International Society of Air Safety Investigators

42nd Annual Seminar
Salt Lake City, Utah

Title of Research

Understanding Pilots' Cognitive Processes for Making In-flight Decisions under Stress

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Abstract:

In flight operations, pilots are confronted with many problems that occur in continually changing situations that create a level of stress and lead to accidents. To make rapid decisions, pilots make decisions using a holistic process involving situation recognition and pattern matching. This research investigated 157 pilots from a B747 fleet to find out how pilots make in-flight decision in such stressful situations. The research method is based upon evaluating the situational awareness, risk management, response time and applicability of four different decision-making mnemonics in six in-flight scenarios. The data obtained in this research suggests that the FOR-DEC may be suitable as a basis for providing training which will be applicable for covering all basic types of decision. FOR-DEC was evaluated as the most applicable mnemonic-based decision making process across the six different scenarios used. It also had significantly superior performance compared with the other three mnemonic-based methods evaluated (SHOR, PASS & DESIDE) when making recognition-primed decisions, response selection decisions, non-diagnostic procedural decisions, and problem-solving decisions.

Keywords: Accident Prevention, Aeronautical Decision-making, Human Errors, Stress, Time Pressure

Introduction

The advent of improved accident investigation technology in recent years, such as cockpit voice recorders, along with a more systematic review of accident statistics, has produced a growing realization of the significance role of pilot judgment errors in flight operations (Buch and Diehl, 1984). Jensen and Benel (1977) found that decision errors contributed to 35% of all nonfatal and 52% of all fatal general aviation accidents in the United States. Diehl (1991) proposed that decision errors contributed to 56% of airline accidents and 53% of military accidents. Furthermore, Li and Harris (2008) suggested that 69% of accidents were relevant to pilots' in-flight decision errors. O'Hare (2003) reviewed aeronautical decision-making and came to the conclusion that 'it is difficult to think of any single topic that is more central to the question of effective human performance in aviation than that of decision-making'. Current FAA regulations require that decision-making be taught as part of the pilot-training curriculum (FAA, 1991), however, little guidance is provided as to how that might be accomplished, and none is given as to how it might be measured, outside of the practical test.

Aeronautical knowledge, skill, and judgment have always been regarded as the three basic faculties that pilots must possess. The requisite aeronautical knowledge and operating skills have been imparted in flight training programs and have subsequently been evaluated as part of the pilot certification process. In contrast, judgment has usually been considered to be a trait that good pilots innately possess or an ability that is acquired as a by-product of flying experience. A decision bias is not a lack of knowledge, a false belief about the facts, or an inappropriate goal, nor does it necessarily involve lapses of attention, motivation, or memory. Rather, a decision bias is a systematic flaw in the internal relationship among a person's judgments, desires, and choices. Human reasoning depends, under most conditions, on heuristic procedures and representation that predictably lead to such inconsistencies. It follows that human reasoning processes are error prone by their very nature (Cohen, 1993). Although a great deal of research has demonstrated that decision making is a primary component of pilot performance, this concern has not translated well into systematic training programs. Aviation specialists have suggested that rational judgment is a function of both motivation and information processing. Another approach to improving pilot decision making is the use of prescriptive aids such as the ARTFUL decision tree (O'Hare, 1992). However, using these assumes that sufficient time exists to proceed through a prescribed decision making checklist.

Literature Review

Time pressure has several obvious but important implications for decision-making. Firstly, decision makers will often experience high levels of stress, with the potential for exhaustion and loss of vigilance; secondly, their thinking will shift, characteristically in the direction of using less complicated reasoning strategies (Payne, Bettman, & Johnson, 1988). Stiensmeier-Pelster & Schurmann (1993) indicated that time stress may affect the process of decision making in a variety of ways depending on the type of decision. It may lead to reallocation of cognitive resources from the decision process to the stress coping process. Time stress may also change the goals of the decision-making process. Under time stress, cognitive resources may be allocated from the decision-making process to monitoring of the flow of time as part of a coping strategy (Zakay, 1993). Klein & Thordsen (1991) observed that decision makers in difficult situations and under time stress did not appear to use the classical approach to make decisions, even when they were trained in that approach. Much of the research on qualitative changes in cognitive performance, when stressors such as time pressure are present, is broadly consistent with the conflict theory of decision making proposed by Janis and Mann (1977). Edland & Svenson (1993) found that under time pressure the following changes were observed in the decision-making processes: (1) an increased selectivity of input of information; (2) attributes perceived to be more important were given more weight under time pressure than in situations with no time pressure; (3) the accuracy of human judgment decreases; (4) the use of non-compensatory decision rules becomes more frequent than compensatory rules requiring value tradeoffs; (5) there is a decrease in the ability to find alternative problem-solving strategies; (6) motivation is attenuated.

Benson and Beach (1996) found that time pressure made the screening phase of problem identification less systematic. Unsystematic identification and screening processes can also occur in decisions concerned with ill-defined problems. The quality of decision-making may suffer even more from time stress in this case. Keinan (1987) found that under stress the range of alternatives and dimensions that are considered during a decision-making process is significantly restricted, compared with normal conditions. In brief, the effects of time stress on decision making are: (1) a reduction in information search and processing; (2) increased importance of negative information; (3) defensive reactions increase, such as neglect or denial of important information; (4) bolstering of the chosen alternative occurs; (5) forgetting important data happens; (6) poor judgments and evaluation are more likely; (7) there is a tendency to use a strategy of information filtration. Information that is perceived as being the most important is processed first, and then processing is continued until time is up.

The processes of decision-making center around two elements; situation assessment, which is used as a pre-cursor to generate a plausible course of action, and mental simulation to evaluate that course of action for risk management (Endsley, 1993). If a pilot recognizes there is sufficient time for making wide-ranging considerations, s/he will evaluate the dominant response option by conducting a mental simulation to see if it is likely to work. If there is not adequate time, the pilot will tend to implement the course of action that experience (if any) dictates is the most likely to be successful. Klein (1993) found that whereas experts used a recognition-primed or perception-based decision process to retrieve a single likely option, novices were more likely to use an analytical approach, systematically comparing multiple options, and experience affects the processes of decision-making by improving the accuracy of situation assessment, increasing the quality of the courses of action considered and by enabling the decision maker to construct a mental simulation. Furthermore, Endsley (1997) defines situation awareness (SA) as 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the future'. In a dynamic tactical environment, effective decision-making is highly dependent on situation awareness which has been identified as a critical decision component (Endsley & Bolstad, 1994). Situation assessment is the process by which the state of situation awareness is achieved and is a fundamental precursor to situation awareness, which is itself the precursor for all aspects of decision-making (Prince & Salas, 1997).

Automated aids in aviation industry are designed specifically to decrease pilots' workload by performing many cognitive tasks, not only including information processing, system monitoring, diagnosis and prediction, but also controlling the physical placement of the aircraft. Flight management systems (FMS) are designed not only to keep the aircraft on course, but also to assume increasing control of cognitive flight tasks, such as calculating fuel-efficient routes, navigating, or detecting and diagnosing system malfunctions. An inevitable facet of these automated aids is that they change the way pilots perform tasks and make decisions. However, the presence of automated cues also diminishes the likelihood that decision makers will make the cognitive effort to process all available information in cognitively complex ways. Parasuraman and Riley (1997) describe this tendency toward over-reliance as 'automation misuse'. In addition, automated cues increase the probability that decision makers will cut off situation assessment prematurely when prompted to take a course of action by automated aids. Automation commission errors are errors made when decision makers inappropriately follow automated information or directives (e.g., when other information in the environment contradicts or is inconsistent with the automated cue). These errors have recently begun surfacing as by-products of automated systems. Experimental evidence of automation-induced commission errors has also been provided by full-mission simulations in the NASA Ames Advanced Concepts Flight Simulator (Mosier, Skitka, Heers and Burdick, 1998).

Orasanu and Fisher (1997) investigated the five highest performance pilots and the five lowest performance pilots in a flight simulation study, and found a tendency for high performance pilots to be more likely to use low workload situations to make plans and collect more relevant information compared with the poorer performing pilots. High performance pilots also demonstrated greater situation awareness.

Method

Participants:
There were 157 pilots participated in this research, consisting of 57 captains and 99 first officers. Data was missing for one participant. The full demographic data collected including teaching experience, flying hours, and training background is presented in Table 1).

Four Aeronautical Decision-making Mnemonics:
The SHOR mnemonic (Wohl, 1981) consists of four steps: Stimuli, Hypotheses, Options, and Response. It was originally developed for use by U.S. Air Force tactical command and control, where decisions were required under high pressure and severe time constraint. In this situation, decisions require near-real-time reactions involving threat warning, task rescheduling and other types of dynamic modification. The SHOR methodology is basically an extension of the stimulus-response paradigm of classical behavioral psychology developed to deal with two aspects of uncertainty in the decision-making process, information input uncertainty followed by the evaluation of the consequences of actions, which creates the requirement for option generation and evaluation.
The PASS methodology was originally developed by a civil airline (Delta) to train pilots as part of a CRM training program. It consists of four steps: Problem identification (define/redefine problems); Acquire information (seek more information); Survey strategy (survey/resurvey strategies); Select strategy (Maher, 1989). After the selection of a solution strategy, if the problem is not solved, then the pilot should re-enter the problem solving loop once more.
The FOR-DEC mnemonic comprises of six steps: Facts, Options, Risks & Benefits, Decision, Execution, Check (Hormann, 1995). It incorporates an analysis of risk and benefits when handling in-flight situations, including assessing the effects of time pressure, continually changing conditions, distraction, and having incomplete information.
The DESIDE (Murray, 1997) was developed on a sample of South African pilots and comprises of six steps: Detect, Estimate, Set safety objectives, Identify, Do, Evaluate. The DESIDE method is a practical application to aid pilots in making in-flight decisions adapted from conflict-theory model of Janis and Mann (1977).

The Development of Six In-flight Scenarios:
To develop scenarios for assessing the effectiveness of the ADM mnemonics which corresponded to Orasanu’s (1993) six generic decision making categories, six focus groups were conducted, one for each scenario. Each focus group comprised two human factors specialists, three senior B-747 instructor pilots and the director of Crew Resource Management Departments of the participating airlines. The purpose of these focus groups was to ensure enough detailed information for pilots was included to enable them to make a decision and hence to evaluate the performance of the four ADM mnemonics. These six scenarios developed were as follows.

Go/no go decisions: A Boeing 747-400 departed from Taipei to Los Angeles, take-off weight 833,000 pounds. The warning light of 4L door suddenly illuminated while the aircraft was taking off from Taoyuan Airport runway 05 with an indicated air speed of 120 kt……

Recognition-primed decisions: A Boeing 747-400 departed from Los Angeles to Taipei with landing weight 533,000 pounds. The aircraft planed to land at Taoyuan Airport runway 06, visibility 3,000 meters, cloud base 500 feet. Auto pilot engaged during instrument approach, ILS signal is suffering interference and Glide Slope indication is fluctuating……

Response selection decisions: A Boeing 747-400 departed from Hong Kong to Taipei, and planned to land at Taoyuan Airport runway 05 with landing weight 533,000 pounds. The ATC cleared “Direct to TONGA, descend and maintain flight level 290, clear to JAMMY via TONGA 3A RNAV ARRIVAL”. When aircraft is 3 miles from TONGA, communication was is lost, and there is a failure to contact ATC……

Resource management decisions: A Boeing 747-400 departed from Hong Kong to Taipei, and planed to land at Taoyuan Airport runway 05 with landing weight 533,000 pounds. ATC cleared “Direct to TONGA”; descend and maintain 11,000 feet; clear to JAMMY via “TONGA 3A RNAV ARRIVAL”. 3 miles before BRAVO, the Captain (PF) suddenly became incapacitated, and provided no response to standard CALL OUT twice ……

Non-diagnostic procedural decisions: A Boeing 747-400 departed from Taipei to Los Angeles, from Taoyuan Airport runway 05 with take-off weight 833,000 pounds at 22:30 local time. When climbing to 1,000 feet with Thrust Reduced to CLB, the aircraft suddenly began to vibrate significantly. PM found No.1 ENG vibration indication abnormal, although other ENG indications were normal. By this time the aircraft has cross through a cloudy area with light turbulence. It was difficult to judge whether vibration caused by ENG or turbulence; it was unclear whether to continue to destination airport or return to base……

Problem-solving decisions: A Boeing 747-400 departed from Taipei to Los Angeles, from Taoyuan Airport runway 05 with take-off weight 833,000 pounds. During the climb through 1,000 feet after departure, the fire warning system of No.4 ENG was activated, 10 seconds later, the aircraft began to vibrate heavily and a big “BANG” was heard. The relevant No.4 ENG systems failed totally, and the fire warning disappeared.....

ADM Evaluation Instruments

To develop a rating instrument for the subsequent evaluation of the suitability of the four ADM mnemonic-based methods in the six in-flight scenarios, six focus groups were formed, one for each scenario. Each comprised two human factors specialists and three B-747 instructor pilots. The six selected scenarios were analyzed by the focus group members using all four mnemonic methods. This process provided the material for the construction of a rating form to evaluate the suitability of the ADM mnemonics for decision-making training. The narrative responses describing the decision-making process by which the participants would arrive at their decision was evaluated using the criteria of situation assessment, risk management, response time and applicability.

Administration of Evaluation Forms

As a result of the length of the scenarios and the number of ratings required, each participant only evaluated the ADM decision techniques in three scenarios, either scenarios 1, 3 & 5 or scenarios 2, 4 & 6. The ADM rating forms were distributed to all pilots of B-747 fleet of the participating airlines. Completed instruments were returned to the Crew Resource Management Department. For each participant an overall score for each mnemonic method in each scenario was created by summing the scores across four dimensions of situation assessment; risk management; response time; and applicability giving a potential range of scales between 4 (low suitability) to 36 (high suitability).

RESULTS

Sample Characteristics

In total, data were collected from 1,871 evaluations of scenarios. There were 312 completed rating forms for the go/no go decisions scenario; 311 for the recognition-primed decision-making scenario; 316 for the response selection decision-making scenario; 310 for the resource management scenario; 312 for the non-diagnostic procedural decisions-making scenario, and 310 completed rating forms for the creative problem-solving scenario (Table 2).

Table 1 Demographic data from Participants

Demography	Category	Frequency	Percentage
Job description	Captain	57	36.3%
	First officer	99	63.1%
	Missing data	1	.6%
	total	157	100.0%
Gender	Male	151	96.2%
	Female	5	3.2%
	Missing data	1	.6%
	Total	157	100.0%
Age	30 or under	7	4.5%
	31-40	68	43.3%
	41-50	54	34.4%
	51 or above	26	16.6%
	Missing data	2	1.3%
	Total	155	100.0%
Training background	Ab-initio	74	47.1%
	CPL	23	14.6%
	Ex-military	48	30.6%
	Other	11	7.0%
	Missing data	1	.6%
	Total	157	100.0%
Flying hours	Less than 2000 hrs	9	5.7%
	2001-5000hrs	42	26.8%
	5001-10000hrs	53	33.8%
	10000hrs and above	51	32.5%
	Missing data	2	1.3%
	Total	157	100.0%

Table 2 The Mean Scores and Standard Deviations for four Different Mnemonics decision-making methods in each of the Six Scenarios.

Item	*N*	*M*	*SD*
Scenario 1 SHOR	79	6.67	1.39
Scenario 1 PASS	78	6.42	1.63
Scenario 1 FORDEC	77	6.83	1.67
Scenario 1 DESIDE	78	6.43	1.51
Scenario 2 SHOR	78	6.41	1.56
Scenario 2 PASS	78	6.59	1.25
Scenario 2 FORDEC	77	6.99	1.30
Scenario 2 DESIDE	78	6.75	1.27
Scenario 3 SHOR	79	6.59	1.14
Scenario 3 PASS	79	6.81	1.03
Scenario 3 FORDEC	79	7.43	1.10
Scenario 3 DESIDE	79	6.99	1.21
Scenario 4 SHOR	77	6.83	1.47
Scenario 4 PASS	77	6.67	1.27
Scenario 4 FORDEC	78	7.11	1.41
Scenario 4 DESIDE	78	6.91	1.40
Scenario 5 SHOR	78	6.47	1.31
Scenario 5 PASS	78	6.72	1.11
Scenario 5 FORDEC	78	7.50	1.14
Scenario 5 DESIDE	78	7.08	1.09
Scenario 6 SHOR	77	6.81	1.46
Scenario 6 PASS	78	6.73	1.25
Scenario 6 FORDEC	77	7.20	1.33
Scenario 6 DESIDE	78	6.94	1.19

Scenario 1: Go/no go Decisions

The highest overall rating of suitability for the ADM mnemonics in the go/no go decision-making scenario by participants was FORDEC followed by SHOR, DESIDE, and PASS (Table 2). There were no significant differences in the ratings of suitability among the four ADM mnemonics ($F=2.192$, $P>.05$) in table 3.

Table 3: One-way ANOVA table for Go/no go scenario broken down by the four different ADM mnemonics

Source	*SS*	*DF*	*MS*	*F*	*P*	*Post-Hoc*
SS_{tr}	8.963	2.243	3.997	2.192	.108	NS
SS_b	430.394	76	5.663	3.106	.045	
SS_E	310.694	170.430	1.823			
SS_T	750.051	248.673	11.483			

Scenario 2: Recognition-primed Decision

The highest overall rating of the suitability for the ADM mnemonics by participants was for FOR-DEC followed by DESIDE, PASS, and SHOR (Table 2). There were significant differences among the rated overall suitability of the four ADM mnemonics in this scenario (F=5.22, *P*<.007). Further comparisons using post-hoc t-tests showed significant differences between FOR-DEC (M=6.99, SD=1.30) vs SHOR (M=6.41, SD=1.56); and FOR-DEC (M=6.99, SD=1.30) vs PASS (M=6.59, SD=1.25) in table 4.

Table 4: One-way ANOVA table for Recognition-primed scenario broken down by the four different ADM mnemonics

Source	*SS*	*DF*	*MS*	*F*	*P*	*Post-Hoc*
SS_{tr}	13.116	1.962	6.684	5.223	.007	
SS_b	365.685	76	4.812	3.759	.028	FOR-DEC>SHOR
SS_E	190.832	149.129	1.280			FOR-DEC>PASS
SS_T	569.633	227.091	12.776			

Scenario 3: Response Selection Decision

The highest overall rating of suitability for the ADM mnemonics by participants was for FOR-DEC followed by DESIDE, PASS, and SHOR (Table 2). There were significant differences among the rated overall suitability of the four ADM mnemonics in this scenario（*F*=14.63, *P*<.000）. Further comparisons using post-hoc t-tests showed significant differences between FOR-DEC (M=7.43, SD=1.10) vs SHOR (M=6.59, SD=1.14) ; FOR-DEC(M=7.43, SD=1.10) vs PASS (M=6.81, SD=1.03) ; and FOR-DEC(M=7.43, SD=1.10) vs DESIDE (M=6.99, SD=1.21) in table 5.

Table 5: One-way ANOVA table for Response Selection scenario broken down by the four different ADM mnemonics

Source	*SS*	*DF*	*MS*	*F*	*P*	*Post-Hoc*
SS_{tr}	30.296	3	10.099	14.637	.000	FOR-DEC>SHOR
SS_b	235.322	78	3.017	4.372	.007	FOR-DEC>PASS
SS_E	161.443	234	.690			FOR-DEC>DESIDE
SS_T	427.061	315	13.806			

Scenario 4: Resource Management Decision

The highest overall rating of suitability for the ADM mnemonics in the resource management decision-making scenario by participants was FORDEC followed by DESIDE, SHOR, and PASS (Table 2). There were no significant differences in the ratings of suitability among the four ADM mnemonics（*F*=2.639, *P*>.05）in table 6.

Table 6: One-way ANOVA for Resource Management scenario broken down by the four different ADM mnemonics

Source	*SS*	*DF*	*MS*	*F*	*P*	*Post-Hoc*
SS_{tr}	7.833	2.120	3.695	2.639	.071	
SS_{b}	368.648	76	4.851	3.465	.034	NS
SS_{E}	225.542	161.106	1.400			
SS_{T}	602.023	239.226	9.946			

Scenario 5: Non-diagnostic Procedural Decision

The highest overall rating of suitability for the ADM mnemonics by participants was FOR-DEC followed by DESIDE, PASS, and SHOR (Table 2). There were significant differences among the rated overall suitability of the four ADM mnemonics in this scenario（*F*=20.494，*P*<.000）. Further comparisons using post-hoc t-tests showed significant differences between FOR-DEC (M=7.50, SD=1.14) vs SHOR (M=6.47, SD=1.31) ; FOR-DEC (M=7.50, SD=1.14) vs PASS (M=6.72, SD=1.11) ; and FOR-DEC (M=7.50, SD=1.14) vs DESIDE (M=7.08, SD=1.09) in table 7.

Table 7: One-way ANOVA for Non-diagnostic Procedural scenario broken down by the four different ADM mnemonics

Source	*SS*	*DF*	*MS*	*F*	*P*	*Post-Hoc*
SS_{tr}	45.491	2.183	20.840	20.494	.000	FOR-DEC>SHOR
SS_{b}	253.880	76	3.341	3.285	.039	FOR-DEC>PASS
SS_{E}	168.696	165.896	1.017			FOR-DEC>DESIDE
SS_{T}	468.067	244.079	25.198			

Scenario 6: Problem-solving Decision

The highest overall rating of suitability for the ADM mnemonics by participants was FOR-DEC followed by DESIDE, PASS, and SHOR (Table 2). There were significant differences among the rated overall suitability of the four ADM mnemonics in this scenario（*F*=3.379，*P*<.032）. Further comparisons using post-hoc t-tests showed significant differences between FOR-DEC (M=7.50, SD=1.14) vs PASS (M=6.72, SD=1.11) in table 8.

Table 8: One-way ANOVA for Problem-solving scenario broken down by the four different ADM mnemonics

Source	*SS*	*DF*	*MS*	*F*	*P*	*Post-Hoc*
SS_{tr}	8.593	2.222	3.867	3.379	.032	
SS_{b}	307.459	75	4.099	3.583	.028	FOR-DEC>PASS
SS_{E}	190.704	166.655	1.144			
SS_{T}	506.756	243.877	9.11			

DISCUSSION

In flight operations, pilots are confronted with many problems that occur in continually changing situations that do create certain level of stress and leading to human error accidents. To make rapid decisions, pilots make decisions using a holistic process involving situation recognition and pattern matching. Within this framework, pilots' situation awareness becomes the driving factor in the decision-making process. In general, aviation training organizations do not have specific methods or techniques for decision-making instruction during ab-initio training. The ability to make decisions in the air has often been regarded as by-product of flying experience rather than training. However, the data obtained in this research, , suggests that the FOR-DE may be suitable as a basis for providing training which will be applicable for covering all six basic types of decision. FOR-DEC was evaluated as being the highest-rated scale for its applicability across six different decision-making scenarios. It was rated as potentially having superior performance compared to the other three mnemonic methods (SHOR, PASS & DESIDE) in Go/no go decision, Recognition-primed decisions, Response selection decision, Non-diagnostic procedural decision, and Problem-solving decision scenarios (Table 9).

Table 9: Summary of rankings of the five ADM mnemonic methods across the six decision making scenarios

Scenarios / **Mnemonics**	Go/no go decision	Recognition-primed decision	Response selection decision	Resource management decision	Non-diagnostic procedural decision	Creative problem -solving
SHOR	2	4	4	3	4	4
PASS	4	3	3	4	3	3
FOR-DEC	**1**	**1**	**1**	**1**	**1**	**1**
DESIDE	3	2	2	2	2	2

Kaempf & Orasanu (1997) suggested that under conditions of time pressure, decision makers need help to determine what is occurring in the environment around them. Therefore, decision aids and training should provide decision makers with the tools and skills necessary to accurately and quickly make situation assessments. FOR-DEC was rated highly for situation assessment, risk management, and applicability. It was thought to be comprehensive and thorough; clear about how to identify the safest actions; and it also had a logical order and was easy to remember. However, it did require much more time to perform this analysis and produce a response. The qualitative data suggest that SHOR was regarded by pilots as providing a method for a quick decision-making response in urgent situations with a logical order for flight operations safely. PASS also matched airlines pilots training guidelines as it had clear and specific procedures to follow. DESIDE were regarded as being comprehensive but enough time was needed to undertake this method. FOR-DEC was rated as the highest performance of all mnemonics.

Pilots advised that practicing FOR-DEC in the simulator was extremely important before attempting to apply it in a real life situation. FOR-DEC was rated by cadet pilots as the best ADM mnemonic–based decision making method for promoting good resource management decisions as would be expected of a methodology originally developed to promote good CRM. The qualitative data elicited from pilots' showed that FOR-DEC has characteristics to deal with non-urgent situations as a result of its good situation assessment and risk management characteristics; it was thought that it prompted a comprehensive approach in terms of the number of factors that it encompassed in the decision making process; it was regarded as providing a specific and clear approach to analyze a situation and it possessed a logical order that was easy to remember. However, it did require more time to undertake the required steps and analyze and respond to the changing situation. An implication of the fact that many decisions must be made under stress is that training should include extensive practice to learn key behaviors (Driskell & Salas, 1991). However, Zakay & Wooler (1984) found that practice without time pressure did not enhance decision-making under time constraints. This suggests that, if decision-making is likely to be required under time pressure or other stressful conditions, practice should include task performance under those conditions.

SHOR was developed for use in U.S. Air Force tactical command and control scenarios, where decisions were likely to be made under high pressure and within severe time constraints. These situations involve making near-real-time decisions involving threat warning and rescheduling, and often require dynamic modifications to plans (Wohl, 1981). The contents of SHOR match the requirements of the scenarios requiring urgent decisions. As SHOR is basically an extension of the stimulus-response (S-R) paradigm of classical behaviourist psychology, it explicitly addresses the requirement to deal with two aspects of uncertainty in the decision-making process; information input uncertainty (relating to hypothesis generation and evaluation) and consequence-of-action uncertainty (which creates the requirement for option generation and evaluation) (Wohl, 1981). SHOR is able to promote quick responses in a time-limited situation and it also corresponds to the basic principles of briefing during tactical training. The qualitative data from pilots also revealed that the four steps in SHOR fulfilled the requirements to deal with time-limited, urgent situations. It has simple steps with high applicability; it is easy to practice and it promotes the logical procedures required for safe action. Payne, Bettman, and Johnson (1988) found that, under time pressure, a number of heuristic choice strategies are more useful than attempts to apply a truncated normative model. Subjects adapt their decision-making strategies in reasonable ways when placed under time constraints. Under time pressure, the likelihood of making serious errors increases. Decision makers tend to ignore relevant information, make risky decisions and perform with less skill (Keinan, 1987).

Pilots consistently selected FOR-DEC as the best mnemonic-based decision making method in the go/no go decision, recognition-primed decision, response selection decision, resource management decisions, non-diagnostic procedural decision scenarios, and problem-solving decision all of which were urgent, potentially high risk, time-critical situations and required prompt actions. The pilots' comments suggested that FOR-DEC had the required characteristics to deal with urgent situations as it promoted quick responses. It was simple and easy to remember; it fitted the constraints inherent in time-limited and critical situations; it matched the general format of a pre-flight briefing; it was easy to put into practice; and it was thought that its logical procedures promoted safe action. The principal limitation of the present study was that it only elicited pilots' opinions about the efficacy of these decision-making techniques. As a result, research needs to be undertaken to produce empirical performance data to establish if training in the use of ADM mnemonic-based methods such as FOR-DEC can actually improve pilots' in-flight decision-making. There is a raising need for future study to justify the effectiveness of ADM training interventions based FOR-DEC mnemonics methods across all different types of decision-making scenarios encountered in stress situations. The cognitive processes employed by pilots also need to been investigated in a series of reliable tools.

CONCLUSIONS

Orasanu (1993) suggested that the six basic types of decisions each impose different demands on the decision-maker and require different approaches. This research suggests that the FOR-DEC mnemonic forms a suitable basis for decision-making training that encompass the requirements for these six basic decision making situations. It was rated as being the best ADM mnemonic method in critical, urgent situations and was regarded as superior for knowledge-based decisions which required more comprehensive considerations. To optimize the effectiveness of decision-making training, it is suggested that it will be necessary to deliver instruction using the FOR-DEC mnemonic-based method.

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