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Distributed Information Behavior Among Flight Crews in a Simulated Environment

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DISTRIBUTED INFORMATION BEHAVIOR AMONG FLIGHT CREWS IN A SIMULATED ENVIRONMENT

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The purpose of this study was to assess concepts from Information Science to develop and initially validate a framework to study the information behavior of flight crews in the civil aviation domain. Distributed use of information within groups remains a weak link between actual information, the meaning given to information, and the sense made of the information. Principles from information science, psychology, and communication studies are used to analyze how flight crews in a simulated environment (fail to) make use of essential, safety critical information through analysis of the corresponding flight transcripts using a six-point Information Behavior Grid. The results of this research indicate differences in the way flight crews identify, gather and use information based on their performance level. This study discerns that high performing flight crews practice different information behaviors than low performing or accident involved flight crews. This work serves as a way to operationalize crew resource management through understanding the social practice of information structuring within the distributed collective practice of the flight crew. This work also serves as a tool to inform crew training and is applicable to other domains where work is supported through distributed collective practice.

Introduction

In aviation operations, flight crews must incorporate efficient and effective communication of essential safety-critical information to avoid accidents. Consistent, procedural responses to clearly defined situations are a normal part of conducting a flight, yet there are frequently indeterminate circumstances under which crews must use their personal judgment to negotiate meaning with members of their team to arrive at a solution. The process of how people employ sources and channels of information to satisfy a need is known as (human) information behavior (Wilson, 2000). This research explores the relationships between the distinct principles of crew information behavior, crew performance, and mission outcome to study the social construction of information in practice.

The Information Environment in Flight

Pilots must transform data from multiple interfaces into meaningful flight information. Given the safety critical nature of aviation operations, pilots must incorporate efficient and effective communication of essential information to avoid accidents. Flightcrews are trained to employ consistent, procedural responses to clearly defined situations as a normal part of flight operations, yet there are frequently indeterminate circumstances under which crewmembers must use personal judgment and negotiate the meaning of their personal judgment with other members of the crew to arrive at a solution. As such, crewmembers become information resources in the larger, distributed environment.

On the flightdeck, information processed in concert with other crewmembers may be more robust than information processed by each individual, yet it requires social, organizational and even technological devices for the continued support of group information retrieval and effective information use in increasingly complex situations. Crewmembers may not be as effectively organized in their communication of information as they could be, leading to misinterpretation of information, and dangerous situations. According to Hutchins, "Social organizational factors often produce group properties that differ considerably from the properties of individuals" (Hutchins, 1996, p. xx). Efficient information retrieval and use relies on patterns of group size, individual interaction, interaction through time and distribution of knowledge. Thus the cognitive properties *between* group members depend on the character of the social organization of the group, rather than the cognitive properties of the individuals *in* groups. This social organization forms the basis from which to study distributed negotiation of information between group members on the flightdeck using principles from the domain of Information Science.

Information Practice

Information needs vary at different stages of a process. The distinction perhaps can be made between whether information is a thing or a process and whether information is objectively or socially constructed. Buckland (1991) notes that objects such as data and documents have the qualities of imparting knowledge or communicating information, serving as information *things*. An information *process* on the other hand, is concerned with the procedure of being informed, a change in knowledge, not just the discrete form of the information *thing*. While finding the *thing* is an end goal, users need to be able to get through the *process* and barriers to it, of deciphering just what is the necessary information *thing* and how to get it. To do this, a person employs their collection of individual abilities consisting of experience, knowledge, resources to gather information, use the information, and communicate this knowledge. This is what Marchionini (1995) designates as *personal information infrastructure*. According to Marchionini:

> "A personal information infrastructure is a collection of interrelating mental models for specific information systems; mental models for events, experiences, and domains of knowledge; general cognitive skills (e.g., inferencing, recognizing salience) and specific cognitive skills related to organizing and accessing information (e.g., filing rules, reading); material resources such as information systems, money, and time; metacognitive resources for planning and monitoring thought and action; and attitudes toward information seeking and knowledge acquisition" (1995, p.11).

As people use information, they develop mental models of the skills needed to access information and understand how information is organized. When technology is brought into the information process, it can augment cognitive skills by assisting the user in finding and using information. Technology can also change the strategies users employ to acquire information, confusing or disorienting them, thus impacting their abilities and performance. Therefore, when interacting with information people learn to take advantage of what is easily available or understandable.

Information Behavior Grid

The Information Behavior Grid (IBG) (von Thaden, 2003, 2004) was developed using principles from Information Science, human factors science and communication studies (Wilson, 2000; Ellis, 1989,1993,1997; Choo, Detlor, and Turnbull, 2000) to measure distributed patterns of information needs, seeking and use among distributed groups. Applied to this research, the IBG is a tool to distinguish whether accident involved flight crews practice different patterns of distributed information behavior than those of non-accident involved flight crews. In the context of this study, it is not about measuring human error nor distinguishing the precise moment a decision is made, but rather to observe social information interaction in an attempt to measure distributed information practice and use of essential, safety critical information. This is accomplished through analyzing transcripts of crew interaction during simulated flight using the IBG.

Given the dynamics and training in aviation operations, information behavior may be understood as either passive/conditioned behaviors or active/formal behaviors. Pilots tend put information into practice two ways, they actively engage in a methodical, systematic, defined process of making sense of the environment, an almost feed-forward activity (although the process actively engages understanding past events to make sense), or they passively, casually survey the environment or their instruments to evaluate the environment, a more experiential, "seat-of-the-pants" endeavor. In other words, pilots tend to function informally or formally, looking *at* or looking *for* information. These distinctions of information behavior allow a general understanding of their work practice. Although these categorizations may lose some of the crews' intricate information strategies, the real need is to understand whether they base their information behavior solely on personal experience or formal methodology. This grid has been updated in place of the original model developed by von Thaden (2003) and von Thaden & Wiegmann (2004)(for a complete discussion see von Thaden, 2004). Figure 1 shows the layout of the Information Behavior Grid described below.

	Information Need	Information Seeking	Information Use
Exploration	Casual/ Conditioned Identification	Casual/ Conditioned Gathering	Casual/ Conditioned Use
Exploitation	Methodical Systematic Identification	Methodical Systematic Gathering	Methodical Systematic Use

Figure 1. *The Information Behavior Grid.*

In *Conditioned Identification* (CI) general areas of interest are passively viewed (scanned) using casual or informal means. There is no specific information need communicated but simple queries may be formulated or addressed on broad search areas. *Conditioned Gathering* (CG) may consist either of broadly sweeping varied resources to detect change signals and take advantage of easily accessible information or CG may consist of passively fixating on a limited area or instrument. In *Conditioned Use* (CU), information may be discovered serendipitously through passively browsing a number of different resources. CU may also entail passively or habitually acknowledging a change within narrow boundaries or using personal rather than technical criteria to arrive at a decision. In *Methodical Identification* (MI) general areas of interest or trends are actively recognized using practiced viewing patterns (schema). Specific detailed targets are actively sought or simple specific needs are updated and expanded through an ongoing search. *Methodical Gathering* (MG) of information involves actively browsing in preselected sources or instruments using prespecified protocols (methods/ procedures) to acquire information, such as attending to a checklist. MG also consists of active, ongoing measurement. *Methodical Use* (MU) of information entails actively increasing specific knowledge about areas of interest, relevance, or change. Relevant information is used for determining a specific course of action. MU also entails meticulous confirmation (verification) of information.

Method

The purpose of this study was to empirically evaluate the distributed information behavior of flight crews in the simulated environment. Specifically, advanced student pilots in a CRM course at the University of Illinois' Aviation Division (operating under FAR Part 141 approved curriculum guidelines) were observed participating in simulated flight exercises consisting of 5 distinct mission-based dynamic scenarios to various destinations around the United States. Over the course of the semester, pilots completed classroom assignments and learned the concepts relating to societal/cultural, industry, governmental regulatory agency, organizational, group, and individual influences on behavior and crew resource management. Simulated flights served as practical experience to learn the concepts of CRM. Laboratory and flight sections used a multi-engine Frasca 142 Flight Training Device (FTD), complete with dual instrumentation and controls simulating a Piper Seminole with Lycoming IO-360-A1H6, 180 hp engines and a maximum takeoff weight of 3800 lbs. Participants were familiar with the Piper Seminole and Frasca 142 FTD as they had completed multi-engine ratings in a previous semester at the University of Illinois using the same equipment.

Two students flew each mission together as a crew in normal, abnormal, and emergency situations to gain practical experience for working together as a team. Before flight simulations (i.e., missions) commenced, pilots were required to ensure the necessary documentation was aboard each simulated flight as would be required in actual operations including proper checklists, operating manuals, maps, charts, and any other equipment necessary to conduct the mission. Each mission consisted of a mission briefing, preflight planning, the simulated exercise, and debriefing. Pilots were given the necessary information to plan their route of flight and obtain necessary weather and advisory information. The missions, and their consequences, were simulated just as they would be in real world applications. Pilots were to fill out the required paperwork at the end of each mission. In the case of violations, incidents or accidents, pilots were required to fill out the necessary reporting forms at the end of each mission. Instructors acted as Air Traffic Control and Company Briefers when appropriate.

Twenty students were registered for the course. Participation was completely voluntary, no monies were paid to participants, no interventions occurred as a result of their videotaped sessions and there was no penalty for non-participation. Nineteen students agreed to allow use of their performance data in the simulated flights to be utilized in this study. Participants (n = 19) were on average 22.75 years of age with an average total flight time of 389.11 hours.

Pilots completed 5 different simulated scenarios over the course of the semester. Each pilot flew each mission as the pilot flying (PF) and the pilot not flying (PNF) the aircraft. In each case, the Pilot in Command (PIC) consisted of the PF or Captain of the mission and the Second in Command (SIC) consisted of the PNF, or First Officer of the mission. These pairings allowed the pilots to each have a turn acting as Captain and First Officer in each scenario. This was achieved by having one pilot act as Captain for the first leg of the flight, and then switch roles for the second, or return, leg of the flight.

The sessions were videotaped and transcribed resulting in 49 usable transcriptions. Restricted recordings of crew pairings not participating in the experiment, occasional problems with video recording equipment or the audio portion of the recording, or simply forgetting to turn on the equipment, resulted in 49 usable taped scenarios. Twenty-four total distinct crew pairings were captured in the recorded simulations for the nineteen pilots. Though the entire simulated laboratory session was recorded, the last 20 minutes of each mission (i.e. approach to landing phase) was used for the present analysis. The missions were evaluated for outcome (accident or non-accident), crew performance (high, average, low), and independently coded for crew information behavior using the IBG.

During the transcription accuracy check, each mission was evaluated for crew mission performance (high, average, low) by observing the interactions of crewmembers during each mission. This classification allowed for an analysis of the mission as well as to determine how crew performance may vary across the semester. The following criteria were used to assess mindful attention and heedful interaction (adapted from Weick and Roberts (1993) discussion of collective mind). Crews that displayed high professionalism, preparedness, and carried out heedful interactions the majority of the mission were categorized as High Performance (HP). Crews that displayed low professionalism, were not prepared for the mission, and were heedless in their interactions the majority of the mission, were categorized as Low Performance (LP). Crews that displayed neither superbly high nor excessively low performance were categorized as Average Performance (AP).

After the crew performance was assessed, each of the transcriptions was hand-coded by the researcher at the speech act level for instances of crew information behavior, blind to crew performance and to mission outcome. Each speech act was coded considering the PIC, SIC, and Instructor as part of the flight environment. Communication that could not be understood was recorded as non-codeable (NC), and that having no relevance to the flight mission was coded as Not Pertinent (NP). Nineteen speech acts were listed as non-codeable throughout the 49 tapes and not included in the analysis. Where appropriate, Instructor's communications were coded when they acted as briefers or controllers in the mission, as they represent part of the flightdeck's information environment. Five transcripts were randomly selected from the various stages of coding (2 early, 1 mid, and 2 later in the process). These transcripts were then re-coded by the same researcher without access to previous codings. An intra-rater reliability test was performed on 5 selections using percent agreement. Intra-rater reliability resulted in the acceptable score of 0.88, with no further reliability testing performed.

Results

For the 49 missions 11,869 observed information behaviors were coded, with an average of 242 behaviors per case across the scenarios. Figure 2 shows that combining the data for all missions, MU accounted for the highest percentage of information behavior at 32%, followed by MG at 19%, and CU at 18%, then CG at 12%, MI at 10%, CI at 7%, and NP at 2%. When viewed in the aggregate, information use is greater than information identification and gathering, and methodical information use is greater than conditioned information use. Information gathering is greater than information identification, but less than information use, and methodical information gathering is greater than conditioned information gathering. Information identification is less frequent than information gathering and information use, and methodical information identification is greater than conditioned information identification. Overall, conditioned information behaviors appear less frequent than their methodical counterpart. Non-pertinent information behavior occupies the least percentage of behavior overall.

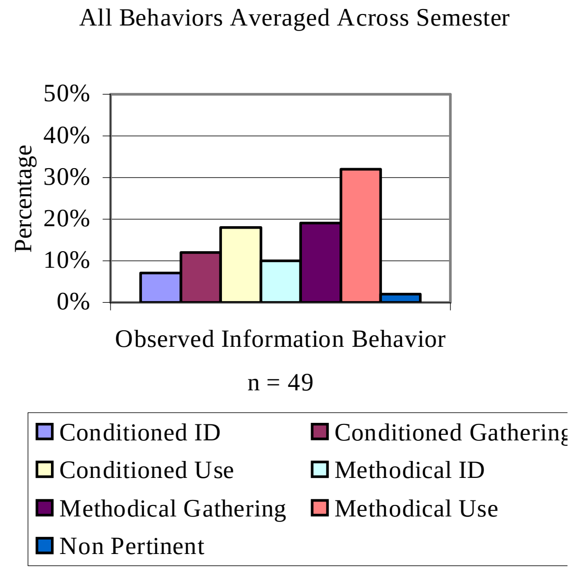

Figure 2. *Percent total observed Crew Information Behaviors across semester.*

Using the performance criteria, a total of 16 missions (33%) were classified as high performance, 14 (28.5%) as average performance and 19 (38.5%) as low performance (Table 1).

Table 1. *Distribution of performance groupings by scenario for 49 missions.*

Mission	**Team Performance**			
	High	Avg	Low	Total
Scenario 1	5	2	1	8
Scenario 2	3	6	3	12
Scenario 3	3	3	6	12
Scenario 4	1	1	2	4
Scenario 5	4	2	7	13
Total	16	14	19	49

Among the high performance grouping, MU accounts for 36% of the behavior, MG is 21%, MI is 10%, CU is 17%, CG is 8%, CI is 5%, and NP is 3%. Non-pertinent and methodical use behaviors were displayed more frequently in the high performance missions than in any other. These missions also contained the lowest frequency of observed behaviors for conditioned identification, conditioned gathering, conditioned use and methodical identification (see Figure 3). Among the average performance grouping, MU accounts for 32% of the behavior, MG is 19%, MI is 11%, CU is 17%, CG is 12%, CI is 8%, and NP is 1%. Methodical identification, and methodical gathering behaviors were displayed more frequently in the average performance missions than any other. Among the low performance grouping, MU accounts for 28% of the behavior, MG is 16%, MI is 9%, CU is 21%, CG is 16%, CI is 9%, and NP is 1%. Conditioned identification, conditioned gathering, and conditioned use behaviors were displayed more frequently in the low performance missions than any other missions.

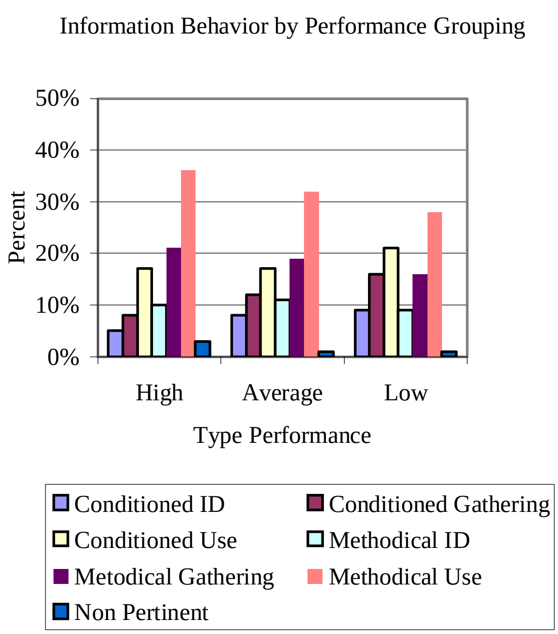

Figure 3. *Percent information behavior by performance grouping for 49 missions.*

The average number of information behaviors was smallest for the high performance missions, and largest for the average performance missions. From the data it appears high performance missions have less frequent information interaction overall (M = 229.44), followed by low performance missions with more frequent information interaction (M = 242.63), and average performance with the highest overall information interaction per mission (M = 256.29). This is not surprising since a tight coupling of activities between crewmembers, allowing a comprehensive shared understanding, marks high performance. Average and low performing teams appear not to share this tight coupling of activity or cohesive representation of the environment, resulting in the need for more interaction at lower fidelity.

A total of 8 missions resulted in an accident. All accident missions are contained within the low performance crew grouping, yet all low-performance crews did not have an accident. A means comparison between the three performance groupings reveals flight hours may account for significant differences between high and low performing crews, but does not appear as a significant difference between low and average crews or average and high crews (Table 2).

Table 2. *Comparison of crew flight hours between performance groupings (p<.05).*

Flight Hours						
Crew Performance	N	Mean	Std Dev	t	df	Sig.
High	14	496.68	255.55			
Average	12	345.88	187.81	1.69	24	.104
High	14	496.68	255.55			
Low	17	312.65	71.80	2.61	14.70	.02
Average	12	345.88	187.81			
Low	17	312.65	71.80	.584	13.29	.569

Analyzing the missions for crew performance factors in addition to information behavior results in a chi-square distribution revealing statistical significance (X^2_{12} = 320.62, p<.001). In particular it can be assumed that crew information behavior differs in relationship to crew performance.

Conclusion

When viewed as a whole, the observed information behaviors display a pattern in which methodical information behaviors are higher than that of their conditioned counterparts, with a low amount of extraneous non-pertinent chatter. It is reasonable to expect higher instances of methodical information behavior in aviation operations during the approach segment of the flight due to the prevalence of procedures and checklists. Since this portion of the flight also represents a period of higher workload, whether in the presence or absence of a system malfunction, crews require clearly defined processes and information that is easily accessible (Sarter & Woods, 1991). Information provided by and obtained through the use of checklists and procedures would necessarily be conspicuous as methodical information behaviors. Crews who properly employ checklists and procedures will more than likely have a higher incidence of methodical behavior, exploiting information processes. Crews who are more casual about procedures or who are not so comfortable with the airplane instrumentation may employ more conditioned "seat-of-the-pants" information behaviors and explore more avenues of potential information rather than exploit formal processes. The most significant differences though, lie between the way high performing crews act as a team in the negotiation of information meaning, and the way low performing crews (successful and accident) contend with information meaning. There are higher amounts of conditioned behaviors and lower amounts of methodical information behaviors among low performing groups than high performing groups.

What the proper proportion of information activity may be has yet to be determined through continued research. It appears overly methodical, or information exploiting, behaviors to the detriment of conditioned, or information exploring behaviors, may lead a crew to overlook the discovery new information that may contain cues that their previous assessment of the situation was flawed. However, the reverse appears to hold true also. Overly casual, conditioned information exploration behavior may lead a crew to mis-perform critical action sequences necessary for flight safety (see von Thaden, 2004). The balance remains to be determined, but this research approach may lead to the demonstration of the equilibrium in the information practice of high performing crews.

This study has shown it is possible to discern differences in the information practice of accident and non-accident involved flight crews. Effective information practice involves engaging in a variety of information behaviors that span across the 6 categories of the IBG. The IBG is a useful tool for understanding distributed information practice among flight crews, which may in turn inform improved crew resource management training and accident investigation. This framework also has the portability to be applied in other high risk, safety critical domains where work is performed through distributed collective practice, such as healthcare, nuclear power, and space exploration.

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