CBAQ: DEVELOPMENT OF CRM BEHAVIOR ANALYSIS METHOD FOR MISSION FLIGHT CREW TRAINING

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Abstract

Crew Resource Management (CRM) training is considered to be one of the most effective methods for reducing human errors or minimizing their effects. The CRM Behavior Analysis Questionnaire (CBAQ) was developed to detect threats and errors affecting "mission" flight operations such as rescue and patrol, and to identify essential factors by introducing CRM skills behavioral markers. About six hundred mission flight crew members took part in this study, and the CBAQ responses collected, which included 5,000 items of text data, were analyzed by a combination of text and data mining methods. The results of the study provided strong evidence for the reliability of the CBAQ, and have been incorporated into a new mission flight crew CRM training program.

1 Introduction

More than 55% of aircraft accidents have been attributed to crew-related actions, namely human errors, and a lack of CRM skills has been a contributing factor in many of these. In Japan, CRM training has been mandatory for scheduled commercial transport flight crews since 1998 because of its effectiveness in reducing accidents caused by human error.

However, it has hitherto been difficult to introduce CRM training into organizations that carry out "mission" flights, such as search, rescue and maritime patrol, because it is difficult for such organizations to design CRM training programs on their own. Although some mission crews have participated in airline CRM training to gain knowledge to develop their own programs, airline programs are not entirely suitable because they are designed for scheduled commercial transport operations and some basic CRM elements, e.g. mission, threats affecting normal flight and CRM skills behavior markers [1], are quite different from those in mission operations.

In order to design CRM training that can be tailored to the specific mission operations of different organizations, we developed a CRM behavior analysis questionnaire (CBAQ) to identify threats and human errors in normal mission flights and to detect essential CRM skills.

About six hundred mission flight crew participants took part in this study and the CBAQ responses collected, including 5,000 items of text data, were analyzed by a combination of data and text mining methods using a text mining tool [2].

This paper describes the CBAQ, the analysis method, and results obtained from the collected CBAQ response data.

2 CRM Behavior Analysis Questionnaire (CBAQ)

The CBAQ is a self-administered questionnaire; that is, instead of observation by a third party, a participant records his own experiences during mission flight. As shown in Figure 1, the CBAQ format consists of a list of "positive" and "negative" CRM behavior factors regarding one's own and other crewmember behaviors, the mission phases in which they can occur, and an area for recording free text

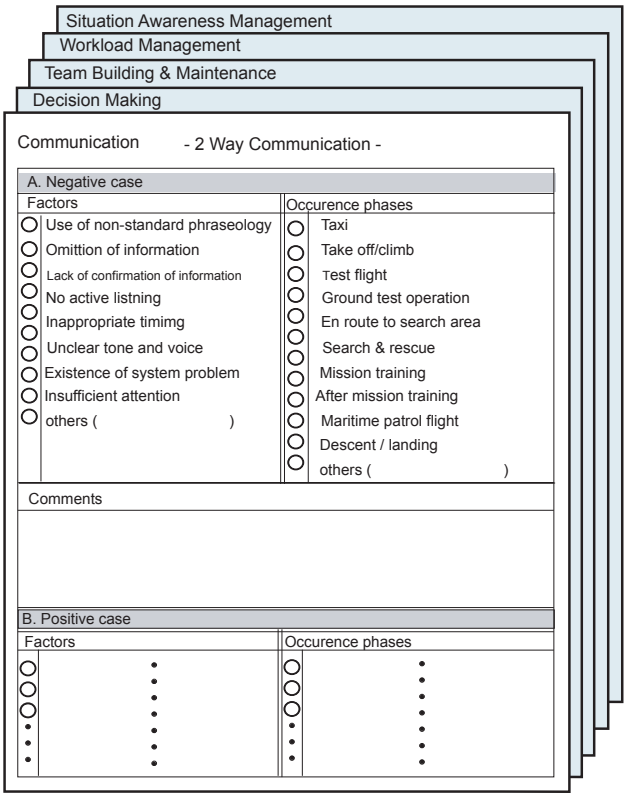

Figure 1 Part of CBAQ

comments about concrete CRM cases. The factors were obtained by extracting CRM behavior attributes from JAXA's CRM skill behavioral markers for airline flight crews [3] as shown in Figure 2, and for maritime self-defense force flight crews [4]. The negative case factors are shown in Table 1. Mission flight crews also indicated the phases in which the factors occur ("occurrence phases") as shown in Fig. 1.

3 Analysis Method

The negative and positive CRM behavioral factors (grouped by communication, decision making, team building and maintenance, workload management and situational awareness management) recorded by about 600 participants were analyzed from the collected CBAQ data. The analysis method is briefly described as follows.

(1) Estimation of CRM cluster and elements

The JAXA CRM skills were categorized by CRM cluster and element shown in Figure 2. If there was an uneven distribution of skills between the clusters or elements derived from the collected CBAQ data, the categorization was reconsidered. Moreover, we identified skills that were specifically required in each occurrence phase.

(2) Estimation of behavioral markers

"Ranking analysis" using a text mining tool [2] was conducted in order to estimate behavioral markers. The ranking analysis generates a list of factors which subject mission flight crews selected, ordered by percentage.

(3) Estimation of "Threats"

"Cluster analysis" and "abstract map analysis" using a text mining tool [2] brings out the threats. Cluster analysis groups these according to similarity of subject, and abstract map analysis extracts frames of concept by connecting text items that have a high degree of similarity.

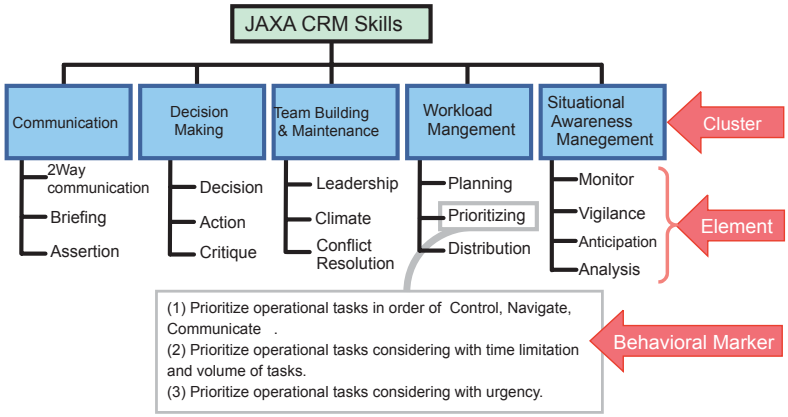

Figure 2 JAXA CRM Skills

Table 1 The Factors of negative cases in CBAQ

Communication		
Two-Way Communication	Briefings	Assertion
- Use of non standard phraseology - Omission of information - Lack of confirmation of information - No active listening - Inappropriate timing - Unclear tone and voice - Intercom fault - Insufficient attention	- Briefings becoming routine - Insufficient time of briefing - No opportunity for briefings - Inappropriate briefing method and content - No active participation in briefings	- Hesitation in speaking up if you have question - Not verbalizing ideas, opinions or recommendations frankly - Lack of assertiveness on issues you think bear a higher degree of risk
Decision Making		
Decision	Action	Critique
- No establishment of "Bottom Lines" for safety - Non-participative decision making - Non-objective decision making	- Not confirming decision - Not acting on decision	- No review when carrying out decision - No review after carrying out decision - Inappropriate contents of review
Team Building &Maintenance		
Climate	Leadership/Followership	Conflict Resolution
-No open atmosphere in the cabin - Inappropriate relationship - Inappropriate authority gradient - Inappropriate crewmember's motivation	- Unclear intention - Lack of Leadership or Followership	- Having too much confidence in oneself - Conflict of opinion leads to conflict of feeling. - Subjective analysis - Undesirable communication
Workload Management		
Planning	Prioritizing	Distribution
- Insufficient preparation and planning - Not taking sufficient time - Depending on wishful thinking	- Insufficient understanding of prioritizing - Prioritization not based on "Fly first" - Prioritizing without recognizing the time constraints and requirements of the task	- Ineffective task distribution and redistribution - No monitoring of crew performance - Ineffective task allocation to automated systems
Situational Awareness Management			
Monitor	Vigilance	Anticipation	Analysis
- No sharing of awareness of the situation inside or outside of the cockpit - No sharing of system mode awareness	- Point concentration (fixation) - Complacency	- No anticipation of future situation - No anticipation of threats	-Not using a resource sufficiently -Insufficient objective analysis - Failure to create a climate allowing free communication

If the authors could not understand the meaning of an item of text identified by cluster analysis, the authors referred to the raw text data.

(4) Define behavioral markers

Behavioral markers were developed as the threat-management behaviors extracted by (2) and from analysis of positive CRM cases.

(5) Select typical example of positive and negative cases

Typical positive and negative behaviors were selected as example behaviors for each behavioral marker as shown in 4.4.1-(1). For example, positive case and negative cases were selected from text items of collected CBAQ data.

4 Results

4.1 Estimation of CRM cluster and elements

The overall results of the CBAQ are shown in Figure 4. The horizontal axis shows the amount of negative CRM behavior factors collected from the CBAQ. As shown in Fig. 4, since the CRM skills are uniformly distributed between the clusters and elements, the same definitions for CRM cluster and elements were adopted as for the JAXA CRM skills as shown in Fig. 2. The percentage of occurrence phases for each of the CRM skill elements are shown in Figure 5. As is apparent from the Fig. 5, the percentage of mission flight, "Patrol flight" and "Search and rescue", are larger than those of another occurrence phases. These indicate that CRM behavioral markers and cases should focus on mission flights.

4.2 Estimation of behavioral markers

An example ranking analysis result for "Vigilance" in the "situational awareness management skills" cluster is shown in Figure 6. As shown in Fig. 6, each flight crew selected "Complacency" first and "Point concentration" second. This indicates that behavioral markers for "Vigilance" should be developed in order to avoid complacency and point concentration behaviors.

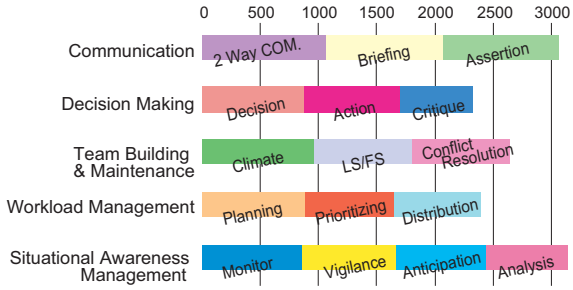

Figure 4 Totalized CBAQ results

Note COM: Communication,

LS/FS: Leadership / Followership

4.3 Threats

The "threats (factors for induced human errors)" identified from the results of text mining are shown in sections 4.3.1–4.3.5 below. Examples of "Cluster analysis" results for "Vigilance" in negative cases are shown in Figure 7 and Table 2. Table 2 derives estimated factors of "point concentration" which correspond to the threats and countermeasures which form the basis of the behavioral markers constructed from the "Cluster analysis" result as shown in Fig. 7.

4.3.1 Communication Skills

(1) Two-Way Communication

- Radio confusion
- Inappropriate timing
- Similar-sounding words (e.g. "kouka" (descent) and "touka" (drop) in Japanese)
- No response
- Prejudice
- Differences in motivation, experience and situation awareness
- Idea of "Skills should be obtained by own observation" (no communication)
- Unable to control the intercom system
- Variations in standard phraseology between operating bases
- Squaring up against other crewmember
- Harsh tone and quick voice reveals if there is no margin
- Omission of information
- Rapid-fire orders

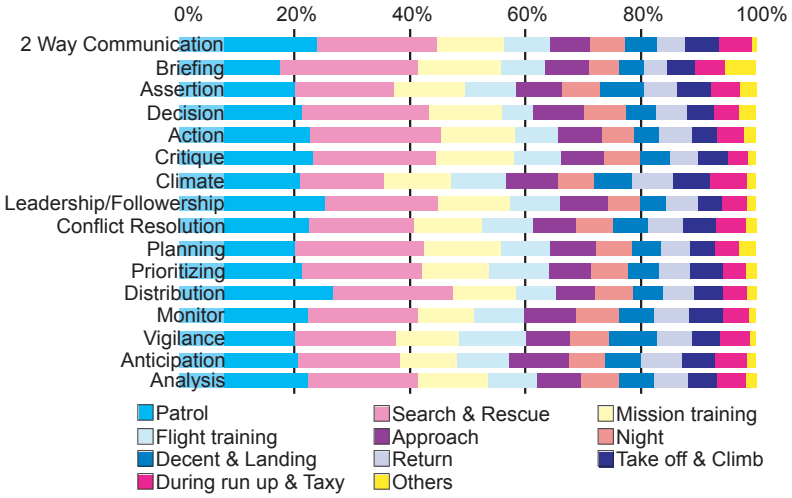

Figure 5 Distribution of occurrence phases of each CRM Skill element

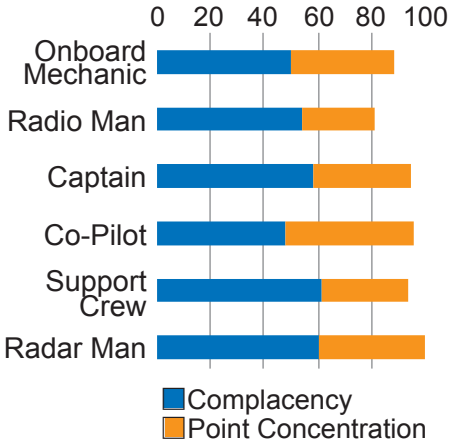

Figure 6 Ranking analysis result for "Vigilance"

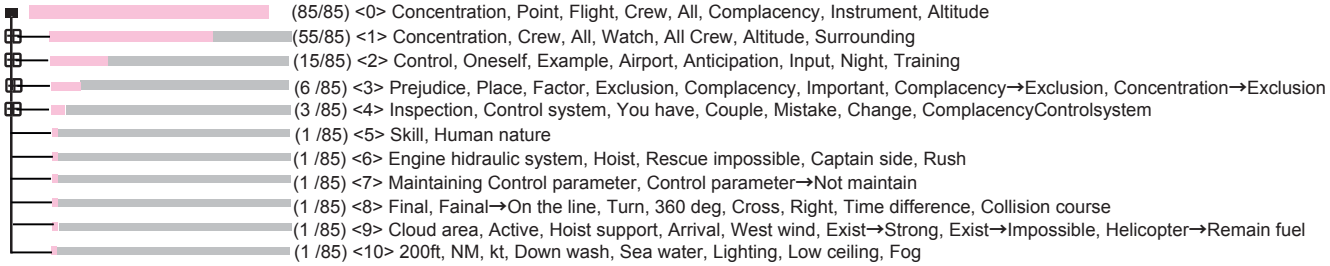

Figure 7 Cluster analysis result extracting "point concentration"

(2) Briefing

- Time pressure
- Low motivation for briefing
- No briefing for potential risk factors
- Failing to understand the contents of the briefing due to hurriedness

(3) Assertion

- Steep authority gradient
- Differences in knowledge, skills and experience
- Lack of confidence
- Unconcerned crew
- Even if I don't speak up, we will probably be safe
- Missing timing of assertion
- Reserve
- Tension
- Fear that may be unable to rely on other crewmember
- Fear of uncomfortable atmosphere
- Fear of radio confusion

4.3.2 Decision Making Skills

(1) Decision

- Bad weather
- No common awareness of when aircraft must turn back
- Unconcerned crew (loss of CRM team concept)
- Non-talking crew member
- Egoistic crew member
- Neglecting crew member's advice
- Lack of confidence
- Following experienced leaders and crew members
- Lack of experience
- Team member's lack of attitude

Table 2 Factor of advancing "point concentration" and Measure

Text of cluster analysis	Estimation Factor	Cases	Countermeasure
Concentration	High workload No recheck		Create behavioral markers for "Distribution" of "Workload Management"
All crew Concentration Watch	All crew concentrate on the mission and neglect keeping watch.	- Object on the sea - Problem has occurred - Sudden rescue - Ship search - Search at night	Create behavioral markers for "avoidance of point concentration"
Control Training	- Beginning of flight training - During instrument flight training	Fully attended control at the beginning of flight training	
Control Night	- Night flight	Flying visually as in daylight causes difficulties at night (e.g. vertigo) due to greatly reduced visual information	Create behavioral markers for "avoidance of complacency"
Oneself	Having too much confidence in oneself	Having no doubts about own thinking	Create behavioral markers for "Avoid complacency and confirm situational data thoroughly"
Aerodrome	Lack of experience of a particular aerodrome		Create behavioral markers for "avoidance of complacency"
Prejudice	Highly experienced expert		ditto
Place Complacency	Similar place name		ditto

- Up to the ears in each task
- Pressure from other crew member and base
- Speaking up is useless by tacit agreement
- Fatigue
- Conducting mission aimlessly
- Fixation on carrying out the mission
- Lack of information
- Loss of leadership
- Many kinds of choices
- Using individual emotions

(2) Action

- Saying "Yes" without understanding decision
- Individual decision-making
- Making a decision alone and not telling the crew
- Uncertain confirmation
- Unable to confirm final decision due to radio confusion
- Prejudice as to what other crewmembers understand
- Low skills and high workload
- No confirmation of decision
- Lack of explanation

(3) Critique

- Once you decide, you don't review the decision
- No time margin
- Take the first decision as being correct
- Persistence in first decision
- In case of successful, there is no review

4.3.3 Team Building & Maintenance Skills

(1) Climate

- No friendship between crewmembers
- Coercive attitude
- Steep authority gradient such as between officers and non-officers
- Senior crew unconcerned about crew coordination
- Not listening and not permitting crew to talk
- Shouting at crewmember who commits an error
- Selfish captain
- Crew has no motivation for the mission or learning
- Taciturn crew
- Crew is in bad mood

(2) Leadership/Followership

- Hesitation to state own intentions
- Lack of correct words for conveying intentions clearly
- Insufficient experience and knowledge
- No concrete order
- Order spoken in a quiet voice
- Lack of CRM team concept
- Absence of followership

(3) Conflict Resolution

- Pushing through own opinion
- Oppressive opinion
- Young crew holds back own opinion
- Passive attitude (I only follow you)
- Bad atmosphere
- Bad human relationships
- Judgment in only own experiences
- Steep authority gradient such as captain and rank
- Non-talking crew member
- Crew is in bad mood
- Not listening other crew member's opinion
- Judgment based on individual like or dislike

4.3.4 Workload Management Skills

(1) Planning

- Insufficient preparation and planning
  - Emphasis on response time
  - No time in case of sudden event
  - Insufficient checking of weather
- Wishful thinking
  - Things will work out.
  - Prejudice that weather will be good
  - Take good weather on trust because weather on departure was good
  - Prejudice that I can land easily because I have experiences many times of landing
- Sudden change
- Underestimation of planning
- Inadequate task distribution
- I have to hurry
- Insufficient briefing
- Lack of information
- Weather change suddenly

(2) Prioritizing

- No understanding of prioritizing in a team
- Confusion due to many considerations
- Difference of awareness between commander and other crew
- Inexperience in prioritizing
- Misunderstanding between crew in the air and headquarters staff on the ground
- Neglecting "Fly First" due to concentration
- High concentration on procedure
- High concentration on briefing
- High concentration on mission
- High concentration on Flight Management System (FMS) input
- Missing important task

(3) Distribution

- I can manage the task alone
- Insufficient briefing
- Not monitoring crew performance
- Allocating work only to a certain group
- No team motivation
- No consideration of prioritizing
- Own workload is high
- Inappropriate allocation of tasks to automation
- Point concentration

4.3.5 Situational Awareness Management Skills

(1) Monitor

- I can ill-afford to monitor
- Difference of awareness between crew members
- Hesitation to report
- Insufficient experience and knowledge
- Night flight
- Coercive attitude
- Complacent assumption that other crew members understand

- Complacent assumption that I already entered the data into the FMS
- Non-confirmation of FMS input and mode changes
- Insufficient briefing
- Neglecting other crew member
- "Hurry up" syndrome
- Not adhering to standard procedures and call outs
- Not sharing knowledge of flight status with other crewmembers
- Point concentration
- Carelessness

(2) Vigilance

- High concentration on mission
- Complacency that mission is easy
- Weather in departure area is good
- Insufficient experience
- Excessive fatigue/low thinking ability
- Feeling of security having completed mission
- High workload
- Placing too much confidence in oneself and others
- Lack of information
- Having prejudice from an advance information
- Night flight
- Inexperienced airport
- Similar place-name
- Mode Confusion (Pilot)

(3) Anticipation

- Inadequate consideration of weather
- High workload
- Insufficient experience
- Sudden bad weather
- Difference of awareness between crew members
- Lack of situation awareness among team
- Orientation
- Unclear patrol ship motion
- Unclear mission motivation
- Complacency
- Optimistic thinking
- Insufficient investigation of threats

(4) Analysis

- Steep authority gradient
- Subjective judgment of information
- Emotional disturbance
- Time constraint
- High workload
- Optimistic thinking
- Complacent assumption and not listening to other crewmembers' advice
- Complacency
- Insufficient investigation
- All necessary information will follow later
- An available resource is not coming
- Not using an available resource

4.4 Behavioral Markers

Behavioral markers derived from analysis 3-(4) are shown as 4.4.1–4.4.5. Lack of space does not allow us to present all the behavioral markers added to typical positive and negative case selected from text items of CBAQ data.

4.4.1 Communication Skills

(1) Two-Way Communication

- Don't shorten a message, and deliver it accurately.

Typical positive case

Don't make assumptions about a crewmember's skill and behavior and don't shorten a message, and deliver it accurately.

Typical negative case

When the co-pilot advised the captain for avoidance of other traffic, he said "base is ~~direction", because "A base" was nearby. However, there was also a "B base" nearby, and the captain misunderstood the co-pilot's advice and mistook the direction.

- Confirm that a message has been accurately communicated.
- Communicate messages to other crewmembers clearly, at an appropriate speed.
- Communicate messages to other crewmembers in appropriate timing.
- Use standard phraseology.
- Communicate messages accounting for Inter Communication System (ICS) characteristics.
- Use body language to enhance understanding.
- Listen actively.
- Confirm understanding.

(2) Briefing

- Create opportunity for briefings that include various scenarios.
- Create sufficient time for briefings.

- Brief main points concisely.
- Confirm the contents of mission and procedure with all crewmembers.
- Brief what you estimate the situation to be.
- Brief routine issues for confirmation.
- Emphasize the importance of questions and the offering of information in the briefing.
- Explain concretely in briefings if there are deviations from usual procedures.
- Take account of other crew members' knowledge and explain special points to be aware of for a particular flight operation.
- Participate in the briefing actively.

(3) Assertion

- Don't hesitate to speak up and ask a question.

Typical positive case

Don't assume that the captain must know what he is doing when carrying out a task; don't overlook it but speak up if you have a question or problem.

Typical negative case

Since I thought we were probably O.K., I delayed discovery of the bad condition.

- Verbalize ideas, opinions or recommendations to enhance safety.
- Be more assertive for issues involving higher degrees of risk.
- Respond actively to other crewmembers' statements.

4.4.2 Decision Making Skills

(1) Decision

- Establish the "Bottom Lines" for safety.

Typical positive case

During a patrol flight in winter, since we decided that we would return if we encountered strong snow, we turned back while en route.

- Use other team members' opinions.

Typical negative case

In the case of a difficult hoist mission, the captain alone judged the hoist performance and did not ask the hoist operator's opinion.

- Participate in decision-making
- Consider the merits and demerits of alternatives and make a decision that matches the objective.

(2) Action

- Present operational decisions to other crewmembers and confirm their understanding.
- Understand each crew member's task and execute the task.

(3) Critique

- Review a decision or action as long as possible.
- Review a decision just after it has been made.
- Consider whether the team's behavior was optimal or not when taking action.
- Accept the results of the process openly.
- Deal with positive as well as negative aspects of team performance.

4.4.3 Team Building & Maintenance Skills

(1) Climate

- Recognize the influence of your own behavior on team performance.
- Don't bring a bad atmosphere on the ground into the cabin in the air.
- Monitor team performance and maintain an optimum environment.
- Encourage the other crewmembers to speak up and ask questions.
- Express confidence in other crewmembers.

(2) Leadership

- State your intention clearly.
- Help the team effort with foresight.

(3) Conflict resolution

- Don't create a conflict of feeling from a conflict of opinion.
- Don't put too much confidence in oneself in own rank and experience, but analyze objectively.
- Focus on "What is right?" not "Who is right?"
- Base your opinion on objective analysis, and don't hesitate to change your opinion as indicated.

4.4.4 Workload Management Skills

(1) Planning

- Confirm what you should decide at least and anticipate threats.
- Create time for advance preparation

Typical positive case

Create time to prepare while en route to the search area, etc.

- Prepare for high workload phases of flight during low workload phases.

- Don't depend on wishful thinking.

(2) Prioritizing

- Confirm prioritizing in the team.
- Prioritize based on "Fly first".
- Prioritize by recognizing the time constraints and the requirements of the task.
- Prioritize according to the urgency of tasks.

(3) Distribution

- Distribute tasks so that everyone's time is utilized while no one is overtaxed.
- Monitor your own performance and that of other crewmembers.
- *Use automated systems as a task distribution resource.*

4.4.5 Situational Awareness Management Skills

(1) Monitor

- Monitor the situation inside and outside the cockpit and share the information.
- *Verbalize all initial entries and changed entries to the Flight Management System and autopilot.*

(2) Vigilance

- Verbalize own thinking and what you try to do.
- Confirm crew's task distribution.

Typical negative case

Both of the two-man cockpit crew carried out the same task, resulted neglecting visual watch. In this case, a bird appeared in front of the aircraft and they had to hurry to avoid it.

- Brief on how to deal with situations that may lead to point concentration beforehand.
- Avoid complacency and confirm situational data thoroughly.
- Confirm and indicate if you feel something to strange.
- *Disengage automated features at once and reset your situational awareness if you feel something may be amiss.*

(3) Anticipation

- Anticipate the future situation based on the present situation and confirm the anticipated situation with the team.
- Anticipate the potential risks in different scenarios.

(4) Analysis

- Use a variety of resources to collect information.
- Analyze the situation objectively, based on the information gathered.

5 Discussion

This study provides empirical evidence for the effectiveness of a combination of data and text mining of collected CBAQ data. CBAQ was designed as a tool to extract threats, to develop CRM skills behavioral markers, and to select typical negative and positive behavior cases. If our questionnaire had comprised only text items, it would have been difficult to extract threats and to create behavioral markers.

Since a text mining tool only visualizes text items, an intelligent approach and experience are required. In the future, it is considered that more intelligent text mining is necessary for developing non-technical skills training.

6 Conclusion

This study has proposed a CRM Behavior Analysis Questionnaire (CBAQ) as a useful tool for designing CRM training programs tailored to the specific needs of organizations conducting mission flights. By analysis of the data collected by CBAQ using a combination of text and data mining methods, threats and errors affecting mission flight have been identified and, at the request of a participating organization, new CRM skills behavioral markers for its crews have been developed. The study provides strong evidence for the reliability of the CBAQ, and the results have been incorporated into the organization's new CRM training program.

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