apply the information learned in the training at the workplace.

9.2. Step 9b: evaluate the effectiveness of training (attitude questionnaire)

The 30 individual statements in the questionnaire were grouped into four categories, communication, decision making, situation awareness, and personal limitations. Although items concerned with teamworking and leadership were included, they were not labelled explicitly as separate categories. The reason for this is that these concepts can be incorporated into the four categories that were included in the questionnaire. It was not possible to test this structure using factor analysis, as the ratio between items and participants should be at least 1:5 with subject sizes below 300 (Ferguson and Cox, 1993; Tabachnick and Fidell, 1996). The ratio was only about 1:2 in the current study. Therefore, it was necessary to assume the factor structure for further analysis.

An assessment was made of the internal reliability of the factors using Cronbach's alpha. Although 0.7 is regarded as the limit for an acceptable reliability coefficient, lower thresholds are sometimes used in the literature (e.g. Gregorich et al., 1990 reported alpha values of between 0.47 and 0.67 for the CMAQ). A total of nine items were dropped from the OAQ to increase the alpha levels of the factors. However, the alpha scores for the decision-making factor were negative, and dropping items was not found to have an effect (see Table 5). Although the alpha value is supposed to be positive, sampling error can produce a negative average covariance

Table 5
Cronbach's alpha values and mean and standard deviation for each factor

Factor	Alpha scores		Mean and standard deviation (in parentheses)	
	Before	After	Before	After
Decision making	-0.67	-0.92	3.5 (0.42)	3.6 (0.41)
Situation Awareness (3 items dropped)	0.50	0.52	4.1 (0.43)	4.1 (0.43)
Communication (4 items dropped)	0.66	0.67	4.2 (0.32)	4.2 (0.31)
Personal limitations (2 items dropped)	0.46	0.57	3.7 (0.34)	3.9 (0.34)

in a given sample of cases (Nichols, 1999). Therefore, the reliability of the decision making factor was found to be unacceptable.

Table 5 shows the mean score on a five-point scale for each factor. A score of 3 or above indicates a positive attitude to the topics covered in the CRM training. Four two-way ANOVAs were run with one within subjects variable (time: before versus after), and one between subjects variable (company: operators versus contractors) for each of the four dependent variables (communication, decision making, situation awareness, and personal limitations). There were only significant positive effects of the training for the decision making factor ($F=3.7$, $P<0.05$, $df=1, 70$) and personal limitations factors ($F=3.1$, $P<0.05$, $df=1, 70$). There were no significant effects of training on the situation awareness or communication factors, and no difference between contractors and operators.

9.3. Step 9c: evaluate the effectiveness of training (Accident scenario)

Participants were given accident scenarios from which to identify the causes before and after the course. The participants' explanations of the possible causes of the two scenarios were grouped on the basis of the categories provided on the answer sheet (planning, communication, team working, supervision, personal limitations, and other). The differences before and after training in terms of the number of codes were not significant as measured by an independent t -test (scenario 1, $t=-1.6$, $df=37$, n.s.; scenario 2, $t=1.1$, $df=40$, n.s.). Four industrial psychologist were asked to find as many possible human factors causes of the two accidents as possible. Table 6 illustrates that the experts tended to attribute a greater number of causes to communication, and overall found more human factors causes than the offshore personnel.

10. Discussion

This study has described how a prototype CRM training for offshore personnel was designed and evaluated. The conclusions drawn from the evaluation are described below.

10.1. Reactions

The overall impression from running these prototype courses was that CRM training could have benefit for the offshore oil and gas production industry. The responses from the course feedback questionnaire showed a generally positive reaction towards the training course, although some delegates were already familiar with aspects of the material covered. However, there were some criticisms of the training course which need to be addressed if the course is to be used more widely.

It would be useful to obtain additional case studies of offshore events in narrative form, but of particular benefit would be video re-enactments of incidents. There should also be further emphasis placed on the CRM skills, rather than their

Table 6

Mean and standard deviation (in parentheses) of the frequency of causes identified

Categories	Scenario 1		Scenario 2		Experts (n=4)	
	Before (2 courses, n=31)	After (1 course, n=13)	Before (1 course, n=13)	After (2 courses, n=31)	Scenario 1	Scenario 2
Planning	1.6 (0.8)	1.5 (0.7)	1.4 (0.7)	1.5 (0.8)	2.3 (0.5)	1.5 (0.6)
Communication	1.0 (0.8)	1.3 (0.5)	1.4 (0.9)	1.7 (0.7)	3.8 (0.5)	3.3 (1.0)
Team working	1.5 (0.5)	1.6 (0.9)	1.4 (0.7)	1.5 (0.7)	2.3 (0.5)	1.8 (1.0)
Supervision	1.6 (1.1)	1.1 (0.6)	1.5 (0.8)	1.1 (0.9)	2.3 (0.5)	1.5 (0.6)
Personal limitations	1.7 (0.8)	1.5 (0.7)	1.4 (0.5)	1.4 (0.6)	1.5 (0.6)	1.3 (0.5)
Other	1.6 (0.9)	2.5 (3.7)	2.1 (0.3)	1.9 (0.8)	1.3 (0.5)	1.8 (1.0)
Total	8.0 (1.8)	9.1 (2.4)	9.1 (2.0)	8.3 (2.0)	13.3 (1.0)	11.0 (0.8)

theoretical basis. The participants do not require a detailed knowledge of the theoretical background, as long as they have an understanding of how these concepts effect their individual and team performance (Johnston, 1997). Finally, as mentioned earlier individuals who have experience of working offshore should carry out the training, with the psychologists being involved in the evaluation and development of the course material.

10.2. Attitude assessment

The hypothesis that the training will lead to an increase in positive attitudes to the concepts covered in the training was only supported for two of the factors (decision making and personal limitations). No differences were found between the attitudes of the operating company personnel and the contracting staff towards the CRM concepts.

There are possible explanations for the lack of a significant positive shift in attitudes across all of the factors. Firstly, it is possible that the training simply did not have the desired effect on the attitudes of the participants. Alternatively, as this sample of offshore personnel already had such positive attitudes to CRM concepts prior to the training, it might have been difficult to improve these still further. Also the sample size was very small in comparison to those studies which have found significant attitude change after CRM training using the CMAQ in aviation. For example, Gregorich (1993) had a sample of 1191 flight crew. Cohen (1962) states that if a small effect size is expected (as the studies in aviation suggest), a sample size of at least 200 is required to correctly reject the null hypothesis.

There is a need to develop a reliable scale to assess attitudes to CRM concepts in non-aviation populations. This suggests that in the next iteration of the questionnaire, more work is required to develop reliable items. This is particularly true for the decision-making factor. A possible method of developing a reliable decision-making scale would be to develop a large pool of items which are designed to

measure this construct. DeVellis (1991) states that it is not unusual to begin with a pool of items that is three or four times as large as the final scale. Carrying out interviews with subject matter experts may help in the development of a large item pool. These items could then be tested to allow an evaluation to be made of their reliability and validity of the items.

10.3. Knowledge assessment

The hypothesis that the training would result in an increase in the human factors knowledge of the participants was not found to be the case as measured using vignettes. A possible confounding factor was that the course participants generally desired to complete the task as quickly as possible after the training so that they could leave. Therefore, it is possible that the course participants did not put a similar amount of effort into completing the task after the training as they did prior to the training course. They were either returning home from 2 weeks of working offshore, or were going offshore to work as soon as the training was completed.

Andersen and Bove (2000) tested the use of vignettes to assess Team Resource Management for Air Traffic Control personnel. They did not find a clear significant difference between experienced and inexperienced Air Traffic Control personnel. However, rather than rejecting this technique for assessing knowledge, it is suggested that this may need to be used in association with multiple choice tests which have been used successfully in aviation (e.g. Salas et al., 1999a). A vignette could be used to provide the basis of the test, however, specific multiple choice questions could be used to elicit information about the human factors information contained within the vignette. This would ensure that the test approximates realistic psychological and social situations for a given workplace.

11. Conclusion

This study has shown that the offshore CRM training was well received. There was a slight indication of a change in attitudes to CRM skills as a result of the training. However, as discussed earlier the baseline may have been higher for this company than is typical and the attitude and knowledge measures were untested and may not have been sufficiently sensitive.

The development of valid techniques to assess CRM attitudes and skills are required. This is important because it is necessary to establish whether the training is having the desired effect (Holt et al., 2001). Evaluation allows adjustments to be made to the design or delivery of training (Goldstein, 1993), provides information on the allocation of resources (Salas and Cannon-Bowers, 2000), allows an assessment to be made as to whether the training is providing value for money (Taylor, 2000), and highlights areas for recurrent training.

As described earlier, the effect of the offshore CRM training on behaviour was not examined. The aviation industry is addressing this issue and the use of behavioural marker systems such as NOTECHS (Avermaete and Kruijssen, 1998) to measure

CRM skills are becoming more widespread. The research carried out in aviation that was required to develop behavioural marker systems should also aid the development of behavioural observation systems in other high-reliability industries. There is also a need to identify metrics to allow any evaluation of the effects of CRM training at an organisational level to assess whether it is improving the safety performance of the organisation (O'Connor et al., 2001; Salas et al., 2001). It is important that industries that are beginning to use CRM training do not repeat the errors made in aviation. CRM training must be based on a needs analysis, a theoretically valid training methodology tailored for the industry and the personnel who will be attending the courses.

Our experience with this prototype course suggests that aviation CRM could successfully be adapted for the offshore oil and gas production industry. One of the great strengths of the CRM field is the willingness of training providers and companies to share experiences of developing and delivering CRM. The common goal of improving safety transcends organisational competitiveness and industrial parochialism. Moreover, the core philosophy of CRM provides a basic drive for the step change in work culture required to reduce accidents towards the desired target zero.

Acknowledgements

This project was part of a larger study funded by the UK Health and Safety Executive and 13 oil and gas companies and managed by Dr Kathryn Mearns. The views presented here are those of the authors and should not be taken to represent the position or policy of the organisations involved. We thank the sponsoring companies, in particular the asset managers from the company that gave us access, and the crews who attended the courses.

References

- Andersen, V., Bove, T., 2000. A feasibility study of the use of incidents and accident reports to evaluate effects of Team Resource Management in Air Traffic Control. *Safety Science* 35, 87–94.
- Avermaete, J., Kruijssen, E., 1998. The Evaluation of Non-technical Skills of Multi-pilot Aircrew in Relation to the JAR-FCL Requirements (NLR-CR-98443). NLR, Amsterdam.
- Belton, S., 2001. CRM training in the nuclear industry. Presented at the Third CRM Users Group Workshop, University of Aberdeen, October.
- Boyd, R., 1996. Preparing a Team to Operate the Judy Platform—Through Empowerment and Motivation, Success? Unpublished master's thesis. Robert Gordon University, Aberdeen, Scotland.
- Bryden, R., O'Connor, P., Flin, R. (1998). Developing CRM for offshore oil platforms. Presented at the Human Factors and Ergonomics Society conference, Chicago, September.
- CAA, 1998. United Kingdom Aeronautical Information Circular: Flight Crew CRM Training Standards (AIC 114/1998). CAA, London.
- Cohen, J., 1962. The statistical power of abnormal-social psychological research: a review. *Journal of Abnormal and Social Psychology* 65, 145–153.
- Connolly, S., 1997. Analysis of Time Factors and Experience in Relation to Incidents and Accidents over the Period 1989/1990 to 1995/1996 (Unpublished HSE Report).

- DeVellis, R.F., 1991. *Scale Development: Theory and Applications*. SAGE Publications, London.
- FAA, 1998. *Advisory Circular: Crew Resource Management Training (AC No: 120–51C)*. US Department of Transport, Washington.
- Ferguson, E., Cox, T., 1993. Exploratory factor analysis: a users' guide. *International Journal of Selection and Assessment* 1 (2), 84–94.
- Flin, R.H., 1995. Crew resource management for teams in the offshore oil industry. *Journal of European Industrial Training* 19 (9), 23–27.
- Flin, R., Martin, L., 2001. Behavioural markers for CRM: a review of current practice. *International Journal of Aviation Psychology* 11, 95–118.
- Flin, R., Mearns, K., Gordon, R., Fleming, M., 1996. Risk perception by offshore workers on UK oil and gas platforms. *Safety Science* 22, 131–145.
- Flin, R., O'Connor, P., Mearns, K., 2002. *Crew Resource Management: improving teamwork in high-reliability industries*. *Team Performance Management* (in press).
- Gliner, J.A., Haber, E., Weise, J., 1997. Use of controlled vignettes in evaluation: does type of response method make a difference? *Evaluation and Program Planning* 22, 313–322.
- Goldstein, I.L., 1993. *Training in Organizations*. Wadsworth, Belmont, CA.
- Gordon, R. (1998). The contribution of human factors to accidents in the offshore oil industry. *Reliability and System Safety* 61, 95–108.
- Gregorich, S.E., 1993. The dynamics of CRM attitude change: attitude stability. In: Jensen, R. (Ed.), *Proceedings of the 7th International Symposium of Aviation Psychology*. Columbus, Ohio, Ohio State University, pp. 509–512.
- Gregorich, S., Helmreich, R., Wilhelm, J., 1990. The structure of cockpit management attitudes. *Journal of Applied Psychology* 75, 682–690.
- Gregorich, S.E., Wilhelm, J.A., 1993. Crew resource management training assessment. In: Wiener, E.L., Kanki, B.G., Helmreich, R.L. (Eds.), *Cockpit Resource Management*. Academic Press, San Diego, pp. 173–196.
- Helmreich, R.L., Merritt, A.C., 1998. *Culture at Work in Aviation and Medicine: National, Organizational and Professional Influences*. Ashgate, Aldershot.
- Helmreich, R.L., Merritt, A.C., Wilhelm, J.A., 1999. The evolution of crew resource management training in commercial aviation. *International Journal of Aviation Psychology* 9, 19–32.
- Helmreich, R.L., Wilhelm, J.A., 1991. Outcomes of crew resource management training. *International Journal of Aviation Psychology* 1, 287–300.
- Holt, R., Boehm-Davis, D., Beaubien, M., 2001. Evaluating resource management training. In: Salas, E., Bowers, C., Edens, E. (Eds.), *Improving Teamwork in Organizations: Applications of Resource Management Training*. Lawrence Erlbaum Associates, New Jersey, pp. 165–190.
- JAA, 2001. *JAR-OPS,1 amendment 3 (November 2001), Crew resource management—flight crew*. EC Joint Aviation Authorities, Hoofddorp, Netherlands.
- Johnston, N., 1997. Teaching human factors for airline operations. In: Hunt, G.J.F. (Ed.), *Designing Instruction for Human Factors Training in Aviation*. Avebury, Aldershot, pp. 127–160.
- Kerlinger, F., 1996. *Foundations of Behavioural Research*. Holt, Rinehart & Winston, New York.
- Kirkpatrick, D.L., 1976. Evaluation of training. In: Craig, R.L., Bittel, L.R. (Eds.), *Training and Development Handbook*. McGraw Hill, New York.
- Kirkpatrick, D.L., 1998. *Evaluating Training Programs*. Berrett-Koehler, San Francisco.
- Klein, G., 1997. An overview of naturalistic decision making applications. In: Zsombok, C.E., Klein, G. (Eds.), *Naturalistic Decision Making*. Lawrence Erlbaum, Mahwah, pp. 49–60.
- Lauber, J.K., 1984. Resource management in the cockpit. *Air Line Pilot* 53, 20–23.
- Mearns, K., Flin, R., Fleming, M., Gordon, R., 1997. *Human and Organisational Factors in Offshore Safety (OTH 543)*. HSE Books, Suffolk.
- Mearns, K., Flin, R., Gordon, G., Fleming, M., 1998. Measuring safety culture in the offshore oil industry. *Work and Stress* 12 (3), 238–254.
- Miles, R., 1999. Progress in the understanding of shift working offshore. Presented at the I.ChemE/Ergonomics Society Conference, London, March.

- Miles, R., O'Connor, P., 2000. CRM training for UK offshore safety inspectors. Presented at the SPE International Conference on Health, Safety, and the Environment, Stavanger, Norway, June.
- Mineral Management Service, 1997. Accident Statistics 1995–1996. Available from: <http://mms.gov/eod/safety.htm>.
- Nichols, D.P., 1999. My coefficient alpha is negative!. SPSS Keywords 68.
- O'Connor, P., Flin, R., Fletcher, G. Literature Review: Methods used to evaluate the effectiveness of CRM training in the aviation industry. 2001 Grant report (121/SRG/R&AD/1) to UK Civil Aviation Authority London: CAA.
- O'Connor, P., Hoermann, H. J., Flin, R., Goeters, K. M., Lodge, M. & the JARTEL Group, 2002. Developing a method for evaluating CRM skills: a European perspective. *International Journal of Aviation Psychology* 12 (3), 265–288.
- Oser, R.L., Salas, E., Merket, D.C., Bowers, C.A., 2001. Applying resource management training in naval aviation: a methodology and lessons learned. In: Salas, E., Bowers, C.A., Edens, E. (Eds.), *Improving Teamwork in Organizations: Applications of Resource Management Training*. Lawrence Erlbaum Associates, Mahwah, NJ, pp. 283–301.
- Parkes, K.P., 1992. Mental health in the oil industry: a comparative study of onshore and offshore employees. *Psychological Medicine* 22, 997–1009.
- Salas, E., Burke, C.S., Bowers, C.A., Wilson, K.A., 2001. Team training in the skies: does Crew Resource Management (CRM) training work? *Human Factors* 43 (4), 641–674.
- Salas, E., Cannon-Bowers, J.A., 2000. The anatomy of team training. In: Tobias, L., Fletcher, D. (Eds.), *Training and Retraining: A Handbook for Business, Industry, Government, and the Military*. MacMillan, New York, pp. 312–335.
- Salas, E., Fowlkes, J.E., Stout, R.J., Milanovich, D.M., Prince, C., 1999a. Does CRM training improve teamwork skills in the cockpit? Two evaluation studies. *Human Factors* 41 (2), 326–343.
- Salas, E., Prince, C., Bowers, C.A., Stout, R.J., Oser, R.L., Cannon-Bowers, J.A., 1999b. A methodology for enhancing crew resource management training. *Human Factors* 41 (1), 161–172.
- Tabachnick, B.G., Fidell, L.S., 1996. *Using Multivariate Statistics*. HarperCollins, New York.
- Taylor, J.C., 1998. Evaluating the effects of Maintenance Resource Management (MRM) interventions in Airline safety. Report presented to the FAA. FAA, Washington.
- Taylor, J. C. 2000. A new model for measuring return on investment (ROI) for safety programs in aviation: an example from airline maintenance resource management (MRM). Presented at the Advances in Aviation Safety Conference, paper number 2000–01–2090, Daytona Beach, Florida, April.
- Wexley, K.N., Latham, G.P., 1991. *Developing and Training Resource Management in Organizations*. Harper Collins, New York.
- Wiener, E., Kanki, B., Helmreich, R. (Eds.), 1993. *Cockpit Resource Management*. Academic Press, San Diego.

Vitea

Paul O'Connor BSc, MSc, PhD is a research assistant at the University of Aberdeen and works in the Industrial Psychology Group. He carries out research into teamworking and team training in high-reliability industries.

Rhona Flin BSc, PhD, CPsychol, FBPsS, FRSE is Professor of Applied Psychology at the University of Aberdeen and Director of the Industrial Psychology Group. She conducts research into industrial safety, Crew Resource Management training, emergency management, and incident command. Her books include 'Sitting in the Hot Seat' (Wiley), 'Decision Making Under Stress' (Ashgate: edited with Salas, Strub & Martin) and 'Incident Command' (Ashgate, 2002, edited with Arbuthnot).