Air Traffic Control Specialist Decision Making and Strategic Planning – A Field Survey

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16. Abstract

This study investigated Air Traffic Control Specialists' perspective regarding decision making and planning and related cognitive processes such as learning, memory, and situation awareness. The results of 100 semi-structured interviews indicated that controllers emphasize the importance of safety, situation awareness, planning skills, backup strategies, and the collective nature of their task. Participants reported that they plan their first actions and start building their mental picture prior to assuming control of their position. They indicated using flight progress strips to support their memory. Controllers described that they become more conservative when facing difficulties like high workload, fatigue, aging, and bad weather. Concerning the respective effects of experience and facility type, the more experienced participants were, the more likely they reported formulating backup plans. Terminal controllers were more likely than en route controllers to report using the first strategy that they develop instead of considering alternatives when a potential conflict is detected or when workload is high. Terminal controllers also indicated that they were less likely to wait and see when they are not sure if there is a conflict. Finally, respondents expressed a need for conflict probes, better weather information, data link communication, and better radars.

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EXECUTIVE SUMMARY

The Panel on Human Factors in Air Traffic Control Automation proposed to increase the level of automation in Air Traffic Control (ATC) facilities to accommodate the growth in the number of flights projected over the next decades. They also recommended that automation efforts in the near future focus on the development of decision aids for conflict resolution and for maintaining separation. Developing efficient decision aids requires a good understanding of human decision making and planning. Human factors researchers from the Federal Aviation Administration William J. Hughes Technical Center conducted semi-structured interviews with 100 Air Traffic Control Specialists (ATCSs) to examine their perspective regarding controller decision making and planning and related cognitive processes such as learning, memory, and situation awareness (SA).

ATCSs described a variety of decision-making and planning strategies. They reported that they plan their first actions and start building their mental picture prior to assuming control of their position. Most controllers indicated that they always try to formulate a backup plan. The more experienced participants were, the more likely they reported formulating backup plans. The strategies reported by participants sometimes varied according to their type of facility. Terminal controllers were more likely than en route controllers to report using the first strategy that they develop instead of considering alternatives when a potential conflict is detected or when workload is high. Terminal controllers also indicated that they were less likely to wait and see when they are not sure if there is a conflict.

Some common themes pervaded participants' answers to many of the questions. First, participants often reported becoming more conservative or cautious (e.g., use a larger buffer) when confronted with difficulties like bad weather, high workload, fatigue, and aging. This reflects the main priority of ATC of ensuring safety. Participants' reports also emphasized the collective nature of ATC. Controllers must coordinate their actions and plans with many other actors, such as pilots and controllers working with and around them. Results suggest that controller SA generally includes knowledge of the skills and preferences of the other controllers. The importance of teamwork was also emphasized when participants reported fighting boredom by watching other sectors and protecting other controllers. Helping without a specific request corresponds to the highest level of team coordination. Finally, participants' responses suggest that ATC is a service industry and that honoring pilots' requests is their duty. Participants indicated that they consider honoring requests based on their workload, on the potential impact on the traffic in their own sector, and on the impact on the controllers' workload in the next sectors.

Some of the responses may facilitate the development and implementation of decision aids adapted to the needs of controllers. Decision support systems should consider the crucial role of SA in controller decision making and planning. For example, according to participants, experienced and skilled controllers would have a greater SA than novices and less skilled controllers. Future decision aids could assume that the level of SA would vary according to the experience and ability of controllers. Future support systems should also consider that controllers start forming their mental picture before assuming control of their position and provide them with the relevant information. Decision aids could also help controllers to maintain their SA of surrounding sectors and positions. Electronic flight strip systems may have

to provide users with ways or procedures that will replace the flight strip procedures that currently support controller memory. Participants' reports emphasized the difficulties bad weather creates and the need to develop systems that will support controllers in these conditions.

This study should provide investigators with different targets of opportunity for future studies. One could determine the importance of the different types of information that controllers collect to establish their mental picture and to identify which ones are not usually covered in the position relief briefing. Another study could investigate the frequency that memory techniques and separation strategies reported by the participants are used and if usage varies according to controllers' experience and type of facility. Another investigation could help to assess how much controllers agree on what characterizes skilled controllers by asking them to rate the importance of the different factors identified in the present study.

The participants most often requested conflict probe type decision aids. This coincides with the Panel on Human Factors in Air Traffic Control Automation's recommendation to develop automated decision aids for conflict resolution and maintaining separation. Moreover, many controllers reported that they have limited trust for existing systems. A future study could therefore concentrate on controllers' perceived needs regarding conflict probes to ensure that future automation will meet their expectations. Some controllers wished that data block presentation could be modified. An interesting question would be to determine if an automated system emphasizing different types of information according to the situation would help controllers. Similarly, other participants wished that data blocks be added to ground radar displays. Determining tower controllers' needs could facilitate the implementation of such a feature.

The present study has provided a greater knowledge of controller decision making and planning. The results may guide designers of decision support systems and help them match these tools with users' perceived needs and facilitate user acceptance. The results will also help to identify targets of opportunity for more focused interviews in field facilities.

1. Introduction

Air Traffic Control Specialists (ATCSs) are decision makers in a dynamic environment involving many actors, constant updating of relevant information, and, sometimes, conflicting goals. They often need to make difficult decisions with incomplete information, under time pressure and high workload. The Panel on Human Factors in Air Traffic Control Automation proposed to increase the level of automation in Air Traffic Control (ATC) facilities to accommodate the growth in the number of flights projected over the next decades (Hopkin, 1998; Wickens, Mavor, Parasuraman, & McGee, 1998). They also recommended that automation efforts in the near future focus on the development of decision aids for conflict resolution and for maintaining separation. To be effective, these decision support systems must rely on good models of human decision making (Mosier, 1997; Mosier & Skitka, 1996).

1.1 Background

In FY 1999, the Research Development & Human Factors Laboratory at the William J. Hughes Technical Center initiated the first in a series of studies to investigate ATCS decision-making strategies. Human factors researchers from the National Airspace System (NAS) Human Factors Branch (ACT-530) conducted semi-structured interviews with 100 ATCSs to examine their perspective regarding controller decision making and planning. The goal was to explore controllers' views of important issues related to the information they use, difficulties encountered, and potential improvements. ACT-530 designed the study to expand the knowledge base and serve as a foundation on which to build future research on decision support automation and training.

1.2 Literature Review

1.2.1 Decision Making and Planning in Air Traffic Control

Controllers collaborate with pilots, technical staff, management, and other controllers to assure the safe, orderly, and expeditious flow of air traffic. They ensure safety by guaranteeing minimum separation between aircraft. To do so, they must reserve a block of airspace around each aircraft. This space is defined by altitude and lateral dimensions and is shaped like a "hockey puck" (see Figure 1). The size of the reserved block has different values in different regions of the airspace, as defined in the ATC Handbook (FAA, 2000a). For example, under Instrument Flight Rules (IFR), the minimal vertical separation is 1000 feet at or below Flight Level (FL) 290. Above, it becomes 2000 feet. Factors like the aircraft performance characteristics and navigation systems in use also determine the size of the restricted airspace. The role of the controller is to not let the reserved airspace of two aircraft overlap (Nolan, 1994). If they do overlap, a separation error occurs.

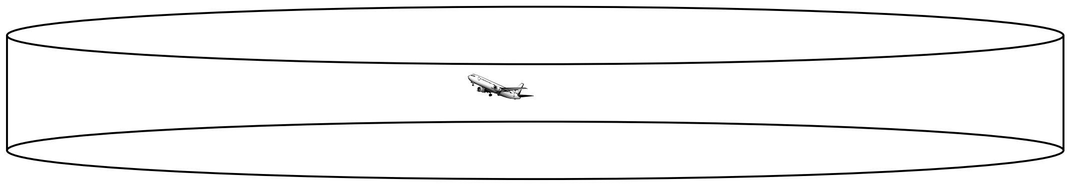

Figure 1. Illustration of aircraft restricted airspace.

ATCSs use different techniques to ensure aircraft separation. Some of the most common ones are speed control, altitude change, radar vectors, and holding patterns (Ammerman, Becker, Jones, & Tobey, 1987). The frequency with which controllers use separation techniques differs greatly from one type of facility to another. For example, reducing speed in Air Route Traffic Control Centers (ARTCCs) may not be desirable because it would reduce air traffic efficiency. However, final approach controllers in terminal radar approach control (TRACON) facilities may use speed control extensively.

Ensuring the safety of aircraft is a controller's main priority, but another part of the Federal Aviation Administration (FAA) mission is to guarantee the efficient flow of traffic through the NAS. Provided that safety is not compromised, airline companies, pilots, and the traveling public have an interest in efficient traffic flow. Controllers must address the sometimes-conflicting goals of safety and efficiency "through an intricate series of procedures, judgments, plans, decisions, communications, and coordinated activities" (Wickens, Mavor, & McGee, 1997, p. 21), in an environment in which errors may have dramatic consequences.

Decision makers working in complex environments make errors (Reason, 1990). In the context of ATC, Wickens et al. (1997) proposed that there are two types of errors: operational errors and controller errors. An operational error is a formal designation and occurs when the reserved airspace of two aircraft overlap or when minimum separation criteria are not met between aircraft and terrain, obstacles, or obstructions (FAA, 1987). This type of error has more serious safety implications. Controller errors refer to "a much wider range of inappropriate behaviors that result from breakdowns in information processing" (Wickens et al., 1997, p. 103). These errors may have minor safety implications or severe ones.

Most operational errors are made under conditions of moderate to light levels of workload, traffic complexity, and traffic volume, and when controllers are working under the combined radar/radar associate function (Redding, Ryder, Seamster, Purcell, & Cannon, 1991). Redding and his colleagues suggested that deficient Situation Awareness (SA) due to a lack of vigilance in monitoring caused many errors. Redding and Seamster (1994) confirmed the previous findings when observing that most operational errors occur with traffic levels of moderate complexity, with an average of only eight aircraft under control, and immediately following a shift break. They also proposed that failure to maintain adequate SA was a major cause of operational errors.

Faulty controller decision making may also result in operational errors or compromised safety. For example, in November 1975, an Eastern Airlines DC-10 and a Trans World Airlines L-1011 almost collided head-on while operating on the same airway at FL 350 (Danaher, 1980). The pilot of the DC-10 avoided the midair collision with an evasive maneuver that still resulted in 24 persons being injured. Investigation of the incident revealed that a Cleveland ARTCC radar controller had cleared the Eastern Airlines flight to climb through FL 350 to FL 370, while the L-1011 was cruising at FL 350. The controller was aware of the potential conflict but decided to wait hoping that separation would be ensured when the two aircraft passed each other. This is referred to as "anticipated separation." The controller assumed that he could keep monitoring the aircraft on his radar and determine in time if new clearances would need to be issued. However, the controller became absorbed with secondary tasks, and another controller relieved him 1 minute before the near-collision. The second controller detected the unresolved conflict 50 seconds after taking over the position and immediately instructed the DC-10 to descend. One second before the descent instruction was issued, the DC-10 captain sighted the other aircraft, which prepared him to execute the evasive maneuver promptly. Deficient decision making, the first controller's decision not to take immediate positive action, almost caused a midair collision.

Despite the challenges confronting ATCSs, the number of operational errors is still relatively low. However, the projected increase in air traffic will put more pressure on the system and emphasize the need to reduce the likelihood of errors. The Panel on Human Factors in Air Traffic Control Automation suggested "decision making may be improved by training and displays that are sensitive to strategies that do work in real-world environments" (Wickens et al., 1997, p. 108). The group subsequently recommended that automation efforts in the near future focus on the development of decision aids for conflict resolution and maintaining separation (Wickens et al., 1998). One concern of the panel is that automated decision aids relying on incorrect models of human decision making may result in systems that are less efficient than the human alone (Hopkin, 1988; Mosier, 1997; Mosier & Skitka, 1996). The development of decision support technologies should therefore benefit from an enhanced understanding of the decision-making and planning processes used in operational settings by ATCSs. Understanding what situations make the task of controllers difficult and impair their performance will help to design the most effective decision aids (Leroux, 1997).

1.2.2 Cognitive Model of the Controller's Task

Decision making is a complex process. An understanding of its mechanisms requires examining decision making in a larger framework in which it interacts with many other cognitive processes. Figure 2 illustrates a generic model of the cognitive processes involved in the ATCS's task, proposed by Wickens et al. (1997). The model includes five cognitive stages or processes that intervene between events (on the left) and actions (on the right): selective attention, perception, SA, decision making and planning, and action execution. The model suggests that controllers selectively attend to and perceive events to build and maintain awareness of the situation. SA is the principal input to decision making and planning, which may result in the execution of actions like communications and keyboard use. The model also illustrates the contribution of memory in the controller's task. Immediate memory supports computations and maintains an awareness of the dynamic aspects of the situation. Prospective memory allows remembering actions to be

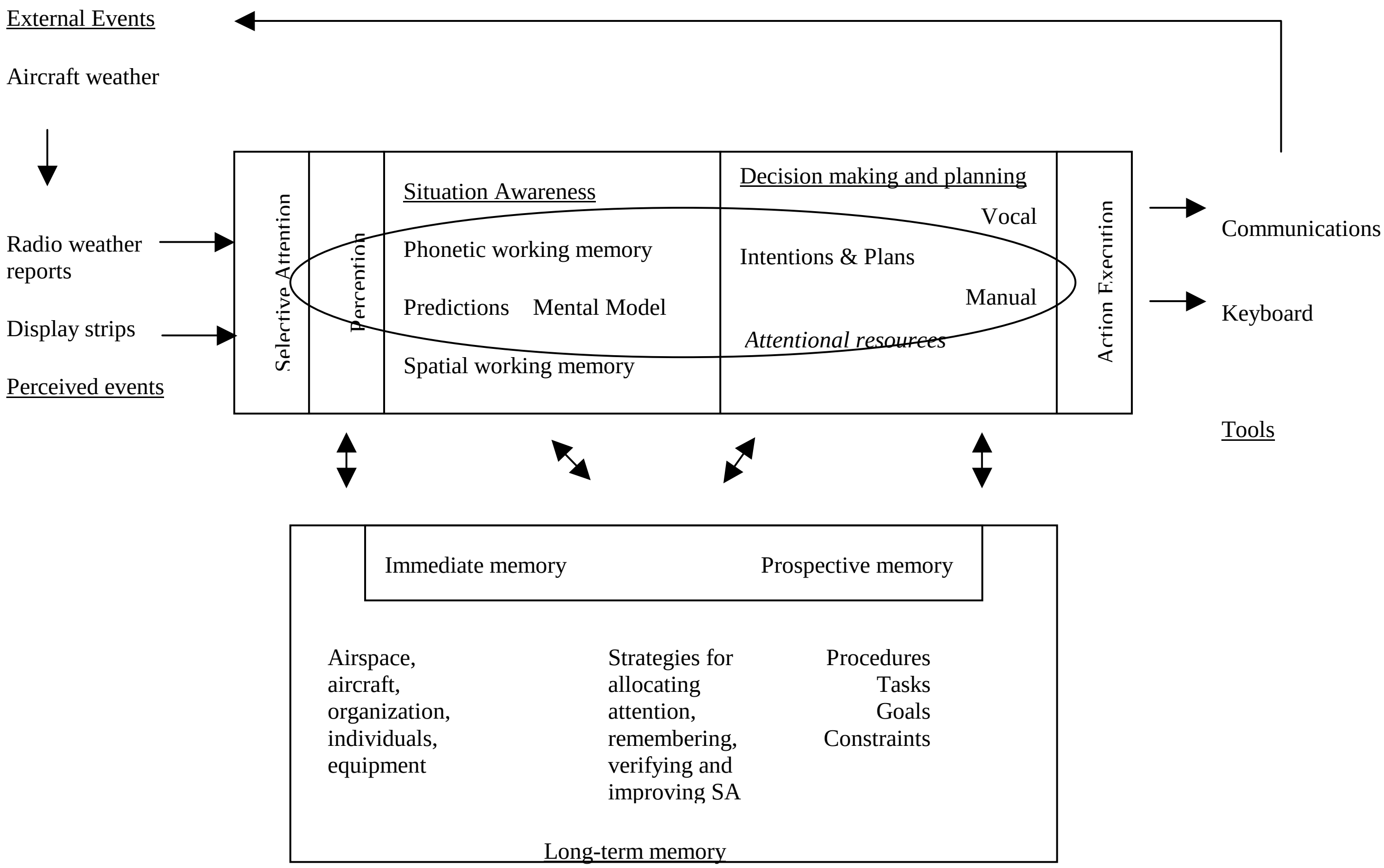

Figure 2. Adaptation of Wickens et al.'s (1997) cognitive model of the controller's task.

performed in the near future. Controllers draw on the structures of long-term memory to access their static knowledge of the airspace, radar equipment, and weather (Redding et al., 1991). Controllers' knowledge of ATC and strategies supporting processes like decision making and planning reside in long-term memory. Decision making and planning are highly dependent on the processes of attention, perception, memory, and SA.

Controllers attend to and perceive events that come in many different forms. These events include visual changes on the radar display. Visual scanning of the radar display is a crucial activity for controllers. Scanning influences decision making and planning because it plays a major role in conflict detection and the acquisition and maintenance of SA. Soundly made decisions may still result in mistakes if they are based on information acquired through deficient scanning processes. Breakdowns in the serial process of scanning may result in a critical event being missed, making decision making more vulnerable (Stein, 1992). However, Redding et al. (1991) concluded that lack of attention and active processing of information appears to be largely responsible for the misuse or misidentification of data rather than decreased visual scanning.

SA greatly influences decision making (Endsley & Smolensky, 1998). For example, the selection of a problem-solving strategy is based on SA. Similarly, the goals of the decision maker influence SA. Endsley (1988) generally defined 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 near future" (p. 97).

In a dynamic environment like ATC, a controller must remain aware of critical features that vary constantly. Endsley (1995) stressed the importance of SA for decision making by pointing out that inaccuracies or lapses in SA might lead to a disaster, even if the decision maker makes the right decision. However, Endsley added that poor SA does not always lead to poor performance. For example, a decision maker might realize his or her lack of SA and adopt strategies that will reduce the likelihood of poor performance. According to Endsley, an understanding of SA should allow design improvements to decision support systems that will provide decision makers with the information they need in an appropriate form.

Several studies have investigated what information ATCSs seek to maintain aircraft separation and their awareness of the situation. The list of relevant pieces of information is very long (known winds, weather patterns, airspace considerations, aircraft turn rate, descent and ascent rate, etc.), but some seem to play a greater role than others. For example, Helbing and Eyferth (1995, as cited in Hutton, Olszewski, Thordsen, & Kaempf, 1997) observed that call sign, altitude, cleared altitude, and exit waypoint accounted for 93% of all demands of information in their study. Altitude and relative position were best memorized and used more frequently by Bisseret's (1971) subjects, who had been told that the experiment was concerned with problem-solving time and not memory. After analyzing verbal protocols and interviews, Leplat and Bisseret (1966, as cited in Vingelis, Schaeffer, Stringer, Gromelski, & Ahmed, 1990) proposed that controllers are interested in the future states of pairs of aircraft, and they found that the following six attributes are compared in this order:

a. Altitude
b. Flight paths
c. Longitudinal separation
d. Relative speeds
e. Direction of flights after reporting points
f. Lateral separation

Determining what information is used under different strategies in different conditions would certainly lead to the design of decision-making aids that would be compatible with the decision style and actions of ATCSs. Knowing what type of information is prioritized in different situations should lead to the development of displays that are sensitive to the strategies used by controllers in their operational settings (Wickens et al., 1997).

Controllers rely heavily on their memory to execute their tasks. The FAA recognized the need to investigate the impact of memory on ATC operations (Stein, 1991). A handbook providing information and helpful hints on human memory was developed for controllers (Stein & Bailey, 1989).

To help controllers reduce the frequency of operational errors caused by memory lapses, the Technical Center launched a 3-year research program to develop practical and effective memory aids (Vingelis et al., 1990). Gromelski, Davison, and Stein (1992) observed that controllers perceive memory aids as crutches for unskilled controllers and that the three memory aids they used the most involved strips: strip management, tilted strips, and strip marking. Based on these observations and some of the other data collected during the 3-year research program, Stein and Bailey (1994) published a new controller memory guide and made it available in ATC facilities.

Used as a memory aid, flight strips facilitate strategic planning and prospective memory. Flight strips also support controller decision making by providing vital flight plan information and allowing the detection of conflicts. However, use of flight strips vary enormously between facilities.

1.2.3 Factors Influencing Decision Making

Wickens et al.'s (1997) cognitive model of the controller's task illustrates that decision making and planning are highly influenced by their interaction with cognitive processes like SA and memory. Decisions and plans are also determined by the characteristics of the decision maker, task, and context.

1.2.3.1 Decision Maker Related Factors

Investigating how experts make efficient decisions and plans will certainly benefit the development of automated decision aids. However, understanding what differentiates novices from experts, or, in other words, how expertise develops, might be even more crucial. One concern of the Panel on Human Factors in Air Traffic Control Automation is that novices who use decision support expert systems do not perform as well as experts (Mosier, 1997). Novices using automated aids seem to achieve the most satisfactory results when "the task is routine and covered by standard procedures" (Mosier & Skitka, 1996, p. 210). This suggests that automated decision support systems will be potentially more efficient if they integrate user models that reflect different levels of expertise.

Many studies have examined the effects of expertise on decision making and use of strategies. According to Brehmer (1992), experienced subjects have learned that, to perform well in a complex dynamic system, they have to adopt "grandmother rules." More specifically, compared to less experienced subjects, they will make fewer decisions, collect more information before making a decision, and check the results of their decisions before making new decisions.

Dreyfus and Dreyfus (1984) suggested that novices tend to make decisions in a careful, analytical fashion, whereas experts appear to make decisions quickly rather than making serial and exhaustive searches. Similarly, Klein (1989) proposed that, in real-world situations, experienced decision makers learn a large set of patterns and associated responses and that, in general, they do not compare a set of alternatives based on their predicted outcomes but, instead, recognize a situation and retrieve an appropriate response.

In their extensive cognitive task analysis of en route ATC, Redding et al. (1991) observed how novice, intermediate, and experienced controllers use strategies. When compared to novice controllers, experienced controllers tend to use a smaller number of strategies, which include more control actions and aircraft. Experienced controllers also use a greater variety of different strategies, which indicates that they possess a wider repertoire of strategies.

According to Redding et al. (1991), experts use more workload management strategies than novices. They especially use strategies allowing them to identify aircraft that can be expedited through their sector and reduce the number of aircraft to which they need to attend. Intermediates also used more workload management strategies than beginners did, suggesting that the use of these strategies increases with experience. The authors also concluded that the greater the number of strategies used overall, particularly monitoring strategies, the fewer the errors. More specifically, three workload management strategies are closely associated with a reduced number of errors: determining what to do to eliminate a factor, identifying aircraft that are not a factor, and determining how to expedite aircraft through your sector.

Another controller-related factor that is often highly correlated with experience is age. Few studies investigated the effects of aging on performance. Becker and Milke (1998) suggested that “the ability to handle simultaneous visual and auditory input or to return to a task after a break to complete another task is critical to success and is the sort of cognitive function most affected by age” (p. 944). The authors also pointed out that many of the controllers forming the current ATC workforce were hired after the Professional Air Traffic Controller Association strike and subsequent 1981 firing by then President Reagan. They stressed the importance of determining the nature and extent of the effects of aging because they believe that “a high proportion of the ATC workforce will be at risk for displaying age-related changes in job performance efficiency over the next 10 years” (p. 944).

Many studies have investigated the effects of aging on cognition (Fisk & Rogers, 1997). Age-related decrements in decision-making processes have been observed in tightly controlled laboratory experiments, but studies conducted in more natural settings or in the workplace have shown more similar performance levels among older adults and younger ones (Walker, Fain, Fisk, & McGuire, 1997). Many of these studies have argued that, in numerous working environments, individuals can use varying task strategies and control the scheduling of different tasks, allowing older adults to keep performing normally by using different decision heuristics (Davies, Taylor, & Dorn, 1992; Johnson, 1990). It is also believed that domain-relevant experience or skill maintenance might help older individuals to maintain their performance level (Morrow, Leirer, Altieri, & Fitzsimmons, 1994). Controllers may change the way that they approach traffic separation problems or may bring to bear cognitive processes that are not affected by aging (Becker & Milke, 1998).

Gromelski et al. (1992) reported that 9 out of 10 controllers contend that they experience boredom on the job. Few have identified ways to avoid this situation. Boredom may promote overconfidence and lack of attention, which would make decision making vulnerable. Low workload episodes could represent an opportunity for controllers to adopt strategies that are less cognitively economical or to employ infrequently used strategies.

Many other controller-related factors might influence ATCS decision making and planning. Stress may promote problem solving rigidity (Cowen, 1952). Fatigued subjects tend to choose riskier strategies (Holding, 1974). High trait anxiety subjects appear to adopt strategies that would result in more control over time-constrained tasks (Leon & Revelle, 1985). Finally, depressed individuals may lack the same levels of motivation and willingness as the less depressed and make an ineffective use of strategies (Williams, Watts, MacLeod, & Mathews, 1988).

1.2.3.2 Task-Related Factors

Decisions made by decision makers are contingent on many task-related factors. In ATC operations, for example, the complexity of the sector for which they are responsible, the volume and complexity of the traffic, and time pressures may influence controllers.

In a simulation presented to approach controllers, Sperandio (1971) observed that, under low traffic loads, controllers used more direct routings, which required that they consult aircraft performance information more frequently. Under heavy traffic loads, controllers tended to use standardized routings and more holding patterns, which required less performance data. According to Sperandio, controllers maintained their performance level by using the standardized routings, which reduced the number of variables they needed to process. Under the low workload condition, using direct routes was more work for the controllers because they had to process more variables, but it fulfilled their need to maintain a certain level of activity.

As described by Sperandio (1978), controllers regulate their increasing workload (or maintain it at an appropriate level) by using successively more economical strategies. As traffic increases, controllers might progressively use more standardized routings to allow them to process a smaller number of variables for each aircraft and help them treat “each aircraft as one link in a chain whose characteristics remain stable and not as an independent body moving in free space among other independent moving bodies” (p. 196).

Sperandio (1978) proposed that workload also influences decision-making processes by determining which objectives controllers will prioritize. Although ATC objectives may sometimes conflict, Sperandio suggested that they are hierarchically organized. The fundamental objective for the ATCS is to maintain safety by observing separation standards, immediately followed by the goal of maintaining a high rate of progress of aircraft through the system. The secondary objectives would relate to providing ATC service and increasing efficiency such as assigning requested altitudes and routes to maximize fuel efficiency. As their workload increases, ATCSs often take secondary objectives less and less into account to concentrate on the primary ones.

1.2.3.3 Contextual Factors

Controllers have to make their decisions and plan their separation strategies with the collaboration of pilots, technical staff, management, and other controllers. The controllers working with them and around them, the type of management leadership, and the requests of pilots may influence how controllers make their decisions and plan their strategies.

Redding et al. (1991) reported that many ATC errors are made when controllers are working under the combined radar/radar associate function. They suggested that this situation probably promotes overconfidence and a lack of vigilance, which in turn jeopardizes the quality of decision making. Sperandio (1978) also suggested that, as the task load increases, the tasks of the associate become increasingly dependent on the tasks of the radar operator and consequently tends to overload the principal operator even more.

ATC is a service industry and pilot and airline requests heavily influence controllers' separation strategies and decisions. For example, they make their requests for different routes or to fly at aircraft optimal altitudes to allow time savings, fuel economy, and greater comfort for passengers. An important goal for ATCSs is to satisfy users' requests as long as safety and the efficiency of the airspace is not compromised. By giving airspace users more flexibility in determining their own flight routes, the implementation of Free Flight proposals (Planzer & Jenny, 1995; RTCA 1995a, 1995b) might also increase the number of pilot requests. It is currently unknown how this will impact controller decision strategies.

Training also has an influence on controller decision making. ATCSs receive their training in several phases. The Air Traffic Control Academy in Oklahoma City offers initial qualification and basic training (e.g., TRACON controllers take the Academy basic radar course). However, the assigned facility provides most of the advanced training. The ATCS training program has often changed over the years. For example, when the ATCS Nonradar Screen program was operational, the emphasis was on screening candidate controllers instead of training them (Fisher & Kulick, 1998). In 1992, the ATCS/Pre-Training Screen (PTS) replaced the previous program, and the Academy implemented a train-to-succeed curriculum. However, due to technical considerations, PTS did not last very long and is currently on hold.

An important part of the facility training consists of on-the-job training (OJT), where developmental controllers work the different positions of the facility under the close supervision of an instructor. Previously, instructors were told not to teach their personal strategies or techniques (Fisher & Kulick, 1998). It was believed that trainees should be allowed to develop their own preferences. The extent to which different controllers will have learned from the instructors might vary. Controllers may also have learned or perfected their skills outside of formal training. For example, Sperandio (1978) pointed out that, although controllers might be exposed to the entire repertoire of operational strategies during formal training, it is through personal experience that they really learn how to alternate from one strategy to another.

1.2.4 Theories, Models, and Approaches of Dynamic Decision Making

The development of decision support systems will benefit from a better understanding of the factors influencing controller decision making and planning. A long history of decision-making research will also contribute to that development. The study of decision making has generated many theories and formal models of decision making (for reviews of the literature, see Doherty, 1993, Edwards, 1987; Letho, 1997, and Lipshitz, 1993), which all serve one or more of the three following purposes (Sarma, 1994):

a. Normative models aim to characterize optimal or most efficient decision-making processes.

b. Prescriptive models attempt to describe how decision makers should be trained or how decision aids should interact with them.

c. Descriptive models try to identify the psychological processes used by decision makers.

Models of decision making also differ along many other dimensions. For example, theories may aim to explain individual versus group decision making. Most of the initial efforts in decision-making research resulted in normative and prescriptive models, developed in the fields of economics and statistics, quantitatively representing a rational and optimal decision maker. Many have suggested that classical decision theory is too rigid and static to provide an adequate representation of decision making in real-world environments (Beach & Lipshitz, 1996) and that approaches emphasizing the dynamic nature of decision making must be adopted (Brehmer, 1992).

Edwards (1962, as cited in Brehmer, 1992), in his classic description, identified the characteristics of a dynamic decision-making environment:

a. It requires a series of decisions.

b. The decisions are not independent.

c. The state of the problem changes, both autonomously and as a function of the decision maker's actions.

Brehmer later added a fourth item to the list:

d. The decisions have to be made in real time.

Edwards (1962, as cited in Brehmer, 1992) and Toda (1962, as cited in Brehmer, 1992) made the first efforts to understand dynamic decision making by applying the subjectively expected utility theory (von Neumann & Morgenstern, 1947), a classical decision theory, to dynamic problems instead of static ones. They adopted a normative-descriptive approach in which the behaviors of real decision makers were compared to an ideal decision maker. Discrepancies would have suggested that limitations are imposed on decision makers. Their approach suffered from at least two problems identified by Rapaport (1975). First, as dynamic problems become complex, it quickly becomes impossible to find analytical solutions to solve them. Second, even when decision makers adopt strategies largely different from the ideal ones, the outcomes are often the same. The "flat maximum problem," as it is designated, makes identifying the limitations imposed on the subjects difficult.

Cognitive Continuum Theory (Hammond, 1980) is a more recent approach to dynamic decision making. It suggests that decision-making activities are located on a cognitive continuum varying from highly intuitive decisions to very analytical ones. In a review of previous research, Hammond (1993) showed that the decision-making tendency to rely on analysis instead of intuition augments when:

a. The number of cues increases.

b. Cues are measured objectively instead of subjectively.

c. Cues are of low redundancy.

d. Decomposition of the task is high.

e. Certainty is high.

f. Cues are weighted unequally in the environmental model.

g. Relations are nonlinear.

h. An organizing principle is available.

i. Cues are displayed sequentially instead of simultaneously.

j. The time period for evaluation is long.

Payne, Bettman, and Johnson (1988, 1993) contributed to the development of a similar approach, the theory of contingent decision making. This theory adopts a cost-benefit framework in which decision makers compare the cognitive effort against the accuracy of different decision strategies. The characteristics of the task and its context determine cognitive effort and accuracy. Decision makers will switch strategies to reduce the cognitive effort, increase accuracy, or respond to time pressures. The theory of contingent decision making is in agreement with Sperandio's (1978) description of controllers regulating their increasing workload by adopting strategies that are more economical.

Naturalistic decision making, a recent strain in decision-making research, has focused on the critical aspects of operational settings and more natural and dynamic environments (for reviews see Klein, Orasanu, Calderwood, & Zsambok, 1993 and Zsambok & Klein, 1996). This approach criticizes traditional models of decision making for their emphasis on laboratory studies and for having no direct relevance to real-world decisions (Klein, 1989).

The Recognition-Primed Decision Model (RPDM) is one representative of naturalistic decision-making models. Klein (1989) developed the RPDM after observing the decisions made by firefighters and experts from other fields in their naturalistic environment. He concluded that experts make most of their decisions without comparing different alternatives, contrary to what traditional models postulate. Instead, experts are involved in a situation recognition process in which, based on their experience, they classify the situation and immediately consider the typical way to handle it. After evaluating the feasibility of the option, they implement it if they foresee no problems. If something might go wrong, the decision maker will modify the option or simply reject it and consider another typical solution.

Experts from domains like fire fighting, paramedics, and other time-pressured environments use the RPDM to represent the decision-making activities (Klein et al., 1993). Some studies have also applied this model to ATCS decision making (Hutton et al., 1997; Mogford, Allendoerfer, Snyder, & Hutton, 1997; Mogford, Murphy, Roske-Hofstrand, Yastrop, & Guttman, 1994). The model has certainly gained some popularity among researchers investigating dynamic and time-pressured domains like ATC, but it also received some criticisms (Doherty, 1993). One shortcoming of the RPDM is that, by focusing on expert decision making, it might fail to represent the evolution of a novice becoming an expert. By representing only the processes of expert decision makers, the models might fail to serve prescriptive purposes such as indicating how decision aids should interact with less experienced controllers.

Beach (1993) provided us with an interesting summary by describing four revolutions in the development of behavioral decision theory. The first one occurred when it became clear that decision makers rarely examine all the alternatives to a decision, that they use heuristics (Tversky & Kahneman, 1974) or that they adopt a satisficing rule (i.e., settle for the first choice that is "good enough") instead of optimizing (Simon, 1955). The second one consisted of realizing that decision makers choose between strategies to make decisions, as illustrated by the contingency theory (Payne et al., 1993) and the cognitive continuum theory (Hammond, 1980). According to Beach, the third one is presently occurring because we are recognizing that decision makers rarely make choices and, instead, rely on prelearned procedures, as suggested by the RPDM (Klein, 1989). Beach reveals that the last one is just beginning. Decision research is adopting a multidisciplinary perspective drawing not only on economy but also on cognitive psychology, organizational behavior, and systems theory.

1.3 Purpose and Rationale

The purpose of the present study was to enhance our current knowledge of controller decision making and planning. Such knowledge may improve the design and implementation of new decision support tools. It also investigated controllers' opinions, preferences, and beliefs regarding their decision-making and planning operational practices and assessed their concurrence with theories such as those presented in the introduction. Reducing the potential mismatch between controllers' perceived needs and future decision aids was another goal. Finally, this study investigated if the opinions, perceived needs, and operational practices of controllers differ between individuals according to some variables such as their age, the type of facility in which they work, and their level of experience in ATC.

2. Method

2.1 Participants

The researchers interviewed 103 ATCSs who participated in the study on a voluntary basis (recruitment letter is presented in Appendix A). At the request of a local union representative, two interviews were not completed. Another one was not completed because the participant had to return to the operation. We therefore discarded the results of the three participants. Table 1 presents selected demographics of the 100 ATCSs who completed their interview (more extensive demographics are presented in Appendix B in Tables B1 to B3). Study participants included 7 females and 93 males. Eight participants were staff members maintaining their operational currency. The age[1] of participants ranged from 27 to 57 years and averaged 41.4 (*SD*=5.71). Their ATC experience varied from 4.5 to 36 years with a mean of 17.6 (*SD*=5.93).

The Technical Center local Institutional Review Board (IRB) reviewed and approved the study protocol. The IRB Application Form is presented in Appendix C.

[1] Age statistics exclude one missing value.

TABLE 1. SELECTED DEMOGRAPHICS OF STUDY PARTICIPANTS (N=100)

Demographics	Participants
Gender	
Females	7
Males	93
Facility Type	
Air Traffic Control Tower (ATCT)	13
TRACON	6
Combined ATCT/TRACON	13
ARTCC	68
Average Age (Years)	41.4 (*SD*=5.7)
Average ATC Experience (Years)	17.6 (*SD*=5.9)

Participants included controllers from ATCT, TRACON, combined ATCT/TRACON, and ARTCC facilities. A majority of the respondents, 68 out of 100, worked in ARTCC facilities. Participating controllers spent between 8 months and 31 years at their current facility (*M*=13.0, *SD*=6.1). These results suggest that controllers have spent most of their career at the same facility (13 years out of 17.6 average). Results show that 30% of participants have had some experience in facility types different than the one in which they work. The proportion of participants who have worked in other types of facilities is smaller in ARTCCs (15%) than in the three other types of facility (38%). Although 30% have had some experience in other facility types, results indicate that this type of experience was limited to an average of 1.6 years for all the participants (*SD*=2.9).

We visited high traffic level facilities (Table 2) from six different FAA regions[2]. We selected one ATCT, one TRACON, and one ARTCC from each region, and these facilities were closely located geographically to minimize travel costs.

2.2 Apparatus and Interview Protocol

2.2.1 Audio Tape Recorders

With the consent of respondents, the researchers collected audio recordings of the interviews. We viewed the tapes only as a means to backup the collected information. Sudman, Bradburn, and Schwarz (1996) reported that there is no evidence that the use of a tape recorder in an interview affects responses.

[2] The research team visited only one TRACON and one ARTCC in the Western-Pacific Region.

TABLE 2. AIR TRAFFIC CONTROL FACILITIES VISITED

FAA Region	Facility
Northwest Mountain	Denver ARTCC
	Denver TRACON
	Denver ATCT
Southwest	Fort Worth/Dallas ARTCC
	Fort Worth/Dallas TRACON
	Fort Worth/Dallas ATCT
Eastern	Washington ARTCC
	Dulles TRACON/ATCT
	Reagan National ATCT
Southern	Atlanta ARTCC
	Atlanta TRACON
	Atlanta ATCT
Great Lakes	Chicago ARTCC
	O'Hare TRACON
	O'Hare ATCT
Western Pacific	Los Angeles ARTCC
	Santa Barbara TRACON

2.2.2 Interview Questions Development

The questionnaire consisted of two parts: the demographic questions and the interview questions (Appendix D). Demographic questions included

a. gender,
b. type of facility,
c. facility level,
d. status as ATCSs or staff maintaining operational currency,
e. number of years of ATC experience,
f. number of years in their current facility,
g. number of years in different types of facility, and
h. age.

The second part of the questionnaire contained 26 open-ended questions. Recent research has shown that respondents tend to limit their answers to close-ended questions to the choices offered to them and will neglect to volunteer an opinion not included in the response choices, even if the researcher does not wish them to do so (Bishop, Hippler, Schwarz, & Strack, 1988; Presser, 1990). According to Krosnick (1999), open-ended questions should be considered a viable tool of research, and many criticisms regarding their usage have proved to be unfounded. For example, Geer (1988) has shown that open-ended questions work well even with people who are not very articulate. Contrary to a common belief, respondents do not tend to answer open-ended questions with the most salient possible response instead of the most appropriate one (Schuman, Ludwig, & Krosnick, 1986). Finally, Krosnick also mentioned that some older studies had shown the superior reliability and validity of open-ended questions over close-ended ones (Hurd, 1932; Remmers, Marschal, Brown, & Chapman, 1923). Therefore, we selected the open-ended format for the questions so that the ATCSs' responses would not be restricted.

We first determined the issues addressed in the interview and the construction of the questions after a review of the relevant literature on decision making and planning. A first set included questions adapted from Gromelski et al. (1992) and some questions developed by the researchers and a subject matter expert (SME). Five SMEs reviewed the questions and offered their advice regarding their relevance, understandability, and interest. The researchers selected a subset of questions based on the advice of the SMEs and submitted them to a pretest. We conducted the pretest of the questionnaire with five non-bargaining unit ATC staff from the Atlantic City International Airport Terminal and from the Philadelphia International Airport Terminal. We used conventional methods of questionnaire pretesting (Bischoping, 1989; Nelson, 1985) to identify questions that respondents had difficulty understanding or that they interpreted differently than we intended. While one researcher conducted the interview, the other sat in the same room and observed. We alternated roles after each interview. After interviewing a total of five respondents, we discussed their experience in a debriefing session in which they identified problematic questions (requiring further explanation, with confusing wording, difficult to read, which respondents refuse to answer, etc.) and made the necessary adjustments.

The resulting semi-structured interview included sets of open-ended questions about SA, ATC expertise, decision making and planning in specific contexts, interacting with pilots and other controllers, and decision aids. SA questions requested that respondents describe their scanning techniques, how they establish their mental picture, and how much they are aware of the surrounding sectors or controllers. Participants revealed what memory techniques they use to maintain the picture and remember actions that they want to execute later.

Another set of questions examined participants' opinions regarding ATC expertise. Participants described how they improve their skills after becoming ATCSs, how their decision making and planning changed with experience, and what characteristics experienced and expert ATCSs possess.

Many questions addressed the different strategies controllers use in specific contexts. Participants described how much planning they do before assuming control of their position, if it is sometimes better to wait when they are not sure if there is a conflict, if the first strategy they think of is sufficiently good when they identify a conflict, if they consider alternative strategies even in high workload situations, if they use backup plans, when they use a buffer, and when they ask for help.

Other questions addressed the strategies controllers use when confronted with potentially difficult situations. Participants explained how they or other controllers deal with boredom, high workload, fatigue, and aging. They also identified which situations make decision making and planning the most difficult.

Controllers continually interact with other controllers and aircraft pilots. Participants had to describe how controllers working with or around them influence their planning and separation strategies. Other questions investigated how they decide whether to honor pilot requests and what influence direct routes have on their decision making and planning.

Finally, we asked the participants about the decision and planning support tools that they use and which tools are available to them. Interviewers also asked participating controllers to describe which and how decision making and planning aids could benefit them.

2.3 Procedure

2.3.1 Interviewers

A subject matter expert and a human factors researcher separately conducted half of the interviews each. A Technical Center Psychologist had instructed the interviewers in interview techniques.

2.3.2 Interviews

We conducted semi-structured interviews to investigate the decision-making processes and separation strategies used by controllers in their operational settings. Seashore (1987) suggested that interviews are "highly efficient in accepting unanticipated responses, clarifying ambiguous meanings, and adapting the interview somewhat to the particular case" (p. 319). The interviews focused on controller decision making and planning, but they also examined processes such as SA and memory, which Wickens et al. (1997) depicted as critical components in their model.

Researchers traveled to the participants' workplaces and spent approximately one day at each facility. The duration of each interview was approximately 45 minutes. Interviewers conducted the interviews in a private setting to help ensure confidentiality and minimize organizational disturbance. Before conducting each interview, the interviewer

a. thanked the controllers for their cooperation;

b. described the goals of the study;

c. emphasized that confidentiality and anonymity would be ensured, that the names of the respondents would not be written on the questionnaire, and that no background information would allow the respondents to be identified;

d. mentioned that the researcher would take notes but that the participants could consult the notes any time they might wish to do so;

e. asked permission to use an audio tape recorder to allow us to complete the handwritten notes if necessary and mentioned that participants usually forget about the audio tape recorder after the interview starts; and

f. asked if the participants had any questions.

To ensure confidentiality and anonymity, we did not identify participants with their name on the questionnaire, and the protocol interview did not contain questions that could conceivably be used to identify the participants. We secured completed forms and audiotapes at all time. After receiving the preceding instructions, each respondent received a copy of the study consent form (presented in Appendix E). Every participant read the form, acknowledged understanding its content, and indicated willingness to participate in the study by signing the form. After signing the form, the researcher kept the signed copy and offered a copy to the respondent.

We first completed the controller background information section. Each interview began with the first question in the interview protocol. We then proceeded sequentially through the list of questions. When answering a question, controllers may have addressed issues covered in other parts of the questionnaire. In this situation, we let the participant elaborate and recorded the additional comments under the respective section on the response sheet. When we asked a question for which a partial answer had already been given, we reminded the controller of the initial comments and asked for more elaboration.

In order to clarify the meaning of the answers and to gather more comprehensive data, we invited participants to comment or elaborate on their answers. We were also instructed to feel free to clarify the meanings of questions and response choices if participants expressed uncertainty or asked for help. Many researchers have suggested that rigid interviewing, a prevailing principle in survey research, which instructs interviewers to avoid interfering in this manner, might compromise data quality (Briggs, 1986; Mishler, 1986; Suchman & Jordan, 1990). Schober and Conrad (1997) even demonstrated that conversational interviewing could enhance the validity of reports. Gromelski et al. (1992) suggested that the major advantages of conducting an in-depth (conversational) interview are "that the interviewer can

a. ask for examples to clarify a point;

b. explore the meanings of various phrases that respondent use;

c. probe, that is, ask a question in a variety of ways, to ensure that he or she understands the point that the respondent is making;

d. observe body language of the respondent; and

e. pursue new topics that the respondent may rise, thereby adding to the comprehensiveness of the data gathered" (p. 7).

The last question asked the participant if there was anything that should have been asked about strategic planning but was overlooked. After the last question, we thanked the participant again for his or her cooperation, reemphasized that confidentiality would be preserved, and asked if there were any questions.

2.4 Data Analysis

2.4.1 Data Entry and Coding

Three data entry clerks performed the data entry, which consisted of transcribing all of the handwritten answers onto spreadsheet files. Researchers assigned a list of numerical codes to each question. A different code represented every different answer to a question. When an answer included more than one statement (e.g., "I use a larger buffer when there is weather or high workload"), data entry clerks assigned every statement a different numerical code and another code represented the multiple-statement answer. They also reserved codes like "99" for missing data and "88" for "don't know" responses.

2.4.2 Content Analysis

A human factors researcher performed the content analyses by analyzing every question independently. This task consisted mainly of regrouping answers or statements into meaningful categories. Then, we assessed the direction (e.g., raising SA versus hindering it) or the frequencies they implied (e.g., never, sometimes, or always). Some answers did not lend themselves to inclusion in a larger category but did provide unique, interesting insights. We included these low-frequency items in expanded tables in Appendix B. We regrouped questions according to the themes to which they referred (e.g., SA, workload). A second human factors researcher and a SME also examined the resulting groupings. Both concurred with the content analysis performed by the first human factors researcher.

2.4.3 Statistical Analyses

The statistical analyses consisted almost entirely of descriptive analyses leading to the presentation of raw frequency and contingency tables. Frequency tables in the Results section indicate how many participants reported each item. Total frequencies will not necessarily add up to 100 (the number of participants in the present study) because the same participant could report more than one item when answering a question or may not have commented at all on the items included in a particular table. Frequency tables present the items that participants thought of when answering open-ended questions in the semi-structured interview format. Therefore, participants' reports are not exhaustive, and they do not necessarily indicate how frequently the different items were used or their importance. Thus, only raw frequencies were presented. Neither percentages nor proportions were appropriate and neither was computed. The open-ended question format allowed us to identify issues within categories for future research. The questions were not designed, in most cases, for inferential statistical analyses between groups.

Inferential analyses were performed as appropriate with nonparametric statistical tests: chi-square, Mann-Whitney U, and the Jonckheere-Terpstra test for ordered alternatives (Rossini, 1997).

3. Results

Researchers present the participants' answers in the following sections: SA, memory and flight progress strips, expertise, decision making and planning, pilots and controllers' requests, decision-making and planning difficulties, and aids to decision making and planning.

3.1 Situation Awareness

Controller decision making, planning, and strategies depend highly on SA (Endsley & Smolensky, 1998). When they assume control of their position, ATCSs must maintain a continuously changing mental picture of the airspace. Respondents described how they establish their mental picture prior to assuming control of the position (question 1a). Answers to question 1a indicated that controllers form their mental picture from many different types of information, which they gather from different sources. Table 3 shows that the two sources of information reported the most often were the radar display and the flight progress strips.

TABLE 3. SOURCES OF INFORMATION USED BEFORE ASSUMING CONTROL OF POSITION

Source of Information	Number of Participants
Radar display	50
Flight progress strips	26
Status board	17
Data blocks	10
Observe relieved controller	6

Participants reported using 27 different types of information when forming their mental picture. Table 4 shows that the answers reported most often were that controllers form their mental picture by looking for conflicts and checking the status of the weather.

TABLE 4. TYPES OF INFORMATION GATHERED BEFORE ASSUMING CONTROL OF POSITION

Type of Information	Number of Participants
Conflicts	19
Weather	16
Flow of traffic	8
Equipment status	7

Note. Expanded list of answers is presented in Table B4, Appendix B.

Thirty-five participants also specified when they usually start forming their mental picture. Table 5 reveals that 34 of these controllers reported starting to form their mental picture before or during the relief briefing. Only one controller declared establishing a mental picture after the briefing, by "tuning out" what the relieved controller said.

TABLE 5. MOMENT WHEN MENTAL PICTURES ARE FIRST FORMED

Moment	Number of Participants
Before the briefing	7
During the briefing	27
After the briefing	1

Scanning skills are critical for SA. Question 3 investigated if and when controllers modify the way they scan their radar display. Table 6 presents some of the comments made by the participants regarding their scanning techniques. It indicates that 38 respondents declared that their scanning changes depended on the context and that 30 reported that they always try to scan the same way, using the same pattern consistently. Twenty-two participants mentioned that the way they scan is specific to the sector in which they work. For example, one controller reported using a V-like scan when working approach control, instead of scanning in a circular, around-the-clock fashion. According to 22 participants, their scanning was not always uniform because they tend to pay more attention to hot spots or, in other words, regions where conflicts occur frequently or where they seem likely to happen. Other participants added that controllers are sometimes vulnerable to tunnel vision, when all their attention becomes focused on a subpart of their sector and they become unaware of the activity in the rest of the airspace.

TABLE 6. COMMENTS REGARDING SCANNING TECHNIQUE

Comment	Number of Participants
Scanning technique changes according to context	38
Always try to use the same scanning technique	30
More time is spent scanning the hot spots	22
Scanning technique depends on sector	22

Twelve participants identified some of the factors that result in controllers changing the way they scan the radar display. Such factors included traffic patterns, bad or foggy weather, automation, runway configuration, traffic complexity, and volume.

Some participants indicated that the type of information they seek is always the same when they scan. More precisely, 17 controllers reported always using the same type of information, whereas 7 indicated that the type of information they sought varied according to the context.

Question 14 asked tower controllers how much they are aware of what is going on at the other positions and radar controllers how much they are aware of what is going on in adjacent sectors. Thirteen controllers reported that they monitor the activity in other sectors by listening to the other controllers in the room. Participants indicated that their awareness of other sectors depended on a few different factors. For instance, 24 controllers reported that their workload determined how much they were aware of what was happening in other sectors. The busier they are, the more they focus on their own sector and, therefore, become less aware of what happens in other sectors.

According to some participants, experience also influenced their level of awareness. They suggested that, with experience, controllers became more aware of other sectors or positions. Experience increased awareness by making controllers more aware of traffic flows (e.g., know when rush is coming), more familiar with the sectors they work in, and familiar with a greater number of sectors and positions.

How much controllers are aware of what is going on in other sectors depends on the type of sector and which sector they were working. Some controllers commented on the influence of sector characteristics on awareness. Table 7 presents some of these comments, indicating that controllers have a greater awareness of sectors in their own area and when they are sitting next to each other.

TABLE 7. COMMENTS REGARDING AWARENESS OF OTHER SECTORS

Comment
Aware of sectors that impact your flow of traffic
Greater awareness of feeding sectors
Greater awareness of sectors in own area
Very aware, especially when sitting beside adjacent sector
ARTCC controllers do not see the other sectors on the radar scope as much as TRACON controllers
Depends on configuration of airspace
Greater awareness of arrival sectors that I feed (need to know if the “door will slam”)
Greater need to know when high altitude and low altitude sectors in ARTCC feed each other
In TRACON, less with sectors well below
Local controller knows what the other local controller does and ground controller knows what the other ground controller does
More aware when familiar with sector
Must keep up with satellite and departure sectors
TRACON departure sector is aware of arrival sectors

3.2 Memory and Flight Progress Strips

Wickens et al.'s (1997) cognitive model implies that memory is the foundation on which SA, decision making, and planning stand. Question 4 asked controllers to identify the personal techniques that they use to help them maintain the picture and remember plans that they want to execute later. Respondents offered a large number of techniques. The most popular answers are presented in Table 8. These results reveal that memory techniques involving the use of flight progress strips are, by far, the ones that were mentioned the most often. Nineteen respondents declared having no need for such techniques.

TABLE 8. PERSONAL MEMORY TECHNIQUES USED BY CONTROLLERS

Personal Technique	Number of Participants
Flight progress strips	59
J-Ring [ARTCC only]	22
Data block management [TRACON and ARTCC only]	20
No need/none	19
Writing on notepad	13
Avoid having to remember	12
Help from others ("D-side"/radar associate or pilots)	7
Fix things immediately this way I will not forget (Think of it, you do it)	7

Note. Expanded list of answers is presented in Table B5, Appendix B

Table 9 presents controller memory techniques involving the use of flight progress strips. The two most often reported techniques were to offset the strips in the holding bay and to mark the strips.

TABLE 9. MEMORY TECHNIQUES INVOLVING THE USE OF FLIGHT PROGRESS STRIPS

Technique	Number of Participants
Offsetting strips	28
Strip marking	25
Pulling out or holding strip	5
Sequencing strips/Positioning strip	3
Consulting/reviewing strips	2
Use the strip to indicate closed runways	2
Planning	2
Pointing to or touching strips to reinforce memory	2

In question 2, participants reported using flight strips for different reasons. We can see in Table 10, which lists the 6 most popular reasons, that 55 participants reported using them for quick reference, 42 as a memory aid, 33 as a backup, 23 to maintain the picture, 17 to detect conflicts, and, finally, 9 to plan.

TABLE 10. REASONS TO USE FLIGHT PROGRESS STRIPS

Reason	Number of Participants
Quick reference	55
Memory aid	42
Backup	33
Maintain picture	23
Detect potential conflicts	17
Planning	9

3.3 Expertise

Some of the questions in the present study investigated participants' opinions regarding how ATCSs develop their expertise and what constitutes ATC expertise. Question 6 asked how controllers keep improving their planning and separation skills after formal training, or more specifically, after their OJT was completed and they become ATCSs. Table 11 summarizes the answers to question 6. As many as 49 of the respondents mentioned that controllers keep improving their skills just by going to work on a daily basis and performing their normal duties.

TABLE 11. METHODS USED BY CONTROLLERS TO KEEP IMPROVING AFTER FORMAL TRAINING

Method	Number of Participants
Through experience (daily practice and repetition)	49
Watching other controllers	20
Learning from difficult situations	18
Desire to improve and professional attitude	16
Trying new and different techniques	15

Note. Expanded list of answers is presented in Table B6, Appendix B

According to 20 interviewees, controllers improve their skills by observing other controllers performing their duties. They also mentioned shadowing controllers in other departments (quality assurance, airspace and procedures, and Traffic Management Unit [TMU]) as a beneficial activity. Six respondents also reported that receiving other controllers' input helped them improve.

Eighteen respondents reported that controllers improve when they encounter difficult situations and learn their way out or how to avoid such situations. Sixteen participants specified that controllers improve only if they have the desire to learn and maintain a professional attitude at work.

Besides describing how controllers can keep improving their separation and planning skills, a few participants also mentioned factors making continuous learning more difficult. They mentioned that the environment is not conducive to improvement, that refresher training and computer-based instruction are useless, that there are no more simulation practices of emergency situations, and that conflict alert prevents learning.

We asked participants to describe how their approach to planning and separating aircraft changed with experience (question 5). Table 12 depicts the most common answers. More specifically, controllers reported most often that, with more experience, their SA, comfort and confidence, and planning have improved.

In question 22, we asked participants to describe what special skills, attributes, or techniques allow some controllers to handle large volumes of traffic with ease. Controllers provided a long and diverse list of skills, attributes, and techniques. Only two participants declared that these controllers have no common traits.

TABLE 12. IMPROVEMENTS RESULTING FROM GREATER EXPERIENCE

Improvement	Number of Participants
Greater SA	32
More comfortable and confident	27
Better planning	23
Increased familiarity with sectors and controllers	14
Better knowledge of aircraft type performance	12
Act earlier	10
Developed automatisms	8
Less conservative	8
More conservative	6

Note. Expanded list of answers is presented in Table B7, Appendix B

Participants defined controllers who easily handle large volumes of traffic with 32 personality traits. Table 13 presents the three traits mentioned the most often. According to the most commonly suggested traits, “jet jocks,” as one participant designated them, would be self-confident, calm, and intelligent.

TABLE 13. PERSONALITY TRAITS OF CONTROLLERS HANDLING LARGE VOLUMES OF TRAFFIC WITH EASE

Personality trait	Number of Participants
Self confident	18
Calm	17
Intelligent (common sense, logical, etc.)	13

Note. Expanded list of answers is presented in Table B8, Appendix B

Respondents have also identified a large number of skills and attributes that they think allow some controllers to easily handle large volumes of traffic. Table 14 indicates that the most frequently mentioned attributes are a superior SA, the capacity to think and act rapidly, good planning and prioritization skills, and experience.

TABLE 14. SKILLS AND TECHNIQUES OF CONTROLLERS WHO EASILY HANDLE LARGE VOLUMES OF TRAFFIC

Skill	Number of Participants
Superior SA	34
Think, decide, and act quickly	21
Good at planning and prioritizing	15
Good communicators	12
Experienced	10

Note. Expanded list of answers is presented in Table B9, Appendix B

Question 17 asked respondents to define what "bet on the [out]come" means to them and if they thought that experienced controllers and novices "bet on the [out]come" as often. The question allowed interviewers to ensure that respondents defined betting on the come as something close to not ensuring positive separation. Table 15 indicates that 15 respondents judged that experienced controllers "bet on the [out]come" more often than novices, that 20 thought that novices do it more often than experienced controllers, and finally, that 31 answered that the two groups do it to the same extent. The same table also shows that participants who chose the experienced controllers had 14.4 years of experience on average. Participants who said that there was no difference were more experienced than the previous group, with 17.9 years, but they were less experienced than those who chose the novices, who had 20.1 years of experience. These results suggest that the more experienced the participants, the more likely they were to believe that novices "bet on the [out]come" more often than experienced controllers. Conversely, it suggests that the less experienced controllers were, the more likely they were to report that experienced controllers "bet on the [out]come" more often. A Jonckheere-Terpstra test for ordered alternatives (Rossini, 1997) verified this trend by showing that the averages for these three groups occurred in that specific order (τ=.28, p=.004).[3]

TABLE 15. EXPERIENCE OF PARTICIPANTS ACCORDING TO THEIR OPINION ON WHICH GROUP OF CONTROLLERS "BET ON THE [OUT]COME" THE MOST OFTEN

	Experience (years)		
Group	N	Mean	*SD*
Experienced	15	14.4	5.3
Novices	20	20.1	5.9
Same (No difference)	31	17.9	5.8

[3] The *p*-value for the Kendall statistic is equivalent to the two-tailed *p*-value for the Jonckheere statistic.

3.4 Decision Making and Planning

When asked how much planning they have already done once the briefing is over and they assume their position (question 1b), many respondents suggested that the number of planned actions or "moves" depended on a variety of factors. For instance, some controllers indicated that more planning was required when one of the conditions listed in Table 16 was in effect.

TABLE 16. CONDITIONS REQUIRING MORE PLANNING WHEN ASSUMING POSITION

Condition
Sector is busy (high volume)
Pending conflicts or urgency
IFR day
Complex traffic or sector
Fast sector
Do not respect the relieved controller much
Briefing is not easy
Do not know the relieved controller
Sequencing sectors
Position other than local controller

Many controllers have reported that, once they assume control of the position after the relief briefing, they already know what their first few clearances or "moves" will be. Figure 3 presents the number of planned actions reported by the 58 respondents who provided such estimates. Controllers suggested that they have already identified an average of 3.5 actions when they assume control of a position.

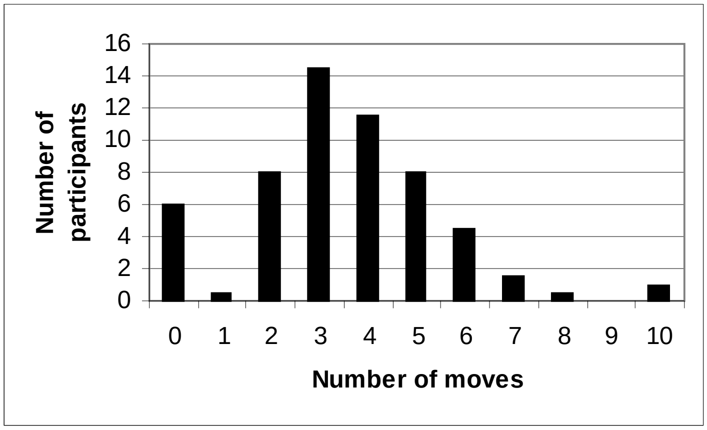

Figure 3. Number of actions planned by controllers before they assume control of position.

Interviewers also investigated what strategies controllers adopt when they are not sure if there will be a conflict (question 20). More specifically, participants had to indicate if they thought that it was sometimes better to wait and see how the situation developed or if they thought that it was always better to intervene immediately and resolve the issue. We see in Table 17 that 62 participants answered that it is sometimes preferable to wait and see, whereas 34 thought that it was always better to act immediately. The same table also indicates that only 8 terminal[4] controllers out of 30 thought that it was sometimes better to wait and see, whereas a majority of ARTCC controllers, 54 out of 66, believed the same. Not surprisingly, a chi-square test confirmed that ARTCC controllers were more likely than terminal controllers to wait and see how the situation developed when they were not sure if there was a conflict (χ^2=27.43, p<.001).

TABLE 17. STRATEGIES USED WHEN CONFLICT IS UNCERTAIN BY TYPE OF FACILITY

	Strategy		
Type of Facility	Sometimes Wait And See	Always Act Immediately	Total
Terminal	8 (.27)	22 (.73)	30
ARTCC	54 (.81)	12 (.19)	66
Total	62	34	96

Note. Relative frequencies in parentheses.

Table 18 reveals that controllers who believed that it is sometimes better to wait and see had, on average, 16.7 years of experience. Those who professed that it is always better to act immediately had 19.4 years of experience. A Mann-Whitney test revealed that this difference is statistically significant (U=704, p=.007) and suggests that, with experience, controllers become more likely to report that it is always better to act immediately in such a situation.

TABLE 18. ATC EXPERIENCE AND STRATEGY USED WHEN CONFLICT IS UNCERTAIN

	Experience (years)		
Strategy	N	Mean	*SD*
Sometimes wait and see	62	16.7	6.5
Always act immediately	34	19.4	4.2

[4] Given that most participants were from ARTCCs, the respondents from ATCTs, TRACONs and combined ATCT/TRACONs were regrouped under the label "Terminal" in all statistical tests examining the effect of the type of facility in which controllers work.

In question 18, researchers asked participants how often, when identifying a potential conflict, do they use the first strategy that they think of and do not need to consider other alternatives. Table 19 indicates that 16 terminal controllers professed using the first strategy 85% of the time in such situations, whereas 35 ARTCC controllers reported doing so only 60.2% (the other 49 participants did not provide a quantitative estimate). A Mann-Whitney test showed that this difference is statistically significant (U=149, p=.007).

TABLE 19. USE OF FIRST STRATEGY IN CONFLICT SITUATION BY TYPE OF FACILITY

	Use First Strategy (%)		
Type of Facility	N	Mean	*SD*
Terminal	16	85.0	23.6
ARTCC	35	60.2	37.3

A Spearman rank correlation test showed that there is a small but significant relationship between ATC experience and the frequency with which controllers use the first strategy (r_s=.20, p=.04). These results suggest that, with experience, controllers would be more likely to report using the first strategy that comes to their mind.

Question 21 explored the use of two different strategies in a high workload situation. Table 20 reveals that 43 participants reported that, in a high workload situation, they used the first satisfactory strategy that they thought of, whereas 36 made sure to consider a few alternatives before doing anything. Responses from the other 21 participants could not be categorized into either one of the two previous response categories. Table 20 also indicates what strategies controllers consider when under high workload in function of the type of facility in which they work. More specifically, 21 out of 28 terminal controllers reported adopting the first satisfactory action that they think of in a high workload situation. Only 22 out of 51 ARTCC controllers reported the same. A chi-square analysis revealed that the type of facility has a significant effect on the strategies considered under high workload (χ^2=7.40, p=.01). In other words, it seems that ARTCC controllers are more likely than terminal controllers to report that they consider different alternatives when their workload is high.

TABLE 20. STRATEGIES CONSIDERED UNDER HIGH WORKLOAD

	Strategies Considered		
Type of Facility	First Satisfactory One	Alternatives	Total
Terminal	21	7	28
ARTCC	22	29	51
Total	43	36	79

We performed an analysis to determine if ATC experience had an effect on the strategies used in a high workload situation. The 43 participants who reported that they used the first satisfactory strategy had 18.2 years (*SD*=5.4) of experience, whereas the 36 who said that they make sure to consider a few alternatives had 18.0 years (*SD*=6.6). A Mann-Whitney U test showed that there was no significant difference between these two groups (U=676, *p*=.55).

We asked controllers if they normally had a backup plan in case their initial strategy did not work, and we invited them to specify under what conditions they formulate such plans (question 19). We also clarified that what we meant by "having a backup plan" was to have a planned (thought-out) backup strategy before sending the initial clearance. Having a backup plan did not refer to just knowing that there was something else that could be done if the initial strategy did not work. Table 21 shows that 65 of the 100 respondents reported that they always try to formulate a backup plan. Another group of five controllers answered that they sometimes try to formulate one. Sixteen revealed that they do not formulate backup plans.

TABLE 21. USE OF BACKUP STRATEGIES BY CONTROLLERS

Backup strategy	Number of Participants
Always try to formulate a backup plan	65
Sometimes try to formulate a backup plan	5
Do not formulate a backup plan	16

A test examined if ATC experience had any effect on the formulation of backup strategies. Table 22 presents the average number of years of experience and its *SD* for the controllers who formulate backup strategies and those who do not. This table shows that controllers who formulate backup strategies have in average 3.6 years of experience more than controllers who never formulate backup plans. A Mann-Whitney test showed that this difference is statistically significant (U=349, *p*=.02).

TABLE 22. ATC EXPERIENCE ACCORDING TO USAGE OF BACKUP STRATEGIES

	Experience (years)		
Formulate Backup Strategy	N	Mean	*SD*
Always/Sometimes	70	18.4	5.7
Never	16	14.8	5.2

Some participants described conditions in which they formulated a backup plan. Table 23 presents these conditions.

TABLE 23. CONDITIONS IN WHICH CONTROLLERS FORMULATE BACKUP PLANS

Condition
When you have enough time (not too busy)
Need back up plan when not routine (unusual situation)
When the situation is close
During bad weather
Experienced controllers do it more
When emergencies occur
When betting on the come (need a way out)
When radar associate (D-side) and radar position (R-side) work on same sector
When busy
When the situation is very complicated
When you expect restrictions (or closures)
When training you would formulate a back up plan
Pilots from other countries
Questionable controller abilities
Always, certainly during IFR

In question 16, participants told interviewers in which context they build a buffer beyond minimal separation. Two controllers reported never or rarely using a buffer, but 30 others claimed that they used a buffer most of the time. Table 24 shows in which conditions controllers reported using a larger buffer than usual. The two most often reported conditions were in bad weather and in a busy sector.

TABLE 24. CONDITIONS IN WHICH CONTROLLERS USE A LARGER BUFFER

Conditions	Number of Participants
Bad weather	35
Busy sector	30
Weaker controllers	9
Other facilities request	7
Equipment failure	6

Note. Expanded list of answers is presented in Table B10, Appendix B

In question 10, interviewers asked the participants when they tend to ask for help or when controllers should ask for help. Respondents identified different factors leading controllers to ask for help. As shown in Table 25, 19 respondents indicated that controllers ask for help when the number of flight strips is large or when they cannot keep up with them. The number of flight progress strips is an indication of how many aircraft are under their control and of how many are arriving in their sector. Controllers also often reported that they might ask for help when there is bad weather, high volume of traffic, communication problems, or high workload.

TABLE 25. FACTORS LEADING CONTROLLERS TO ASK FOR HELP

Factor	Number of Participants
Large number of flight strips	19
Bad weather	10
High volume of traffic	10
Communication problems	9
High workload	9
Complex traffic	6
Personal factors	6
Unusual situations	6
Excessive coordination	5
Emergency	4
Military operations	3

Many controllers have also revealed that personality plays an important role when it comes to asking for help. For example, 15 participants reported that controllers prefer not to ask for help because doing so is a sign of weakness. Conversely, four participants indicated that controllers should not have a problem with asking for help and not interpret it as a negative thing.

Other controllers mentioned that knowing when to ask for help is a precious skill. According to 16 participants, controllers must learn to ask for help before it is too late. For example, a radar controller (R-side) should ask for help before becoming too busy to brief a radar associate (D-side) coming to help. One participant suggested that, in such a situation, a controller should request the help of a tracker (radar coordinator position) instead of a D-side and, therefore, avoid having to brief anyone. One participant complained that controllers ask for help too early, but three others complained that they were sometimes chastised for doing so.

Some controllers have offered their opinion regarding the role of Operational Supervisors (OSs) in this matter. For example, five participants reported that they did not need to ask for help because supervisors usually offered it themselves. Similarly, four other controllers stated that they should not have to ask for help because OSs should be offering it. Two participants added that supervisors should play a larger role in this type of situation. Another respondent complained that supervisors did not honor requests for help and another that supervisors offered too much help.

According to five participants, radar stations were designed to be operated by at least two controllers and should always be staffed accordingly. Understaffing was also considered a problem by three controllers who indicated that sometimes nobody was available to provide some help.

3.5 Pilots' and Controllers' Requests

ATCSs collaborate and interact with many other actors when they accomplish their tasks. They must coordinate their efforts with pilots and other controllers. Results suggest that many controllers might consider whom the other controllers were when they formed their mental picture. When asked how much do they adapt their decisions and planning to the requests, personality, and skills of the controllers working with and around them (question 13), many stated that they did so according to the characteristics listed in Table 26. More specifically, 43 controllers reported that they consider the skill level, 16, the preferences, and 5, the personality of the controllers working with and around them.

TABLE 26. CHARACTERISTICS OF OTHER CONTROLLERS CAUSING PARTICIPANTS TO ADAPT THEIR DECISION MAKING AND PLANNING

Characteristic	Number of Participants
Skill level	43
Preferences	16
Personality	5

Question 15 asked participants to describe under what conditions they honored pilots' requests and how they influenced their decisions and strategic planning. Sixty-six claimed to honor pilots' requests as often as possible, but only 5 declared rarely doing so. Table 27 presents the conditions in which controllers did not honor pilots' requests.

TABLE 27. SITUATIONS WHEN CONTROLLERS DO NOT HONOR PILOTS' REQUESTS

Situation	Number of Participants
When it impacts negatively on other controllers or sectors	29
When it increases workload too much	29
When it impacts negatively on other aircraft or general traffic	22
If in contradiction with rules or restrictions	8
In bad weather (performance not as much a priority)	7
When working on an emergency with another aircraft	2

Some participants described the strategies they used when they could not honor a pilot request. A controller would sometimes forward the request to the next controller or ask the pilot to make the request again in the next sector. Some participants believed that they should apologize or explain to pilots why they cannot satisfy their request. Another possibility was to offer alternatives to pilots. When a request could not be honored right away, some controllers will ask the pilot to remind them of the request later. One participant reported that, when very busy, he would sometimes not wait for a pilot to make a request and, instead, offer a direct route to the aircraft to help lower his workload.

Question 12 investigated how direct flights influenced controller decision making and planning. Results revealed that 25 participants (23 terminal and 2 ARTCC controllers) who work in environments where direct flights were a very rare occurrence judged this question was not relevant. Thirty-seven controllers (31 ARTCC and 6 terminal controllers) reported that direct flights had no influence on their decisions and plans, but many described how direct flights helped or hampered their efforts. Table 28 presents some of the benefits mentioned by the participants who reported that direct flights are helpful to them.

TABLE 28. BENEFITS OF DIRECT FLIGHTS

Benefit
Expedite aircraft through my airspace
It is providing a service
Allows to avoid situations or conflicts
Help to separate
Reduce workload
Solve problems or situations
Climb aircraft to requested altitudes
Makes me more aware of potential conflicts
Takes aircraft out of main flow
Much easier to control
Help not having all aircraft going to the same fix
Alleviates boredom

Another group of controllers described some of the disadvantages of direct flights (presented in Table 29). Some participants complained that it is more difficult to determine the trajectory of direct flights and that they also changed the crossing points where conflicts usually occur. For these controllers, direct flights increased workload, planning, and made it more difficult to detect potential conflicts. Some respondents also indicated that direct flights have disadvantages mostly in arrival sectors or terminal areas.

TABLE 29. DISADVANTAGES OF DIRECT FLIGHTS

Disadvantage
Increase difficulty
Difficult to project where airplanes are going
Makes planning harder or requires more planning
More problematic for arrival sectors or terminals
Increase workload
Change the crossing points where conflicts usually occur
More difficult to detect conflicts with the strips
Increase complexity
Interfere with sector boundaries (boundary riders cause massive point outs)
Require more coordination
More difficult to visualize
Easier to keep aircraft on routes in nonradar environment
Generate continuous change
Often a burden because the next guy won't be able to take it
Often impacts next controller
Require more attention

Some participants reported in which conditions they would honor a direct flight request (see Table 30). In general, controllers honored such requests when their workload was not too high and based on how much impact the request would have on other controllers and aircraft.

3.6 Decision-Making and Planning Difficulties

In question 11, participants described how they deal with boredom and how boredom influences their separation strategies and planning. Six controllers mentioned that boredom was something that they welcome. For these controllers, boredom represented an opportunity to relax and catch their breath. Similarly, 14 controllers reported rarely being bored because of the high level of activity in their facility.

Some participants reported which strategies they used to avoid some of the negative effects boredom may have. Others described how they tried to remain busy to avoid becoming bored. Table 31 shows that the strategies reported the most often were to talk to their colleagues and concentrate more or try to stay focused on their task. Other strategies included protecting other controllers and watching the activity in other sectors.

TABLE 30. CONDITIONS IN WHICH DIRECT FLIGHT REQUESTS ARE HONORED

Condition
Honor most requests for direct flights
Offer direct routes when not too busy
No negative impact on aircraft or system
Depends on how far they can go before they have to get back on route
Use them more in the Western US than in the East
Offer direct routes if D-side is not too busy
If there is an emergency
Honor requests if they don't require too much computer entries
Offer direct routes in own sector or area

TABLE 31. COPING STRATEGIES USED TO DEAL WITH BOREDOM

Coping Strategy	Number of Participants
Talking with colleagues	43
Concentrate more (stay focused)	25
Try to help (or protect) other controllers	9

Note. Expanded list of answers is presented in Table B11, Appendix B

We asked participants to describe how very high workload influenced their separation decisions and planning (question 8). Participants offered a long list of answers. Table 32 shows that they became more conservative or erred on the safe side. According to 21 participants, a very high workload required controllers to do everything faster (thinking and executing). Nineteen participants mentioned that, in a high workload situation, controllers must act early and avoid a wait and see situation.

When asked in what ways fatigue influences the strategies they choose (question 9), a large number of controllers indicated that fatigue had some negative effects. Table 33 shows that controllers reported that fatigue hinders performance, makes it more likely for mistakes to occur, diminishes awareness, impairs strategies, and fosters a negative attitude. Nineteen respondents reported that fatigue has no negative effect.

TABLE 32. INFLUENCE OF HIGH WORKLOAD ON SEPARATION DECISIONS AND PLANNING

Influence	Number of Participants
Become more conservative (safer)	32
Do everything faster	21
Act early (rather than wait and see)	19
Intensify planning	12
Ensure that communication is efficient	12
Increase level of attention/awareness	12
Use standard procedures and routes	11
Avoid using strategies requiring monitoring	9
Use more buffer	9

Note. Expanded list of answers is presented in Appendix B, Table B12

TABLE 33. EFFECTS OF FATIGUE

Effect of fatigue	Number of Participants
Diminished performance	33
Mistakes	17
Diminished awareness	12
Strategies impairments	12
Negative attitude	9

Respondents also revealed which strategies they adopt when they have to deal with fatigue. As indicated in Table 34, the most popular strategy reported by controllers when they were tired was to become more cautious or conservative. Another strategy was to avoid the most demanding positions.

TABLE 34. COPING STRATEGIES ADOPTED WHEN FATIGUED

Coping Strategy	Number of Participants
More cautious or conservative	24
Avoid demanding positions	13
No wait and see - resolve things now	8
Offer less service	6
Ask for help or assistance	5
Concentrate more	4
Keep it simple, stick to the basics	4
Engage in physical activity (stand up, drink water, move around)	2
Plan ahead as far as possible/further out	2
Slow down traffic	1
Easy sector - stay during breaks	1

When asked about the effects of age on controller decision making and planning (question 7), 13 participants responded that such effects do not exist. However, Table 35 indicates that many participants have identified some negative effects. The most commonly mentioned one, reported by 45 participants, was that age slows controllers down.

TABLE 35. EFFECTS OF AGE ON CONTROLLER PLANNING AND DECISION MAKING

Effect of Age	Number of Participants
Slow down	45
None	13
Degraded memory	9
Diminished skills	5
Less ego	4
Do not work as well with others	4
Less flexible	4
More stressed	3
Do not handle high volume of aircraft as well	3
Diminished physical abilities (e.g., impaired hearing)	2
Less motivated	2
More difficult to keep up with the pace	2

Many participants reported that age had some negative effects on controllers' skills, but 12 participants suggested that these effects were not as great on older controllers who relied more on their experience and less on their skills. Participants suggested that older controllers employed some adaptive strategies, such as those listed in Table 36. The two strategies mentioned the most frequently were to be more cautious or conservative and to rely more on planning. Statements such as becoming more prudent, playing safe, taking less chances, not betting on the come, and being more careful were regrouped under the category "more cautious and conservative."

TABLE 36. ADAPTIVE STRATEGIES TO MITIGATE AGE-RELATED EFFECTS

Adaptation	Number of Participants
More cautious or conservative	18
Rely on planning	11
Act early	5
Use more buffer	3
Use memory aids	3
Use flight progress strips	2
Ask for help sooner	2
Avoid difficult or busy sectors	2

In question 23, participants identified which situations made it the most difficult for them to maintain separation. Table 37 shows that a majority of controllers, 79 out of 100, identified bad weather as one of the most difficult situations. Other popular answers were the presence of weaker controllers (14), high volume traffic (12), and equipment failure (12).

TABLE 37. MOST DIFFICULT SITUATIONS IN WHICH TO MAINTAIN SEPARATION

Situation	Number of Participants
Bad weather	79
Weaker controllers	14
Traffic (high volume or complex)	12
Equipment failure and outage	12
Weaker or uncooperative pilots	11
Poor communications	10
Restrictions	8
Unusual situations	7
Disturbance in control room	5
Aircraft varying in performance	5

We also asked participants to describe how the most difficult situations influenced their separation strategies and planning. Table 38 presents a list of the reported effects of bad weather on controllers' work. In general, controllers have less control over aircraft in bad weather, and it adds a lot of uncertainty and difficulty.

TABLE 38. EFFECTS OF BAD WEATHER

Effect
Less control over aircraft
Adds uncertainty
Makes planning more difficult
Requires to use different flows than standard routes
Creates congestion
Increases amount of communications
Lack of weather information
Slowing things down
Happens quickly
Lose options
Airlines have different standards
No wrong altitude and no changing altitude unless requested
More point outs and coordination
In-trail restrictions, overload of information
No situation makes separation more difficult
Ten times harder
Keep double checking everything on Airport Surface Detection Equipment (ASDE) radar when visibility is low
Can't see aircraft through window
Work fewer aircraft because can't see them
Require more attention
Can't make good decisions because don't know what the options are
Requires more thinking and planning

Some participants also mentioned which strategies they usually adopted when the weather was bad. As shown in Table 39, some of the reported strategies were to use more buffer and to rely more on vertical separation.

TABLE 39. STRATEGIES ADOPTED DURING BAD WEATHER

Strategy
Use more buffer
Use vertical separation
Do more planning
Be more conservative (cautious)
Pay more attention (stay focused)
Being assertive and ensure that pilots are aware of who is controlling the sector
Become much more strict with what aircraft need to do
Ensure things are done immediately
Work fewer aircraft because can't see them
Keep double checking everything on ASDE radar when visibility is low
Stop departures and concentrate on flying aircraft
Need to indicate to pilots exactly where to deviate around weather

3.7 Aids to Decision Making and Planning

In question 24, participants identified the planning and conflict detection aids that were available to them and which they used. Their responses varied according to many dimensions such as the level of automation and the function of the different decision-making and planning aids. Table 40 lists the automated planning and decision aids reported by the participants. Conflict alert was the most frequently mentioned tool.

TABLE 40. PLANNING AND CONFLICT DETECTION AIDS USED BY CPCs

Tool	Number of Participants
Conflict Alert	50
Minimum Safe Altitude Warning (MSAW)	29
Traffic Situation Display (TSD)	2
Runway incursion device [ATCT only]	1
Traffic Alert and Collision Avoidance System (TCAS) [cockpit only]	1
Traffic Management Advisor (TMA) [TRACON and ARTCC only]	1

Although conflict alert was the aid cited the most often, many controllers have criticized it. More specifically, 26 participants have made at least one of the complaints presented in Table 41. According to these controllers, it appears that the conflict alert is not a reliable tool.

TABLE 41. PARTICIPANT COMPLAINTS REGARDING CONFLICT ALERT TOOL

Complaint
Wrong more often than right (too many false alarms)
Usually comes off too late, when separation is already lost
Usually know that it will go off, 99% of the time it comes off when actions are already initiated
Can't count on it in arrival sectors - No confidence
Too many misses
Inadequate between IFR and VFR (Visual Flight Rules) aircraft
Better in high altitude

Similarly, some respondents expressed some criticisms about MSAW. Nineteen participants had complained about the reliability of this tool (wrong too often), 11 declared that MSAW was of little help to them (rarely used or not relevant), and finally, 3 reported that MSAW alerts them too late.

Many of the reported controller decision-making and planning aids were radar based. For example, as shown in Table 42, j-ring and vector line were radar-based features often reported by the participants.

TABLE 42. RADAR-BASED TOOLS SUPPORTING CONTROLLER DECISION MAKING AND PLANNING

Tool	Number of Participants
J-Ring [ARTCC only]	43
Vector Line [TRACON and ARTCC only]	41
Route line [ARTCC only]	23
History [TRACON and ARTCC only]	19
Radar/Data tags	13
Range bearing [ARTCC only]	5
Flight Plan Readout [ARTCC only]	2
Data block management (Offset data blocks) [TRACON and ARTCC only]	2
Other	5

The other decision-making and planning aids reported by the controllers are presented in Table 43. These include flight progress strips and weather-related tools such as windshear alert, weather computer display, and Doppler radar. Participants also reported some non-automated tools like their coworkers, status board, notepad, and binoculars.

In question 25, participants had to identify what other types of aids would help their decision making and planning. Table 44 shows that the types of aids mentioned most frequently were conflict probes, better radar equipment, better weather status information, and data link. Most of these suggestions are presented in more detail in Appendix B, Tables B14-B30.

TABLE 43. OTHER TOOLS SUPPORTING CONTROLLER DECISION MAKING AND PLANNING

Tool
Flight progress strips
Windshear alert (ATCT and TRACON only)
Coworkers (brother's keeper)
Status board
Notepad
Binoculars (ATCT only)
Weather computer display
Doppler weather radar
Runway closure signs
Information Display System (IDS) 4 (Airport info, Automatic Terminal Information Service (ATIS), In-trail restrictions)
Lights on strip boards

TABLE 44. TYPES OF AIDS THAT WOULD BENEFIT CONTROLLER DECISION MAKING AND PLANNING

Type of aid	Number of Participants
Conflict probe	24
Better weather status information	18
Data link	17
Better radar	14
Data block improvements	12
Use of color display	11
Electronic flight progress strips	9
Planning tools	9
Ground radar improvements	8
Better radio/communications	8

Note. Expanded list of answers is presented in Table B13, Appendix B

Many of the types of aids identified by the participants were systems currently under implementation or development, such as conflict probes, data link communication, electronic flight progress strips, and planning and projection tools. Many en route controllers said that they would welcome User Request Evaluation Tool (URET) or a long-range conflict probe that would consider aircraft in other sectors (as shown in Appendix B, Table B14). Some terminal controllers mentioned that they would like Airport Movement Area Safety System (AMASS) to be available to them. The third most popular type of aid was data link communication. Specific answers (see Appendix B, Table B16) suggest that participants believed that this type of aid would help prevent the congestion of frequencies. Some participants also expressed that they would welcome the possibility of using automated computer entries for repetitive clearances (e.g., arrivals using the same descents) or the possibility of sending the same clearance to many aircraft at the same time (e.g., speed clearance for multiple aircraft). Nine participants mentioned that electronic flight strips would be helpful, and two of them added that electronic flight strips should be implemented on touch screen displays and include conflict detection tools. Nine participants reported that they would like to use specific planning tools such as Final Approach Spacing Tool (FAST), Surface Management Advisor (SMA), TSD, and CTAS (listed in Appendix B, Table B20). Some participants expressed their interest in tools that would allow them to project the trajectory of aircraft. More precisely, these respondents have suggested that they use CTAS route display or some tools that would allow them to project flight routes when considering flight plan changes, see the route display of aircraft in other facilities, and project altitude based on rate of climb. Some respondents thought that their decision making and planning would be facilitated if their computer and themselves had access to databases including all fixes in the NAS, all call signs, and airports (as shown in Appendix B, Table B24). Finally, three participants believed that automating aircraft cockpits would also benefit them (Appendix B, Table B30). For example, one mentioned that TCAS is helping controllers because pilots maintain a greater awareness of the situation and need to ask fewer questions.

Participants also identified many types of aids that would improve the display of information on their radar monitor. Many controllers expressed the desire to have more accurate weather information on their radar display (suggestions are presented in Appendix B, Table B15). Besides adding better weather information, participants also wanted their radar display to present the general information more accurately and the equipment to be more reliable (as shown in Appendix B, Table B17). Some participants suggested some modifications to the display of data blocks on the radar monitor (Appendix B, Table B18), such as giving more prominence to specific types of information (e.g., speed and heading). Some participants have described how the use of color displays could enhance the information they receive (Appendix B, Table B19). They proposed that different colors should be used to help remembering overflights, identifying arrival airports, preventing conflicts, depicting weather information, discriminating VFR aircraft, and designating spacing programs. Many tower controllers expressed that their decision making and planning would benefit from an improved ground radar system (Appendix B, Table B21) and seven participants suggested that ASDE should use data blocks.

Eight participants suggested improving the radio communication system. More specifically, as shown in Appendix B, Table B22, they suggested that better radios would reduce the congestion of frequencies, that a visual cue on the radar display should indicate which aircraft is communicating to the controller, that clearances with similar call signs should not be confused, and that aircraft communications should not interfere with controller to aircraft transmissions.

Some suggested that some improvements could be made to the physical ergonomics of their equipment and environment (Appendix B, Table B27). For example, they suggested optimizing the lighting conditions in the control room, redesigning Display System Replacement (DSR) with more room for trackers (radar coordinator position) in ARTCCs, removing mullions from tower cabs, improving flight progress strip holders, and acquiring cordless headsets.

Other controllers reported that some organizational adjustments and changes to current procedures and regulations would help their decision making and planning (Appendix B, Table B27). For example, some participants mentioned that they would benefit from departures and arrivals that would be more spread out, better work schedules, less interference from traffic management, and sectors and facilities staffed with more people. Participants described different ways to reduce the amount of manual entries they need to perform (Appendix B, Table B25). First among these propositions is the elimination of the 6.7.10 amendment requiring controllers to type many entries when an aircraft needs to be rerouted. Two participants indicated that aids that would reduce coordination would also be a benefit for controller decision making and planning (as shown in Appendix B, Table B25). They suggested that point outs and interim altitudes between facilities be automated. The five controllers who reported that changes to airspace and regulations would help their decision making and planning proposed a few modifications (Appendix B, Table B29). For example, four participants suggested some form of separation standard reduction. Other respondents have made some suggestions regarding controller training. As shown in Appendix B, Table B28, these participants believe that training standards should be raised, that training aids to learn the performance characteristics of different airplanes should be available, that tower training on simulators should be offered, and that controllers should complete a refresher test every year.

The last question, question 26, invited participants to identify issues related to controller decision making and planning that had been overlooked during the interview. A majority of the respondents (54 out of 100) found nothing to add. Others identified issues that had not been addressed during the interview (Appendix B, Table B31) such as the influence on decision making and planning of factors like working schedules, TMUs, personal factors, management, and labor relations. Participants also discussed training, made general comments, identified problems in ATC, and made diverse suggestions, which are presented in Appendix B, Table B14.

4. Discussion

The present study investigated a large array of issues related to controller decision making and planning. This discussion will summarize some of the themes and trends extracted from the participants' reports and identify some targets of opportunity for future field studies. Because a semi-structured interview format with open-ended questions was used, the study was exploratory in nature. However, the findings were revealing about ATCS decision-making processes and strategies.

4.1 Study Sample

The present investigation examined the decision-making and planning processes of controllers working in en route and terminal facilities. However, participants were not equally distributed across facility types. The majority, 62 out of 100 participants, were ARTCC controllers. This type of field study is challenging in terms of sampling. Participants are more accessible in ARTCCs because these facilities are staffed by much greater numbers of controllers than towers and TRACONs. It is therefore not surprising that ARTCC controllers represented such a large proportion of the study sample. Further, the number of females in the workforce is growing, but they remain the minority. This fact was reflected in the small number of female participants in the sample (7%). Participants in the present study were highly experienced (average of 17.6 years).

4.2 Situation Awareness and Memory

When they assume control of their position, ATCSs must maintain a continuously updating mental picture of the airspace. SA for ATCSs refers to the perception and integration of elements such as aircraft and to the comprehension and projection of their future status. The important role of SA in controller decision making and planning was often depicted in the results. A greater SA was the most frequent response when participants were asked how they improved with experience and what characterizes controllers who can easily handle large volumes of traffic. Participants' reports suggest that controllers start to establish their mental picture prior to assuming control of their position, mostly during the position relief briefing. Standard ATC operating procedures dictate a step-by-step process for conducting a transfer of position. This process ensures a complete transfer of status information to relieving controllers. Most common answers imply that controllers observe the radar display, flight progress strips, and status board to detect aircraft conflicts and assess the weather conditions to begin forming their SA.

Participants' reports often illustrated the collective nature of ATC. Controllers are team players who must coordinate their actions and plans with pilots and many other controllers. Participants said that they try to remain aware of the activity of controllers in neighboring sectors. For example, being aware of the workload of controllers in feeding and receiving sectors is often crucial. Their reports also revealed that controllers often try to be aware of who the controllers in the other sectors are. Interviews revealed that a large proportion of the participants consider the skill level of the controllers working with and around them when making decisions or planning. Participants also indicated that it is sometimes imperative to consider the preferences of some controllers. For example, before giving a direct route to an aircraft, a controller should consider if the next controller usually accepts direct routes or not.

One way that controllers maintain their SA is by scanning their environment. Many participants reported that they try to maintain the same scanning technique but that the adopted technique varies according to the context, especially the type of sector. Many participants also described that their scanning process is sometimes interrupted when they focus on areas of high activity or complexity. Some controllers warned against the danger of "tunnel vision."

Follow-up studies could explore the importance of the different types of information they use to form their mental picture. Determining if these types of information are covered or not during the position relief briefing could be very useful.

SA and cognitive activities such as decision making and planning depend highly on memory. The present study adapted a question from Gromelski et al.'s (1992) study to investigate controllers' use of memorization techniques (question 4). Results suggested that flight progress strips, in facilities where they are used, play a major role in supporting controller memory. This observation supports Gromelski et al.'s findings. For example, controllers described that they support their memory by writing on the flight progress strips and by offsetting them in the strip bays. Some approach controls have eliminated strips and some ARTCCs are phasing them out with the implementation of URET. Controllers in these facilities are finding alternative memory supports in the capability of the new tools. Another investigation could assess with which frequency controllers use the different memory techniques reported in this study and how that may change with proposed automation. It would be interesting to know if their answers would vary according to experience and facility type.

4.3 Controller Skills and Experience

Many controllers indicated that they keep improving their skills after formal training simply by going to work everyday and assuming their functions. As some controllers said, "practice, practice, and practice" are keys to keep improving. Other participants added that experience does not suffice. Controllers will improve only if they have a desire to do so and if they adopt a professional attitude. According to other respondents, the type of experience also matters, and controllers will improve by experiencing difficulties and learning how to overcome them. Other reports suggest that vicarious learning may play a significant role in controller improvement because 20 participants indicated that they learn by observing other controllers working. Some general comments suggested that, because of organizational constraints, little formal training is available to controllers after they become certified and that refresher training and computer-based instruction are of little use. Participating controllers also described that, with experience, they have greater SA, become more comfortable and confident, and improve their planning skills.

Investigating how participants defined experienced and skilled controllers was important because controllers may attempt to emulate their more skilled peers. What controllers believe constitutes ATC expertise may also have a significant impact on the way they learn and exercise their skills. Participants have described skilled controllers with a very long list of attributes, skills, and techniques. According to the traits and skills mentioned the most often, participants believe that outstanding controllers are self-confident, calm, intelligent, have a greater SA, think and act quickly, plan and prioritize well, and are good communicators. This portrait reflects some of the most popular responses collected by Gromelski et al. (1992), which were that outstanding controllers are good at planning and prioritizing, have good SA, and are good communicators. No characteristics were unanimously reported, which suggests that controllers might not agree completely on what skills or attributes should be acquired to become a better controller.

4.4 Decision Making and Planning

One goal of the present study was to investigate the strategies that controllers use in different situations or contexts. Results showed that controllers identify their first strategy even before assuming control of their position. Participant answers indicated that a majority of controllers generally already know what actions they will execute first when they assume control of their position. Answers suggested that the number of planned actions depends on the difficulty or complexity of the situation. Planning a greater number of actions before they assume control of their position allows controllers to regulate or maintain their workload at a more comfortable level. Participants emphasized the importance of planning skills, as evidenced when reporting them to be a characteristic of outstanding controllers and one aspect they had themselves improved with experience. Moreover, a large proportion of participants reported always trying to formulate a backup plan as part of their overall planning process.

Formulating a backup plan before implementing a strategy or before delivering clearances most likely produces a higher workload for controllers, but it also provides them with a quick alternative on which to rely. A majority of the participants, 65%, reported always trying to formulate a backup plan in case their initial strategy would not work. Meanwhile, 16% of respondents declared never formulating backup plans. Further analyses revealed that reports of using backup plans did not differ between terminal facilities and en route ARTCCs. Results showed that the more experienced controllers were, the more likely they were to report that they formulate backup plans. This result may indicate that, with experience, controllers believe that it is advantageous to formulate a backup plan. Another possibility is that experienced controllers are able to come up with a strategy more rapidly than less experienced controllers and that they consequently have more time to elaborate backup plans. It is also possible that experienced controllers are simply less reluctant to admit that they formulate such plans.

Controllers' most important task is to maintain separation between aircraft. The ATC regulations precisely define minimum separation standards to which controllers must abide. Controllers reported situations in which they use a larger separation to ensure that safety will be maintained. Participants described that they tend to use a larger buffer when the sector activity is high (bad weather, high traffic volume, military operations), for personal reasons (fatigued, do not feel well, distracted), at the request of management or other facilities, or to avoid putting too much pressure on the next sectors.

Some participants pointed out that controllers prefer not to ask for help because they consider it to be a sign of weakness. Participants' answers also suggest that knowing when to ask for help is a critical skill for controllers. ATCSs may not want to ask for help too early because they may be chastised for doing so, but waiting too long makes it harder for them to get help. For example, when a radar associate controller comes to help a radar controller, the latter will need to brief the former, and consequently raise workload. Therefore, a radar controller may wait too long and become too busy to ask for help. One suggested solution was for radar controllers to avoid having to brief their helper by requesting the help of a tracker instead of a radar associate controller.

Some of the answers also emphasized the role of supervisors in offering help. Similarly to ATCSs, OSs must offer help to their staff not too early and not too late. They must skillfully ensure that optimum staffing is assigned when air traffic is demanding and avoid leaving extra controllers at positions where the task load is light. Supervisors are often inclined to combine positions of operations to allow their staff to take longer or more frequent breaks, but they risk being caught with less than optimal staffing if traffic increases suddenly (Spring, 1998). Some participants indicated that they wished that stations always were staffed by at least two controllers, as they were designed to be.

Controller tasks certainly vary according to the type of facility in which they work. It is not surprising that participants from different facility types sometimes reported using different strategies. For example, in a high workload situation or when a potential conflict is detected, controllers in terminal facilities were more likely than en route controllers to report using the first strategy that they develop instead of considering alternatives. Terminal controllers also indicated that they are less likely to wait and see when they are not sure if there is a conflict. Tower and TRACON environments are generally more structured than ARTCCs and leave less time for controllers to direct aircraft traffic. This may explain why terminal controllers were less likely to report considering alternatives and waiting before issuing clearances.

The present study was exploratory in nature and was not intended to evaluate the formal models or theories presented in the introduction. It is relevant though to examine if controllers agreed with these theories. The observation that experienced participants seemed more likely to report using the first strategy that they think of instead of examining different alternatives when identifying a potential conflict is in agreement with Dreyfus and Dreyfus (1984) and Klein's (1989) RPDM. They postulate that experts rarely evaluate different alternatives. However, the participants of the present study emphasized the importance of formulating backup plans, an aspect not found in previous efforts to represent controller decision making with the RPDM (Hutton et al., 1997; Mogford et al., 1994; Mogford et al., 1997). The importance of backup plans may be an aspect unique to expert decision-making domains like ATC, where safety is the main priority.

4.5 Pilots and Controllers Requests

Most controllers considered ATC to be a service industry. Most participants indicated that they always try to honor pilots' requests, based on their workload, on the potential impact on the traffic in their own sector, and on the impact on the controllers' workload in the next sectors. Some participants added that they should always tell pilots why they cannot honor their request or offer them alternatives.

4.6 Decision-Making and Planning Difficulties

As described in cost-benefit theories of decision making (Payne et al., 1988, 1993; Sperandio, 1978), results of this study also suggest that when controllers become very busy, they adopt strategies that will help to reduce their workload. For example, they will try to do everything faster, avoid having to monitor the situation, act early, intensify planning, and ensure that communication is efficient (not to have to repeat). Interestingly, the type of strategy mentioned by the largest number of participants was not a workload reduction strategy but to become more conservative. Similar strategies like increasing their level of attention and awareness and using more buffer might not lead to a workload reduction but, instead, ensure safety. These observations suggest that in a high workload situation, controllers would greatly focus on maintaining a safe operation. In addition, other studies indicated that most controller errors occur during periods of low to moderate levels of activity (FAA, 1988; Stager, Hameluck, & Jubis, 1989).

The strategies adopted by controllers when they become tired were similar to the ones adopted under high workload. Being more conservative was also the most frequently mentioned strategy adopted when controllers become fatigued. Most of the other strategies focused on reducing controller workload. For example, controllers would avoid demanding positions, act immediately instead of monitoring a developing situation, ask for help, and slow down the traffic.

When participants described how they deal with boredom, the most common answers were that they engage in casual conversation with the other controllers and that they concentrate more. This reflects results obtained by Gromelski et al. (1992). Participants also mentioned a series of other activities besides distracting themselves that help them fight boredom. Many activities consisted of trying to remain busy or finding additional work. For example, controllers will try to increase their involvement in their sector by reviewing flight strips, offering more service, trying different techniques, and checking the weather. Other strategies consisted of finding additional work outside of controlling their sector like revising documentation and manipulating or adjusting equipment controls. Another group of strategies focused on ensuring the safety of the operation. For example, when bored, some controllers will project potential scenarios, slow down, use more memory joggers, use more buffer, check things twice, check for errors, make clearances as early as possible, and become more conservative. Participants reported fighting boredom by watching other sectors and protecting other controllers. Some considered helping others without a specific request as the highest level of team coordination (Bowers, Blickensderfer and Morgan, 1998).

A large proportion of the respondents believed that age had the effect of slowing controllers down. As they become older, controllers would think and act less rapidly. This position is in agreement with the literature on the effects of aging on cognition (Morrow & Leirer, 1997). Most controllers would agree that aging has some negative effects on controller performance, but many believe that older controllers can maintain their level of performance by relying on their experience and using compensatory strategies (Davies et al., 1992; Johnson, 1990) such as being more conservative and relying more on planning. Believing that one should adopt compensatory strategies with age may be key to maintaining a high level of performance and comfort over the years.

A few participants reported that military traffic is a factor adding some complexity to their tasks. Military traffic was identified as a reason to ask for help or to use a larger buffer. Rodgers, Mogford, and Mogford (1998) found military traffic to be a factor with a statistically significant relationship with the number of operational errors in en route sectors.

Weather plays a critical role in ATC operations. For example, bad weather was responsible for 69.2% of delays in 1999 (FAA, 2000b). Many controllers reported collecting weather status information before or when relieving another controller. A majority of participants identified bad weather as the most difficult condition for controllers. Bad weather sometimes forces controllers to use a larger buffer and put all aircraft at different altitudes (rely more on vertical separation) while trying to direct airplanes around the bad weather, often through a narrow corridor. ATCSs will sometimes ask for help or stop honoring pilot requests in bad weather. Many participants indicated that they make sure to have a backup plan when the weather is inclement. Many participants also expressed that an aid that would provide them with better weather information would be of benefit to their decision making and planning. Some suggestions were to enhance the presentation of weather information on radar displays with colors and to provide a way to gather weather information at different altitude levels.

Many answers emphasized that safety is the main priority of ATC. Participants described that becoming more conservative or cautious (e.g., use larger buffer) is the strategy to adopt when confronted to many difficult situations, such as bad weather, high workload, fatigue, and aging.

4.7 Decision Aids

Identifying how further automation could support controller decision making and planning was an important goal of the present study. Study participants identified which supporting tools they use or have access to in their work environment. The most frequent answers were conflict alert, J-Ring, vector lines, MSAW, route lines, and history. They provided many answers and the different decision aids varied along different dimensions. First, some tools are available only in some types of facilities. For example, J-ring is available only in ARTCCs, vector lines are available in both TRACONs and ARTCCs, and TCAS is an aircraft cockpit tool. Decision support tools also vary according to their level of autonomy. Conflict alert, MSAW, and TCAS are highly automated aids that operate without much intervention from the users compared to notepads and binoculars. The different aids also varied according to their function. For example, conflict alert, MSAW, and TCAS are tools for conflict avoidance; data block management and notepads support controller memory; and Doppler weather radar and binoculars provide more specific information to controllers. Many controllers reported that they have limited trust for conflict alert and MSAW, which they consider to be wrong too often.

Respondents also established what other types of aids may help their decision making and planning. Many are existing systems or concepts currently under development or implementation [e.g., URET, AMASS, and Next Generation Radar (NEXRAD)]. The suggestions most often reported included conflict probes, better weather information, data link communication, and better radars. Participants' request for conflict probes coincides with the Panel on Human Factors in Air Traffic Control Automation's recommendation to focus near-term automation development on decision aids for conflict resolution and maintaining separation (Wickens et al., 1998). Although only 10 came up with no suggestions, participants may have had more suggestions if they had more time to think about this issue. A different survey format might have been more efficient in collecting a larger number of propositions on this issue.

Some controllers expressed an interest in modifying data blocks presentation. Suggestions seemed to differ greatly from one participant to another. For example, one controller would have liked to see headings in data blocks, another mentioned rates of descent and climb, and one suggested that information should not be shared (or alternating more often). A future investigation could examine if changes should be made. Knowledge of the strategies used by controllers in different contexts such as the type of sector or the level of workload could allow displays to emphasize the information most relevant to controllers at that moment. Another interesting question would be to determine if an adaptive data block system presenting or emphasizing different types of information according to the present situation could help controllers. Other controllers requested ground radar displays using data blocks. Determining what types of information tower controllers need could facilitate the integration of such a feature.

Some controllers reported their need for tools or systems that could reduce the amount of coordination and communication they must achieve in the current system. Many participants believe that data link communication would benefit them. Others wished that they could send multiple clearances in parallel and make automated point outs.

Some of the answers made by the participants may offer some useful guidelines to developers of future decision aids. Reports regarding controller SA suggest that decision support systems should assume that the level of SA varies according to the experience and skill of the controllers. Participants indicated that they start forming their mental picture before they assume control of their position. Decision aids should therefore provide controllers with relevant information at that time. Participants' reports also suggest that decision aids should help controllers to maintain or enhance their SA of other sectors and positions. Participants emphasized that they use flight progress strips to maintain their memory. Future electronic flight strip systems will therefore need to provide controllers with alternative ways to support their memory. Future decision aids should support controllers when they are confronted by bad weather, the situation considered to be the most difficult by a majority of the participants.

Finally, an additional study focusing on decision making and the strategies within the ATCT environment could complement the results of the present study, in which ARTCC controllers represented a majority of the participants. A follow-up survey could investigate which factors contribute the most to ATCT complexity and which strategies they use to deal with these complexities. Further, questions could examine decision-making issues related to the use of ATCT procedures such as LAHSO and position and hold. A systematic review of types of information they use and where the information is represented may provide a baseline of the current environment to assist in the transition to future automation. As a follow-up to the controllers request from the present study, the next study could also focus on controllers' expectations regarding one requested technological change: ground radar data blocks (targets identification). Comparing the perspectives of local and ground tower controllers could highlight important differences in decision strategies and information needs.

The present study has provided a greater knowledge of controller decision making and planning. The results may guide designers of decision support systems and help them match these tools with users' perceived needs and facilitate user acceptance. The results will also help to identify targets of opportunity for more focused interviews in field facilities.

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ACRONYMS

ACE	Automatic Clutter Eliminator
AMASS	Airport Movement Area Safety System
ARTCC	Air Route Traffic Control Center
ASDE	Airport Surface Detection Equipment
ATC	Air Traffic Control
ATCS	Air Traffic Control Specialist
ATCT	Air Traffic Control Tower
CID	Computer Identification
CTAS	Center TRACON Automation System
DSR	Display System Replacement
FAA	Federal Aviation Administration
FAST	Final Approach Spacing Tool
FL	Flight Level
IDS	Information Display System
IFR	Instrument Flight Rules
IRB	Institutional Review Board
MSAW	Minimum Safe Altitude Warning
NAS	National Airspace System
NEXRAD	Next Generation Radar
OJT	On-The-Job Training
OS	Operational Supervisor
PTS	Pre-Training Screen
RPDM	Recognition-Primed Decision Model
SA	Situation Awareness
SMA	Surface Management Advisor
SME	Subject Matter Expert
TCAS	Traffic Alert And Collision Avoidance System
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control
TSD	Traffic Situation Display
URET	User Request Evaluation Tool
VFR	Visual Flight Rules

Appendix A

Participants Recruitment Letter

Air Traffic Control Specialist Decision Making and Strategic Planning – A Field Survey

FAA William J Hughes Technical Center

Research and Development Human Factors Laboratory

Background

The Research and Development Human Factors Laboratory is conducting a study on controller decision making and strategic planning. With potential applications to air traffic control training, error analysis, and decision aid design, a better understanding of Air Traffic Control Specialists decision making and strategic planning is necessary.

Purpose

This goal of this study is to investigate how Air Traffic Control Specialists make their decisions and how they plan their strategies in operational settings. Human Factors researchers will conduct interviews to identify what factors influence controllers' decisions and what techniques they use to achieve their tasks.

Participants

The Human Factors Laboratory is looking for volunteer controllers to participate in interviews that will be conducted in their facility. The facilities will be visited in August and September and they will include major terminal and en route facilities.

Your only direct benefit is your opportunity to participate. The benefit for Air Traffic Control Specialists derived from the results of this study may include a better understanding of decision making and planning in air traffic control which could reduce the likelihood of operational errors, improve training and promote the development of adapted decision aids.

Procedure

The time requirement for the interview is approximately 45 minutes. One Human Factors researcher will conduct the interview, which will be held in a private setting. The records of this study are strictly confidential, and you will not be identifiable by name or description in any reports or publications about this study. The interviewer will take notes during the interview and participant controllers will be welcomed to consult the notes if they wish to. Audio recordings will also be made to allow interviewers to complete their notes after the interview. All collected information is for use within the Research and Development Human Factors Laboratory only.

Your data will be collected by code number and no permanent record of your name will be maintained.

Rights of Participants

Participation in this study is strictly voluntary and the privacy of participants will be protected. No individual names or identities will be recorded or released in any reports. Strict adherence to all Federal, Union, and ethical guidelines will be maintained throughout the study. The purpose of the study is to scientifically assess the previously cited concepts, not to evaluate the individual controllers.

Point of Contact

Your support is important to the success of this project, and your cooperation will be greatly appreciated. If you have any additional questions, then please do not hesitate to contact me.

Earl S. Stein, Ph.D. Engineering Research Psychologist

Technical Project Lead (609) 485-6389

William J Hughes Technical Center, ACT-530

Bldg. 28, Research and Development Human Factors Laboratory.

FAA William J. Hughes Technical Center

Atlantic City International Airport, NJ 08405

You may also contact Mr. Anthony Buie, SATS, Project Controller Subject Matter Expert (609) 485-4869.

Appendix B

Summary Tables

Table B1. Gender, Status, Facility Type And Facility Level Of Study Participants (N=100)

Gender		
	Females	7
	Males	93
Controller status		
	ATCSs	92
	Staff (maintaining currency)	8
Facility type		
	ATCT	13
	TRACON	6
	Combined ATCT/TRACON	13
	ARTCC	68
Facility Level		
	8	4
	10	12
	11	13
	12	71

Table B2. Age And Experience Of Study Participants (N=100)

Variable	Minimum	Maximum	Mean	Median	Standard deviation
Age*	27	57	41.4	41.0	5.71
ATC experience	4.5	36.0	17.6	17.0	5.93
Experience at current facility*	0.8	31.0	13.0	13.0	6.09
Experience in other type of facility					
ATCT	0.0	10.6	0.6	0.0	1.67
TRACON	0.0	5.0	0.1	0.0	0.63
Combined ATCT/TRACON	0.0	11.0	0.7	0.0	2.07
ARTCC	0.0	7.0	0.2	0.0	1.00
Overall	0.0	11.0	1.6	0.0	2.91

* statistics exclude one missing value (n=99)

Table B3. Number Of Participants With Experience In Other Types Of Facility

	Experience in other type of facility		
Type of facility	Yes	No	Total
ATCT	5	8	13
TRACON	6	0	6
Combined ATCT and TRACON	9	4	13
ARTCCs	10	58	68
Total	30	70	100

Table B4. Types Of Information Gathered Before Assuming Control Of Position

Type of information	Number of participants
Conflicts	19
Weather	16
Flow of traffic	8
Equipment status	7
Traffic volume	5
Runway configuration	4
Restrictions	4
Altitudes of aircraft	4
Directions/headings of aircraft	3
Look for unusual situations	2
Look at sector incoming and outgoing aircraft	2
Look for same altitudes	2
Quick look at other sectors	2
Look for situations requiring immediate attention	2
Limited data blocks	1
Check for special activities	1
Speed of aircraft	1
Determine climb rates	1
Types of aircraft	1
During relief briefing - look for traps	1
Familiarize with new procedures	1
Handoffs	1
High altitude sector - look at navigational aids (NAVAIDs) and traffic scenarios first	1
When local controller, look at aircraft in relation to runways (departing or sitting)	1
Look at briefing manual/binder	1
Look at whom controller is talking to	1
Observe traffic on radar - identify normal traffic	1

Table B5. Personal Memory Techniques Used By Controllers

Personal technique	Number of participants
Flight progress strips	59
J-Ring (ARTCC)	22
Data block management (TRACON and ARTCC)	20
No need/none	19
Writing on notepad	13
Avoid having to remember	12
Help from others (“D-side” [radar associate] or pilots)	7
Fix things immediately this way I will not forget (Think of it, you do it)	7
Look at radar	6
Preplanning	5
Leader line length (TRACON and ARTCC)	5
Status information board	3
Temporary altitudes/Enter assigned altitude	3
Attention	3
Scope marking (tape or grease pencil) (TRACON and ARTCC)	2
Repetition	2
Pointing	2
Look at the routes used	2
Break situation into segments	1
Move computer display features (TRACON and ARTCC)	1
Get into rhythm	1
Memorizes (word association) VOR identifiers and call signs	1
Establish priorities	1
Checklist - preposition relief	1
Rote memorization	1
Forms a mental 3-dimensional picture	1
Double check data	1
Make sure that issued clearances will ensure separation the 1st time	1
Not get bogged down by details	1
Not worry or think about aircraft not in the picture	1
Try to forget things that happened earlier	1
Use shortcuts not to have to remember	1

Table B6. Methods Used By Controllers To Keep Improving After Formal Training

Method	Number of participants
Through experience (daily practice and repetition)	49
Watching other controllers	20
Learning from difficult situations	18
Desire to improve and professional attitude	16
Trying new and different techniques	15
Review rules, procedures, changes, aviation information, etc.	8
Input from other controllers	6
Formal training (refresher training, Computer-Based Instruction [CBI], Dynamic Situation [DYSIM] Laboratory, passing from 6 to 8 sectors)	6
Doing it by yourself (without instructor looking over shoulder)	4
Becoming more familiar with the facility sectors and pilots	4
Practicing basic techniques, not going away from them/Using proper techniques	2
Develop automatisms	2
Consistency working the traffic	2
Increasing level of confidence and comfort	2
Being an OJTI (on-the-job training instructor)	2
Doing what is required by the book	1
Find your limits - stretch the rules	1
Flying in the cockpit (observing pilots)	1
Working busy traffic	1
Shadowing Airspace and Procedures, Quality Analysis TMU	1
Continue to use methods that work	1
Remember plans that do not work	1

Table B7. Improvements Resulting From Greater Experience

Improvement	Number of participants
Greater SA	32
More comfortable and confident	27
Better planning	23
Increased familiarity with sectors and controllers	14
Better knowledge of aircraft type performance	12
Act earlier	10
Developed automatisms	8
Less conservative	8
More conservative	6
Improved communication skills	5
Easier in general	4
More wait and see	4
Stick to the basics	4
More organized	4
Use more finesse	3
More assertive	1

Table B8. Personality Traits Of Controllers Handling Large Volumes Of Traffic With Ease

Personality trait	Number of participants
Self confident	18
Calm	17
Intelligent (common sense, logical, etc.)	13
Assertive/aggressive	7
Ego	5
Patient	5
Like the job	4
Work well with others	2
Organized	2
Decisiveness	2
Less ego (at ease with themselves, confidence without ego)	2
Drive to excel/Willing to push themselves/Better themselves/Learn more	2
Good attitude	1
Professional	1
More outgoing	1
Adapt to pressure	1
Cockiness	1
Lack of fear	1
Not lazy	1
Boisterous (outgoing, flamboyant)	1
Shorter with people who are not as good	1
Work harder	1
Witted	1
Spontaneous	1
Controlling	1
Good work ethic	1
Comfortable	1
Love a challenge	1
Strong willed	1
Self analytical	1
Responsible	1

Table B9. Skills And Techniques Of Controllers Who Easily Handle Large Volumes Of Traffic

Skill	Number of Participants
Superior SA	34
Think, decide and act quickly	21
Good at planning and prioritizing	15
Good communicators	12
Experienced	10
Good scanning skills	7
Skilled at multitasking	6
Patient	5
Good memory	5
Good habits and techniques/Solid techniques	5
Knowledge of aircraft, rules and regulations	3
Organized	3
Efficient (don't do unnecessary things and save communications)	3
Skilled with keyboard	2
Reliable personal technique - "same thing, same way, all the time"	2
Pay attention to details	2
Do not need to think - overlearned actions/ automatisms	2
Comfortable running airplanes closer	2
Work at a steady pace - don't rush	1
Use different techniques	1
Technique: analyze, take action, know that it works and move on	1
Take time to consider how operation can operate better	1
Take handoffs in timely fashion	1
Take charge and make decisions	1
Stay busy	1
Proactive	1
Organized thinking	1
Not planners, just react	1
More flexible - don't stick to plan A necessarily	1
Good vision and hearing	1
Good training techniques	1
Efficient -	1
Don't bet on the come - use positive control	1
Always work the traffic the same, independently of the amount of traffic (moderate or heavy)	1
Adapt to pressure	1
Ability to consider all options when separating airplanes	1

Table B10. Conditions In Which Controllers Use A Larger Buffer

Condition	Number of participants
Bad weather	35
Busy sector	30
Weaker controllers	9
Other facilities request	7
Equipment failure	6
When fatigued or tired	4
To help out next controller	4
Unusual events	3
Unknown performance aircraft	3
Emergency	3
Unreliable pilot	2
Management request	2
When turning or climbing aircraft	1
When one aircraft doesn't fit	1
When in conflict, will give more of a turn and then fine tune	1
When I need to gain time	1
When extra talking needed	1
When don't feel well	1
When coming off an extended vacation	1
When aware of incoming holding	1
When approaching the limits	1
When aircraft types/performance are different	1
Time to go home	1
Sometimes to reduce communications with aircraft	1
Pilot request	1
Personal distractions	1
Other sector reaching capacity	1
Moderate traffic	1
If I sense worse case scenario is coming	1
Heavy jets or military aircraft	1
Depends on the tone of voice of other controllers	1
Depends on the scale used on radar	1
Airline in negotiation	1
2 aircraft converging at bad angle	1

Table B11. Coping Strategies Used To Deal With Boredom

Coping strategy	Number of participants
Talking with colleagues	43
Concentrate more (stay focused)	25
Try to help (or protect) other controllers	9
Watch other sectors	7
Review flight strips	5
Revise documentation	5
Offer more service	4
Take more breaks	4
Doodling	3
Need to slow down	3
Project potential scenarios	3
Use less buffer	3
Become less conservative (take more chances)	2
Check weather	2
Converse with the pilots	2
Do some planning	2
More wait and see	2
Try different techniques	2
Use more memory joggers	2
Become more conservative	1
Check things twice	1
Continually remind myself to check for errors	1
Daydreaming	1
Increase involvement in sector	1
Look at route displays	1
Look at the charts	1
Look through flight plan database	1
Make it more interesting	1
Make list	1
Move data blocks	1
Performing mental exercises	1
Play with the equipment	1
Playing tic-tac-toe	1
Reevaluate earlier actions	1
Stay inside my airspace	1
Try to keep busy by offering direct routes and soliciting reports	1
Turning up the radio (not to doze off)	1
Use more buffer	1
Use time to look at other fixes or approaches	1
Want to make clearances as early as possible	1
Watch limited data blocks	1
Writing down notes about non work related things	1
Writing grocery lists	1
Writing songs	1

Table B12. Influence Of High Workload On Separation Decisions And Planning

Influence	Number of participants
Become more conservative (safer)	32
Do everything faster	21
Act early (rather than wait and see)	19
Intensify planning	12
Ensure that communication is efficient	12
Increase level of attention/awareness	12
Use standard procedures and routes	11
Avoid using strategies requiring monitoring	9
Use more buffer	9
Do less planning	8
Offer less service	8
Rely on help more	7
Use altitude more	6
Slow myself down	6
Slow traffic	6
Less finesse (e.g., turn more than less)	6
Run airplanes closer (less buffer)	5
Prioritize	5
Increase scanning rate	5
No influence on separation decisions	4
Become less conservative	3
Use what works	3
Use flight progress strips	2
No conversations with other controllers	2
More deliberate	2
Need to be more efficient	2
Reach out, call out	2
Use visual separation	2
Try to expedite aircraft through the sector	2
Look at speeds more than altitudes	1
Use more wrong altitudes	1
Do not accept wrong altitudes	1
Try to detect conflicts further out	1
Do not focus attention as far out	1
Become more stressed	1
Use more J-rings	1
Scanning is more broken up	1
Write down - memory jogger	1
Remember what needs to be done later	1
More prepared	1
Put emotions aside - not feel rushed	1
Greater sense of urgency	1
Assume tighter control	1
Do more, try to get everything covered	1
More paper stops	1

Ask ARTCC to give a heading to an airplane	1
Use crossing restrictions	1
Work at constant pace	1
Get aircraft in quicker	1
Assign speeds	1
No influence on planning	1
Use data blocks	1
No second guess	1
More precise decisions - make it work, right or wrong	1
Stop and think before giving clearance	1
Make sure it works	1
More careful about altitude changes	1
More precise on vectors	1
Not let the number of aircraft coming or leaving rush your decisions	1

Table B13. Types Of Aids That Would Benefit Controller Decision Making And Planning

Type of aid	Number of participants
Conflict probe	24
Better weather status information	18
Data link	17
Better radar	14
Data block improvements	12
Use of color display	11
Electronic flight progress strips	9
Planning tools	9
Ground radar improvements	8
Better radio/communications	8
Organizational improvements	7
Databases	7
Reduce manual entries	6
Projection tools	6
Ergonomic improvements	6
Training	5
Airspace and regulations improvements	5
Cockpit	3
Less coordination	2
Developers of new ATC equipment should consider controllers' input	1
Reduce time not looking at the screen	1
Make pilots more attentive	1
Messages on radar display - help controller keep his eyes on radar display	1
ACE replaced by faster tool (don't have time to wait for page to load up)	1
Automated conflict resolution - displayed on PVD (plan view display)	1
STARS (Standard Terminal Automation Replacement System)	1
Call sign blinking when aircraft is in free track (helps ensure automatic handoffs)	1

Table B14. Type Of Conflict Probes Desired By Participants

Conflict Probe	Number of participants
Conflict probe that considers traffic in other sectors (long-range conflict probe)	8
URET (User-Request Evaluation Tool)	8
AMASS (Airport Movement Area Surface System)	4
UPR (conflict probe tool in CTAS)	1
Conflict detection and resolution tools like in Europe	1
Electronic flight strips with conflict detection	1
Use colors on radar display to facilitate conflict prevention	1
Improve conflict alert on overtakes	1

Table B15. Desired Improvements To Weather Status Information Display

Improvement	Number of participants
More accurate weather information on radar display (e.g., NEXRAD)	15
Colored weather information on radar -	1
Display weather at more levels	1
Doppler radar information displayed on scope when requested	1

Table B16. Comments Regarding Data Link Communication

Comment	Number of participants
Use Data Link to avoid congestion of the frequency	11
Use DDTC (Data link Delivery of expected Taxi Clearances)	2
Ability to use automated computer entries for arrivals using the same descents	1
Data link would make pilots better at listening	1
Implement Data Link with triple-check acknowledgment (pilot to copilot to controller)	1
Ability to send speed clearances to more than one aircraft at a time	1

Table B17. Desired Improvements To Radar Displays

Improvement	Number of participants
More accurate information - speeds/ground speed	3
More accurate information - radar/No target jumps	3
Reliable equipment/Improve existing aids	2
Use backup radar that would be the same as the primary one	1
More reliable and precise radar information	1
Larger screens on D-Brite (Digital Bright Radar Indicator Tower Equipment) with larger characters	1
More accurate and up-to-date information	1
Better radar - digitized radar	1
Better secondary radar	1
Better radar - beacons and data tags not disappearing	1
Designators for all aircraft in low altitude sectors	1
Range rings	1

Table B18. Proposed Modifications To Data Blocks

Modification	Number of participants
Presentation of speed and destination in data block not alternating (presented on same line constantly or alternating more often)	1
Auto data block separation	1
Add one line on data block with 2 fields with shared info: Headings, Airplane Type, Destination, and Next Fix	1
Display rates of descent and climb	1
Ground speed replaced with aircraft type and destination when putting cursor on the data block	1
Assigned heading and speed in data block	1
Add one line on data block with heading and assigned heading	1
Add one line on data block with destination and type of aircraft	1
Route display in data block (as in DSR)	1
Visual cue on data block showing which aircraft is on frequency	1
Display in data block in which sector the aircraft is in	1
Color coded data blocks for spacing programs	1

Table B19. Suggestions Regarding Use Of Colors On Radar Display

Suggestion	Number of participants
To help remember overflights	2
To identify arrival airports (CID or leader link)	2
To facilitate conflict prevention	1
Colored weather information	1
Colored VFR aircraft	1
Color coded data blocks for spacing programs	1

Table B20. Requested Planning Aids

Planning tool	Number of participants
FAST - Final Approach Spacing Tool (CTAS tool)	2
SMA - Surface Movement Advisor	2
Traffic Situation Display (TSD) - TMU tool presenting traffic information across the USA in front of each controller	2
CTAS route display	1
Ghost target generator for final approaches (presented in different colors)	1
Tool that recommends runway assignment	1

Table B21. Desired Improvements To Ground Radar Suggested By Tower Controllers

Improvement	Number of participants
Data blocks on ASDE	7
Display ASDE on window so controllers see through	1
Integrated D-Brite and ASDE radar information	1

Table B22. Suggested Improvements To Radio Communication System

Suggestion	Number of participants
Better radios or frequencies to avoid congestion of the frequency	7
Visual cue on data block showing which aircraft is on frequency	1
Something to reassure clearances (problem with similar call signs)	1
Should be able to overpower and transmit to other aircraft when microphone is stuck	1

Table B23. Organizational Improvements

Suggestion	Number of responses
Arrival and departures schedules that are more spread out	2
Better work schedules (less tiring)	1
Involve D-side in planning	1
Less management	1
Less interference from TMU	1
Two people per sector	1
Get rid of National Command Center (micromanagement causes delays)	1
Hire more personnel	1
Flow control - restrictions to avoid congested sectors	1
More reliable monitor alert in TMU (better predictions of traffic flow)	1

Table B24. Implementation Of Databases

Database	Number of responses
Computers should know all fixes/Database of fixes/Route key to any fix (beyond 1st ones out of own airspace)	7
Database of all call signs (useful with new or unusual call signs)	1
Airport identifications recognized by ARTCC Host computer	1

Table B25. Suggestions To Reduce To Amount Of Manual Entries

Suggestion	Number of responses
Reroute amendments via other means than the 6.7.10 (use route key)	3
Faster data entry - reduce the need to wait for computer to process entries	1
Recall function as in DSR to reduce flight plan entry time	1
DIAK keyboard	1
STARS will require too many computer entries	1

Table B26. Suggestions Regarding Trajectory Projection Tools

Suggestion	Number of responses
Ability to project flight routes when considering changes to flight plans	2
Route display of aircraft in other facilities	1
Projection of altitude based on rate of climb	1
Use CTAS route display	1

Table B27. Suggested Improvements To Ergonomics Of Equipment And Environment

Suggestion	Number of responses
Need to establish what are the optimal lighting parameters in the control room	1
DSR configuration does not leave enough room in sectors for trackers	1
Enhance ergonomics of equipment	1
Remove mullions (support for glass in tower cab)	1
New strips holders are too tight	1
Use cordless headsets	1

Table B28. Suggested Improvements To Controller Training

Suggestion	Number of responses
Raise standards of training programs	2
Training aid to help controllers (especially trainees) learn the performance characteristics of different airplanes	1
Tower training on simulators	1
Annual refresher (scored)	1

Table B29. Proposed Changes To Airspace And Regulations

Change	Number of responses
Reduced separation above 29000 feet	2
Reconfigure busy sectors	1
Special VFR procedures	1
More airports capable of VFR	1
Reduced separation requirement when aircraft crosses behind other aircraft	1
Reduced front-to-front separation (3 miles instead of 5)	1
Allow visual separation above actual standard	1

Table B30. Suggested Improvements To Aircraft Cockpits

Improvement	Number of responses
Free Flight: better cockpits would help controllers	1
TCAS in cockpits is benefit to controllers because pilots see the traffic and won't ask useless requests	1
Equip all aircraft with RNAV (area navigation) for bad weather	1

Table E31. Decision-Making And Planning Issues Overlooked During The Interview

Issue	Number of responses
Effects of work schedule (rotating shifts, time on position, etc.)	6
Effect of TMU restrictions - interaction with TMU	4
Personal factors (personal life and sleep gotten the night before)	3
Influence of management	2
Labor relations	2
Ability to think in three dimensions	1
Radar scope settings	1
Eurocontrol traffic management concepts	1
Influence of moods	1
Influence of morale	1
Interaction with supervisors	1
Personality (how to cope with other people)	1
Questions investigating why controllers make specific decisions	1
Thinking at different positions (R-side versus D-side)	1

Table B32. Suggestions Made By Participants In Question 26

Suggestion	Number of responses
Elevate requirements for hiring	2
System needs to focus more on security than on saving money to airlines	1
Rerun scenarios with systematic air traffic operations research initiative - check if what I just said would be the same, observe real-time decision making	1
Research controllers who have not had errors and look at their techniques	1
Recognition that human make mistakes, even the best controllers	1
Need to know how to improve planning and self criticizing, also need to realize how you performed	1
Need airlines to schedule flights more spread out	1
How to prevent hear back and read back errors: concentrate on read backs	1
Going back to basics, ensuring all employees meet the basics	1
Airline representative in control room	1
Need to select capable people who can make fast decisions	1

Note. Relative frequencies in parentheses.

Table B33. Comments Regarding Controller Training

Training issue	Number of responses
Provide refresher training	3
Provide computer-based instruction (CBI lessons) on decision making	2
Training is the most important	1
Screening process was better than "train to succeed" philosophy	1
Need to improve training	1
Controllers should learn how to be flexible, adapt, and improvise	1
Controllers should be trained not only on how to separate but on how to be efficient	1
A system that would replay a sector during a certain amount of time would be a great training tool	1

Table B34. Air Traffic Control Problems Identified By Participants

Problem	Frequency
Delays not only because of command also because of lack of skills	1
Difficult to automate decision making	1
FAA should improve "esprit-de-corps"	1
Frequency congestion	1
Pilot listening skills Vs. cockpit duties	1
Pilots are difficult to predict	1
Separation strategies have been the same since 1957 and need to be improved	1
Traffic augments but human capacity stays the same	1
Problem with people going from lower to higher facilities	1
System needs to be modernized	1
Problem with DSR, difficult to assume R-side and D-side at same time	1

Table B35. General Comments Made By Participants In Question 26

Comment	Frequency
Making good decisions or being a good controller is a matter of talent, not training	3
Decision making is as good as the individual (healthy, good attitude)	1
Good controllers can adapt (innovate), can't box everything or proceduralize everything	1
Easy to be a ATCS (consists simply in deciding when and how much to change the altitude, vector, and speed of aircraft)	1
Most important question: why some controllers work large volume of traffic with ease?	1
Decision making is based on experience (having seen it) and you always learn (see things never seen before)	1
Experience is overriding factor for everything	1

Appendix C

Institutional Review Board

FEDERAL AVIATION ADMINISTRATION

INSTITUTIONAL REVIEW BOARD APPLICATION FORM

I. THE RESEARCH PROPOSAL	
Principal Investigator: Jean-François D'Arcy	Degree: Ph.D.
Lab/Routing Symbol: ACT-530/System Resources Corporation	Phone: (609) 625-5669 x154
Title: Human Factors Engineer	
Co-Principal Investigator: Earl S. Stein	Degree: Ph.D.
Lab/Routing Symbol: ACT-530	Phone: (609) 485-6389
Title: Engineering Research Psychologist, Technical Project Lead	
Collaborating Investigators (give identifying info for each):	
Project Title: Air Traffic Control Specialist Decision Making and Strategic Planning – A Field Survey	
Sponsor:	
PLANNED STARTING DATE AND ANY CONSTRAINTS ON START DATE. 7/99 Constraints:	

II. STUDY POPULATION	
Age Range: 18-65	Gender: Male ☒ Female ☒
Special Qualifications: Current Air Traffic Control Specialists	
Source of Subjects:	
Number of Subjects: 150	
Exclusion Criteria (if any):	
Mark any of the following subject groups that are included: Children ☐ Pregnant Women ☐ Mentally Disabled ☐ Elderly ☐ Prisoners ☐ Federal Employees ☒ If any of these groups are included, you might consult with the IRB Chair prior to submitting this application.	

III. USE OF INVESTIGATIONAL DRUGS OR DEVICES	
Does this study involve the use of investigational drugs or devices?	Yes ☐ No ☒

USE OF IONIZING RADIATION	
Does this study involve the use of ionizing radiation?	Yes ☐ No ☒

V. REQUEST FOR EXEMPT STATUS OR EXPEDITED REVIEW	
I request this application be considered as: (Attach explanation of why exempt or expedited criteria are met.)	Exempt ☐ Expedited ☒

FEDERAL AVIATION ADMINISTRATION

INSTITUTIONAL REVIEW BOARD APPLICATION FORM

VI. PROTOCOL REFERENCES

Page No.	Topic
___	Purpose
___	Background
___	Risks
___	Inclusion/Exclusion Criteria
___	Duration of Participation
___	Early Termination Criteria
	EXPERIMENTAL PLAN
___	Subject's Assurances
___	Facilities
___	Methods/Procedures
___	Risk Analysis
___	Medical Monitoring
	DATA
___	Collection/Analysis
___	Statistical Justification
___	Confidentiality
	LIST OF REFERENCES
___	LIST OF ATTACHMENTS TO PROTOCOL

CONSENT FORM REFERENCES

Page No.	Topic
1	Description of study population
1	Benefits
1	Compensation/Injury
2	Contact Point for Subject's Questions
1	Confidentiality
1	Withdrawal with impunity

FEDERAL AVIATION ADMINISTRATION

INSTITUTIONAL REVIEW BOARD APPLICATION FORM

VII. CERTIFICATION/SIGNATURE

I certify that the information contained herein (application, research protocol, consent form if required) is true and correct, and that I have received approval to conduct this research project from all persons named as collaborating investigators and from my division management.

P.I. SIGNATURE: __________________________ DATE: __________

Appendix D

Interview Protocol

Interview Number___________

Interview protocol

Introduction

Thank the respondent for his/her cooperation. **Present** yourself and your role in the study.

Describe the **goal** of the study: "The goal of the study is to gain a better understanding of the decision-making and planning techniques used by Air Traffic Control Specialists in operational settings. We are presently interviewing active ATCSs from different types of facilities and we ask them questions on how they make their decisions, what information they use, what factors influence them, etc. We believe that enhancing our understanding controller decision making and planning could help to improve training and lead to the development of decision support systems that will be adapted to the users."

Another objective of the study is to present the results in a **technical report**, and maybe in scientific publications or conferences.

Emphasize that **confidentiality** and **anonymity** will be protected.

Insist that we are interested in the methods used by Air Traffic Control Specialists in general and not by the answers of specific individuals. Specify that there are **no right and wrong** answers and that what we are interested in are the opinions of Air Traffic Control Specialists.

Specify that you will **read** the questions to the respondent and that they should feel free to ask you to repeat or to explain questions that are not clear.

Mention that you will be **taking notes** but that they should feel free to look at them at anytime.

Ask permission to use audio **tape recorder** to allow researchers to complete their handwritten notes

Ask the respondent to read the **consent form** carefully and to sign two copies if she/he agrees.

Sign and keep the consent form and give one copy to the respondent.

Ask if there are any questions.

Controller background information

Sex: 1) Female 2) Male

Type of facility: 1) Tower only
2) TRACON only
3) Tower and TRACON
4) ARTCC

Your facility level: ______

Your position: 1) ATCS 2) Staff (staff currency)

Interview Number___________

Years in ATC: ______ ______

Years Months

Years in your facility: ______ ______

Years Months

Other facility type experience (in number of years):

Tower only: ___________

TRACON only: ___________

Tower and TRACON:___________

ARTCC: ___________

May I ask you your age? _______

[**START RECORDER**]

Interview Number___________

Questions

Q-1. A) How do you establish the mental picture prior to assuming control of the position?

B) Once the briefing is over and you assume your position, how much planning have you already done?

Q-2. How do you use flight strips? Do you use them to identify potential conflicts, for quick reference, backup to radar data, memory aid (memory jogger), or to help maintain the picture?

Q-3. Does the way you scan your radar display change depending on the situation? Do you always look for the same type of information?

Q-4. We are interested in memory as you use it. What personal techniques do you use that help you maintain the picture and remember the plans that you will execute only later on?

Q-5. How did your way to plan and separate aircraft change with experience?

Q-6. How do controllers keep improving their planning and separation skills after formal training?

Q-7. What is the effect of age on controller planning and decision making or what have you observed that more seasoned controllers do differently?

Q-8. As your workload increases to the point where you are really busy, how does it influence your separation decisions and planning?

Q-9. In what ways does fatigue influence the strategies you choose?

Q-10. When do you tend to ask for help or when should controllers ask for help?

Q-11. How do you deal with boredom on position and how does it influence your separation strategies and planning?

Q-12. How do direct flights influence your decisions and planning?

Q-13. How much do you adapt your decisions and planning to the requests, personality and skills of the controllers working with and around you?

Q-14. [**RADAR ONLY**] How much are you aware of what is going on in adjacent sectors?

Interview Number___________

[**TOWER ONLY**] How much are you aware of what is going on at the other positions?

Q-15. Under what conditions will you honor pilots requests and how does it influence your decisions and strategic planning?

Q-16. When do you build a buffer beyond minimal separation?

Q-17. What does "bet on the come" mean to you and do novices and experienced controllers "bet on the come"?

Q-18. When you identify a potential conflict, how often do you use the first strategy that comes to your mind and do not even need to consider other alternatives?

Q-19. Do you normally have a backup plan, in case your initial strategy does not work? **[Under what conditions do you formulate a backup plan?]**

Q-20. When you are not sure if there is a conflict, is it sometimes better to wait and see how the situation develops or is it always preferable to act immediately and resolve the issue?

Q-21. In a high workload situation, would you tend to act rapidly and implement the first satisfactory action that comes to your mind or would you make sure to consider a few alternatives before doing anything?

Q-22. To your knowledge, do controllers who handle large volumes of traffic with ease have any special skills, attributes or techniques?

Q-23. What situations or conditions make it the most difficult to maintain separation and how do they influence your separation strategies and planning?

Q-24. Some planning and conflict detection aids are available to you (e.g., MSAW [**TRACON and En route**] conflict alert). Do you use any of them and how do they influence your decision making and planning? [**Probe for more examples**]

Q-25. What other types of aids would help your decision making and planning?

Q-26. **[Last question]** Is there anything that I should have asked you about decision making and planning that I overlooked?

Close out

Thank the respondent for his/her cooperation.

Reemphasize that confidentiality and anonymity will be protected.

Ask if there are any questions.

Appendix E

Informed Consent Form

FAA William J. Hughes Technical Center

Research Development and Human Factors Laboratory

Air Traffic Control Specialist Decision Making and Strategic Planning – A Field Survey

Individual's Consent to Voluntary Participation in a Research Project

I, ______________________________, understand that this study, entitled "Air Traffic Control Specialist Decision Making and Strategic Planning – A Field Survey" is sponsored by the Federal Aviation Administration and directed by Dr. Earl Stein ACT-530 NAS Human Factors Laboratory and assisted by Dr. Jean-François D'Arcy.

Nature and Purpose:

I have been recruited to volunteer as a participant in the project named above. The purpose of this study is to explore with an interview the decision-making and planning techniques used by Air Traffic Control Specialists in operational settings. The purpose of this study is to scientifically investigate the planning and decision-making concepts. Participants are subject matter experts and researchers are not evaluating them in any way. The time requirement for this task is approximately 45 minutes.

Interview Procedure

During the interview, the interviewer will ask some biographical information and questions regarding decision making and operational planning in air traffic control. The interview will be held in a private setting. The interviewer will take notes during the interview and I may consult the notes if I wish. Audio recordings will also be made to allow researchers to verify or complete the handwritten notes after the interview. If I make the request, the tape recorder will be turned off. All collected information is for use within the Research and Development Human Factors Laboratory only and will be kept confidential.

Benefits

I understand that the only direct benefit to me is the satisfaction of knowing that I contributed to our knowledge about decision making and planning in air traffic control.

Participant's Assurances:

I understand that my participation in this study is completely voluntary. I am participating because I want to. The researcher has adequately answered any and all questions I have about this study, my participation, and the procedures involved. I understand that the researcher will be available to answer any questions concerning procedures throughout this study. I have not given up any of my legal rights by consenting to this interview.

I understand that records of this study will be kept confidential, and that I will not be identifiable by name or description in any reports or publications about this study. Audio recordings are for use within the Research and Development Human Factors Laboratory only. Any of the materials that may identify me as a participant cannot be used for purposes other than internal Research and Development Human Factors Laboratory without my written permission. I understand that I can withdraw from the study at any time without penalty or loss of benefits to which I am otherwise entitled.

If I have questions about this study or need to report any adverse effects from the research procedures, I will contact Dr. Jean-François D'Arcy at (609) 625-5669 ext. 154. I may also contact Dr. Earl Stein (609) 485-6389, the Air Traffic Human Factors Technical Lead at any time with questions or concerns.

I have read this consent document. I understand its contents, and I freely consent to participate in this study under the conditions described. I have received a copy of this consent form.

Research Participant: _________________________Date: ___________

Investigator: ________________________________Date: ___________