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The Identification of Training Needs for Developing Aeronautical Decision Making Training Programs for Military Pilots

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THE IDENTIFICATION OF TRAINING NEEDS FOR DEVELOPING AERONAUTICAL DECISION MAKING TRAINING PROGRAMS FOR MILITARY PILOTS

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This research applies Human Factors Analysis and Classification System (HFACS; Wiegmann & Shappell, 2003) analyzing aviation accidents in the R.O.C. Air Force between 1978 and 2002 in order to identify the training needs of aeronautical decision-making (ADM). There were 523 accidents associated with 1762 human errors. The results indicated that decision errors had been involved in 223 (42.6%) accidents. Without in-depth analysis of decision errors in military aviation, it is unlikely to identify precisely the training needs of ADM and the nature of the training content required to prevent the decision errors in aviation (Patrick, 2003). This research found that 'decision-errors' has significant association with lieutenant pilots and at landing phase, and pilots at the rank of 'cadet' (experience) flying 'training aircraft' (tools) practicing 'close pattern' (missions) at 'landing phase' (working environment) with the highest probability of accidents. It is important to understanding the junior pilots were very vulnerable to the decisions and supervisions made by high-level management. As Dekker (2001) described that human errors is systemically connected to the tools, tasks, and operational and organizational environment of operators, it is important to clarify the role of decision errors in pilot's tools, tasks, experience, and operating environment in military aviation in order to develop effective ADM training programs for military pilots.

Introduction

Identification of ADM Training Needs

Decision making performance in the aviation domain is a joint function of the features of the tasks and the pilots' knowledge and experience relevant to those tasks (Orasanu & Connolly, 1993). Orasanu (1993) has pointed out that no evidence exists to support the development of training techniques to improve all-purpose decision making skills. There are six different component skills involved in the six different types of decisions.

For improving aviation safety, it is important to identify the training needs for ADM. The Interservices Procedures for Instructional System Development (IPISD, Branson et al., 1975) was developed in the context of US military training. The intention was to disseminate principles concerning the development of training programs. The IPISD model divided the development of training into five main phases: analyze, design, develop, implement and control. Without accurate analysis, it is not possible to identify the ADM training needs and the content of training programs required for preventing aviation accidents. There are two general types of analysis techniques: task analysis which is used in training development for analyzing the knowledge, skills, and attitudes required by the operator in order to execute the task efficiently, and error analysis which focuses on errors in task performance (Patrick, 2003). Both analysis techniques can help to identify training needs and training content. The first type of task analysis is described as a traditional form of job/task/cognitive analysis. It breaks down work into a series of subtasks that have to be accomplished in a logical fashion. The second type, error analysis, is used to identify where training can be profitably directed for curing weaknesses. Dekker (2001) has proposed that human errors are systematically connected to features of the operators' tools and tasks, and error has its roots in the surrounding system. Analyzing incidents or accident reports can obtain a great deal of valuable information for identifying training needs for subsequent training to mitigate human errors.

Human Factors Analysis and Classification System

HFACS is a generic human error framework originally developed for US military aviation as a tool for the investigation and analysis of the human factors aspects of accidents. HFACS is based on Reason's (1990) system-wide model of human error in which active failures are associated with the performance of front-line operators in complex systems and latent failures are characterized as inadequacies or mis-specifications which might lie dormant within a system for a long time and are only triggered when combined with other factors to breach the system's defenses. These latent failures are spawned in the upper management levels of the organization and may be related to manufacturing, regulation and/or other aspects of management. As Reason (1997) noted, complex systems are designed, operated, maintained, and managed by human beings, so it is no surprising that human decisions and actions are implicated in all organizational accidents.

HFACS examines human error in flight operations at four levels. Each higher level affects the next downward level in HFACS framework.

- Level-1 'Unsafe acts of operators': This level is where the majority of causes of accidents are focused. Such causes can be classified into the two basic categories of errors and violation. Decision-errors are in this level.
- Level-2 'Preconditions for unsafe acts': This level addresses the latent failures within the causal sequence of events as well as more obvious active failures. It also describes the context of substandard conditions of operators and the substandard practices they adopt.
- Level-3 'Unsafe supervision': This level traces the causal chain of events producing unsafe acts up to the front-line supervisors.
- Level-4 'Organizational influences': This level encompasses the most elusive of these latent failures, fallible decisions of upper levels of management which directly affect supervisory practices, as well as the conditions and actions of front-line operators (Shappell & Weigmann 2001; 2003 & 2004; and Weigmann & Shappell 1997; 2001a; 2001b; 2001c & 2003).

Between 1996 and 2000, the Republic of China (R.O.C.) Air Force converted from the F-104 to a series of new generation fighters including F-16, Mirage 2000-5 and the self-developed IDF. To improve flight safety, R.O.C. Air Force Headquarters investigate the pattern of mishaps annually. The findings are that accidents attributable solely to mechanical failure decreased markedly in the recent years, but the contribution of human error has declined at a slower rate. Jensen and Benel (1977) found that decision errors contributed to 35% of all nonfatal and 51% of all fatal general aviation accidents in the United States between 1970 and 1974. Diehl (1991) following Jensen and Benel's research found that decision errors contributed to 56% of accidents in airlines and 53% of accidents in military aviation between 1987 and 1989.

In order to improve aviation safety there is a need for military pilots to be trained in making decisions related directly to the specific tactical environment. However, there is no research on the identification of training needs for aeronautical decision-making (ADM) and for developing the content of training programs for military pilots in the R.O.C. Air Force. This study applies the Human Factors Analysis and Classification System (HFACS) for analyzing human factors accident data from the R.O.C. Air Force. For developing effective ADM training programs, it is necessary to understand the association of decision errors with pilots' tools (aircraft), tasks (missions), ranks (flying experience), and flight stages (environment).

Method

Data

The data were comprised of the narrative descriptions of accidents occurring in the R.O.C Air Force between 1978 and 2002. In total, the complete data set comprised 523 accidents in this 25 year period.

Demographic Variables

This investigation analysed each accident using the following demographical variables.

1. Type of aircraft: the types of aircraft involved in accidents included fighters (F16, M2000, IDF, F104, F-5, etc.), cargo aircraft (B1900, C130, C123, C47, etc.), and training aircraft (AT3, T34, etc.).
2. Missions: accidents occurred when pilots' were performing missions that included air interception, air combat tactics, instrument flight, cross country, transition, surface attack, close pattern, test flight, and exercise.
3. The flight stages in which accidents occurred included: taxi before take-off, take-off, climb-out, flight in the operational area, decent, approach, landing and taxi after landing.
4. The ranks of pilots involved in accidents included: cadet, lieutenant, first lieutenant, captain, major, and lieut. colonel (above).

Classification Framework

This study used the HFACS framework as described in Wiegmann & Shappell (2003). The first level of HFACS categorizes events under the general heading of 'unsafe acts of operators' that can lead to an accident including and comprises of four sub-categories of 'decision errors'; 'skill-based errors'; 'perceptual errors' and 'violations'. The second level of HFACS concerns 'preconditions of unsafe acts' which has a further seven sub-categories of 'adverse mental states'; 'adverse physiological states'; 'physical/mental limitations'; 'crew resource management'; 'personal readiness'; 'physical environment', and 'technological environment'. The third level of HFACS is 'unsafe supervision', including 'inadequate supervision'; 'planned inappropriate operation'; 'failure to correct a known problem', and 'supervisory violation'. The fourth and highest level of HFACS is 'organizational influences' and comprises of the sub-categories of 'resource management'; 'organizational climate' and 'organizational process'.

Coding Process

Each accident report was coded by two investigators, an instructor pilot and an aviation psychologist. These two investigators were trained on the HFACS framework together for 10 hours to ensure that they achieved a detailed and accurate understanding to the categories of the HFACS. They then analyzed each accident report independently. To avoid over-representation from any single accident, each HFACS category was counted a maximum of only once per accident. The count acted simply as an indicator of presence or absence of each of the 18 categories in a given accident.

Results

Sample Characteristics

A total of 523 accidents were analyzed. In these accidents, 1,762 instances of human error were recorded within the HFACS framework. Initial results found that acts at the level of 'unsafe acts of operators' were involved in 725 (41.1%) of instances; the 'preconditions for unsafe acts' level was as a causal factor in 552 (31.3%) of cases; the 'unsafe supervision' level was involved in 221 (12.5%) instances, and the 'organizational influences' level in the model was involved as a factor in 264 (15 %) cases. Decision errors were involved in 223 (42.6%) accidents. The inter-rater reliabilities assessed using Cohen's Kappa varied between 0.440 and 0.826, a range of values spanning between moderate and substantial agreement. Fourteen HFACS categories exceeded a Kappa of 0.60, which indicates substantial agreement. Four categories had Kappa values of between 0.40 and 0.59 indicating moderate levels of agreement (Landis & Koch, 1977) (table 1).

Effect of Aircraft Type

At the level of 'unsafe acts of operators', there were no significant associations with aircraft type. At the level of 'preconditions for unsafe acts', the associations of aircraft type with 'adverse mental states', 'crew resource management', and 'personal readiness' were significant. Training aircraft were over-represented in having 'adverse mental states' and 'personal readiness'; cargo aircraft were over-represented in having 'crew resource management' problems, even though the frequency of fighters was the highest. At the level of 'unsafe supervision', the associations of aircraft types with 'inadequate supervision' and 'failed to correct a known problem' were significant. Training aircraft were over-represented in these two categories of accidents. At the level of 'organizational influences', the association of aircraft types with 'organizational process' was significant. Training aircraft were over-represented in the category of 'organizational process' of accidents (see table 2).

Table 1. *The frequency and percentage of accident and reliability of HFACS categories*

HFACS Categories	Accidents' Frequency Percentage, and reliability		
	Frequency	Percentage	Cohen's Kappa
Organizational process	76	14.5%	0.593
Organizational climate	4	0.8%	0.440
Resource management	184	35.2%	0.768
Supervisory violation	8	1.5%	0.694
Failed correct known problem	12	2.3%	0.548
Planed inadequate operations	24	4.6%	0.706
Inadequate supervision	177	33.8%	0.826
Technology environment	44	8.4%	0.608
Physical environment	74	14.1%	0.797
Personal readiness	29	5.5%	0.695
Crew resource management	146	27.9%	0.801
Physical/mental limitation	73	14.0%	0.691
Adverse physiological states	2	0.4%	0.441
Adverse mental states	184	35.2%	0.748
Violations	160	30.6%	0.695
Perceptual errors	116	22.2%	0.667
Skilled-based errors	226	43.2%	0.712
Decision errors	223	42.6%	0.675

Effect of Aircraft Mission

At the level of 'unsafe acts of operators', the association of mission with 'skill-based errors' was significant. The 'close pattern' mission was over-represented in the category of 'skill-based errors' of accidents. At the level of 'precondition for unsafe acts', the association of mission with 'personal readiness' was significant. The 'close pattern' mission was also over-represented in the category of 'personal readiness' of accidents. At the level of 'unsafe supervision', the association of mission with 'inadequate supervision' was significant. Again, the 'close pattern' mission was over-represented in the category of 'inadequate supervision' of accidents. However, at the level of 'organizational influences', there was no significant association between mission and categories in the HFACS framework (see table 2).

Table 2. *The significant association between HFACS categories and demographical variables*

HFACS Categories	Significant association with HFACS categories			
	Types of aircraft	Missions Of pilots	Stages of flight	Ranks of pilots
Organizational process	χ^2=7.74, df=2, p<0.02			χ^2=11.1, df=5, p<0.05
Organizational climate				
Resource management				
Supervisory violation				
Fail correct problem	χ^2=20.6, df=2, p<0.00			
Plan inadequate operation				
Inadequate supervision	χ^2=8.28, df=2, p<0.01	χ^2=20.2, df=8, p<0.01	χ^2=34.6, df=8, p<0.00	χ^2=26.6, df=5, p<0.00
Technology environment				
Physical environment				χ^2=15.1, df=5, p<0.01
Personal readiness	χ^2=9.58, df=2, p<0.01	χ^2=23.1, df=8, p<0.01		
CRM	χ^2=8.35, df=2, p<0.01		χ^2=19.6, df=8, p<0.01	
Phy./mental limitation			χ^2=17.5, df=8, p<0.02	χ^2=32.5, df=5, p<0.00
Adv. physiological state				
Adverse mental states	χ^2=7.55, df=2, p<0.02		χ^2=25.7, df=8, p<0.00	χ^2=18.3, df=5, p<0.00
Violations				
Perceptual errors				χ^2=12.5, df=5, p<0.02
Skilled-based errors		χ^2=17.1 ,df=8, p<0.02	χ^2=63.6, df=8, p<0.00	χ^2=18.1, df=5, p<0.00
Decision errors			χ^2=35.7 df=8, p<0.00	χ^2=11.7, df=5, p<0.03

Effect of Phase of Flight

At the level of 'unsafe acts of operators', the associations of flight phase with 'decision errors' and 'skilled-based errors' were significant. The flight phase of 'landing' was over-represented in these two categories of accidents. At the level of 'precondition for unsafe acts', the association of flight phase with 'adverse mental states' was significant, as was the association of flight phase with 'physical/mental limitations' and with 'crew resource management'. The flight phase of 'operational area' was over-represented in these three categories of accidents. At the level of 'unsafe supervision', the association of flight stages with 'inadequate supervision' was significant. The flight phase of 'landing' was over-represented in the category of 'inadequate supervision' of accidents. At the level of 'organizational influences', there was no significant association between flight phase and any category within the HFACS framework (see table 2).

Effect of Pilot's Rank

At the level of 'unsafe acts of operators', the association of a pilot's rank with 'decision errors' was significant, as was the association of a pilot's rank with 'skill-based errors' and with 'perceptual errors'. The rank of 'lieutenant' was over-represented in these three categories of accidents. At the level of 'preconditions for unsafe acts', the associations of a pilot's rank with 'adverse mental states', 'physical/mental limitation' and the 'physical environment' were significant. The rank of 'lieutenant' was over-represented in categories of 'adverse mental states' and 'physical/mental limitation' of accidents. However, the rank of 'lieut. colonel above' was over-represented in the category of 'physical environment' of accidents. At the level of 'unsafe supervision', the association of a pilot's rank with 'inadequate supervision' was significant. The rank of 'cadet' was over-represented in the category of 'inadequate supervision' of accidents. At the level of 'organizational influences', the association of a pilot's rank with 'organizational process' was also significant. The rank of 'cadet' was over-represented in the category of 'organizational process' of accidents (see table 2).

Discussion

The category of 'decision-errors' at the level of 'unsafe acts of operators' has a significant association with flight phases and rank of pilots. However, it is important to keep in mind that the higher levels affect the next downward level in HFACS framework. It means that decision errors may be affected by 'precondition for unsafe acts', 'unsafe supervisory', and 'organizational influences'. This is particularly true of the category of 'unsafe supervision' at level-3 of the HFACS. This is one of the key factors, for it not only affects the 'decision errors' of pilots, but it also has a significant association with the type of aircraft, mission, flight phase, and rank of pilots (table 2). To precisely identify training needs of ADM, it is necessary to look further into the factors underlying decision errors by applying he HFACS framework.

Although the results showed that fighters had highest frequency of accidents (342), followed by training aircraft (111) and cargo aircraft (56), further analysis found that the training aircraft were significantly associated with 'adverse mental states', 'personal readiness', 'inadequate supervision' and 'organizational process'. The training aircraft have the highest usage in the Air Force, hence there is time pressure for maintenance, checking processes for airworthiness oversight, and instructor pilots may not have time to provide enough training/supervision. Training aircraft are operated by novice pilots who may not be ready for solo. Cargo aircraft were significantly associated with 'CRM' because these types were operating by multi-crew, therefore, CRM was more relevant for crew to perform their tasks than in a one-seat fighter. Fighters were generally under-represented in the HFACS categories. The possible explanation this was that fighter pilots were mature pilots who performed the most demanding tasks in all-weathers, such as interception and air combat tactics. As a result, they were aware of the risk and they were experienced and with a prudent attitude.

There was a significant association between missions and the HFACS framework in three categories: 'skill-based errors', 'personal readiness', and 'inadequate supervision'. Further analysis found the task of 'close pattern' was over-represented in these three categories of accidents. The possible explanation was 'close pattern' practicing of basic take-off and landing skills, was designed for training the novice pilots to operate the aircraft safely. As the pilots were novices with limited experience and operating skills, if the instructor pilots did not provide proper training/supervision, sending a novice solo when he was not ready or had not developed the psychomotor skills, may have resulted in the above three HFACS categories being significant when related to mission of 'close pattern'.

There was a significant association between flight phase and HFACS framework in six categories. At the level of 'unsafe acts of operators', 'decision errors' and 'skill-based errors' were significantly associated with 'landing'. In the landing phase, precise psychomotor skills are required to control the aircraft and occasionally instant decisions and responses are needed. At the level of 'preconditions for unsafe acts' the categories of, 'adverse mental states', 'physical/mental limitation', and 'crew resource management' were significantly associated with the phase of flying in the 'operational area'. The possible explanation was that military tactical training such as air combat tactics or low altitude tactics with high physical and mental requirement on the pilots all occur at this stage. Pilots needed to pay more attention to the cognitive demands while flying in the 'operational area'. They are required to be in a heightened mental state to allow for quick analysis of the dynamic situation to be made followed by swift responses while under time pressure. They also need to have good crew resource management skills to deal with emergent risks and set the priorities for safety issues. At the level of 'unsafe supervisions', 'inadequate supervision' was significantly associated with 'landing'. This was perhaps due to the instructors in the MOB not providing enough supervision, providing inappropriate instruction for landing, or back seat instructor pilots failing to provide suitable training for trainees.

The pilot's rank was related to flying experience. Senior officers normally have more flying hours than junior officers. The rank of 'cadet' was significantly over-represented at the categories of 'organizational process' and 'inadequate supervision'. It was perhaps the junior cadet pilots lack of experience and competence to deal with high levels of supervisions and organizational influences, therefore, they were very vulnerable. The rank of 'lieutenant' was significantly associated with 'decision errors', 'skill-based errors', 'perceptual errors', 'adverse mental states', and 'physical/mental limitation'. Pilots with the rank of 'lieutenant' were the novice pilots (between 200 and 500 flying hours), and at the beginning stage of conversion from training aircraft (AT-3) to fighters (F-16/M-2000/IDF). During this conversion period, it was the tendency of pilots toward having a higher accident rate. The rank of 'lieutenant colonel (above)' was significantly associated with 'physical environment'. The explanation probably that it was only experienced pilots whom were believed to have the ability and the confidence to take the risky tasks in adverse weather or over difficult terrain conditions, so the tasks in an adverse physical environment were assigned to pilots with the rank of lieutenant colonel (and above).

Conclusion

For 25 years, the importance of aeronautical decision-making (ADM) has been recognized as critical to the safe operation of aircraft, as well as accidents avoidance (Jensen & Hunter, 2002). Dekker (2001) described that human errors is systemically connected to the tools, tasks, and operational and organizational environment of operators, it is important to clarify the role of decision errors in pilot's tools, tasks, experience, and operating environment in military aviation in order to develop effective ADM training programs for military pilots. This research finds pilots at the rank of 'cadet' (experience) flying 'training aircraft' (tools) practicing 'close pattern' (missions) during the 'landing phase' (an aspect of the working environment) were likely to be involved in an accident. 'Decision-errors' also had a significant association with the landing phase and lieutenant pilots. However, there are many factors at the upper levels of HFACS framework that will also affect pilots making decisions. It is important to understanding that junior pilots are very vulnerable to the decisions and supervisory practices of senior management

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