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INCREASING SAFETY BY STRESS MANAGEMENT

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Abstract - Psychosocial factors play an important role in occupational health and safety. Stress is probably the most prevalent psychosocial problem and hence stress management ranks among the most promising health and safety promoters. This contribution deals with the stress of air traffic controllers (ATCOs) which results from workload on the one hand and the responsibility for air traffic safety on the other. Four steps in the stress management of German ATCOs will be described aiming at increasing air traffic safety and reducing stress:

A current state analysis with 328 employees of the German Air Traffic Control Services (DFS) revealed a sufficient quantity and quality of safety instruments.

In several field and simulation studies with 130 operational staff, the most important workload factors were identified and implemented in the work agreement. Now German controllers are paid and given breaks according to their workload measured as the number of aircraft under control, the probability of conflict situations between aircraft and pilot errors in the particular airspace, as well as the percentage of climbing/descending opposed to level flying aircraft.

A simulation study with 40 air traffic controllers proved active relaxation to accelerate the recovery after work and to prevent safety problems.

Controllers can experience critical incidents like separation losses between aircraft, near misses or accidents. A critical incident stress management (CISM) can support coping with these problems as a questionnaire survey with 60 air traffic controllers showed. This study was conducted for Eurocontrol, Brussels, and revealed also an improvement of safety culture by the DFS CISM programme. Moreover, an economic return on investment could be proven: Controllers reported a quicker and more sustainable recovery from critical incidents.

In conclusion the DFS implemented a comprehensive safety and stress management which maintains the highest standard of air traffic safety and reduces work stress related problems. In the long run, these measures will pay off also economically.

INTRODUCTION

The German Air Traffic Control Services (*Deutsche Flugsicherung GmbH*, DFS) are responsible for the safe and expeditious coordination of air traffic in and above Germany. Since 1993 the DFS is a private enterprise and works at seventeen centres distributed all over Germany. The two major business divisions are the radar centres for *en route* air traffic and the air traffic control towers responsible for aircraft taking-off or landing at German airports.

Starting point of the initiatives reported here were repeated requests from the unions and individual controllers regarding stress and stress management. Two major sources of stress can be identified:

1. The responsibility for air traffic safety.
2. The workload.

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Air traffic controllers (ATCOs) are well studied subjects in safety and stress research. Their task is to ensure safe separation of aircraft in time and/or space. The combination of high workload, high responsibility for safety and shift work makes air traffic control a stressful job. Martindale wrote in 1977:

"The job of juggling airliners and making snap decisions on which lives depend exacts a steep toll in stress-related diseases, nightmares, and acute anxiety."

Although ATCOs are well-selected with respect to physical and psychological fitness, Baader and Graf found in 1958 among 295 German ATCOs 24% with gastrointestinal, 20% with vegetative, 14% with cardiovascular, and 17% with multiple complaints. A dozen years later, 40 to 80% of the controllers complained about gastrointestinal, 30 to 40% about pain behind the sternum, and 15 to 40% about other preliminary heart attack symptoms (Rohmert & Rutenfranz, 1972). Recently, tinnitus was identified as an ATCO specific, psychosomatic symptom, due to shift work and high levels of stress (Vogt & Kastner, 2002). The dramatic air traffic increase during the last decades added to the problem, although it can partly be compensated by new technologies (Vogt et al., 2002).

However, not only overload, also underload and boredom can lead to safety problems. An analysis of critical incident occurrence by Della Rocco (1999) revealed that most incidents happen during the main traffic (between 8 am and 7 pm), within the first 30 minutes on duty, and after a break (the latter two probably due to insufficient warm-up). Hagemann (2000) reported as safety critical times the take-over of position (probably due to insufficient warm-up) and the time after a traffic peak (due to an overshooting relax response). Moreover, critical incidents were reported to occur during low traffic (due to boredom), high traffic (due to overload) as well as average traffic when high traffic was expected. The latter corresponds to the overshooting relax response which can follow a traffic peak.

Therefore, safety and workload in ATC are related issues of utmost importance.

The responsibility for air traffic safety requires the systematic and extensive use of safety instruments. To prevent critical situations, work agreements should consider stress and manage workload by giving for example breaks in the case of overload. Moreover, a critical incident stress management is needed when controllers experience a separation loss between aircraft or in the worst case an accident despite of safety instruments and appropriate workload. With respect to all four topics (safety instruments, workload, breaks, critical incident stress), the DFS requested scientific support for management decisions and set examples for theory-to-practice. Empirical studies on the four topics will be described in extracts.

SAFETY INSTRUMENTS

Introduction

The core business of air traffic control is safety. Experiences in this branch might be considered as useful also by other industries. The German Air Traffic Control Services DFS maintain a multitude of different safety instruments. The instruments were investigated in a current state analysis in the years 2000 – 2001 and since then were further developed.

Method and material

328 ATCOs were interviewed with respect to the recognition and acceptance of the safety instruments.

Main results

Table 1 shows that the DFS maintains a variety of different instruments in a sufficient quantity and quality. Operational guidelines, standard briefings and incident reporting were already introduced in 1955 with the establishment of German air traffic control services and continuously developed. The other instruments are fairly modern, introduced in the 1990s. Most of the standard instruments like incident reporting, operational guidelines, standard briefings, safety letter, emergency checklists and computer based trainings were known by more than 97% of the interviewed staff at the time of the current state analysis. However, one third or more of the subjects had not heard of the more costly and less frequent procedures like team resource management, safety briefings, emergency trainings and simulation exercises. Meanwhile, DFS has successfully introduced a new team resource management which is used much more frequently. Also a new instrument was developed called the safety manager and was implemented in 2004. This new instrument is a committee of safety consultants from each DFS unit who meet three times a year to discuss safety issues on a meta-level. An emphasis is put on the operational behaviour of staff.

This development shows that DFS effectively learnt from the current state analysis and even improved the safety culture which at all times had a well-established tradition in the organisation.

Table 1 Safety instruments in the DFS

Instrument	Description	Frequency	Medium	Implementation
Operational guidelines	General rules of ATC in Germany	Always available	Book or CD ROM	1955, continuously updated
Computer based trainings	Training of local and central rules and procedures	Four hours per year, annual testing	Computer	1999
Standard briefing	Actual operational notices	Daily	Briefing	1955, continuously updated
Obligatory incident reports	Report and analysis of separation losses and other incidents	Incident based	Report	1955, continuously updated
Emergency checklists	Standards and recommendations for emergencies	Incident based	Checklists	1995
Safety letter	Confidential description of critical incidents	Quarterly	Letter	1999
Safety panel	Discussion of safety issues	Twice a year	Committee	1996
Safety briefing	Information about safety issues	At least annually	Briefing	1999
Radar and tower simulation	Simulation of emergency situations	One day per year	Simulator	1999
Training of emergencies and system breakdowns	Group exercise	Differs in DFS units	Group exercise	Differs in DFS units
Team resource management	Communication and cooperation within teams	Three days per year	Seminar	1999, updated 2002
Safety Manager	Discussion of safety issues at meta-level	Three times a year	Committee	2004

WORKLOAD

Introduction

Many studies have tried to identify the main workload factors in ATC aiming at compensatory measures, for example in the break and shift system. It is widely agreed upon that the most important factor determining workload is the number of aircraft under control (Vogt & Kastner, 2001). The topography of the air space sector controlled by *en route* ATCOs and the visibility for tower controllers have also been considered by some authors (Arad, 1964; Hurst & Rose, 1978; Repetti, 1989, 1993). The speed of the aircraft under control (Hurst & Rose, 1978) and the number of conflicting aircraft (Kimbelton, 1970; Vogt & Kastner, 2001) were only rarely studied. And finally, the information content of radio transmissions (e. g. instruction, information, question, report, inquiry; Reiche et al., 1971; Rohmert & Rutenfranz, 1972), their frequency and duration (Kimbelton, 1970; Hurst & Rose, 1978; Henderson et al., 1990; Zeier et al., 1996) were considered. The investigation of radio transmissions petered out because especially the contents are difficult to measure. Moreover, radio transmissions will be replaced by electronic mail in the future (data-link air-ground).

The number of aircraft under control is the only well-established indicator of ATCO workload. In a multiple regression analysis performed by Hurst and Rose (1978) 53% of stress responses were explained by the number of aircraft. Rohmert and Rutenfranz (1972) predicted heart rate changes from traffic volume and duration. The correlation between predicted and measured heart rate changes was 0.5, and the authors concluded that, firstly, heart rate alone is a satisfactory predictor of stress, and, secondly, the number of aircraft is the main workload factor.

Method and Material

130 male, non-smoking ATCOs were monitored during their work and in simulation studies. An initial exploratory field study with 36 subjects was followed by an *en route* radar simulation (24 controllers) and a tower simulation (16 controllers). Finally, the results of the simulations were confirmed in a validation study under real traffic conditions (54 controllers). Independent variables in all studies were traffic features like the number of aircraft under control, the percentages of climbing and descending, fast and slow, heavy and light aircraft, potential conflicts between aircraft, and pilot errors. The stress responses to these traffic variables were measured with automated blood pressure meters (Takeda Medical TM2420), electrocardiogram, and self-reported concentration, upset, and motivation.

Main results

Table 2 shows the coefficients and error probabilities for the correlation of mean stress responses and traffic features. Apart from overall traffic volume, the number of light (up to 7 t) and heavy, slow (propeller and turbo-propeller up to 640 km/h) and fast as well as level flying and climbing/descending aircraft (vertical traffic) were counted. The difficulty of controlling fast and climbing/descending aircraft is substantial, because it requires fast and three-dimensional information processing. Heavy aircraft cause wake turbulences which can affect smaller aircraft behind them. Since the seven traffic variables were not independent, the significance tests for the correlation coefficients had to be adjusted with respect to the statistical alpha error. The procedure according to Holm was followed (Krauth, 1988, i. e. the smallest error probability had to remain under 0.05/7=0.0071, the second smallest under 0.05/6=0.0083, etc.).

Table 2 Coefficients and one-tailed error probabilities for the correlation of mean physiological responses and self-report with traffic in the exploration study

	Overall	Light	Heavy	Level	Climb/ descend	Slow	Fast
Heart rate	.39	-.25	**.44***	-.01	**.41***	**-.57***	**.58***
	.014	.089	**.006**	.476	**.011**	**.004**	**.004**
Systolic blood pressure	.30	-.14	.34	.03	.27	-.36	.37
	.048	.215	.030	.442	.066	.054	.052
Diastolic blood pressure	.31	.05	.32	-.23	.09	-.25	.17
	.040	.399	.037	.100	.308	.140	.229
Concentra-tion	.36	-.04	.38	.10	**.50***	-.18	.41
	.015	.420	.011	.278	**.001**	.199	.024
Upset	.26	.34	.21	-.06	.02	.21	-.03
	.063	.022	.110	.359	.450	.158	439
Motivation	.29	-.29	.35	-.19	**.55***	-.39	**.52***
	.042	.042	.019	.140	**.000**	.030	**.004**

*Coefficients significant with alpha error correction

Heart rate, blood pressure, as well as self-reported concentration and motivation, tended to increase with the overall traffic volume. Heart rate increases correlated especially with the number of fast aircraft. Also the expected blood pressure increase occurred under this difficult traffic condition, but it remained below alpha-corrected significance. Moreover, higher concentration and motivation were reported. On the other hand, responses tended to be smaller with greater numbers of slow aircraft. Heart rate and self-reported concentration and motivation were higher when more heavy and vertical traffic (climbing and descending aircraft) had to be controlled. There was no correlation between the number of level flying aircraft and physiological stress response.

The exploration study produced new evidence that stress responses not only correlate with traffic volume, but especially with the number of heavy, fast, climbing and descending aircraft.

A simulation experiment was designed in order to systematically vary these traffic features and to determine the sizes of their effects on physiological and self-reported responses. An *en route* scenario was selected since the necessary hardware was accessible and the number of available controllers was largest. The simulated air space was unknown to all subjects. Like in real air traffic control, the subjects and the pseudo pilots received operational guidelines. In order to ensure the planned course of the scenario, a few special instructions had to be included, for example to take over control not before an aircraft had entered the airspace.

Discussing the results of the exploration study with experts revealed quickly the number of aircraft and the portion of climbing/descending machines as the first two simulation variables. However, heavy and fast aircraft are not difficult *per se*. Only in combination with the traffic context, they can cause safety problems, for example the wake turbulence of a heavy aircraft endangering a light one or a fast aircraft catching up with a slower one at the same flight level. Therefore, as the third simulation variable, a meta-stressor was composed called simulated potential conflicts containing cases like these. Finally, pilot errors were included as a fourth simulation variable. There were two levels (high and low) of each of these four variables that were fully combined to a 2x2x2x2 within-subject design. Each of the resulting 16 scenarios lasted 20 minutes. They were presented to the subjects in a randomised sequence. Including appropriate breaks (see below), each ATCO stayed for two days.

Figure 4 shows mean heart rate and systolic responses as a function of workload. The highest difficulty is coded by the capital letters A for 12 aircraft continuously under control, C for six potential conflicts, V for 66 % vertical traffic (i. e. climbing or descending aircraft), E for two pilot errors. Low difficulty is indicated by the respective small letters. Column 1 to column 8 represent runs with a high number of aircraft, 1 to 4 and 9 to 12 those with six potential conflicts, 5 to 8 and 13 to 16 with only two. The percentage of climbing and descending traffic varied from column pair to column pair and pilot errors occurred in the runs represented by every odd column.

Systolic response to the most difficult run was on average 11 mmHg. The corresponding heart rate increase was about 5 and unexpectedly outranked by the response to run ACvE (7 beats per minute).

Statistical analyses revealed significant main effects of the number of aircraft for both dependent variables. Moreover, heart rate and systolic response were significantly affected by the number of potential conflicts. Finally, climbing and descending aircraft statistically had an effect on heart rate. Heart rate response was lower in runs with a higher portion of vertical traffic, indicating that altitude was probably used to separate aircraft (column 1 and 2 compared to 3 and 4, 5 and 6 compared to 7 and 8 etc.).

Pilot errors affected only single stress responses. This confirms the result reported by Vogt and Kastner (2001) that semi-professional and training flights are less stressful than a high number of professionally operated aircraft.

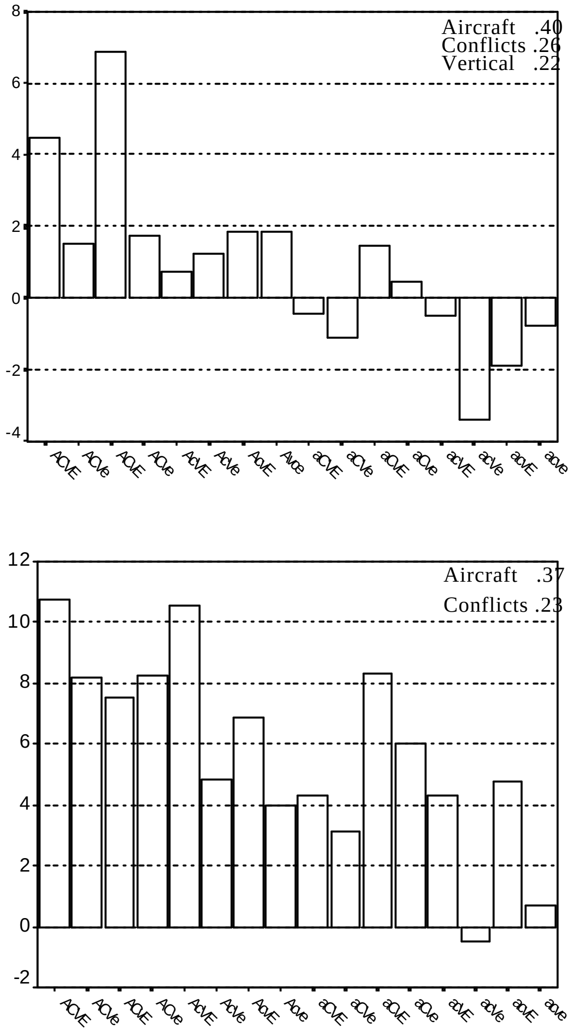
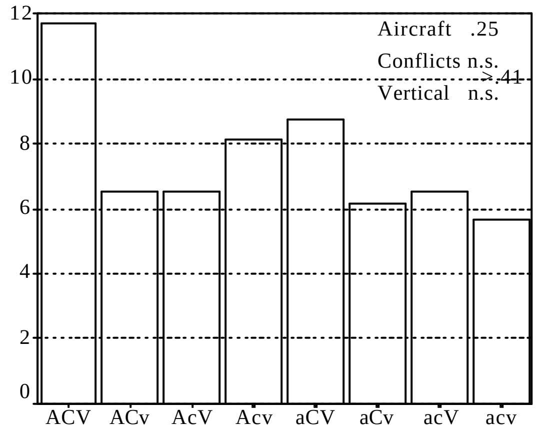


Figure 1 Mean change in heart rate (top) and systolic response as a function of workload
A, a: 12 vs. 6 aircraft continuously under control
C, c: 6 vs. 2 potential conflicts between aircraft at two sampling points
V, v: Always 66 % vs. 33 % vertical traffic, i. e. climbing or descending aircraft
E, e: 2 vs. 0 pilot errors at two sampling points
The top right corner displays statistically significant main effects as well as their effect sizes (varying between 0 and 1)

In order to validate the results of the simulation study, another quasi-experiment was conducted in the field. The objective of this validation study was to prove whether the simulation results are valid under real traffic conditions. For this purpose, as many as 1344 different air traffic control situations were monitored at Munich airport.

An observing controller noted the number of aircraft under control, the number of potential conflicts, the portion of climbing and descending aircraft, pilot errors and other features of the traffic situation in 10-minute-intervals. This procedure was preferred over the objective traffic records used in the exploration study, because potential conflicts and pilot errors are not included in these statistics. This expert protocol was used to post-hoc classify the 1344 situations: Within each control area, each traffic variable was classified as high or low using a median split. In none of the 1344 situations, the experts found other relevant traffic variables than those from the simulation study. Moreover, pilot errors were very rare, such that the classification was limited to number, conflicts and climbing/descending aircraft. Compared to the simulation study, the following bar graphs are missing every odd column (two pilot errors).

The most difficult type of situation (ACV i. e. aircraft number high, conflicts high and vertical traffic high, equivalent to simulation run ACVe) caused on average 12 heart beats per minute over baseline. As expected, the smallest response occurred in situations of type acv. Only the number of aircraft had a significant main effect. In contrast to the simulation, there was a significant interaction between the number of conflicts and the portion of climbing and descending aircraft. Heart rate response decreased with the portion of vertical traffic only when the number of conflicts was high (column 1 vs. 2 and 5 vs. 6) indicating that altitude was used to solve conflicts between aircraft.



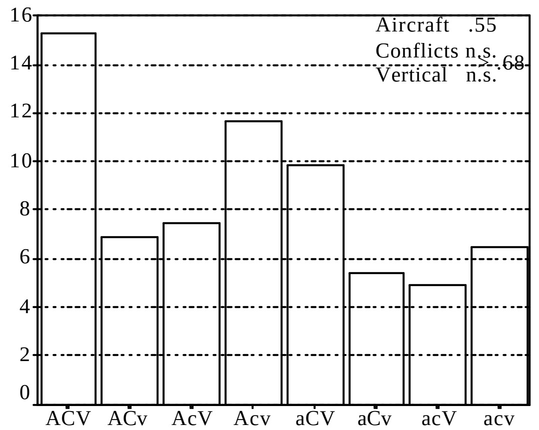


Figure 2 Mean heart rate (top) and systolic response as a function of workload
A, a: Number of aircraft under control high vs. low after median split
C, c: Number of potential conflicts high vs. low after median split
V, v: Vertical traffic (climbing/descending) high vs. low after median split
The top right corner displays statistically significant effect sizes of main and interaction effects (varying between 0 and 1)

A similar but clearer picture was obtained for systolic response. Also under real traffic conditions, stress responses were nearly exclusively affected by the number of aircraft under control and potential conflicts. In accordance with other surveys (Schwarz et al., 2000) the validation study proved that air traffic controllers stress response in simulation is very much like in their real work setting. There is no simulator effect.

Only the results of one group of controllers (area centre control) were shown. The results in the other *en route* areas (upper air and approach control) were similar although less clear. For the tower control, slightly different definitions had to be used: Since the portion of climbing and descending aircraft would be always 100%, observers noted the percentage of traffic mixture, which is decisive for climbing behaviour (jets performing better than propeller aircraft). The category pilot error was broadened to include for example mistakes of airport and apron personnel, and labelled unpredictable events (opposed to the predictable conflicts between aircraft).

In a practice transfer, the traffic variables number of aircraft, climbing/descending machines (traffic mix for tower control), probability of conflicts and pilot errors (unpredictable events for tower control) were implemented in the work agreements of DFS. Now air traffic controllers are paid in seven wage categories considering the workload. Moreover, the break policy was improved by considering the different traffic variables in the quantity of prescribed breaks. Also, the quality of breaks was investigated and whether it can accelerate the recovery from work.

BREAKS

Introduction

The workload should be considered in determining the length of time on position before a break should be given and the duration of the break. Air traffic control requires sustained levels of vigilance which decrease over time while feelings of fatigue increase. Therefore, a break every two hours of continuous work should be allowed (Hopkin, 1995). The employees should have time to walk away from their working position, go to the bathroom and spend time in relaxation facilities at the workplace, where they can have something to drink or chat with colleagues (Hopkin, 1995; Meyer, 1973). The minimum duration of a break should be ten minutes plus ten minutes for every hour worked (Folkard, 2003).

Taking a break is very important especially during night shifts since either low traffic levels induce fatigue resulting from efforts to counter boredom or high traffic load is prevalent. Both conditions meet the de-synchronisation of the body clock.

Kastner et al. (1998) quote from the literature: “Within the first third of a night shift, a 15-minute break should be granted, after the second third half an hour. Moreover, hourly short breaks of 5 to 7 minutes are recommended (Hahn, 1988)”. In air traffic control, however, frequent short breaks would expose ATCOs often to the rather stressful situation of hand-over (realising the complexity of a traffic situation in a short time and taking over from a colleague with little warming-up). This issue was already addressed in the Rohmert and Rutenfranz study (1972, 1975) and mentioned by for example Luczak (1982).

Not only has the quantity, also the quality of a break mattered. This was proven in the simulation study reported above and the relevant results will be described in the following.

Method and material

The 24 ATCOs in the *en route* and the 16 ATCOs in the tower simulation had a 10-minute break after each simulation run. They were randomly assigned to two groups: 12 *en route* and 8 tower controllers read magazines during their break as they frequently do in real life (passive relaxation). The second half was instructed to relax according to the relaxation technique developed by Schultz (1926, 1989).

Main results

Figure 3 shows that 10 minutes active relative to passive relaxation induced a significant unwinding after work in terms of a normalised heart rate. This result was obtained for all simulation runs, independent of their difficulty.

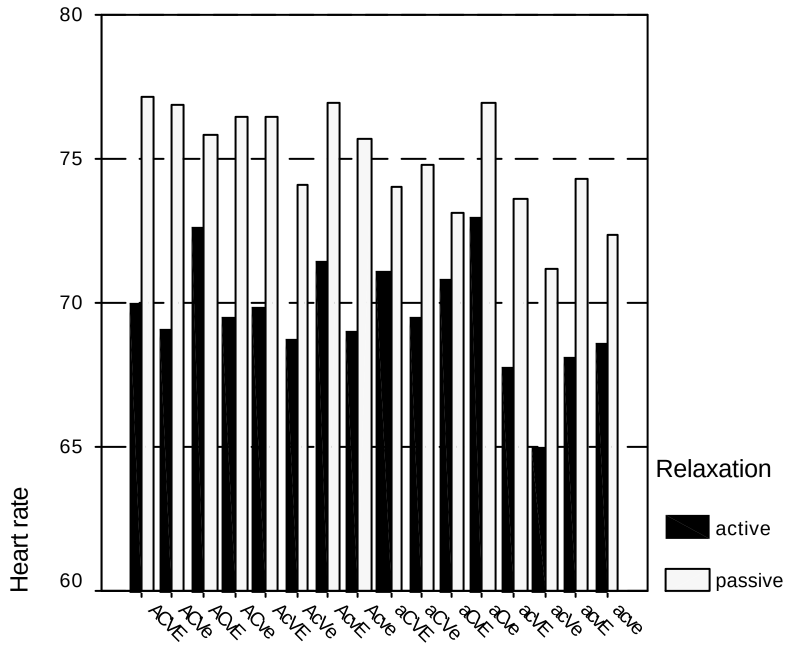


Figure 3 Mean heart rate after active and passive relaxation as a function of workload
A, a: 12 vs. 6 aircraft continuously under control
C, c: 6 vs. 2 potential conflicts between aircraft at two sampling points
V, v: Always 66 % vs. 33 % vertical traffic, i. e. climbing or descending aircraft
E, e: 2 vs. 0 pilot errors at two sampling points

Figure 4 shows the assessment of safety problems the controllers reported after each simulation run grouped for the two conditions of active and passive break. In contrast to the physiological response, which was not significantly differing for the different workloads, the experienced safety problems depended heavily on the number of aircraft in both groups. Although the group differences are small, the active relaxation consistently in all 16 simulation runs led to less experienced safety problems. Interestingly, the difference is greatest in the conditions of high (ACVe), low (acve) and average workload (while high workload is expected due to many aircraft in Acve). This corresponds with the finding of incident investigations which identified the same traffic conditions as critical (Hagemann, 2000).

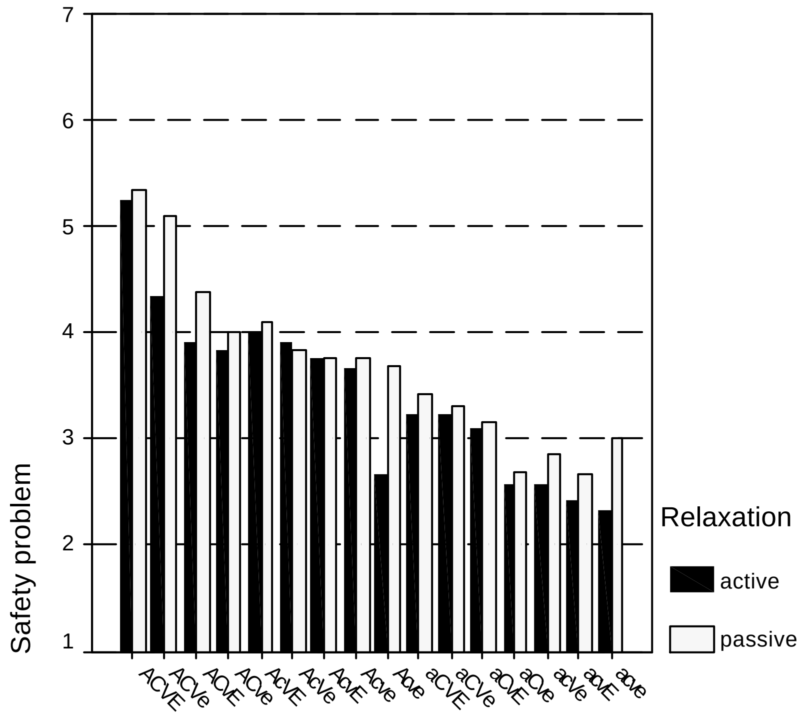


Figure 4 Mean self-reported presence of safety problems (1 not at all; 7 very much) after active and passive relaxation as a function of workload
A, a: 12 vs. 6 aircraft continuously under control
C, c: 6 vs. 2 potential conflicts at the two sampling points
V, v: Always 66 % vs. 33 % vertical traffic, i. e. climbing or descending aircraft
E, e: 2 vs. 0 pilot errors at the two sampling points

The beneficial effect of active relaxation was also found in the tower simulation and with respect to other dependent self-report and physiology responses.

In conclusion, an active relaxation accelerates the reset of physiological stress responses and decreases safety problems. As a practice transfer, the relaxation programme was conceived as a self training on CD accompanied by a booklet. All German controllers can request the two media at their academy.

CRITICAL INCIDENT STRESS MANAGEMENT

Introduction

In the year 1998, DFS started research into appropriate methods and examined the experiences others had in the field of Critical Incident Stress Management (CISM). It was decided to establish a CISM model according to the standards of the International Critical Incident Stress Foundation (ICISF), also known as the Mitchell-Model (Everly & Mitchell, 1997; Mitchell & Everly, 2001; Everly, 1999; Everly, 2000).

The Mitchell-Model is well known for emergency services like police or fire fighters. Some peculiarities of air traffic controllers have to be considered: ATCOs are selected and trained to have a high stress resistance, to work in a team, and to possess individual decision-making abilities. An ATCO must be able to always keep a level head and to take the optimal decision also in difficult situations and on behalf of the people involved (pilots). Controllers know that they can rely on themselves and on the team. Moreover, in case of a critical incident, *en route* controllers have no eye contact to potential victims.

A separation loss of two aircraft, even if considered not critical by pilots, passengers or the public, is an existential threat to the profession of an ATCO. Although a separation loss usually does not lead to an accident, it can cause stress reactions of the controller. This is difficult to understand for non-controllers who therefore can offer less support than a peer ATCO. These considerations led to the decision that the critical incident stress management is offered DFS internally and conducted by colleagues (peers). In order to achieve maximum trust and confidentiality, the controllers voted who of their colleagues they would like to become a peer. It was important that the controllers confide in the peers with respect to their personal skills as well as their integrity. The potential peers were extensively informed about their potential future task and the expectations placed upon them. Then they could decide to accept the vote and to take part in the CISM courses or to refuse. Altogether, 75 peers went through the following ICISF certified training courses CISM group crisis intervention, CISM individuals and peer support, as well as CISM advanced.

In addition, supervision groups are provided for the peers and the so-called CISM Forum, a conference of all DFS peers, is held once a year. At regular intervals, a peer-debriefing is conducted at every DFS unit. Thus, the peers are supported and the quality of their work is maintained.

The peers help their colleagues to cope with the stress responses caused by critical incidents which can heavily impair work performance. Especially the following task requirements can be impaired: Decision making, concentration, identifying known persons or objects (aircraft), memory, decisiveness.

Referring to the self-conception of a controller, these stress reactions cause significant irritations. The professional and the personal self-conception are endangered. The ATCO newly experiences decision-making problems, is unsure and retentive in his actions while he usually was quick, self-confident and clear. Self-doubts and a feeling of abnormality are the consequences. The first step of a successful coping is to stabilise and find back to normal. Apart from the help of a peer a second requirement therefore is the quick and sustainable re-establishment of personal abilities and working fitness. This is in line with the objectives of the ICISF-CISM programme to reduce stress reactions, to restore the ability to work and to avoid post-traumatic stress disorders (PTSD).

Restoring the ability to work is important in the coping process of the individual but it can also be seen as an economic target. Apart from the intangible benefit of an improved safety culture, the mentioned business benefit is one of the main results of the study reported here.

Method and material

Three radar centres were selected for the data gathering: Bremen, Munich, and Karlsruhe. In Bremen, three peers volunteered for a face-to-face interview, six in Munich and four in Karlsruhe. After the interview, the peers were asked to distribute questionnaires among the controllers. A total of forty-seven controller questionnaires and thirteen peer interviews comprised the data basis for the study. Moreover, the manager who introduced the CISM programme in the DFS was interviewed, especially with respect to the implementation and costs of the programme.

Karlsruhe was different in some respects to the other two centres: The accident of Lake Constance at Überlingen affected many controllers in Karlsruhe who saw the catastrophe coming and tried very hard to warn their Swiss colleagues. Two Karlsruhe peers were members of the CISM team sent to Switzerland to treat the Swiss control employees. The Lake Constance mid-air collision, therefore, had a great impact in Karlsruhe and probably more than in the other centres demonstrated the absolute necessity of CISM. This is most probably one reason for the high commitment of Karlsruhe controllers to the programme and the evaluation study which manifested in the high number of questionnaires filled in by Karlsruhe ATCOs (26 of 47).

The peers were instructed to deliver questionnaires to ATCOs and to include both, controllers who had a CISM consulting („CISM-group") and those who had not („non-CISM-group"). Apart from this preposition, they were asked to randomly distribute the questionnaires and to spread them widely with regard to the demographic characteristics of the controllers and the experienced incidents. Both groups used the same questionnaire, in which they among other questions also described a critical incident they experienced and the factors that contributed to recovery. The group-wise comparison only served to demonstrate the differences between controllers who requested CISM after an incident and colleagues who did not. The two groups were expected to be different in many respects and therefore the non-CISM-group is no control group for CISM effects. The expected difference CISM makes must be obtained within the CISM-group.

Both, open and scaled questions were used in the instruments. Open questions concerning for example the perceived aims of the CISM programme were post-hoc categorised with an inter-rater agreement above 94%. Most scaled questions, for example the grade of goal achievement of the CISM programme, were obtained with a German five point scale according to Rohrmann (1978). Rohrmann proved the five steps of the scale to be equally distant and usually normal distributed, which allows for statistical operations like averaging or significance testing. However, the results reported here will be confined to descriptive statistics.

Apart from questions to be answered in Rohrmann steps, percentages, days (of e. g. illness and recovery) or other units, the study instrument also contained items derived from standard questionnaires:

1. Ability requirements which are defined in the Fleishman Job Analysis Survey (Fleishman & Reilly, 1992) and play an important role in the selection process of German air traffic controllers (Deuchert & Eißfeld, 1998). The study subjects were asked to what extent (in Rohrmann steps) task requirements like originality, problem sensitivity, perceptual speed, selective attention, multi-tasking, motivation, self awareness, and stress resistance were impaired after the critical incident.

2. Psychosomatic ailments which are used for example in the Gießener Beschwerdebogen (Brähler & Scheer, 1983) or in the ICISF symptom checklist. Symptoms like drowsiness, intrusive memories, anxiety, flashbacks, emotions of guilt, and upset were rated on a five point scale from "did not occur" to "occurred strongly" after the incident.

Main results

The CISM-group reported a greater temporary impairment of abilities (without questioning the primary ability to work as a controller) such as stress resistance, self awareness, multi-tasking, speed of perception, and motivation (Table 3).

Table 3 also shows the experienced psychosomatic symptoms in both groups: Again, the reactions in the CISM-group were more intense than in the non-CISM-group. Especially intrusive memories, flashbacks, and feelings of guilt were more reported by controllers, who – certainly also due to these symptoms – requested a CISM-consulting.

Table 3 Mean self-reported impairment of abilities and psychosomatic symptoms after a critical incident for controllers who then requested CISM compared to those who did not

	Impaired Abilities (Mean Rating; 1 not at all, 5 extremely impaired)							
	Originality	Problem Sensitivity	Perceptual Speed	Selective Attention	Multi-Tasking	Motivation	Self Awareness	Stress Resistance
CISM	2.1	2.2	2.5	2.5	2.7	2.3	2.9	3.1
Non-CISM	2.1	2.0	1.8	2.1	1.9	1.9	2.1	2.1

	Psychosomatic Symptoms (Mean Rating; 1 did not occur, 5 occurred strongly)					
	Drowsiness	Intrusive Memories	Anxiety	Flashbacks	Emotions of Guilt	Upset
CISM	2.2	3.0	2.4	2.7	2.5	2.7
Non-CISM	2.1	2.4	2.1	1.8	1.9	2.6

The benefits for the DFS safety culture and the goal achievement of the programme were rated very high (Table 4). Both, the group who consulted a peer after a critical incident as well as the non-CISM-group saw the better supervision of their work as the main component of the improved safety culture. One third of the peers mentioned plainly the advances in error culture as the main improvement. In case of the non-CISM-group, the mere presence of peers and the opportunity to consult them seems to be effective, even if this opportunity was never used. Moreover, every employee in the DFS profits from the improvement in the culture of handling personal failures.

Table 4 Improvements in the safety culture through CISM and goal achievement in the view of peers and controllers who requested CISM after a critical incident compared to those who did not

	Improvements in the DFS Safety Culture through CISM (Percent)						
	Willingness to talk	Better Supervision	Error Culture	Open-Mindedness	Acceptance of Emotions	Fit for Work	No Improvements
CISM	--	46.7	6.7	6.7	20.0	13.3	6.7
Non-CISM	7.1	42.9	28.6	--	7.1	7.1	7.1
Peer	16.7	8.3	33.3	16.7	8.3	--	16.7
	Perceived Goal Achievement of CISM in the DFS (Mean Rating; 1 not at all, 5 extremely well achieved)						
	Supervision	Coping	Consulting	Prevention	Fit for Work	Communication Culture	Other
CISM	4.3	--	4.0	4.4	3.0	4.2	4.3
Non-CISM	4.4	4.3	4.0	4.7	4.5	3.5	4.6
Peer	4.9	5.0	4.2	4.8	5.0	4.4	4.3

The goals that were reported for the DFS CISM programme were rated very well achieved (last row of Table 4).

In summary, the improved safety culture and the goal-achievement reflects the total intangible benefit of the DFS CISM programme. It was further investigated whether the monetary benefits of the programme can be estimated in order to convince the management of other organisations to introduce something similar. Since the controllers reported a CISM induced acceleration of their return to work after the critical incident, the business benefits could be calculated on the basis of gained controller days. In a conservative calculation which considered the pilot character of the study, the return on investment was estimated about 250%. Thereby, the DFS CISM programme had amortised in the five years between implementation and evaluation study.

CONCLUSIONS

The current state analysis has shown that DFS maintains and develops a variety of safety instruments and thereby ensures the highest standard of air traffic safety in Germany. This is important because in contrast to the traditional view, where occupational health and safety activities protect employees while they produce something else, safety *is* the main product of air traffic control services.

Moreover, air traffic controllers are the main production factor. Considering their workload is therefore another central aspect of safety management. Several studies proved the number of aircraft under control and potential conflicts between them the main workload factors. Pilot errors, climbing and descending aircraft also can cause stress responses but they are less important than the former two. The number and length of breaks should be aligned with these traffic features in the specific airspace. Moreover, it makes sense to also consider the staffing and the state of engineering of the human-machine-interface at a certain unit. A well-staffed work surrounding and technological support can compensate increasing levels of workload (Vogt et al., 2002). All these factors are considered in the DFS work agreements and ATCOs controlling for example the busy Frankfurt airspace are getting more breaks than their colleagues with less workload elsewhere.

Not only the number of breaks, also their quality can contribute to stress and safety management. It was shown that an active relaxation instruction facilitates a normalisation of heart rate after work. Moreover, the enhanced recovery prevented safety problems in the following work situations. Like DFS other employers in safety-critical work settings should make the active relaxation training available to their employees.

In case the mentioned precautions taken by safety instruments, optimised workload and recovery cannot prevent a critical incident like a separation loss between aircraft, it is important to help the involved employees to cope with the exceptional stress. The DFS CISM programme provides quick and professional support by qualified peers and thereby prevents posttraumatic stress disorders. Moreover, the sustainable recovery of work abilities and the lessons learnt from the incident prevent future problems. Finally, a general improvement of the anyway existent good safety culture could be proven: People talk more about critical incidents in a less blaming fashion and thus learn from experience. This improvement of safety culture and professionalism is of extreme value.

The studies have shown that the benefits of the DFS initiatives are high for both, employer and employees. The controllers appreciate the quick, professional and dedicated support and supervision in safety and stress issues which help them coping with their work. The organisation benefits from the enhanced and sustained fitness for duty of the employees, from increased work motivation, higher productivity and efficiency in general, an accelerated and secured return to work after critical incidents in particular. This pays off also monetarily as demonstrated in case of the DFS CISM programme which had a return on investment of about 250%.

All initiatives reported here significantly contribute to air traffic safety in Germany. Due to the manifold positive effects the efforts will be continued and enforced. An emphasis is put on the comprehensive view facilitating synergies between the initiatives.

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