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Preliminary Studies of Planning and Flight Strip Use as Air Traffic Controller Memory Aids

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16. Abstract

Preliminary studies were conducted with novice participants (aviation students) to investigate the effects of memory strategies (planning and flight strip management) on Air Traffic Control (ATC) performance. Participants were trained to use TRACON II, an ATC simulator for the personal computer, and were then tested in three experiments. The first two experiments tested whether having an opportunity to plan control strategies and having increased planning time influenced performance. The results did not indicate that performance improved under these conditions. Individuals differed widely in their performance regardless of test condition, suggesting that individual strategies may have influenced performance to a greater extent than did the test conditions. Methods which allow for the analysis of individual strategies should be used to conduct future research in these areas.

The third experiment tested the effect of flight strip management (note writing) on performance and on memory for critical information. Correlations revealed that participants who wrote more on strips tended to perform better and also tended to remember more of the commands they had issued to aircraft, suggesting an important role for active flight strip manipulation.

Overall, this work demonstrated that a PC-based simulator can provide a suitable environment in which to test issues in ATC. Realistic scenarios can be developed to accommodate a range of performance abilities, making this a potentially suitable testing device for use with actual air traffic controllers.

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EXECUTIVE SUMMARY

Preliminary research studies were conducted to investigate the effects of two memory strategies (planning and flight strip management) on performance in the Air Traffic Control (ATC) environment. Three experiments were conducted using novice participants (students currently enrolled in an aviation program at a local community college) to determine the most valuable methods for conducting further work on these strategies with actual air traffic control specialists (ATCS's). Experiments were conducted using TRACON II, an ATC simulator for the personal computer. Participants were trained to become fairly proficient with the game before being tested in the experimental conditions. None of the participants had had experience with TRACON prior to these sessions, however, performance was observed to vary greatly between individuals.

Experiment 1 tested the effect that the opportunity to plan strategies had on performance. Participants were tested under two conditions, one which encouraged the development of planned strategies, the other which discouraged their development. The results did not reveal statistically significant differences in performance between these two conditions. Participants did, however, indicate that their perceived level of thinking and concentration was higher for the condition which discouraged planning.

Participant's performance varied in both conditions. More than half of the participants had completed one or both sessions without error. Others, however, made many errors. Post-hoc analyses were conducted to determine what may have been responsible for the differences in performance between these two groups of participants. These analyses revealed that the group of participants that made fewer errors indicated a lower level of stress prior to entering the experiment and had somewhat more experience in the aviation program than did those who made more errors. Regardless of category, error scores increased with reported stress level and decreased with the number of ground courses completed. Better performance was also correlated with lower reported levels of perceived workload, lower levels of "busyness," and lower levels of stress following the test sessions. It was also proposed that individual strategies, which were not directly measured in these experiments, may have affected performance variability.

Experiment 2 tested the effect that an increase in available planning time prior to taking control of the airspace had on performance. Participants were tested under two conditions, one of which allowed for more planning time (5 minutes) than another (2 minutes). More complex scenarios were chosen for this experiment since the majority of participants had performed so well previously.

Overall, performance was poorer in this experiment than the first. Participant's reactions revealed that they found Experiment 2 to be very difficult. Reports indicated that these sessions were very stressful, required a high level of thinking and concentration, kept participants very busy, and produced a high level of perceived workload. All of the post-session reactions differed significantly from those reported in Experiment 1. The results did not reveal a statistically significant effect of planning time on performance, however. Having more time to plan strategies did not result in better performance than having less time to plan.

As in Experiment 1, performance varied between individuals. Some did very well, others very poorly. The group that made more errors reported a somewhat higher level of perceived workload as well as busyness after the experimental sessions than did the group that made fewer errors. Regardless of category, performance was related to perceived workload. As performance level decreased, perceived workload increased. As for Experiment 1, it was possible that individual strategies were responsible for differences in observed performance, although the experimental methods used did not allow for their direct investigation.

Experiment 3 tested the effect of flight strip manipulation (note writing) on memory for critical information and performance. Correlations revealed a relationship between flight strip use (the extent to which flight strips were used to record actions) and memory for issued commands as well as a relationship between flight strip use and performance. Participants who wrote more on flight strips during the session tended to perform better and also tended to remember more of the commands they had issued after the session was completed. Level of perceived workload was also negatively correlated with flight strip use. Those who used flight strips more indicated a lower level of perceived workload.

The results of the third experiment were promising in that they suggested an important role for flight strip manipulation. However, future research will be necessary to determine whether flight strip use is responsible for improved recall and performance. The present results cannot rule out alternative explanations. For example, participants who performed better may have been those who used better strategies which allowed them to be more organized. This, in turn, may have freed time for them to record more actions accurately and to perceive the task as less demanding.

The preliminary studies described here provide information as to the way in which the effects of planning and flight strip management may be effectively investigated with air traffic controllers. Individual differences in performance were observed throughout training and the experimental sessions, despite the fact that participants entered the sessions with the same level of experience using the TRACON II simulator. One possibility is that the individual strategies used by participants may have been responsible for much of the observed variability. It, therefore, appears worthwhile to directly investigate individual strategies in detail. This is applicable to the air traffic controller population, since individual differences in controller's abilities have also been observed. Once an understanding of the strategies used by effective controllers is achieved, these strategies can be developed in others through instruction and training.

1. INTRODUCTION.

1.1 PURPOSE.

Research was conducted to investigate: (1) the effects of planning and organizing information, and (2) the effects of physical activity (note writing) on memory in the Air Traffic Control (ATC) environment. Basic psychological research has found that these strategies enhance memory and both have been cited as important to the air traffic control specialist's (ATCS's) job. However, little experimental work has been conducted directly on these areas involving ATC tasks.

The work described tested novice participants (non-air traffic controllers with aviation experience) on their performance with simulated ATC scenarios using TRACON II (Wesson International, 1990), an ATC simulation game for the personal computer. Participants were taught the basics of the game and were subsequently tested under several experimental conditions in order to determine which conditions enhanced/hindered performance. The three preliminary experiments described in this paper were designed to serve as indicators for the areas of investigation that would prove most useful for future studies with actual air traffic controllers.

1.2 BACKGROUND.

Human performance errors have been cited as the primary source of operational/system errors in the ATC environment (FAA, 1987; Kinney, Spahn, and Amato, 1977). These errors have, in large part, been attributed to memory lapses, yet memory issues have not been widely studied in this domain. This work concentrates on two memory issues that have emerged as highly relevant to the ATC environment (Garland and Stein, 1991; Vingelis, Schaeffer, Stringer, Gromelski, and Ahmed, 1990; Gromelski, Davidson, and Stein, 1992; Stein, 1991). These involve an understanding of: (1) the mental "picture" or conceptual organization of information about the aircraft and airspace under control, and (2) the usefulness of physical activity (i.e., manual updating of flight strips) on a controller's ability to retrieve critical information.

Planning and organizing have been described as critical to the development and maintenance of the ATCS's "picture" (e.g., Whitfield, 1979). In addition, planning and organizing were cited by ATCS's as primary characteristics of outstanding controllers (Gromelski, Davidson, and Stein, 1992).

Reports have also indicated that flight strip management (e.g., marking, arranging their placement) is critical to the ATCS's performance (e.g., Hopkin, 1982). Gromelski et al.'s report recently found that flight strip management was cited by controllers as the most frequently used memory aiding technique. Flight strip management and planning and organizing strategies are likely not independent of one another. In the words of Hopkin (1990), "Strips help the controller to organize work and resolve problems, to plan future work, and to adjust current work in accordance with future plans" (p. 63). In summary, these memory strategies appear promising as areas for further study in the ATC environment.

1.2.1 Memory.

The dominant perspective in memory research suggests that memory operates as an information processing system. Three stages of processing are involved. First, the sensory storage stage maintains an exact copy of the information for a very brief period (up to 1/2 second) in the receptors of the eye and ear (Lindsay and Norman, 1977; Sperling, 1960, 1963). Then in short-term or working memory, information is maintained for several seconds to several minutes. Only a limited amount of material can be accurately retained. Finally, in long-term memory, information is maintained more permanently. Such information, for example, includes the meanings of words, memories of events, memories of established plans and procedures, and visual images. Items from long-term memory can be retrieved or "called up" to working memory and used when needed.

A central concept of information processing theory is that the ability to store and retrieve information from memory is directly related to the strategies or learning activities that one engages in during information acquisition. As Begg and Sikich (1984) described, "You get out of memory what you put into it" (p. 57). Acquisition strategies, therefore, affect the ability to remember; more effective strategies promote more effective retention and recall.

1.2.2 Air Traffic Controllers and Short-term Memory.

Of primary importance to air traffic controllers is short-term or working memory. The ATCS's job requires that varying amounts of information be retained in memory for up to several minutes while being continuously updated. For example, an ATCS must remember each aircraft's call letters and continuously remain aware of changes in heading and altitude for as long as the aircraft is under his or her control. Since forgetting critical information has been noted as a leading cause of system errors, controller memory enhancement is essential for promoting safe traffic management.

The literature on short-term memory emphasizes that it is limited in capacity. Miller (1956) proposed that only five to nine items could be held in short-term memory and recalled accurately. This effect has been observed consistently for static memory tasks, that is, those in which a specified set of information is to be retained, unchanged in memory for a period of time. Air traffic controllers, however, work with information that is dynamic in nature. Not only might they be confronted with a situation in which more that five to nine units of information must be recalled, but they must additionally continue to update memory in order to acquire and maintain pertinent information while discarding irrelevant information. Pertinent information must be recalled quickly and accurately in order for prompt and effective actions to be taken.

Basic research has identified a number of strategies which are useful for enhancing the recall of information from short-term memory. Two strategies, organization of to-be-remembered information and physical activity involving to-be-remembered information, have emerged as relevant to the ATC environment (Garland and Stein, 1991; Gromelski et al., 1992; Stein, 1992; Vingelis et al., 1990).

1.2.3 Organization of Information.

The first strategy concerns the role that the planful organization of incoming information plays in enhancing memory. The following example illustrates this strategy. If a learner is presented with a string of 12 letters to recall: M T V F B I U S A I B M, experiments have demonstrated that he/she will remember more of the letters if the string is organized into meaningful chunks, MTV, FBI, USA, IBM (Crider et al., 1989). This organizational framework is helpful for two reasons. It increases memorability by increasing meaning and it reduces the number of individual units that must be held in short-term memory from 12 to 4.

In another study, Bower, Clark, Lesgold, and Winzenz (1969) also demonstrated that intentionally planning and applying organizational strategies during information acquisition significantly increased the amount of information remembered. They presented two groups of subjects with a list of 112 words. The words were members of four different categorical hierarchies. In one hierarchy, for example, the top level word "MINERALS" was followed in level two by the subcategories "METALS" and "STONES." In level three, "METALS" was further divided into "RARE," "COMMON," and "ALLOYS." "STONES" was divided into "PRECIOUS" and "MASONRY." Three to four examples of each of these types were then included in level four.

One subject group was presented the entire list of 112 words in random order on each of four acquisition trials. After the fourth trial, this group was able to recall an average of 65 words. The second subject group was given the words according to the organized hierarchy. On the first trial they were given only level-one words. On the second, they were first given words from level one followed by the words from level two. On the third, they were given the words from level one, then level two, and then level three. Finally, on the fourth trial they were given all the words beginning with those in level one through to those in level four. This group remembered an average of 100 words, significantly more than the group to whom the words were presented randomly on each of the four trials. Such results suggest that intentionally learning material according to an organized and meaningful plan, in this case "chunking," enables more information to be recalled.

The examples above concern verbal material. Memory enhancement has also been obtained for chunks of visual or imaged information. Visual chunking, like verbal chunking, is useful because it allows a number of items to be associated together, thereby reducing the number of individual units that need to be remembered (Begg, 1978). Studies by Chase and Simon (1973) have demonstrated the usefulness of visual chunking to recall. They found that skilled chess players were able to more quickly and accurately recreate previously viewed chess game configurations than were novices. They concluded that skilled players were better able to organize actual chess game configurations into meaningful chunks which then allowed them to more effectively store and recall the relative placement of individual pieces. When random configurations of chess pieces were to be recalled, however, skilled players fared no better at reconstructing the board than novices, presumably because the information could no longer be grouped in a meaningful way.

It has been suggested that ATCS's use similar organizational strategies to help them effectively remember the aircraft under their control and their relative positions to one another in the airspace (Means, Mumaw, Roth, Schlager, McWilliams, Gagne, Rosenthal, and Heon, 1988). Means et al. suggest that aircraft are grouped according to salient characteristics such as overflights, geographic proximity, or those which could potentially be involved in a conflict.

Chase and Simon's (1973) work indicates that organizational strategies improve with the skill level and experience of chess players. This has also been suggested for ATCS's (Garland and Stein, 1991). Better organizational strategies should, therefore, result in more accurate recall of information about aircraft and should also allow more aircraft to be handled effectively. ATCS's who use organizational strategies should show a higher level of competence on both measures in comparison to those who do not use strategies or to those who use less efficient strategies. The "picture" that is then developed by controllers through the use of effective chunking should, therefore, allow them to be more effective in dealing with a high volume of traffic and should also allow them to be better able to foresee potential conflicts.

Whitfield (1979) interviewed controllers to get their descriptions of the "picture." Descriptions often referred to the "picture as a plan" (p. 22). This suggests that controllers develop a mental representation of what the traffic pattern looks like and how it would look in the future if the aircraft proceeded as expected. The picture is disrupted or lost if reality does not match these expectations. Whitfield concluded from his results that "An unexpected situation requiring a new plan had caused loss of the picture" (p. 22).

1.2.4 Physical Activity and Remembered Information.

A second memory strategy cited as useful for ATCS's involves the use of physical activity with the to-be-remembered information. A number of studies in basic research have indicated that recall of material is enhanced through physical activity. For example, performing action phrases (e.g., "tear up a sheet of paper" and "blow up the balloon") was observed to enhance recall of those phrases (Engelkamp, 1986; Koriat, Ben Zur, and Nussbaum, 1990; Zimmer, 1986). Memory for phrases whose actions were only imagined was not as high. Engelkamp (1986) found similar results for memory of verb pairs (e.g., knock-push). Free recall of the pairs was better when each component was physically acted out rather than just imagined at the time of presentation.

Activity has been cited as essential in order for the ATCS to maintain critical information in memory (Hopkin, 1982). Hopkin (1991b) has argued that flight strip management (writing on them or physically altering their placement to indicate an aircraft's current status) is vital for assisting the controller in maintaining his or her memory of performed actions and to-be-performed actions as well as for helping the controller to keep the "picture." A number of reports have expressed the concern that controllers will be more likely to "lose the picture" if this type of activity is eliminated (Hopkin, 1991a; Jackson, 1989). An experimental assessment of the usefulness of physical activity on memory in the ATC environment is essential to determine how much of a performance decrement may result if such activity is no longer involved.

2. GENERAL METHOD.

2.1 PARTICIPANTS.

Thirty-two novices (non-air traffic controllers) were initially recruited to serve as potential participants in three experiments. These participants were students from the Mercer County Community College Aviation Program in West Windsor, New Jersey. Given their knowledge and interests, it was expected that they would be likely to have the kinds of cognitive skills that would transfer readily to the ATC environment. The experiments conducted with these participants were, therefore, expected to give a good preliminary indication of the type of subsequent work that would be most valuable to conduct with actual air traffic controllers.

Data from at least 16 participants were expected to be necessary for each experiment in order to achieve statistically significant results. Sample size was estimated prior to the training and experimental sessions. The number of participants necessary for achieving significant results is a function of the difference between the test conditions and the variability of performance between individual participants. A greater number of participants is required to detect that a difference between the test conditions is significant if the difference is small and participant variability is high.

Estimates of the expected difference between test conditions and estimates of performance variability are usually made based on prior research. Little prior information is available, however, on novice participant's performance with TRACON II. Estimates about performance were instead derived from the observed performance levels of two novice users (one of whom was one of the authors) prior to the development of the experiments. Their performance was monitored over several sessions and was assessed by the number and kinds of errors made. Errors, for purposes of these experiments, were classified by severity and assigned point scores, as described in detail in a later section. Essentially, the more severe the error the higher the assigned point value. Using this scoring system, an estimate of variability (variance = 6 error points) was made.

The smallest difference between the test conditions which would be necessary in order for significance to be achieved at the probability level of .05 or better was then arrived at using the variance estimate above and the assumption that a number of participants from the original pool of 32 would drop out. It was determined that even a relatively small difference between test conditions (3.2 error points) would be found significant if 16 participants were tested. This number appeared suitable since it meant that half of the participants could drop out without jeopardizing the results.

Students were expected to participate in a training phase in addition to one or all of the experiments. Participants were tested under two conditions in each experiment. Permission for student participation in this research was obtained from the Coordinator of the Aviation Program and the Assistant Dean of Academic Affairs at the College (see appendix A, page A-1). All practice and experimental sessions were conducted in one of the Aviation Department's computer rooms. Each session was run during each allotted 1 1/2 hour time block twice a week. This time was designated as free time for students. Thirty PC's were available and each participant worked at his/her own computer. Participants' data were coded to maintain confidentiality.

Prior to beginning the experiments, a letter outlining the purpose of the project was sent to the Aviation Coordinator for distribution to students in the program (see appendix A, page A-2). This letter acted as an introduction to the experiments and invited interested students to attend a followup session in which further details were discussed and questions about participation answered. It was explained that this study would be used as the basis for further research into the cognitive processes associated with being an air traffic controller. Interested students were then provided with a consent form describing their rights as participants in the study (see appendix A, page A-3) which they were required to sign before the training and experimental sessions got under way.

All those who volunteered to participate were then asked to fill out a preliminary questionnaire which was designed to elicit relevant information about factors that may affect performance in the current study (e.g., aviation, computer, and video game experience, or quality of vision). The preliminary questionnaire is shown in appendix A, pages A-4 and A-5.

A table indicating participants by code number and their participation in each experiment is shown in appendix A, page A-6.

2.2 EQUIPMENT.

The equipment used to conduct the experiments was the TRACON II ATC Simulator for the IBM PC (Wesson International, 1990).

The TRACON II Simulator presents aircraft in sectors surrounding Los Angeles, San Francisco, Chicago, Miami, and Boston. It allows for variables such as sector, number of aircraft, weather, pilot performance, equipment, and number of potential emergency situations to be specified directly. TRACON also allows scenarios to be specifically programmed. This option was used to regulate the scenarios and to ensure that all student controllers received the same traffic scenarios which included arriving, departing, and overflying aircraft. Programmed scenarios were used in all three of the experiments as well as in most of the training sessions. In each of the programmed scenarios the number of relevant airports and fixes within the tested sector (Los Angeles) was reduced. The rationale behind this was that fewer names and locations would have to be learned and would, therefore, bring things to a more manageable level for novices.

Three out of five airports in the Los Angeles sector (LAX, Long Beach, Van Nuys) and an average of 7 of 25 fixes were involved in each scenario. All variables (e.g., weather, pilot performance, equipment) were set to "perfect." Two scenarios were programmed for each experiment. The two scenarios within each experiment were identical to one another except that the aircraft call letters differed between them. This allowed for a more standardized test environment within each experiment but made it so that participants would be less able to recognize them as identical.

Programmed scenarios were created by running random TRACON displays and storing the generated flight strip information in textfiles so that they could be edited by wordprocessor (WORDPERFECT). Individual aircraft were selected to include a range of aircraft types. Each aircraft's flight information was edited to ensure that its flightpath included only airports and/or fixes from the selected set. The times at which aircraft entered the sector were distributed so that a range of about three to about eight aircraft would be present in the airspace at different points in the scenario. (The number of aircraft present in the scenario cannot be controlled precisely since the ability of participants to successfully manage the flow of traffic into and out of the airspace also affects this variable). Once editing was completed, the simulation files were converted back to the DOS editing system so that TRACON could read and execute them.

2.3 TRAINING.

It was expected that participants would require a reasonable amount of training with the simulator to learn how information is presented and how commands are issued. Training was expected to be distributed in four sessions, each conducted on a separate day in order to reduce fatigue as a factor in learning. Distributed practice has long been considered more effective than massed practice for information retention (e.g., Madigan, 1969; Melton, 1967). Allotted time per session was expected to be 1 1/2 hours. After the training sessions began, however, time constraints were realized and session length was reduced to a maximum of 1 1/4 hours. This time reduction, coupled with the observed performance of participants in ongoing training sessions, required that the number of training sessions be extended from four to six.

During the first training session, participants viewed three 20 minute demonstration scenarios that illustrated the basics of TRACON. They were able to observe the way in which 10 aircraft were handled within the Los Angeles sector. Key functions used to issue commands were described, problem situations (crashes, handoff errors, separation errors) were illustrated, and feedback regarding errors was demonstrated.

Along with the information provided by TRACON, the researchers were available to elaborate on these topics and to answer questions during the training sessions. A training/reference manual was developed which included all of the information necessary to control aircraft for the current experiments. The manual included maps of the airspace, information about airports, and information about key commands. It is presented in appendix A, pages A-7 through A-17. This 10 page document was designed to use visual/graphic depictions in lieu of written dialogue as much as possible. The use of visual presentations was based on interviews conducted in 1991 with FAA developmental controllers (Gromelski et al., 1992) who recommended the use of visual presentations as much as possible for training aids. In addition to this extensive manual, a "quick reference" card, summarizing all critical commands and key functions, was provided. This is presented in appendix A, page A-18. An overview of the training manual was provided during the first session. Additionally, color coded patches were placed over the six keys used to issue control commands so that they could be targeted quickly. Participants were then given a few minutes of hands-on experience with a randomly-generated TRACON scenario.

During the second training session, students practiced with additional randomly-generated TRACON scenarios. After observing participants work on these scenarios, it became apparent that a more focused approach to training would be appropriate. New training scenarios were specifically programmed to instruct students how to handle each of the three types of flights (arrivals, departures, and overflights) that could be encountered. This was intended to provide a more systematic approach to training.

During the third training session, students worked with each of three, low-volume (9 aircraft/20 minutes) programmed scenarios: one for arrivals, one for departures, and one for overflights. In the fourth session, participants also had the option to work with higher volume arrival, departure, and overflight scenarios (11 to 13 aircraft/20 minutes). Participants either chose to work with the low volume or high volume scenarios, depending on their perceived level of competence and the level observed by the experimenters.

During the fifth training session, students worked with scenarios that contained a mix of the three different types of flights (12 aircraft/30 minutes), thereby making the scenarios more realistic and more similar to those they would observe during experimental testing. The experimenters also provided individual instruction to those participants who demonstrated difficulty in managing the traffic.

During the sixth and final training session, students worked with more of the mixed-flight scenarios. Participants were also instructed as to how their performance scores would be recorded during the upcoming experiments. They were also given time to practice the self-scoring procedure. Scoring is described below for each experiment.

Sixteen participants from the original pool of 32 remained after the final training session. None of them had had any experience with TRACON prior to their participation in this study. Thirteen participants then went on to complete the first experiment. Student attrition was due to time constraints (e.g., conflict with the start of other classes or with flight time, or travel to and from a job) or loss of interest over the six training sessions. The number of participants completing the first experiment was, therefore, lower than expected would be needed to achieve statistically significant results.

An observational assessment of performance during training indicated that participants varied widely in their ability to manage the traffic in the programmed scenarios. Some frequently experienced separation conflicts, handoff errors, and even crashes, while others were able to perform without making any errors at all regardless of the complexity of the scenarios. One of the experimenters, a retired ATCS, observed and talked with participants during the sessions. He commented that those who appeared more advanced tended to look for control techniques to manage traffic more effectively, beyond the basic control techniques that had been specifically instructed. For example, some of the more advanced individuals were transferring information onto the scope via data tags. This allowed them to type in the destination of each aircraft below its call letters so that they would not need to refer to the flight plan lists. In addition, the use of the "flightplan" command to monitor an aircraft's route, and clearing aircraft direct to the airport instead of issuing headings to each aircraft, appeared to leave these participants with more time to plan their actions. These participants found this information on their own using the "HELP" feature. All in all, the more advanced participants were more proficient and developed more techniques to help them make fewer errors. These participants appeared highly motivated and were concerned with their performance. They knew that separation conflicts took away from their total score and they strived hard not to make errors. The slower students did not appear able to grasp these various techniques until they were taught more specifically about them during subsequent sessions.

3. EXPERIMENT 1: EFFECT OF PLANNING OPPORTUNITY ON SIMULATED ATC PERFORMANCE.

3.1 PURPOSE.

The purpose of the first experiment was to investigate how the opportunity to plan and organize information about aircraft (e.g., heading, altitude, destination) affects the ability to control those aircraft. Performance was compared between a condition which encouraged the use of planning and organizational strategies and one which discouraged their use.

In the ATC environment planning can be encouraged by allowing information about future traffic situations to be available and studied. Early access to information would allow participants the opportunity to make predictions about where aircraft will enter the airspace, whether potential conflicts might occur with other aircraft, and whether the aircraft will require substantial future control commands (arrivals) or not (overflights). Appropriate actions can be selected in advance of the event's occurrence.

Alternatively, planning can be discouraged by keeping participants from having early access to information about aircraft and flight plans. This situation reduces the time available for organizing information and for making predictions about potential conflicts and decisions about how to handle traffic problems by restricting participants to working with each aircraft as it appears on the scope.

3.2 METHOD.

3.2.1 Participants.

Thirteen students attended both sessions of Experiment 1. Responses to items on the preliminary questionnaire indicated that the ages of the participants ranged from 18 to 26 (mean=20.54, SD=2.54). They had completed from one to six (mean=2.62, SD=1.42) semesters in the aviation program and from one to eight (mean=3.08, SD=2.47) ground courses prior to the start of the experiments. Flight experience varied greatly, ranging from 0 for one participant to 250 hours for another (mean=101.69, SD=86.4). Two of the 13 participants also indicated that they had some aviation experience prior to attending Mercer County College but did not elaborate on what that involved.

Participants also rated themselves (1=lowest, 10=highest) in a number of different categories pertaining to more general personal factors that may contribute to performance on the tasks. Participants rated their level of computer experience (mean=5.00, SD=1.96), level of video game experience (mean=7.85, SD=1.54), and quality of vision (mean=8.85, SD=1.83). None of the participants indicated any color vision deficiency. They indicated high agreement in their willingness to volunteer for the study (mean=9.85, SD=.54) and in the assessment of their health (mean=9.54, SD=.86). None of the participants indicated that they were currently taking any medications that would have interfered with their mental or motor abilities. They did indicate variable levels of recent stress (mean=4.23, SD=2.47). Participants also assessed how motivated they were to be involved in the experiments. This question was worded so that a response of 1 indicated the highest level of motivation and 10 the lowest. Participants' responses were generally high (mean=1.69, SD=1.52).

3.2.2 Test Conditions.

3.2.2.1 PLANNING condition.

Under the PLANNING condition, participants were tested during a 30-minute session over which 12 aircraft were presented. Prior to the start of the experimental session, subjects were given a brief 10-minute practice session so that they could become familiar with how this advance information could be used to help them plan actions for the upcoming scenario. Paper flight strips and the paper map of the airspace which included the names of airports and fixes were made available. Flight strip information included the aircraft's call letters, altitude and speed, location at which it would enter the airspace, and destination. Also included was a three-letter abbreviation indicating whether the aircraft was an arrival (TWR), departure (T/O), or overflight (CTR) as well as the time at which each aircraft would enter the airspace. Participants, therefore, had information as to when they would need to make contact with each aircraft, its entering location and destination, as well as its current altitude and speed before the session began. Flight strips for the five aircraft used in the practice session are shown in appendix B, pages B-1 and B-2.

Participants were verbally instructed as to how they could plan ways to handle aircraft during the session. Appendix B, page B-3 describes the type of instruction that participants received. It was suggested that they plot the flightpaths of aircraft, anticipate potential conflicts, and think about how they would direct those aircraft to avoid errors while maintaining efficiency (i.e., not deviating too far from each aircraft's most direct route). Participants were given an opportunity to write notes to help remind them how they would direct traffic during the session. During this practice session, participants were given guidelines for thoughts and activities expected to be helpful in directing traffic in an efficient and organized way. These were provided by an experienced ATCS who was also one of the experimenters. Specific planning and organizing activities for the scenarios were not taught. It was left up to individual participants as to how they would develop the specific strategies that they felt would best help them direct the traffic.

After working through the practice session, participants were given flight strips for the 12 aircraft they were to direct during the experimental session (see appendix B, pages B-4 and B-5). They were then given 10 minutes to plan strategies for managing the traffic. They were instructed in this, as in all experimental conditions, to minimize errors.

Under this condition, the pending flight strips provided by TRACON on the computer screen were continuously visible. This provided another source of information as to which aircraft would be due in the sector within the next few minutes. This information could also be used as a reference for planning. Under this condition, the boundary of the airspace was clearly outlined by dashed lines so that participants would be readily able to determine when an aircraft would be entering the sector. Participants also had access to the "flightplan" command, which showed where each aircraft would head if no intervening commands were issued. This provided a reminder about an aircraft's direction and destination during the session itself.

3.2.2.2 NO-PLANNING Condition.

Under the NO-PLANNING condition, participants did not have access to paper flight strips either before or during the session. Pending flight strips provided by TRACON were also removed from view during the test session. Only the active flight strips were visible on the screen during the session. Participants were also unable to use the "flightplan" command and did not have the boundary of the airspace indicated. These changes were made by editing TRACON's initialization file which allows for color changes such as "blacking out" and for turning other options (boundary, flightplan) to the "off" mode. A 10 minute practice session was provided so that participants could become familiar with working under this condition.

3.3 DESIGN.

Participants were tested according to a 2 x 2 mixed design with two levels of each factor (see table 3-1). The PLANNING and NO-PLANNING conditions served as the two levels of the within-subjects factor (PLAN). Students, therefore, participated under both of these conditions. The order in which the participants worked under each condition was the between subjects factor (ORDER). One-half of the participants worked under the PLANNING condition on the first day of testing and one-half worked under the NO-PLANNING condition. On the second day, participants worked under the alternate condition. Main effects of PLAN and ORDER as well as the effect of the interaction were analyzed by an analysis of variance (ANOVA) using SPSS. An ANOVA is a statistical procedure used to determine whether the differences between two or more means are significant.

TABLE 3-1. DESIGN FOR EXPERIMENT 1 (Participants worked under both the PLANNING and NO-PLANNING conditions in the order indicated)

	PLANNING	**NO PLANNING**
ORDER = 1	1st	2nd
ORDER = 2	2nd	1st

Two programmed scenarios were created as described in the Equipment section above. These scenarios were the same except for the call letters of the aircraft. Scenarios contained six arrivals, four departures, and two overflights. The order in which the scenarios were worked with by participants was counterbalanced across individuals to reduce the possible confounding effect of different scenarios on the conditions under investigation.

3.4 PROCEDURE.

Experiment 1 was conducted on 2 days. On the first day, the participants were randomly assigned to either the PLANNING or NO-PLANNING condition. Six were instructed by one of the researchers as to how to proceed under the PLANNING condition and worked through the corresponding 10-minute practice scenario. In another room, the other seven participants were instructed by the second researcher on how to proceed under the NO-PLANNING condition. The whole group then reconvened. The NO-PLANNING group worked with their 10-minute practice scenario while the PLANNING group spent this time previewing the 12 flight strips and planning strategies for the upcoming test session.

The same procedures were followed on the second day of testing in which participants worked under the alternate condition.

3.5 PERFORMANCE MEASURES.

The dependent variable was the measure of performance obtained by an error-point total. This total was based on the error information provided by TRACON. Errors included crashes, separation conflicts, missed approaches, and handoff errors. Errors were categorized by severity and given different point values according to their severity. Since crashes are the most severe, each was assigned 10 points. Separation conflict errors and losing aircraft off the scope were each assigned 5 points, missed approaches and handoffs made at the wrong altitude were each assigned 3 points, and other handoff errors were assigned 2 points. Feedback on these errors is provided during the scenario by color coded messages on the screen. When these error messages occur the game is halted for several seconds. Participants were given score sheets on which they put a check mark under the appropriate category each time an error message was displayed (see appendix B, page B-6). A summary error count for separation errors, handoff errors, and missed approaches is also provided by TRACON at the end of each session. Participants were to write out these total error counts for each of the categories at the end of a session to double check their own error count accuracy. The error-point total was calculated by the researchers following each session of testing.

In addition to the error-point total, the game score provided by TRACON II at the conclusion of each session was also analyzed as a performance measure. Higher scores reflected better performance. Since the analyses conducted on scores did not provide any additional information to that obtained from analysis of the error-point totals, they are not described further.

In addition to working under the test conditions, participants also filled out information on a post-session questionnaire after each session, which provided subjective ratings of their performance (see appendix B, pages B-7 through B-9). Participants indicated their level of agreement with each probe question by way of a 10-point rating scale (12 in the case of workload). This questionnaire probed for factors that may have contributed to performance during the session (e.g., fatigue, stress). ANOVA's were conducted on these post-session questionnaire variables to determine whether they differed as a function of test condition. The questionnaire also allowed for open responses to questions concerning individual strategies. This information was also examined to determine whether certain self-reported strategies correlated with performance.

The post-session questionnaire variables and the preliminary questionnaire variables were also analyzed by multiple regression analyses to obtain partial correlations between each variable and performance. These were obtained for preliminary questionnaire variables to determine whether performance in the experiment was correlated with the number of semesters completed, number of ground courses taken, number of flight hours completed, computer experience, video game experience, and stress level. These were obtained for post-session questionnaire variables to determine whether performance was correlated with self-reports about performance after each session. These included self-assessment reports and reports about perceived levels of workload, thinking and concentration, busyness, stress, and fatigue.

3.6 RESULTS.

Overall for Experiment 1, error-point totals averaged 4.96 and were very variable (S.D.=4.84). Eight of the participants made no errors in at least one of the two test conditions. One participant made no errors in either condition. Others, however, made a number of errors under both conditions. The highest error-point total for any participant in this experiment was 14.

The mean error-point total was lower than that predicted prior to the start of the experiment. Preliminary estimates had been arrived at by evaluating the performance of two novice TRACON users prior to the work conducted with the group at MCCC. Scenarios for the experiment were then programmed based on these preliminary results that indicated what performance level was likely to be.

The ANOVA indicated that there was no main effect of test condition on performance. Mean error-point totals did not differ significantly between the PLANNING and NO-PLANNING conditions, $F(1,11)=.72$, $p>.1$ (see table 3-2).

TABLE 3-2. MEAN ERROR-POINT TOTAL (AND STANDARD DEVIATION) FOR EACH TEST CONDITION IN EXPERIMENT 1

PLANNING	NO-PLANNING
5.77 (4.97)	4.15 (4.71)

However, analyses of the post-session questionnaire variables indicated that subjectively, participants tended to report that their thinking and concentration level was somewhat higher when they worked under the NO-PLANNING than the PLANNING condition. ANOVA's conducted on these data revealed that this was the only post-session questionnaire variable whose difference approached significance ($F(1,11)=4.45$, $p<.1$). Means and standard deviations for all post-session questionnaire items for the PLANNING and NO-PLANNING conditions are shown in table 3-3.

TABLE 3-3. MEAN RATING AND STANDARD DEVIATION FOR EACH POST-SESSION QUESTIONNAIRE VARIABLE AND EACH TEST CONDITION IN EXPERIMENT 1

	PLANNING		NO-PLANNING	
	Mean	SD	Mean	SD
Workload	5.00	2.42	5.39	1.98
Self-assessment	7.54	1.76	7.85	2.38
Busyness	6.69	2.84	6.15	2.76
Thinking and Concentration	5.85	2.91	6.39	2.60
Stress	4.85	2.97	5.46	2.82
Fatigue	3.69	2.81	3.62	2.73

The main effect of ORDER was also investigated. It was possible that the order in which the participants worked affected their performance. Six of the participants were tested under the PLANNING condition on the first day of testing and the NO-PLANNING condition on the second day (ORDER=1), while the other seven were tested under the NO-PLANNING condition on the first day and PLANNING on the second (ORDER=2). Participants who worked under the PLANNING condition on the first day may, for example, have had a carry over effect to the second day of testing which improved performance under the NO-PLANNING condition. This group may have been better prepared to use minimal advance information such as that provided in the NO-PLANNING condition since they had already had experience working on the development of planning strategies. Those who worked under the NO-PLANNING condition on the first day would be less likely to show such a carry over in performance. Means for each PLAN and ORDER condition are shown in figure 3-1.

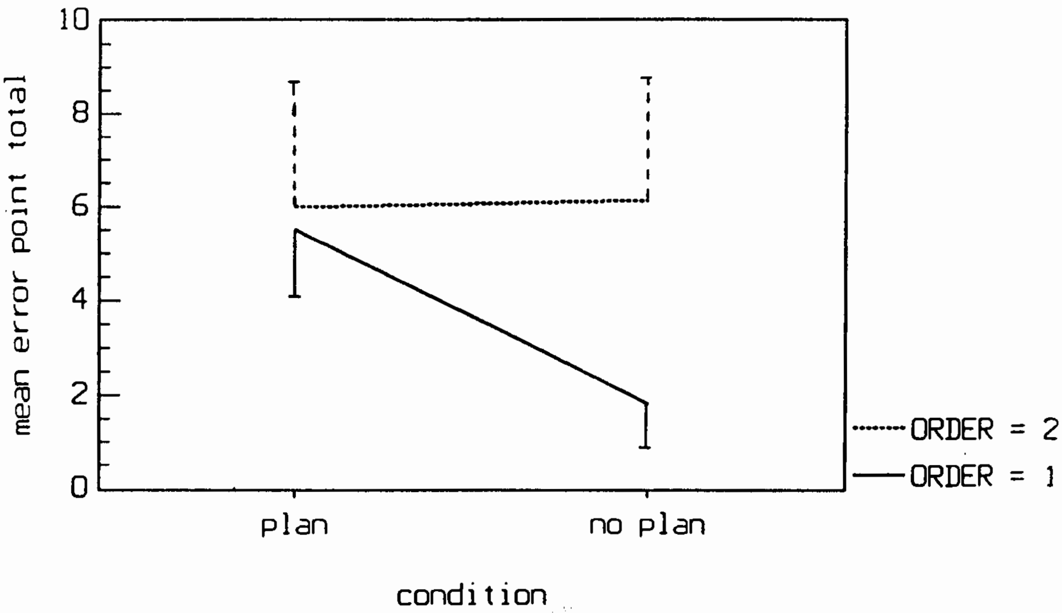

FIGURE 3-1. MEAN ERROR-POINT TOTAL AND STANDARD ERROR FOR EACH TEST CONDITION AND EACH GROUP IN EXPERIMENT 1 (ORDER=1: Group that performed under PLANNING condition first ORDER=2: Group that performed under NO-PLANNING condition first)

The ANOVA revealed that the main effect of ORDER did not reach significance, $F(1,11)=2.10$, $p>.1$. Neither was the effect of the PLAN x ORDER interaction significant, $F(1,11)=.85$, $p>.1$. However, an analysis of covariance (ANCOVA) conducted on these data did indicate that these groups tended to differ in their performance under the NO-PLANNING condition, $F(1,10)=3.19$, $p<.1$. In this analysis, performance under the PLANNING condition was held constant while error-point totals between the groups were compared for the NO PLANNING condition alone. In addition, the group that worked under the PLANNING condition on the first day had a mean error-point total of 5.50 and a mean error-point total of only 1.83 when they worked under the NO-PLANNING condition on the second day. Although a repeated measures t-test, conducted to compare performance under the two conditions for this subgroup, did not reach significance, $t(5)= +1.84$, $p>.1$, five of these six participants had improved performance between the first and second day. The remaining participant did not make any errors on the first day (PLANNING) and made only one error on the second day (NO-PLANNING). This was a separation conflict which accounted for 5 error points.

For the group of participants that worked under the NO-PLANNING condition on the first day and the PLANNING condition on the second day, this trend was not apparent. These participants averaged 6.14 error points the first day and 6.00 error points on the second. Only two of these seven participants showed an improvement from the first day (NO-PLANNING) to the second (PLANNING). One of the other five participants made no errors in either condition.

Since these two groups of participants demonstrated that their performance tended to differ somewhat, ANOVA's were conducted to determine whether they differed in terms of their responses on the preliminary questionnaire. Means and standard deviations for preliminary questionnaire variables for each group are shown in table 3-4. None of these differences reached significance ($p > .1$).

TABLE 3-4. MEAN RATING AND STANDARD DEVIATION FOR EACH PRELIMINARY QUESTIONNAIRE VARIABLE AND EACH TEST CONDITION IN EXPERIMENT 1

	ORDER = 1		ORDER = 2	
	PLANNING First		NO-PLANNING First	
	Mean	SD	Mean	SD
Flight Hours	120.67	88.04	85.43	91.79
Semesters Completed	3.00	1.79	2.29	1.11
Ground Courses Completed	3.33	3.32	2.43	1.72
Computer Experience	5.00	2.37	5.00	1.83
Video Game Experience	8.17	.75	7.57	2.07
Stress	3.16	2.14	5.14	2.61
Vision	8.50	1.97	9.14	1.86
Volunteer	10.00	0	9.71	.98
Health	9.67	.82	9.43	.98
Motivation	1.67	1.21	1.74	1.89

3.6.1 Post-hoc Analyses.

Performance levels varied among participants regardless of experimental condition. The median raw error totals summed over both conditions (PLANNING + NO-PLANNING) was 2. Eight of the participants made between zero and two errors combined in the PLANNING and NO PLANNING conditions (mean=1.25, SD=.71). Five participants made over two errors in both conditions (mean=5.6, SD=2.5). Post-hoc analyses were conducted on these two groups to investigate the potential causes of the variability in observed performance.

Variables measured by the preliminary questionnaire indicated that there was a significant difference in the level of stress each reported before entering the experiment. An ANOVA conducted on stress level with performance as a factor indicated that participants with fewer errors reported a significantly lower level of stress prior to participating in the experiment (mean=3.13, SD=1.89) than did those who made more errors (mean=6.00, SD=2.55), $F(1,11)=5.499$, $p<.05$. There was also a small difference in the mean number of semesters each group had completed prior to the experiment. Participants with two or fewer errors, reported completing an average of 3.13 semesters (SD=1.55), while those with more than two errors reported completing an average of only 1.8 semesters (SD=.84). The ANOVA, however, indicated that this difference just missed significance, $F(1,11)=3.02$, $p>.1$.

Regardless of category, performance was significantly correlated with reported stress level, the number of ground courses taken, and the level of video game experience indicated prior to the experiment ($p<.05$). The correlation matrix is presented in table 3-5. To test this, a multiple regression analysis was conducted on all preliminary questionnaire variables with error-point total as the dependent variable. This procedure examined the effect of each variable alone after partitioning out the effect that it had in combination with any of the others. These partial correlations indicated that an increase in error-point total was positively correlated with reported stress level (+.93) and video game experience (+.74), while negatively correlated with the number of ground courses taken (-.84). In other words, poorer performers indicated higher levels of stress and fewer aviation courses, as well as a higher level of video game experience. None of the other preliminary questionnaire variables reached significance.

TABLE 3-5. CORRELATION MATRIX FOR ALL PRELIMINARY QUESTIONNAIRE VARIABLES AND PERFORMANCE

	WT	AGE	SEM	GRD	FLT	CO	VID	VIS	STR	MO
WT	1.00	.39	-.29	-.36	-.28	.06	.003	-.51	.77	.48
AGE	.39	1.00	.11	.15	.51	-.50	.10	-.46	.53	.40
SEM	-.29	.11	1.00	.64	.46	-.01	.12	.35	.04	-.35
GRD	-.36	.15	.64	1.00	.82	-.13	.39	.09	.04	-.04
FLT	-.28	.51	.46	.83	1.00	-.36	.56	.09	.05	-.03
CO	.06	-.50	-.01	-.13	-.36	1.00	-.09	.28	-.04	-.03
VID	.003	.10	.12	.39	.56	-.09	1.00	.37	-.22	-.37
VIS	-.51	-.49	.35	.09	.09	.28	.37	1.00	-.54	-.91
STR	.77	.53	.04	.04	.05	-.04	-.22	-.54	1.00	.57
MO	.48	.40	-.35	-.04	-.03	-.03	-.37	-.91	.57	1.00

Note: WT=total error-point score, AGE=participant's age, SEM=semesters in program, GRD=number of courses taken, FLT=number of flight hours, CO=computer experience, VID=video game experience, VIS=vision, STR=stress, MO=motivation.

Analyses of the post-session questionnaire variables also reflected some differences between the group that made fewer errors and the group that made more errors. ANOVA's were conducted on each of the post-session variables with performance as a factor. These groups differed significantly in their workload assessments, $F(1,11)=7.39$, $p<.05$. The group with fewer errors had a mean workload assessment rating of 4.19 (SD=1.6) while the group with more errors had a rating of 6.80 (SD=2.08). The group with fewer errors reported a lower level of busyness for the sessions (mean=5.31, SD=2,59) than did the group with more errors (mean=8.2, SD=2.27), $F(1,11)=4.68$, $p<.05$. The group with fewer errors also reported a lower level of stress during each session (mean=3.69, SD=2.11) than the group with more errors (mean=7.5, SD=2.23), $F(1,11)=11.32$, $p=.01$.

In addition, the group that made fewer errors reported a somewhat higher self-assessment rating (mean=8.19, SD=1.56) than did those with more errors (mean=6.9, SD=2.47), $F(1,11)=3.7$, $p<.1$. The group that made fewer errors also reported a lower level of fatigue following the session (mean=2.31, SD=1.56) than the group that made more errors (mean=5.8, SD=3.01), $F(1,11)=8.99$, $p<.01$.

Regardless of category, performance was significantly correlated with perceived workload. A multiple regression analysis was conducted on all post-session questionnaire variables with error-point total as the dependent variable. The correlation matrix is shown in table 3-6. This analysis examined the relationship between overall post-session assessments (e.g., overall workload=workload [PLANNING] + workload [NO-PLANNING]) and performance. Partial correlations determined the relationship between each variable alone and performance after partitioning out the relationship that each had with others. Error-point total was positively correlated with workload (+.78, $p<.05$). That is, perceived workload levels increased as errors increased. None of the other post-session questionnaire variables reached significance.

TABLE 3-6. CORRELATION MATRIX FOR ALL POST-SESSION QUESTIONNAIRE VARIABLES AND PERFORMANCE

	WT	SELF	THINK	TIRED	WORK	BUSY	STR
WT	1.00	-.52	.42	.68	.78	.57	.77
SELF	-.52	1.00	-.65	-.71	-.64	-.57	-.59
THINK	.42	-.65	1.00	.47	.78	.85	.75
TIRED	.68	-.71	.47	1.00	.73	.55	.75
WORK	.78	-.64	.78	.73	1.00	.86	.87
BUSY	.57	-.57	.85	.55	.86	1.00	.79
STR	.77	-.59	.75	.75	.87	.79	1.00

Note: WT=total error-point score, SELF=self assessment rating, THINK=thinking and concentration, TIRED=fatigue, WORK=workload, BUSY=busyness, STR=stress.

As an additional part of the post-hoc analyses, the strategies reported by participants in these two groups were compared. It may have been possible that subjects in the group with better overall performance were using more effective strategies than participants who performed more poorly. While there was no way to determine what strategies were used during the course of the session, participants were asked to report any strategies they used in the post-session questionnaire after the session was completed. These reports were then examined for indications that some type of specific strategy had been used (e.g., "descended arrivals immediately to approach fix").

Seven of the eight participants from the group that made fewer errors reported specific strategies while only two of the five participants in the group that made a higher number of errors did so (see table 3-7 for samples of participant's reports). The other participants did not provide evidence in their reports that they used a specific strategy (e.g., "uncomfortable not being able to see pending strips"). The trends appear to be in the direction expected if strategies assist performance, however, these differences did not reach significance. A chi-square test of independence indicated that the number of participants responding with either specific or nonspecific strategies did not differ between these groups, chi-square(1)=1.42, p>.1.

TABLE 3-7. SAMPLES OF REPORTED STRATEGIES FROM POST-SESSION QUESTIONNAIRE IN EXPERIMENT 1

Specific	Nonspecific
"Landing: turn aircraft as soon as possible onto a heading that will set them up for final approach and then slow them down and descend them."	"...with flight strips...I was able to prepare myself as to the expedition of each aircraft."
"Have traffic immediately go to the altitude it would eventually have to be at for approach. I would tell the aircraft to go directly to the airport when it was inside the approach path instead of giving it vectors."	"Using the flight strips helped to see where the aircraft had to go and made it much easier to control."
"Vectored plane directly to a final approach position for their airports as planes came in. With overflights I just gave them radar contact and didn't communicate with them until the handoff."	"Looked ahead in time about 5 minutes."

3.7 DISCUSSION.

The results of Experiment 1 did not reveal a difference in performance between a condition designed to encourage planning and strategy development and one designed to discourage these activities. A possible reason for this outcome may have been that these experimental conditions did not alter the opportunity to plan as intended. Flight strip removal, which was intended to hinder the ability to form plans before the session began, may not have eliminated the opportunity to plan entirely. Planning may have been carried out successfully after the session had gotten underway. Scenarios may not have been challenging enough to have made preplanning necessary to successful performance. Based on the number of participants who were able to work through these sessions with minimal errors, this seems a likely possibility. Several of the written and verbal comments made by participants after the experiment lend some support to this view. While participants acknowledged feeling more "comfortable" having the paper flight strips available and also indicated requiring a lower level of thinking and concentration for the PLANNING condition when flight strips were available, many indicated that they felt competent enough to have been able to work through the selected scenarios without them.

Participants varied widely in their overall performance levels. Error-point totals ranged from 0 to 14. Eight participants (62 percent) made no errors when working under either one or both conditions, thereby making the effect of even one error in the alternate condition substantial. The tendency toward such a low number of errors for so many participants was not expected. One possible reason for the low error rate may have been the addition of the two training sessions, one of which allowed participants practice with the same number of aircraft that were presented in the experiment. This practice may have enhanced performance for some to an almost perfect level.

Other factors were investigated to determine likely reasons for performance variability. One may have been the level of stress that participants acknowledged before entering the experiment. Those who made fewer errors indicated a somewhat lower level of stress than did those who made more. Aviation experience may also have influenced performance. The number of ground courses completed was significantly correlated with errors. Error scores decreased with the number of courses completed.

Reactions to performance in the experiment also differed between the group of participants that made fewer errors and those that made more. The group that made fewer errors indicated that their level of workload, busyness, and stress were lower than those for the group that made more errors. The group that made fewer errors also reported a lower level of fatigue and assessed their performance more highly. Additionally, partial correlations of post-session questionnaire variables and performance indicated that workload correlated significantly and positively with error-point total. Perceived workload levels increased with errors.

Performance variability may also have been due to variations in the effectiveness of individual strategies. Participants in this experiment were not explicitly instructed to plan specific strategies. The intent of the experiment was only to measure performance when the opportunity for planning was made available. Some options and suggestions were given (e.g., sketch the flightpath), but beyond that, individuals developed and implemented their own specific plans. Some may have developed very effective strategies while others did not. Or, some may have found strategies easier to develop than others. Some participants, for example, may not have been able to quickly identify and implement an appropriate organizational scheme. Such individual differences in the overall ability to generate and execute helpful plans may have resulted in some of the differences observed between participants' performance levels in this experiment. These individually imposed strategies may have played a strong role in performance which outweighed the experimentally imposed conditions.

Bousfield's (1953) work demonstrated that experimental subjects who imposed their own strategies enhanced their performance on a recall task. In his experiment, participants were presented a list of words each of which belonged to one of four different categories (names, animals, vegetables, and professions). The words were presented randomly, but were recalled by category. This type of strategy has been observed to increase the number of words remembered relative to a condition in which no organizational scheme is used. Additional work by Bransford and Johnson (1972, 1973) has also indicated that organizational strategies improve memory. They found that participants in their experiments who made up their own context while hearing an ambiguous passage, remembered more of the passage than those who claimed not to have used a context.

Although it was not possible to determine much about the individual strategies used by participants in this experiment, some information could be obtained from the post-session questionnaire which specifically asked what strategies participants used during the session they had just completed. To investigate strategies more directly, participants would have had to have been observed more closely while working through a session, explaining how and why they were directing traffic as they were. This information could then be evaluated by protocol analysis. While the design of this experiment did not allow for this, some reports from the post-session questionnaire were revealing. Most of the participants who made the fewest number of errors reported specific strategies for the way in which they handled traffic in either one or both conditions. Most focused on arrival aircraft which are the most difficult to manage. Several participants indicated, for example, that they took steps to set up aircraft early for final approach. That is, as soon as contact was made with an aircraft that was to land, they descended the aircraft immediately to final altitude and vectored it as soon as possible to final approach heading. Verbal comments made after the experiment's completion by participants using this strategy, indicated that they chose to do this by sending aircraft direct to the fix located just outside the final approach path of an airport, then turned the aircraft onto final approach and handed it off to land. This acts to standardize the process for landing. Such a strategy reduces the number of commands that need to be issued to an aircraft and helps organize the procedure. Doing this, in turn, presumably leaves more time available for controllers to handle other aircraft or to search for potential conflicts.

4. EXPERIMENT 2: EFFECT OF PLANNING TIME ON PERFORMANCE.

4.1 PURPOSE.

The purpose of the second experiment was to investigate how the amount of available planning time affects the ability to control aircraft. It has been indicated that a large number of controller errors are made during the initial 15 minutes after a controller has taken over a position (Vingelis et al., 1990). These errors may result because the controller has not allowed for sufficient planning time to set up the appropriate "picture" of the situation in which he/she is suddenly immersed. Allowing for more planning time should enhance performance relative to a condition which allows for less time to plan.

4.2 METHOD.

4.2.1 Participants.

Twelve of the students who participated in Experiment 1 participated in Experiment 2. Data from the preliminary questionnaire, therefore, were about the same as those for Experiment 1. The ages of the participants ranged from 18 to 26 (mean=20.67, SD=2.57). They had completed from one to five semesters in the aviation program (mean=2.67, SD=1.5) and from one to eight basic ground courses (mean=3.18, SD=2.56). Their flight experience varied from 0 to 250 hours completed prior to the start of the experiments (mean=105.5, SD=90.98). Two participants indicated having had some aviation experience prior to attending Mercer County Community College, but did not elaborate on what that involved.

Participants' ratings (1=lowest, 10=highest) on their level of computer experience ranged from 2 to 8 (mean=5.08, SD=2.07), video game experience ranged from 6 to 10 (mean=8.08, SD=1.38), and quality of vision ranged from 5 to 10 (mean=8.75, SD=1.91). None indicated any color vision deficiency. Participants indicated high agreement in their willingness to participate in the study (mean=9.83, SD=.58). They also indicated high ratings for their general health (mean=9.50, SD=.90). They did indicate variable levels of recent stress (mean=4.33, SD=2.61). None indicated that they were taking any medication that would interfere with their mental or motor abilities. Level of motivation to participate was generally high (mean=1.75, SD=1.60). This question was worded so that 1 was equal to the highest level of agreement, 10 the lowest.

4.2.2 Test Conditions.

Two experimental conditions were tested that were designed to simulate conditions experienced by controllers taking over a position. In both conditions participants were informed that they would view an ongoing scenario and, that at some point, they would be required to take over control of the aircraft. They were instructed that the experimenter would indicate verbally when to take control. One condition mimicked a situation in which little planning time was allotted before control of the airspace was assumed. The second condition mimicked a situation in which increased planning time was allotted. Each participant was tested under each condition as described below.

4.2.2.1 2-MINUTE condition.

Under this condition, participants were tested on their performance controlling aircraft after viewing an ongoing scenario for 2 minutes. The test scenario was initially controlled by one-half of the participants while the other half (test group) were seated across the room so that they were unable to watch the scene and the way that the traffic was being handled. The test group participants were instructed to join their partners and to begin viewing the scene after a signal was given. They were told to be prepared to take control of the scenario as soon as the words "take over" were announced by one of the experimenters. Participants were not told how much time they would have until that signal was given. They were instructed to use the available time to observe their partners working on the ongoing scenario and to ask questions in order to prepare themselves in ways that they could foresee would best help them direct traffic once they assumed control. Once the test group assumed control, they worked on the scenario for the next 15 minutes while recording their errors on a response sheet as described in Experiment 1.

4.2.2.2 5-MINUTE condition.

Under this condition, participants were tested on their performance controlling aircraft after viewing an ongoing scenario for 5 minutes. The test scenario was initially controlled by one-half of the participants while the other half (test group) were seated across the room. All other aspects of this condition are the same as those described for the 2- MINUTE condition, except that the test group was given 5 minutes to observe the ongoing scenario before being given the take over signal.

4.3 DESIGN.

As in Experiment 1, participants were tested according to a 2 x 2 mixed design with two levels of each factor (see table 4-1). The 2-MINUTE and 5-MINUTE conditions served as the two levels of the within-subjects factor (TIME). Students, therefore, participated under both of these conditions. The order in which the participants worked under each condition was the between-subjects factor (ORDER). One-half of the participants worked under the 2-MINUTE condition on the first day of testing and one-half worked under the 5-MINUTE condition. On the second day, participants worked under the alternate condition. Main effects of TIME and ORDER as well as the effect of their interaction were analyzed by an ANOVA using SPSS.

TABLE 4-1. DESIGN FOR EXPERIMENT 2 (Participants Worked Under Both the 2-MINUTE and 5-MINUTE Conditions in the Order Indicated)

	2-MINUTE	5-MINUTE
ORDER = 1	1st	2nd
ORDER = 2	2nd	1st

Two programmed scenarios were developed as described in the Equipment section above. These scenarios were the same except for the call letters of the aircraft. Scenarios included 26 aircraft presented within a 50-minute time span. Longer scenarios were needed than those in Experiment 1 since participants alternated control of the scenario on each day of testing. One scenario was used for each day.

Test scenarios were revised from those originally developed for this experiment based on the observed level of performance in Experiment 1. In that experiment, 8 of the 13 participants completed at least one test session without making any errors. Since error scores served as the dependent variable, it was determined that scenarios should be increased in complexity in order to obtain a greater number of errors. More aircraft per unit time and more built-in conflicts were, therefore, added to the programmed scenarios.

The dependent variable was the error-point total described in Experiment 1. As in the first experiment, participants were to record their errors on a response sheet as the session progressed. Since participants were entering and exiting the scenario at different times, summary performance information could not be obtained from TRACON II. This summary information can only be obtained when the scenario is ended or temporarily "closed." Neither of these options were viable given that ongoing scenarios were necessary in order for participants to alternate control without a disruption in the traffic flow. Errors were instead obtained only from participant's response sheets which were totalled by the experimenters after completion of the session.

Participants completed the post-session questionnaire at the end of each test session. This information was analyzed by ANOVA's to determine whether factors such as stress, workload, etc., differed as a function of the experimental conditions.

Multiple regression analyses were also conducted on variables obtained from the preliminary and post-session questionnaires to determine whether performance was correlated with any of these factors.

4.4 PROCEDURE.

Experiment 2 was conducted on 2 days. Participants worked in randomly-assigned pairs. On the first day, one-half of the participants worked under the 2-MINUTE viewing condition first, followed by the other half, who worked under the 5-MINUTE viewing condition.

At the beginning of the session, one member of each pair began the scenario and worked for 5 minutes. The other member of each pair was seated across the room until instructed to rejoin his/her partner. After rejoining, this test group was instructed to watch their partners work so that they would be ready to take control of the scenario when the take over signal was given. This signal came after 2 minutes of viewing. The test group then took control of the scenario for the next 15 minutes and monitored their performance by indicating errors on the checklist. Their partners moved to the other side of the room once control was relinquished. After 15 minutes, this group was given the same instructions as described above, but were allowed 5 minutes of viewing time before taking control of the scenario.

On the second day of testing, participants worked under the alternate condition. Those who began the session the previous day and subsequently participated under the 5-MINUTE condition, today worked under the 2-MINUTE condition. Those who had previously worked under the 2-MINUTE condition, today worked under the 5-MINUTE condition.

4.5 RESULTS.

Many more errors were made in this experiment than Experiment 1, despite the fact that test sessions were shorter. The mean overall error-point score was 15.33 (SD=12.42) for Experiment 2, and was 4.96 (SD=4.84) for Experiment 1. A greater proportion of errors was expected for Experiment 2 since the scenarios were programmed to be more difficult.

Participant's post-session questionnaire responses also indicated the increased difficulty of Experiment 2. An ANOVA was conducted to compare the responses given after Experiment 2 to those given after Experiment 1 for the 12 participants who completed both. All of the post-session questionnaire variables in Experiment 2, with the exception of fatigue, were significantly different ($p<.05$) from those reported in Experiment 1. Fatigue neared significance at $p<.1$. The means and standard deviations for each experiment and each variable are presented in table 4-2.

TABLE 4-2. MEANS AND STANDARD DEVIATIONS OF POST-SESSION QUESTIONNAIRE VARIABLES FOR EXPERIMENT 1 AND EXPERIMENT 2

	EXPERIMENT 1		EXPERIMENT 2	
	Mean	SD	Mean	SD
Workload	10.58	4.30	19.67	3.80
Self-Assessment	15.17	2.59	11.25	3.08
Busyness	12.75	5.58	19.00	1.41
Thinking and Concentration	12.17	5.69	18.33	2.61
Stress	10.67	5.50	17.42	2.47
Fatigue	7.59	5.64	10.17	4.37

The means and standard deviations were calculated for each experiment by obtaining a total score for each variable summed over both test conditions. For example, each participant's workload score for Experiment 2 was obtained by adding the workload score from both the 2-MINUTE and 5-MINUTE conditions.

Means for each of the 2-MINUTE and 5-MINUTE conditions are presented in table 4-3.

TABLE 4-3. MEAN ERROR-POINT TOTAL (AND STANDARD DEVIATION) FOR EACH TEST CONDITION IN EXPERIMENT 2

2-MINUTE	5-MINUTE
13.33 (8.39)	17.33 (16.45)

An ANOVA revealed no significant main effect of TIME on performance, $F(1,10)=1.08$, $p>.1$. There was also no main effect of ORDER on performance, $F(1,10)=1.58$, $p>.1$. Participants who performed under the 2-MINUTE condition first and the 5-MINUTE condition second did not differ in overall performance from those who performed under the 5-MINUTE condition first and the 2-MINUTE condition second. The interaction between TIME and ORDER was also not significant, $F(1,10)=.61$, $p>.1$. Means for each TIME and ORDER condition are shown in figure 4-1.

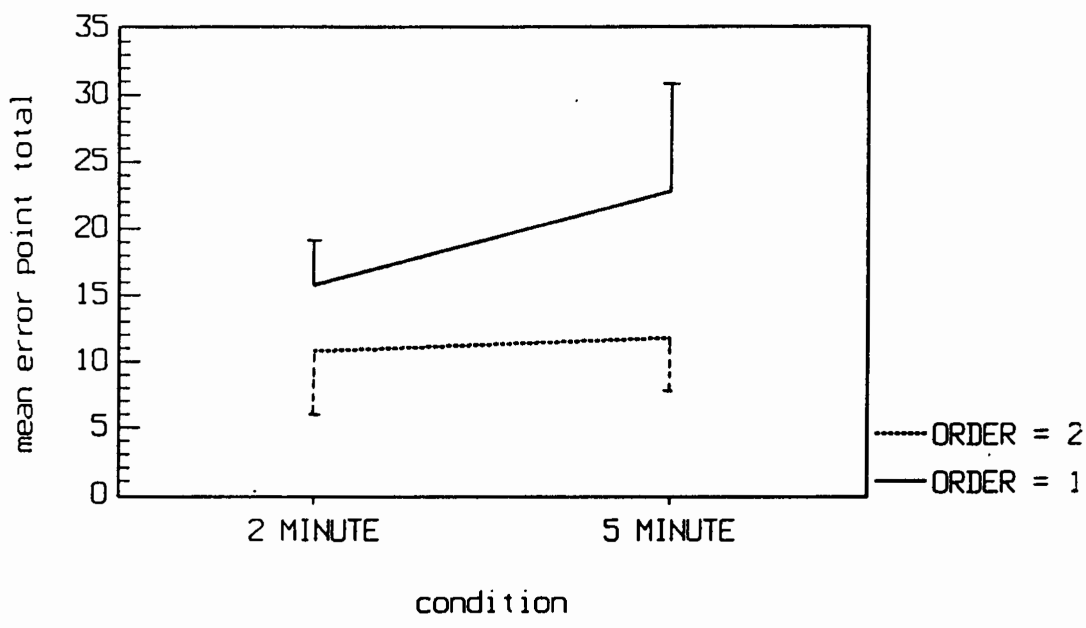

FIGURE 4-1. MEAN ERROR-POINT TOTAL AND STANDARD ERROR FOR EACH TEST CONDITION AND EACH GROUP IN EXPERIMENT 2 (ORDER=1: Group that performed under 2-MINUTE condition first ORDER=2: Group that performed under 5-MINUTE condition first)

One possible reason why performance was not improved after the 5-MINUTE viewing condition may have been due to the fact that the 5-MINUTE condition was always tested later in the scenario than the 2-MINUTE condition. Early in the scenario, traffic was relatively light (up to 8 aircraft), whereas later in the scenario, traffic could potentially have become quite heavy (up to 11 to 16 aircraft). The increase in the number of aircraft provides more of an opportunity for the scenario to get complicated, leading to more of an opportunity for errors. Since the number of aircraft present at different times in the scenario was not measured, it was not possible to further investigate the way in which errors were affected by this variable directly.

An ANOVA was conducted on preliminary questionnaire variables as a function of ORDER to determine if these two groups of participants differed from one another in terms of any of the characteristics with which they entered the experiments. The difference between the level of stress reported by these groups was somewhat significant, $F(1,10)=4.0$, $p<.1$. The group that performed under the 2-MINUTE condition first had reported a somewhat lower level of stress prior to entering the experiments (mean=3.00, SD=1.26) than the group that performed under the 5-MINUTE condition first (mean=5.67, SD=3.01). None of the other differences from the preliminary questionnaire reached significance.

ANOVA's were also conducted on post-session questionnaire variables to determine whether any of these differed as a function of TIME and ORDER. Means and standard deviations for these variables for the 2-MINUTE and 5-MINUTE conditions are presented in table 4-4.

TABLE 4-4. MEAN RATING AND STANDARD DEVIATION FOR EACH POST-SESSION QUESTIONNAIRE VARIABLE AND EACH TEST CONDITION IN EXPERIMENT 2

	2-MINUTE		5-MINUTE	
	Mean	SD	Mean	SD
Workload	10.00	2.13	9.67	1.97
Self-Assessment	5.58	1.51	5.67	2.50
Busyness	9.50	1.17	9.50	.80
Thinking and Concentration	9.08	1.78	9.25	.97
Stress	8.75	1.77	8.67	1.23
Fatigue	5.58	2.61	4.58	2.75

As indicated in the table, means for workload, busyness, thinking and concentration, and stress assessments were quite high under both conditions. Nearly all were at the highest response level possible (workload differed from the others in that it was based on a 12 point rather than a 10 point scale). Differences between the 2-MINUTE and 5-MINUTE conditions did not reach significance for any post-session questionnaire variables ($p > .1$). Neither were there any significant differences for any of these variables as a function of ORDER ($p > .1$). There was one variable, self-assessment, for which the interaction of TIME x ORDER did reach significance, $F(1,10)=5.69$, $p < .05$. It is not clear what would explain these differences in assessments. They do not correspond to observed performance levels.

4.5.1 Post-hoc Analyses.

As in Experiment 1, performance levels varied among individual participants regardless of experimental condition. The median raw error totals summed over both conditions (2-MINUTE + 5-MINUTE) was 5.5. Seven of the participants made between two and six total errors (mean=3.5, SD=1.38). The other five participants made between 9 and 22 total errors (mean=12.6, SD=5.68). This gap in participants' performance was used to separate participants into two groups. The participants in each of these groups were not necessarily the same participants who made up the groups making fewer/greater errors in Experiment 1. Four of the seven participants who made fewer errors in this experiment, also made fewer errors in the first. Two of the five participants who made more errors in this experiment also made more in the first (see table 4-5).

TABLE 4-5. NUMBER OF PARTICIPANTS FROM EXPERIMENT 1 WHO REMAINED IN THE SAME POST-HOC ANALYSIS GROUP IN EXPERIMENT 2

	EXPERIMENT 1	EXPERIMENT 2
Fewer Errors	8	4
More Errors	5	2

An ANOVA was conducted on all preliminary and post-session questionnaire variables between these groups and across the 2-MINUTE and 5-MINUTE conditions. Since the groups were defined by the total number of errors made, error-point totals necessarily differed significantly between them. Of interest, however, was that the effect of the TIME x GROUP interaction was significant, $F(1,10)=7.19$, $p < .05$. This interaction is shown in figure 4-2. These trends indicate that the group that made fewer overall errors, tended to reduce errors between the 2-MINUTE and 5-MINUTE test conditions, while the group that made more overall errors, made more errors under the 5-MINUTE condition than the 2-MINUTE condition.

An ANCOVA was also conducted in which the total error for the 2-MINUTE condition served as the covariate, so that performance under the 5-MINUTE condition alone could be compared between these groups. This analysis revealed that the two groups differed significantly in their performance under the 5-MINUTE condition, $F(1,9)=10.05$, $p<.05$. The group that made fewer errors overall made significantly fewer errors in the 5-MINUTE condition than did the group that made a greater number of errors. These results suggest that participants who made fewer errors overall were less affected by having to work with a greater number of aircraft than those who performed more poorly overall.

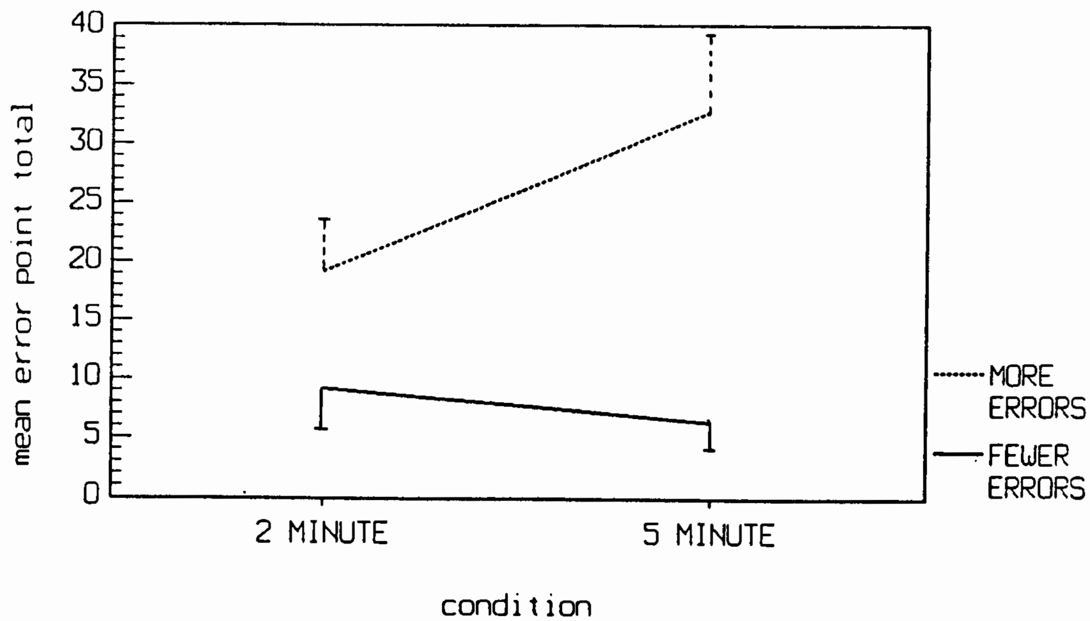

FIGURE 4-2. MEAN ERROR-POINT TOTAL AND STANDARD ERROR FOR EACH TEST CONDITION AND EACH POST-HOC PERFORMANCE GROUP IN EXPERIMENT 2 (Fewer Errors: Group that made 6 or fewer errors over both conditions. More Errors: Group that made 9 or more errors over both conditions.)

ANOVA's conducted on the preliminary questionnaire variables indicated that none differed significantly between these groups ($p>.1$). A multiple regression analysis was conducted on all preliminary questionnaire variables with error-point total as the dependent variable. The correlation matrix is shown in table 4-6. This analysis allowed the correlation of each variable with the error-point total to be determined after partitioning out the effect that it had in combination with others. These partial correlations also did not indicate that any of the preliminary questionnaire variables correlated significantly with performance ($p>.1$).

TABLE 4-6. CORRELATION MATRIX OF PRELIMINARY QUESTIONNAIRE VARIABLES AND PERFORMANCE

	WT	AGE	SEM	GRD	FLT	CO	VID	VIS	STR	MO
WT	1.00	-.06	-.05	.19	-.01	.35	.14	.03	-.11	-.09
AGE	-.06	1.00	.09	.13	.50	-.54	-.002	-.44	.54	.39
SEM	-.05	.10	1.00	.64	.45	-.03	.08	.38	.02	-.37
GRD	.19	.13	.64	1.00	.82	-.15	.38	.12	.01	-.05
FLT	-.01	.50	.45	.82	1.00	-.39	.58	.12	.02	-.05
CO	.35	-.54	-.03	-.15	-.39	1.00	-.20	.31	-.07	-.05
VID	.14	-.002	.08	.38	.58	-.20	1.00	.58	-.41	-.53
VIS	.03	-.44	.38	.12	.12	.31	.58	1.00	-.52	-.91
STR	-.11	.51	.02	.01	.02	-.07	-.41	-.52	1.00	.56
MO	-.09	.39	-.37	-.05	-.05	-.05	-.53	-.91	.56	1.00

Note: WT=total error-point score, AGE=participant's age, SEM=semesters in program, GRD=number of courses taken, FLT=number of flight hours, CO=computer experience, VID=video game experience, VIS=vision, STR=stress, MO=motivation

ANOVA's were also conducted on the post-session questionnaire variables (workload, self-assessment, busyness, stress, thinking and concentration, and fatigue). Means for post-session questionnaire variables are presented in table 4-7. Reports of perceived workload and busyness were both close to being significantly different between the group that made fewer errors and the group that made more (workload: $F(1,10)=4.17$, $p<.1$; busyness: $F(1,10)=3.32$, $p<.1$).

TABLE 4-7. MEAN RATING AND STANDARD DEVIATION FOR EACH POST-SESSION QUESTIONNAIRE VARIABLE FOR EACH POST-HOC TEST GROUP IN EXPERIMENT 2

	Fewer (<6) Errors		More (>9) Errors	
	Mean	SD	Mean	SD
Workload	9.00	1.97	11.00	1.37
Self-Assessment	5.86	2.27	5.30	1.67
Busyness	9.20	1.21	9.90	.45
Stress	8.29	1.70	9.30	.99
Thinking and Concentration	8.71	1.65	9.80	.45
Fatigue	4.50	2.45	5.90	2.88

Additionally, a multiple regression analysis was conducted on the post-session questionnaire variables to determine whether any of them correlated with performance independently of other variables and regardless of the participant's group. The correlation matrix is presented in table 4-8. This analysis found that workload was the only variable that correlated somewhat significantly with error-point total (+.59, $p < .1$). Perceived workload tended to increase as error-point total increased.

TABLE 4-8. CORRELATION MATRIX FOR ALL POST-SESSION QUESTIONNAIRE VARIABLES AND PERFORMANCE

	WT	SELF	THINK	TIRED	WORK	BUSY	STR
WT	1.00	-.22	.39	.20	.51	.43	.49
SELF	-.22	1.00	-.60	-.50	-.29	-.52	-.35
THINK	.39	-.60	1.00	.63	.79	.86	.87
TIRED	.20	-.50	.63	1.00	.35	.37	.57
WORK	.51	-.29	.79	.35	1.00	.80	.90
BUSY	.43	-.52	.86	.37	.80	1.00	.76
STR	.49	-.35	.87	.57	.90	.76	1.00

Note: WT=total error-point score, SELF=self assessment rating, THINK=thinking and concentration, TIRED=fatigue, WORK=workload, BUSY=busyness, STR=stress

Strategies reported by these two groups of participants on the post-session questionnaire variables were also examined to see whether this would provide more insight into the reasons for their performance differences. Specific strategies were not widely cited by participants in either group. No differences were discernable between the groups in terms of these reports. Four of the seven participants in the group that made fewer errors cited strategies, three of five in the group that made more errors cited them. All of the strategies that were reported referred to holding aircraft at fixes or on the ground or indicated the use of data tags. Holding aircraft at fixes and keeping aircraft from departing allow participants to regulate the flow of aircraft. Data tags allow the destination of each aircraft to be placed directly under its call letters on the scope. Tagging allows this information to be readily accessible in that participants do not have to keep referring to the electronic flight strips at the side of the screen. Holding and using data tags were cited either individually or in combination in strategy reports.

Most of the comments referred not to strategies but to difficulty in keeping up with the scenarios. Seven of the participants specifically indicated that there were "too many" aircraft to direct comfortably and effectively. Four of them were from the group that made fewer errors, three were from the group that made more. Seven participants (not necessarily the same seven as above) indicated that it was hard to take over the traffic from a partner because, as one explained, "the traffic was not worked the way I would have worked it." Another described that he "tried to work in the same form the other guy was doing." Four of these seven participants were from the group that made fewer errors, three were from the group that made more errors.

In summary, participants' reports indicated that directing traffic in this experiment was complicated, either because of the number of aircraft, or for some, because they tried to work from a partner's strategy or set up. As one participant responded, his strategy was "No strategy-out of control."

4.6 DISCUSSION.

The purpose of Experiment 2 was to determine whether an increase in available planning time prior to taking control of a scenario improved performance. The data from this experiment do not support this. Differences in performance between sessions for which participants had had 5 minutes of time to view an on-going scenario were not significantly different from sessions for which participants had had just 2 minutes of viewing time.

As indicated, one possible reason why the 5-MINUTE viewing condition did not result in improved performance over the 2-MINUTE condition may lie in the fact that the 5-MINUTE viewing condition was always tested at a later point in the scenario. Since the number of aircraft present on the scope was affected not only by time into the scenario, but also by the performance of the person relinquishing control, scenarios could potentially become very complicated as time progressed. For example, if the participant initially controlling the scenario made contact with each aircraft immediately and/or had difficulty landing or handing off aircraft, then the number of aircraft on the scope may have exceeded a manageable level for those who then took over control. One participant indicated that there were 16 aircraft on the scope when he assumed control. This volume of traffic may have made effective control of the scenario extremely difficult. This difficulty would be expected to be especially apparent for novices. The 2-MINUTE viewing condition, on the other hand, was always tested early in the scenario when traffic was potentially much lighter. During the first 7 minutes of the scenario, eight aircraft had been programmed to enter the airspace; five arrivals, two departures, and one overflight. Even if the participants who initially controlled this scenario made contact with each aircraft immediately and were unable to hand-off or land any of them during this time period, the maximum number that could have been present on the scope when their partners took control would have been eight. While the complexity of a traffic situation can be high even for this number of aircraft, it would most likely be lower than the complexity of a pattern emerging from a combination of 16 aircraft. An increase in planning time may have been useful, but its effects may have been masked by the greater complexity of the traffic situation during which it was tested.

The overall difficulty of the scenarios used in Experiment 2 was reflected in participants' post-session questionnaire responses. Ratings for workload, busyness, thinking and concentration, and stress were very high. The mean rating was close to the top level response for each. This ceiling effect made it impossible to discern a difference in participant's impressions of the two viewing conditions since both were rated as requiring close to maximum effort. Also supporting this, was the result that all of the variables from the post-session questionnaire of Experiment 2 differed from those of Experiment 1. Perceived level of workload, busyness, thinking and concentration, stress, and fatigue were reported higher for Experiment 2. Self-assessment of performance was rated lower.

The apparent difficulty that participants had in Experiment 2 was also observed by the ATCS experimenter as well. He noted "confusion" and "lack of an organized plan and control strategy" on the part of many students. It was observed, for example, that aircraft were sometimes aimed directly at one another. A number of stress indicators were also apparent: fidgeting, sweating, nail-biting, and moving closer to the screen. One student was observed to "freeze."

The scenarios used in Experiment 2 may have been too complex for participants to develop a strategy. Some comments made by participants for example, indicated that they found it difficult to take over control from a partner because they were unable to develop and implement their own plans quickly enough. This view is supported by Whitfield's (1979) work in which he assessed that "the relief must ensure establishing his own picture" (p. 21) in order for control to be successful. He further discussed that problems should be dealt with by the controller leaving the position before the next controller takes over in order to promote effective transition. This was not necessarily the situation in the current experiment. In this experiment, participants were required to take over at a particular time, regardless of whether their partner was in the midst of dealing with one or several problems. While this situation may not be likely to occur in an actual ATC situation, it was used in an attempt to directly investigate the effect of planning time.

An ANOVA conducted on the preliminary questionnaire variables did not indicate that the participants in the experimental groups differed significantly from one another on most of these variables. The only variable for which the difference was somewhat significant was stress. Those who performed under the 2-MINUTE condition first had reported a somewhat lower level of stress coming into the experiment than those who performed under the 5-MINUTE condition first.

For the post-hoc analyses, participants were divided into groups based on their overall performance (error totals less than 6 and greater than 9) to investigate whether performance could be attributed to factors that were not measured in the test conditions. An ANOVA revealed a significant difference for the interaction of group by condition. The group with fewer overall errors, tended to reduce errors between the 2-MINUTE and 5-MINUTE conditions, while those with a greater number of overall errors made more errors under the 5-MINUTE than the 2-MINUTE conditions. This suggests that those who were more effective in managing traffic overall were less affected by the increased complexity of the traffic situation arising in the 5-MINUTE condition than those who were less effective in managing traffic.

The preliminary and post-session questionnaire variables, as well as reported strategies, were analyzed to investigate whether they revealed any differences between these groups. No differences were found between them for the preliminary questionnaire variables. These were investigated because it was reasoned that some of the differences in their performance may have been attributed to differences in flight experience or in the number of aviation courses or semesters completed. It seemed likely that those making fewer errors may be those indicating a greater level of experience on these variables. However, this was not observed. A comparison of post-session questionnaire variables indicated that these groups differed somewhat in their reports of workload and busyness. The group that made more errors overall reported somewhat higher average levels of workload and busyness for the sessions than did the group making fewer errors. The subjective impressions for this measure, therefore, corresponded with objective performance. Additionally, multiple regression analyses were conducted to determine the relationship between these variables and individual performance, regardless of group. None of the partial correlations of preliminary questionnaire variables with performance were significant at either $p < .05$ or $p < .1$. A regression analysis conducted on the post-session questionnaire variables and performance indicated that only the partial correlation for perceived workload and performance was somewhat significant ($p < .1$). This suggests that those who made more errors found the task to be more demanding.

One explanation for the differences observed in performance may again have been due to the use of different individual strategies. As in Experiment 1, specific strategies were not taught to participants. The intent of the experiment was only to examine the effect of increased and decreased planning time availability on performance. Participants were free to develop their own strategies, some of which may have been more effective than others. To more carefully examine specific, individual strategies it would have been necessary to monitor each participant's performance during a session and to ask him/her to verbally describe thoughts and actions as he/she proceeded. This was not possible given the group test environment in which this experiment was conducted. Strategies were asked about in the post-session questionnaire and these were examined to try to get a sense of the individual strategies used. However, most participants focused on the difficulties they had in working with the more difficult scenarios used in this experiment rather than on the kinds of plans and activities that they engaged in. The most common strategy-oriented comments dealt with using "holds" or "data tags." Holds kept aircraft from requiring immediate action and could, therefore, be used to keep the number of aircraft in need of control to a more manageable level. It was one direct way in which participants could regulate the flow of traffic to a level that each found personally easier to handle. Consequently, the amount of information to be maintained in working memory was reduced. Participants using this strategy indicated that they realized that their memory capacity for more aircraft was reaching its limit and took direct action to bring the number that they had to work with under control. Data tags allowed participants to include a meaningful piece of information about an aircraft right on the screen at the location of the aircraft call letters. Tags were usually given to indicate destination (i.e., the airport the aircraft was to land at or the fix at which it needed to be handed off). These data tags reduce the need to have to take one's eyes away from the screen to search for the needed information from the flight strips. Both appear useful given the apparent demands of this experimental situation.

There were no observable differences between the groups in terms of the proportion of participants in each group who cited using holds or data tags. If data tags and holds were critical to performance, a greater proportion of participants in the group making fewer errors may have been expected to indicate using them than the group making more errors. The fact that this result was not obtained does not necessarily negate their effect. These strategies may, for example, have been used as part of broader strategies, some of which were more effective than others. Participants did not elaborate on this, nor did they report, for example, how often these were used. Some may have used them frequently and others less frequently. Frequency of use is another variable that may have been important in distinguishing the groups but it was not measured in this experiment.

Beyond identifying the use of holds or data tags, specific strategies were not reported by participants. It was, therefore, not possible to relate specific strategies to performance.

In summary, this experiment did not find evidence that the amount of planning time made a difference in performance. Participant's performance varied widely regardless of condition. In general, participants indicated that both test conditions were very difficult. Responses on post-session questionnaire variables for both conditions were at nearly the highest level allowed for workload, busyness, thinking and concentration, and stress. Observations of participant's performance suggested difficulty as well in that participants found that Experiment 2 involved a higher level of workload, stress, and thinking and concentration than Experiment 1 and also resulted in more stress, greater fatigue, and a lower level of self-assessment.

Participants were also grouped according to the total number of errors made to determine whether other variables could help account for differences in performance. The variables measured and analyzed in this experiment did not reveal which factors may have been most important in determining performance level. Individual strategies, which could not be assessed given the design of this experiment, may provide the underlying critical information about performance differences. Future experiments are needed which test participants in a manner that better enables investigators to determine what these strategies are.

5. EXPERIMENT 3: EFFECT OF PHYSICAL ACTIVITY (WRITING) ON MEMORY FOR ISSUED COMMANDS.

5.1 PURPOSE.

The purpose of the third experiment was to investigate the effect of note-writing on the controller's ability to remember commands issued to aircraft. Prior reports have suggested that note-writing is vital for maintaining memory of critical information which, in turn, contributes to "keeping the picture."

5.2 METHOD.

5.2.1 Participants.

Thirteen students participated in Experiment 3, all had served in at least one session of one of the other two experiments. This meant that the data from the preliminary questionnaire were quite similar to those obtained in Experiments 1 and 2. The ages of the participants ranged from 18 to 26 (mean=20.46, SD=2.47). They had completed one to four semesters in the aviation program (mean=2.38, SD=1.19) and from one to eight basic ground courses (mean=3.46, SD=2.73). Number of flight hours completed ranged from 0 to 250 (mean=108.54, SD=93.23). Three participants indicated having had some aviation experience prior to attending Mercer County Community College but did not elaborate on what that involved.

Participant's ratings (1=lowest, 10=highest) on their level of computer experience ranged from 3 to 9 (mean=5.46, SD=2.03), video game experience ranged from 5 to 10 (mean=7.77, SD=1.79), and quality of vision ranged from 5 to 10 (mean=9.31, SD=1.44). None indicated any color vision deficiency. Participants indicated high agreement in their willingness to participant in the study (mean=9.85, SD=.55). They also indicated high ratings for their general health (mean=9.54, SD=.88). They did indicate variable levels of recent stress (mean=4.69, SD=2.59). Level of motivation to participate was generally high (mean=1.46, SD=1.39). This question was worded so that 1 was equal to the highest level of agreement, 10 the lowest.

5.2.2 Test Conditions.

Two experimental conditions were to be tested to evaluate the effect of note-writing on memory for issued commands. However, due to a misunderstanding of the instructions, several participants did not carry out the NO-WRITING condition as intended. The NO-WRITING condition was eliminated as described below.

5.2.2.1 WRITING Condition.

Under this condition, participants worked in pairs with half of the participants tested at a time. Participants were instructed that they were to write down each command as it was issued on the paper flight strips provided for 16 aircraft that were to enter the airspace over a 27 minute test session (see appendix C, pages C-1 and C-2). Actually, test sessions were only conducted for 13 minutes, but more flight strips were included so that it would be difficult for participants to anticipate which aircraft would mark the end of the session. A total of 11 aircraft were actually tested in Experiment 3. The note-writing activity was intended to simulate the way that paper flight strips are often used by actual air traffic controllers. Partners also recorded actions independently to monitor accuracy. Sheets on which partners indicated actions are shown in appendix C, pages C-3 and C-4. As always, participants were instructed to work towards minimizing errors during each session.

After 13 minutes of testing, participants were instructed to halt the scenario and to indicate on a response sheet all of the actions performed for each of the aircraft listed. Response sheets are shown in appendix C, pages C-5 and C-6.

Participant's performance was measured by comparing each response to the information provided by partners so that the percentage of correct responses could be calculated. A measure of flight strip use was also obtained by comparing the commands written on the strips by participants to those recorded by partners.

5.2.2.2 NO-WRITING condition.

Under this condition, participants also worked in pairs, with half of the participants tested at a time. Only computer-displayed flight strips were available to participants. They were not provided with paper flight strips and were not allowed to write their commands. Partners recorded these actions independently for scoring purposes. Participants were told, as always, to minimize errors during the session.

As in the WRITING condition, participants were required to halt the scenario and report the commands issued for each aircraft after 13 minutes of testing. Partners' records and participants' response sheets were collected following the session so that the percentage of correct responses could be calculated.

5.3 DESIGN.

Participants were to be tested according to a repeated measures design in which the WRITING and NO-WRITING conditions served as the two levels of the tested factor. Unlike previous experiments, Experiment 3 used percentage of correct responses for memories of specific actions as the primary dependent variable, rather than an error-point total.

Experimental testing was conducted on 2 separate days. On the first day, all of the participants were tested under the NO-WRITING condition. One-half of the participants worked first, while the other half acted as partners. For the second half of the session, participants performed the alternate role. On the second day of testing all participants were tested under the WRITING condition. Again, one-half of the participants worked first, while the other half acted as partners, and for the second half of the session, participants performed the alternate role. Participants completed the post-session questionnaire following each session.

Some of the participants were unclear about the instructions for the NO-WRITING condition. They wrote out actions while working during the session. This happened because score sheets were distributed to participants prior to the start of the session while the instructions were being given. These instructions informed them that they would be asked to write out each of the commands they issued to aircraft <u>after</u> the experimenter indicated that the session had ended. However, a number of them began writing on the available sheets as they were working. Since it could not be accurately determined how much information was written during the session, the entire session was subsequently eliminated. This made it necessary to investigate the effect of note-writing on memory differently than originally intended. To examine this effect, correlations between the proportion of notetaking and proportion of remembered commands were conducted for data in the WRITING condition alone. During the WRITING session, response sheets were distributed after the session so that participants would not be able to mark anything on them until that time. The flight strips on which they did record their actions during the session were taken away from them immediately after the session so that they would not have access to their "notes."

Two programmed scenarios, identical except for the call letters of the aircraft, were used during the test session. They were created as described in the Equipment section above. Scenarios were programmed so that 16 aircraft would enter the airspace in 27 minutes. However, only the first 11 aircraft were actually included in the 13 minute test sessions, 9 arrivals, 2 departures.

As in previous experiments, information from the post-session and preliminary questionnaires was also analyzed to determine the extent to which these variables were related to performance.

<u>5.4 RESULTS</u>.

Partners wrote out each of the actions taken by those controlling the scenario. This provided a record of the actual commands issued. The percentage of remembered commands was calculated by determining the total number of correct responses indicated on response sheets divided by the total number of actions recorded by partners. Overall, the percentage of remembered commands ranged from 0 to .81 (mean=.39, SD=.30).

Flight strip use was calculated to determine whether note writing correlated with remembered commands. Flight strip use was determined by totalling the number of actions indicated by participants on the flight strips and dividing by the number of actions recorded by partners. Flight strip use ranged from .23 to 1.0 (mean=.67, SD=.28). The percentage of remembered commands was positively and significantly correlated with flight strip use, $r = +.82$, $p < .001$. These data are plotted in figure 5-1. **This result suggests that those who tended to write more of the issued commands on flight strips while working also tended to remember more of those commands after the session was completed.**

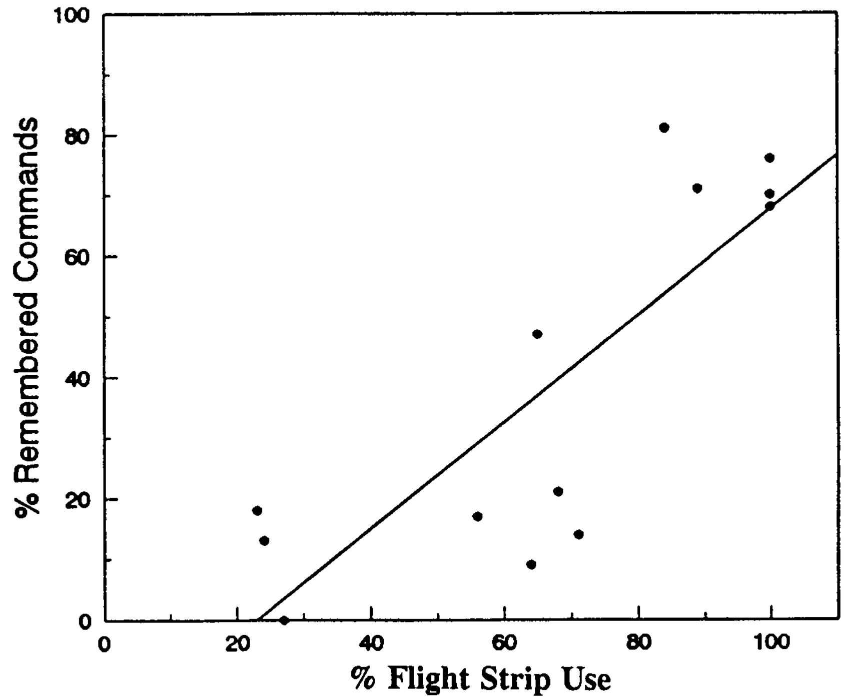

FIGURE 5-1. PLOT OF PERCENTAGE OF REMEMBERED COMMANDS WITH PERCENTAGE OF FLIGHT STRIP USE

During this experiment, participants were not asked to monitor their individual errors while working as they had during Experiments 1 and 2. Since this experiment was concerned with the effects of note writing on flight strips, only note writing was required during the session. It would not have been feasible for participants to write notes and indicate errors during the session since this would have taken too much time away from actually controlling traffic. TRACON II's post-session performance evaluation was used to obtain information on the number of crashes, number of missed approaches, and number of handoff errors as well as the total performance score and the number of aircraft worked during the session. Since participants made relatively few errors during this session (6 of 13 participants made no errors), these variables would have been inadequate as dependent measures. Instead, TRACON performance scores and the total number of aircraft worked were used as measures of performance.

TRACON performance scores are based on control efficiency. Points are deducted when aircraft are diverted from their most direct route and added when aircraft are landed or handed off successfully. Point values are weighted to reflect the severity of errors (i.e., more points are deducted for separation conflicts than for handoff errors). The maximum score possible varies as a function of the number of aircraft programmed into a scenario per unit time. Including more aircraft per unit time allows for a greater potential score, but also makes the scenario more complicated, increasing the chance for errors. Final performance scores can be either positive or negative. In Experiment 3, performance scores ranged from 200 to 4760. To simplify the analyses, scores were divided by 1000 and rounded to the nearest tenth. Thus, the converted scores for Experiment 3 ranged from .2 to 4.8 with a mean of 2.37 (SD=1.79).

The number of aircraft worked refers to the total number of aircraft that the participant was able to successfully direct to appropriate destinations. The number of aircraft worked in this experiment ranged from 0 to 5 (mean=2.92, SD=1.85). A low number was not unexpected. Since the test session involved 11 aircraft entering the airspace over 13 minutes, there was not enough time for most of these aircraft to travel completely to their destinations.

Performance scores were positively correlated with flight strip use (r=+.73, p<.01, see figure 5-2). Participants who wrote on strips more tended to have better performance scores than those who wrote less. One participant experienced a crash, and as a result did not receive a score. His data are not included in the analyses but are reported separately below.

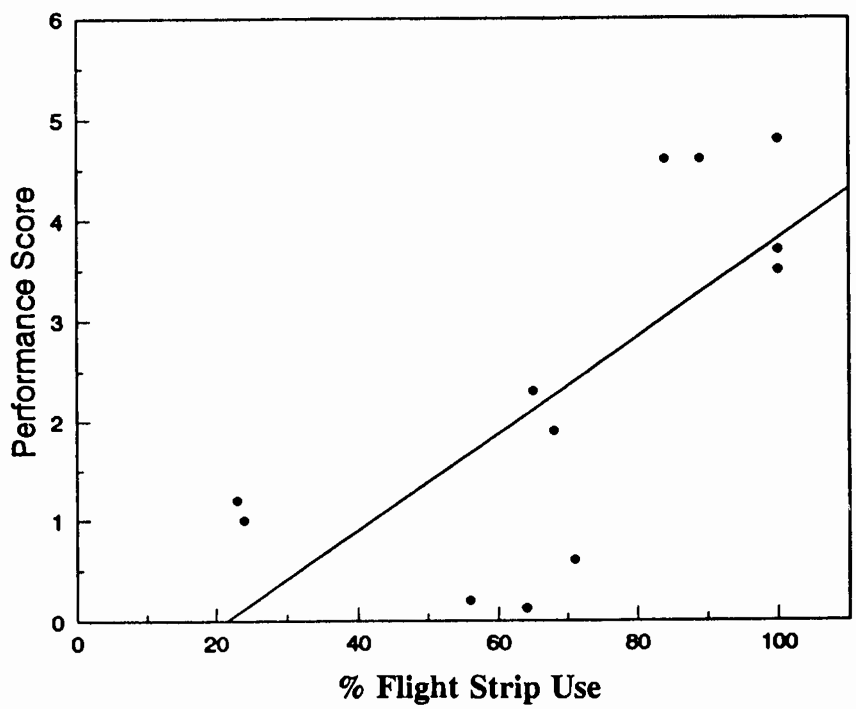

FIGURE 5-2. PLOT OF PERFORMANCE SCORE WITH PERCENTAGE OF FLIGHT STRIP USE

The percentage of remembered commands was also strongly correlated with performance score ($r=+.95$, $p<.001$). The better the participant's score, the more he/she remembered (see figure 5-3).

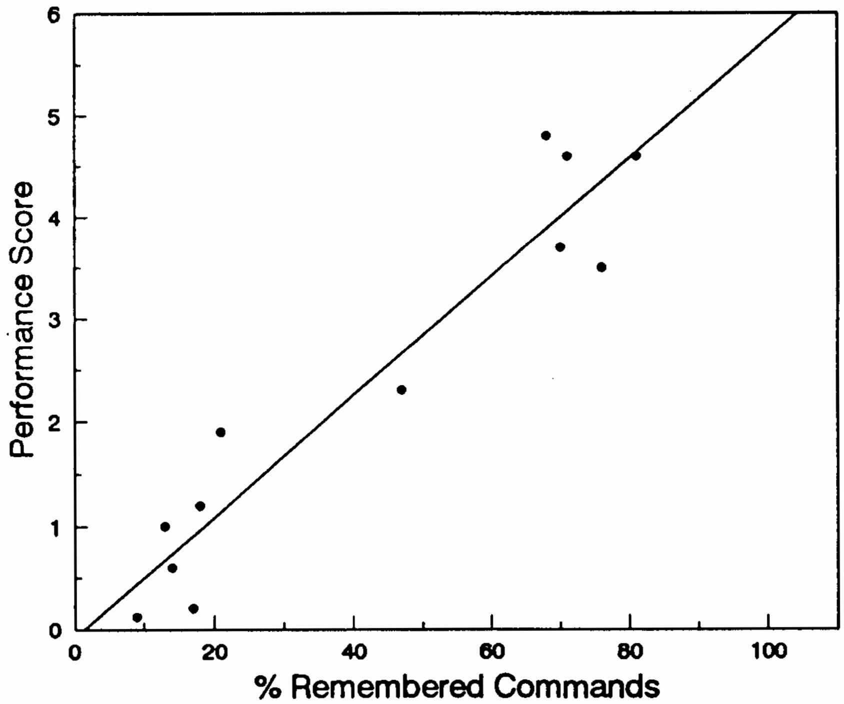

FIGURE 5-3. PLOT OF PERFORMANCE SCORE WITH PERCENTAGE OF REMEMBERED COMMANDS

The percentage of remembered commands was significantly correlated with the number of aircraft worked successfully during the session ($+.89$, $p<.001$). This suggests that the higher proportion of remembered commands did not result because these participants had fewer commands to issue (see figure 5-4).

Workload assessments were negatively and significantly correlated with flight strip use ($r=-.71$, $p<.01$). Those who wrote more on strips during the session indicated having less workload than those who used them less. Two other post-session questionnaire variables were also correlated with performance. Stress was negatively correlated with the percentage of remembered commands ($r=-.64$, $p<.01$). Memory for more commands was related to a lower level of reported stress. Score was also negatively correlated with stress ($r=-.61$, $p<.01$). The higher the score, the lower the reported level of stress. Self-assessment scores were positively and significantly correlated with the number of aircraft worked ($r=+.67$, $p<.01$). The more aircraft successfully handled, the better self-assessment reports tended to be. None of the other post-session questionnaire variables were significantly correlated with any of the performance measures (flight strip use, percentage of remembered commands, performance score or number of aircraft worked, $p > .1$).

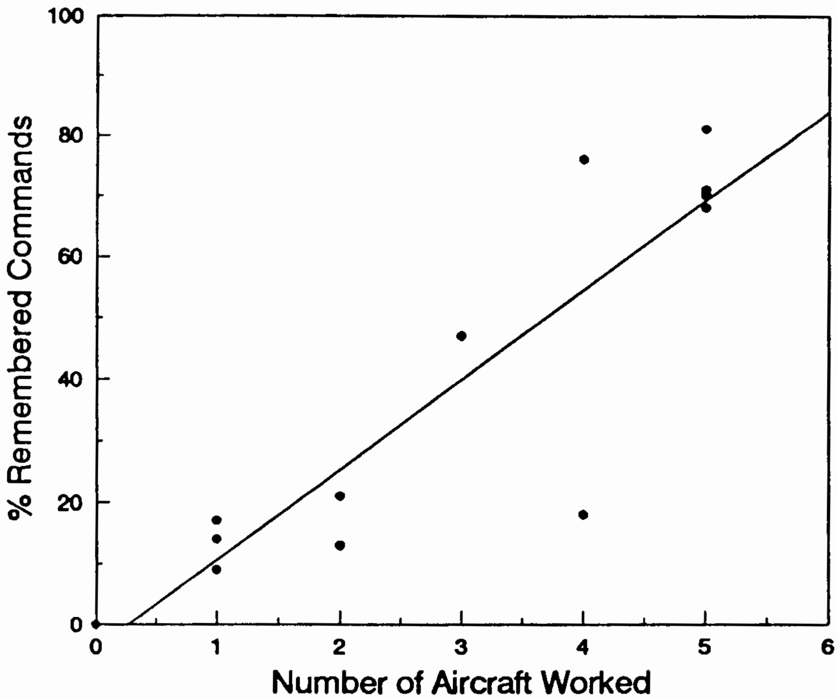

FIGURE 5-4. PLOT OF PERCENTAGE OF REMEMBERED COMMANDS WITH NUMBER OF AIRCRAFT WORKED

Multiple regression analyses indicated that none of the variables measured by the preliminary questionnaire were significantly correlated with any of the performance measures (percentage of remembered commands, performance score, flight strip use, or number of aircraft worked, $p > .1$).

As noted above, one participant experienced a crash and as a result, no TRACON performance information was available for him. A separate examination of his flight strips and response sheet indicated that he used flight strips minimally (.27). He was also unable to indicate any of the specific actions he had taken for the aircraft on his response sheet. He rated workload at the highest level possible (12), as well as busyness (10), how much thinking and concentration he needed (10), and how much stress he experienced during the session (10). He evaluated his performance at the lowest possible level (1). In his post-session comments he did not cite any reasons for this performance. This participant had, however, less experience than most others in that he had only completed one-half of Experiment 1 in addition to the training sessions prior to this experiment.

5.5 DISCUSSION.

The results of Experiment 3 suggest that an increase in flight strip use is associated with better memory for critical information. Writing notes about issued commands on the strips while working through the session correlated with better recall of these commands after the session was completed when all reference information had been removed from the scope. Performance scores also tended to increase with flight strip use and with memory for commands.

The results indicated that better memory for commands was not likely to have been due to having fewer total commands to remember since memory for commands was also correlated with the number of aircraft worked. Having a greater number of aircraft to control would necessarily require more commands.

The results also indicated that workload evaluations were lower for participants who used flight strips more. The perception of having expended a lower level of effort while working through a session was associated with flight strip use. Flight strip use may, perhaps, have promoted better organization of critical information for each aircraft, allowing the participants who used them more effective control. Flight strips have been suggested as useful for this reason by others (Hopkin, 1992).

The results of this final study are promising in that they indicate a relationship between flight strip use and both memory and performance. However, correlations alone do not provide sufficient support for this since they do not describe cause-effect relationships. It remains to be determined whether writing on flight strips was responsible for the increase in recall. It cannot be ruled out, for example, that "better" participants are those who will not only score higher, but who also have time to devote to note writing and/or who have time to organize and store information more effectively for later recall.

By the same token, "poorer" participants may become easily overwhelmed, and have less attention to devote to note writing. One interpretation of the subjective workload assessments suggests this. "Better" participants tended to report a lower level of perceived workload while those who performed more poorly tended to report a higher level of workload. The relationship between perceived workload and flight strip use has also been noted for actual air traffic controllers. In Gromelski, Davidson, and Stein's (1992) report, half of the 170 controllers interviewed indicated that their use of flight strips either stopped or was substantially reduced under high workload conditions. Under high levels of perceived workload, controllers tend to look for shortcuts. For example, to reduce memory demands they may refuse aircraft requests or move traffic along rigid paths, thereby reducing the number of actions needed per aircraft.

Yet, despite the fact that flight strip use is reported to decrease with perceived workload, strip marking has still been cited by controllers as the most frequently used memory aid, even under the busiest conditions (Gromelski et al., 1992). While writing increases physical workload, it may actually help to keep mental workload manageable. To this end, note writing was suggested as a technique that controllers could use to keep memory lapses from occurring by The Controller Memory Handbook (Stein and Bailey, 1989). This guide to memory suggested, "Even if you are busy, write it down", offering controllers a method to help reduce the mental effort required to keep all essential components of a current air traffic situation readily available without having to push memory to its limits.

6. CONCLUSIONS.

The three experiments conducted during this stage of testing served as initial investigations into the role of two types of memory strategies (planning strategies and flight strip management) that have emerged as potentially the most useful in the air traffic control (ATC) environment.

Novice participants with some aviation experience were tested in all experiments. These experiments were designed so that many participants could be tested simultaneously in a limited span of time. Participants were required to complete several hours of training in order to understand enough about how to control traffic before they were able to participate in the experiments. Thirteen students completed training and participated in the test sessions. This was less than the number that was expected to be necessary to obtain statistically significant results. In addition, participant's performance levels also varied considerably from one to another. These two factors made it difficult to be able to discern how the experimental conditions may have affected performance.

The variability of participants' performance was initially observed during the training sessions and carried through to the test sessions. A few participants seemed to be consistently more efficient than others. One of the experimenters, an air traffic control specialist (ATCS), noted some of the qualities that he observed in these participants. To summarize, the most efficient performers:

a. Used data tags for airport identification
b. Used direct clearances to destinations
c. Minimized keystroke entries
d. Memorized essential information
e. Used vertical separation in lieu of assuming separation would exist
f. Immediately took action to send arriving aircraft towards destinations
g. Were able to use strips as a notepad
h. Used strips to forecast upcoming traffic
i. Used strips to assist in visualizing flight plan routes and as an aid in preplanning control actions
j. Used pending information as an indicator of projected traffic volume

k. Effectively utilized time: Prioritized
l. Displayed as much information as needed on the scope to minimize the need to refer to more distantly located flight strips
m. Effectively moved data tags to eliminate data block overlap
n. Used standardized routings to destinations

Experiment 1 was designed to determine whether the opportunity to plan enhanced performance. This was intended to serve as an initial investigation into the general role of planning in ATCS performance. The results of the present experiment did not indicate that having the opportunity to plan was more beneficial than not having the opportunity. However, ratings concerning the level of thinking and concentration needed to work through these sessions indicated that participants did find that the NO-PLANNING condition was more demanding. Several participants acknowledged a preference for using paper flight strips.

Possible reasons for the lack of significance between performance under the two test conditions were cited. One was that the scenarios used in the experiment appeared to have been relatively easy for the majority of participants to work with. A much lower number of errors were made overall, compared to what was expected. For most participants very few errors were made under either condition, making it difficult to identify a difference between conditions. A second may have been due to the variability in participants performance, since a few participants did experience much more difficulty than others. Other factors may, therefore, have affected performance. When participants were separated into two groups based on their performance levels, the results indicated that those who performed better entered the experiment with a lower level of reported stress and a higher level of reported aviation course experience than those who performed more poorly. These factors may have influenced participants' control abilities more directly or more strongly than did the different test conditions.

The variability of participants' performance also suggests that individual strategies may have played an important role in determining performance. Since specific strategies were not taught, participants were free to develop them on their own. Given the group testing methods used in the present experiments, it was not possible to determine what strategies individuals were using. Some may have been able to plan and implement more effective strategies in comparison to others. Others may simply have been unable to develop strategies at all, perhaps because they felt their knowledge in this area was too limited.

Participants were asked to indicate what strategies they had used on the post-session questionnaire. However, most participants were not very specific in their reports. A lack of experience in providing an introspective analysis of their mental operations may have made it difficult for them to have been more elaborate. The technique of assessing one's cognitive activities typically requires some practice, especially for those who are not accustomed to providing information of this kind.

Experiment 2 was designed to determine whether increased planning time enhanced performance. Again, the results of this experiment were not statistically significant. The results indicated that having more planning time did not reduce errors relative to a condition in which less planning time was allowed. The scenarios developed for Experiment 2 were programmed to include more aircraft and more conflicts than those used in Experiment 1. This was done to increase the number of errors for the majority of participants who had made such a low number of errors in Experiment 1. Based on performance and on participants' reactions, these scenarios were much more complicated than those in Experiment 1. Participants experienced more errors in this experiment than in the last. As in Experiment 1, performance was correlated with perceived workload. Participants indicated a higher level of perceived workload the more poorly they had performed during the sessions.

Several of the participants' comments indicated that they had trouble taking over control of scenarios originally controlled by others. This may have resulted because the experimental conditions did not provide enough time to allow for adequate preparation of strategies or because it was difficult to work with a scenario that had been based on someone else's strategies. Planning did appear to be very disrupted in this experiment. Several participants did not use even simple control commands (data tags, holds) to help them manage the traffic more effectively. As was the case for Experiment 1, it was not possible to determine individual planning strategies, and these may have been critical in distinguishing performance levels.

Experiment 3 was designed to determine the effect of note writing on performance and on memory for critical information. The results indicated that flight strip use was related both to performance and to memory for issued commands. Additionally, the results indicated that as performance and memory increased, perceived workload decreased. Those who used flight strips more, performed better and also felt that the task was less demanding.

Since correlations were used to analyze these data, further investigations are needed to determine whether note writing produced better memory for issued commands, or whether flight strips are, for example, simply used more elaborately by participants who are generally more competent, who develop better strategies, and who then have the time to devote to such additional tasks. Flight strip use may be a component of effective strategies as previously suggested (e.g., Hopkin, 1990). Given the present results, the fact that flight strip management is so frequently cited as useful for maintaining awareness in the ATC environment, and that this technique has considerable controller acceptance, additional investigations into the usefulness of flight strips appear worthwhile.

Over the course of the three experiments, two patterns emerged that are worth noting. For one, factors with which participants entered the experiments as identified by the preliminary questionnaire (reported stress and aviation course experience) were associated only with performance in the first experiment. None were correlated with performance on the second or third experiments. This suggests that the additional practice obtained after participating in subsequent experiments affected performance to a greater extent than did the factors that participants initially brought with them.

Also noteworthy was that performance was correlated with perceived workload in all of the experiments. Participants who performed better, also reported that their level of perceived workload was lower than those who performed more poorly. This was found even in Experiment 3 in which participants manually recorded all of their commands in addition to controlling aircraft. Despite the fact that note writing added to their task, it was nevertheless associated with better performance as well as with reports of lower perceived workload. Those participants who wrote more on strips had better performance scores and felt the session to be less demanding.

Finally, this work demonstrates that a PC-based simulator can provide a suitable environment for testing issues in ATC. Realistic scenarios can be developed and can be structured to accommodate a wide range of performance capabilities. Fewer aircraft and fewer potential conflicts can be programmed into scenarios to test novices or poorer performers, while more difficult scenarios can be programmed to test those who are more experienced. Such realism and flexibility makes this a potentially suitable testing device for actual air traffic controllers. Additionally, the fact that scenarios can be programmed to accommodate different performance levels is especially useful for testing participants individually or for testing them over time. Programmed scenarios can be continuously updated to accommodate the current capabilities of each participant. Matching the scenarios to each participant's capability level would reduce the amount of variability observed between participants and would allow the effects of experimental conditions to be determined more easily.

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APPENDIX A

DOCUMENTS AND TRAINING MATERIALS

PERI

January 6, 1992

Joseph Blasenstein
Coordinator, Aviation Program
Department of Commerce
Mercer County Community College
Trenton, NJ 08690-0182

Dear Joe,

Thank you for agreeing to allow the MCCC Aviation Program to participate in the air traffic controller memory studies that PERI will be conducting for the FAA. PERI will be following the requirements of the American Psychological Association concerning the use of human subjects in experimental research which are outlined as follows:

1) Subjects must be informed as to the general purpose of the experiments and the task requirements, including the length of time they are expected to participate.
2) Subjects must be volunteers who are free to withdraw from the experiments at any time without penalty.
3) Subjects who are students must be informed that participation in the experiments and subsequent performance measures do not in any way relate to or affect course grades, academic standing, or enrollment. Participation must not conflict with academic obligations.
4) Subjects must be informed as to whether participation in the experiments involves any forseeable physical or psychological risk or danger. (NONE)
5) Subject privacy must be maintained. No individual names or identities may be revealed in any reports. (Of course, as a group, the Aviation Program and MCCC will be fully acknowledged for their contribution to the project.)
6) Subjects must read and sign a consent form to indicate that they understand all the information above before they may participate.

To indicate your agreement to let PERI conduct the proposed research experiments under the terms described above, I ask that you and Dean Sanders sign and return one copy of this letter to me at the address below. Thank you in advance for your cooperation and I will speak to you again soon regarding further details.

Sincerely,

Carolina Zingale

Carolina Zingale

Signatures:

Printed Names:

Jacqueline B Sanders

Joseph Blasenstein

Princeton Economic Research, Inc.
322 Wall Street • Princeton NJ 08540
Telephone: 609-924-8891 • FAX: 609-683-4006

100% Recycled Paper

PERI

January 21, 1992

To: Mercer County Community College Aviation Students.

PERI - FAA Air Traffic Controller Memory Enhancement

PERI (Princeton Economic Research Incorporated) will be conducting preliminary research studies for the FAA at Mercer County Community College during the Spring '92 semester. These studies will test the effectiveness of certain memory strategies on air traffic control performance. Since pilots need to interact with and rely on air traffic controllers, any aid to their performance benefits you too! Your input in these studies will be instrumental in helping us to better understand what factors enhance air traffic control performance.

We are selecting aviation students to participate in this research because of your interest in and knowledge of the field. Direct knowledge of or experience with air traffic control is not expected. In our studies we will be using an air traffic control "game" that runs on a PC and will teach you all you need to know. We will allow you some time to practice with it and then keep track of your performance under a few different conditions to determine when the job is handled most effectively. We would also like to get feedback from you directly on what you think makes things easy or hard and what kinds of mental strategies you are using to help you.

Your participation in these experiments is strictly voluntary. You may decide to withdraw at any time without penalty. The work is not related in any way to your academic performance or to course grades. We will be holding these experiments during free time - Tuesdays and Thursdays from 11:00 to 12:30 in room BS-317 beginning the first week of February and continuing until April 2 if necessary. You will not be asked to come to every session we hold! If you decide to participate, the total number of sessions you would attend would be about 10. That would include everything - practice and experiment participation. In addition, for many of the sessions it would not be necessary for you to attend for the entire 1 1/2 hours.

If you decide you might be interested in learning more please leave your name with Joseph Blasenstein and come to our introductory meeting which will be held on Tuesday, January 28th at 11:00 in room BS-306. You will learn more about the details of the experiments and will be able to ask questions before you decide whether to sign up. Thanks in advance for your interest and assistance.

Sincerely,

Carolina Zingale

Carolina Zingale, Ph.D.

Princeton Economic Research, Inc.
322 Wall Street • Princeton NJ 08540
Telephone: 609-924-8891 • FAX: 609-683-4006

PERI - FAA Project: Air Traffic Controller Memory Enhancement

CONSENT FORM:

My signature below indicates my agreement to participate in experiments investigating the role of various memory strategies on the performance of air traffic controllers. These experiments will be conducted by personnel from Princeton Economic Research, Incorporated (PERI) for the Federal Aviation Administration (FAA). I understand that in these experiments, participants will be working with the TRACON II Air Traffic Control Simulator for the pc. They will be allowed practice to become efficient working with this software package, so that they can effectively learn how to obtain information from the display and issue commands from the keyboard. I understand that practice with the simulator is necessary and is expected to take 4 to 5 hours. These sessions are to be conducted during free time - Tuesdays and Thursdays from 11:00 to 12:30 in room BS-317.

Three experiments will be conducted. Each is expected to take about 2 hours. These will again be conducted during the Tuesday and Thursday 11 - 12:30 time slot in BS-317. During testing, performance under various conditions will be monitored and scored. Participants will also be asked to indicate their own assessment of their performance following each test session. In addition, they will be asked to indicate the kinds of techniques they used to help their performance. Statistical analyses will then be conducted on these data in order to determine whether performance differs between the test conditions and what factors contribute to those differences.

I understand that my participation in these studies is strictly voluntary and I may withdraw at any time without penalty. My participation and performance do not in any way relate to or affect my course grades or academic standing. I also understand that my right to privacy will be protected. No individual names or identities are ever released in any reports. The contribution of the MCCC Aviation Program will, however, be fully acknowledged. I understand that there are no forseeable physical or psychological risks associated with participation in these studies.

Signed: ______________________________

Print: ______________________________

Date: ______________________________

PRELIMINARY QUESTIONNAIRE

The purpose of this questionnaire is to find out something about your background and current feelings about this project in order to better understand your performance during the course of the study. All information is collected under your code number and no attempt will be made to link your name to the answers you provide.

1. Participant code: ______

2. Age: _____

3. Semesters in MCCC aviation program: ______

4. Number of basic ground courses completed: ______

5. Number of flight hours completed: _____

6. Have you had any aviation experience prior to your enrollment at MCCC? yes no
   If yes, what and for how long?

   ____

   ____

   ____

7. Using the scale provided, rate your level of computer experience.

1	2	3	4	5	6	7	8	9	10
none									extensive

8. Rate your level of video game experience.

1	2	3	4	5	6	7	8	9	10
none									extensive

9. Rate your current vision.

1	2	3	4	5	6	7	8	9	10
poor									excellent

10. Do you have a color vision deficiency? yes no
    If so, what is it? ______________________________

11. I freely volunteered to participate in this project.

1	2	3	4	5	6	7	8	9	10
strongly disagree									strongly agree

12. I am currently in good health.

1	2	3	4	5	6	7	8	9	10
strongly disagree									strongly agree

If not, are you currently taking any medication that interferes with your vision or thinking abilities? yes no

13. During the last several months, I have been experiencing a relatively high level of stress.

1	2	3	4	5	6	7	8	9	10
strongly disagree									strongly agree

14. I am not very motivated to participate in this study.

1	2	3	4	5	6	7	8	9	10
strongly disagree									strongly agree

EXPERIMENT PARTICIPATION

Participant #	Experiment 1	Experiment 2	Experiment 3
1	+	+	+
2	+	+	+
3	+	+	+
4	+	+	–
5	+	+	+
6	+	+	+
7	+	+	+
8	+	+	–
9	+	+	+
10	+	+	+
11	+	+	+
12	+	+	+
13	+	–	+
14	–	–	+
15	–	–	+

+ participated
– did not participate

PERI/FAA

MEMORY STRATEGIES

TRAINING

MANUAL

JANUARY 1992

TRAINING MANUAL FOR TESTING

COMMONLY USED TERMS, ACRONYMNS AND ABBREVIATIONS ON FLIGHT PROGRESS STRIPS.

What is a "Flight Progress Strip?"

A flight progress strip is a written record of an aircrafts performance as it either takes-off, lands or overflies the airspace controlled by the controller <u>(YOU)</u>. A typical flight plan follows:

SK234 707	250K	00 01	100		MIDDS V165 DOWNE LAX	TWR

WHAT DOES THIS MEAN?????

SK234 ---Scandinavian Airlines flight number 234
707------Type of aircraft. A Boeing 707
250k-----Airspeed 250 knots
0001-----Time of arrival into problem
100'-----Altitude 10,000 feet.(The last two zeros are always dropped in a flight plan.

MIDDS----- An intersection of two routes used by pilots when they navigate.
V165------ A highway in the sky. Victor 165
DOWNE----- Another intersection.
LAX Twr--- The airport of intended landing, Los Angeles.

<u>PENDING</u> Flight progress strips or <u>flight plans</u> that are inactive. The "pending" file will appear about five minutes prior to the flights needing control action.
(PENDING FILES ARE BLUE)

<u>ACTIVE</u> Flight progress strips or <u>flight plans</u> that are active and under your control.
(ACTIVE FILES ARE GREEN)

<u>SELECTED</u> Flight progress strip that you are currently issuing instructions to.
(SELECTED FILES ARE BLACK)

<u>TWR</u> (Tower) Flight plans indicating "TWR" are aircraft destined to land at the airport or "twr" specified. Those airports are:
LAX-----Los Angeles
VNY-----Van Nuys
LGB-----Long Beach
TOA-----Torrance
SMO-----Santa Monica

<u>CTR</u> (Center) Flight plans indicating "CTR" are aircraft overflying the Los Angeles airspace enroute to another "ctr" sector. All identifiers for "ctr" control have five (5) letter characters. e.g. MIDDS, HASSA

<u>T/O.</u> (Take-off) Flight plans indicating "T/O" are aircraft taking off from one of the airports indicated under "twr". These aircraft are going from a "twr" to "ctr" environment.

<u>*</u> (Asterisk) Flight plans having an "*" in front of the routing indicates that control action on that flight plan is needed.

CONTROL ACTIONS NECESSARY TO SAFELY MANAGE TRAFFIC IN THE LOS ANGELES SECTOR

1). <u>OVERFLIGHTS</u> Route of flights that start with a five letter identifiers such as MIDDS and end with "Ctr". You must take a hand-off from the center controller when the aircraft flashes or blinks at you, monitor the aircrafts flight through your airspace, protecting it from other flights at the same altitude and initiate a hand-off to another center controller when the flight is <u>five (5) miles</u> or less from the last five letter identifier or sector boundary.

RULES;
1. Take hand-offs as soon as possible
2. Keep other aircraft at the same altitude at least 3 miles away from each other.
3. If aircraft are less than 3 miles from each other, you must have at least 1,000 ft. separation between aircraft.
4. Make final hand-off when the flight is five miles or less from the sector boundary.

2). <u>DEPARTURES</u> Route of flights that start with T/O and end with "Ctr". These aircraft are on the ground (pending) at the various airports waiting for you to release them (activate the flight plan). Departure aircraft need to be released, separated from other active traffic, monitored to a point <u>five miles</u> from the sector boundary (last five letter identifier) and then handed-off to the next center controller.

RULES;
1. Release aircraft as soon as possible.
2. Make sure you have at least 3 miles vertical or 1,000ft. horizontal separation from all other traffic in your sector.
3. Insure that aircraft are at the flight planned altitude prior to making your hand-off.
4. Insure that aircraft are going to the proper exit fix.
5. Make final hand-off when the flight is five miles or less from the sector boundary.

3). <u>ARRIVALS</u> Route of flights that end with "Twr". These aircraft are the most difficult to control since you must take a hand-off from the center controller, radar vector or maneuver the aircraft to the appropriate final approach fix, descend the aircraft to the proper altitude, turn the aircraft on the final approach course and clear the aircraft to contact the tower.

RULES;
1. Take hand-offs as soon as possible
2. Make sure you have at least 3 miles vertical or 1000 ft. horizontal separation from all other aircraft in your sector.
3. Descend aircraft to the proper final descent altitude.
4. Radar vector or maneuver the aircraft towards the final approach course.
5. Turn aircraft on to the final approach course outside the final approach fix (F.A.F.) on a heading no greater than thirty degrees from the final approach heading as indicated on the airports chart.
6. Make final hand-off to the tower prior to the F.A.F.

4). <u>TOWER EN-ROUTES</u> Route of flights that start with T/O and end with "Twr".These aircraft are on the ground at one airport, waiting to take off and land at another airport in your sector. You must release or activate the flight as indicated under DEPARTURES, and then follow the instructions pertaining to vectoring as listed in ARRIVALS.

RULES:
1. Release the aircraft as soon as possible.
2. Follow instructions under ARRIVALs listed above.

COMMONLY USED TERMINOLOGY

Request Vector-----Aircraft is requesting assistance to the airport or to a navigational fix.

Request descent----- Aircraft is getting close to the airport of intended landing without having had a clearance to descend to the final approach altitude.

Request release----- Tower controller is asking permission for a flight at his/her airport to fly into your sector under instrument flight rules.

Missed approach---- Aircraft that you cleared for an approach at one of your airports cannot make a safe landing due to being either too high , too close to the airport, too far away from the final approach course, or being at the wrong altitude.

Not on my scope yet--- Center controller reminding you that you are handing the aircraft off outside the 5 mile parameter recognized by the game.

HOW TO COMMUNICATE TO AIRCRAFT AND OTHER CONTROLLERS

In order to communicate to aircraft or other controllers, you must take three specific steps.

STEP ONE----- SELECT AN AIRCRAFT.

When an aircraft, control tower or center controller wants you to assume control of an aircraft (or select the aircraft), you'll hear the request, see the aircraft blinking at you and see the request written on your PC at the bottom of your screen. (Pink area) You can select the aircraft by either of the following means.

a) Scroll ARROW UP or ARROW DOWN to HIGHLIGHT THE AIRCRAFT, THEN PRESS THE ENTER KEY.
b) TYPE THE AIRCRAFT IDENTIFICATION When the App/Dep. prompt appears in the pink area, THEN PRESS THE ENTER KEY.

You now have selected the aircraft that you wish to control.

STEP TWO------- ISSUE A COMMAND INSTRUCTION.

Issue to your selected aircraft the appropriate command instructions as listed in the AIRCRAFT SELECTED COLUMN below.

(KEYBOARD ENTRIES)

Key	AIRCRAFT SELECTED	NO AIRCRAFT SELECTED
ARROW UP	Climb and maintain ____	Scroll up
ARROW DOWN	Descend and maintain_____	Scroll down
ARROW LEFT	Turn left_____	***************
ARROW RIGHT	Turn right_____	***************
BACKSPACE	Disregard previous command	Cancel last entry
SPEED	Change speed to _____	*****************
DIRECT TO	Cleared direct to ______	*****************
SAY HEADING	Say heading and airspeed	*****************
RESUME NORMAL	Resume speed and own navigation	*****************
HAND-OFF	Hand-off to CTR or TWR	*****************
HOLD AT	Hold at (designated fix)	*****************
ENTER	Release traffic on ground Take hand-off from center	Select aircraft (most important)
SEMI-COLON (;)	To issue multiple commands e.g. Command (;) Command	*****************
PLUS (+)	Zoom in	*****************
MINUS (-)	Zoom out	*****************
SLANT (/)	Move aircraft leader to------	*****************

STEP THREE-----Define the specific parameters such as altitude or heading using the numbers functions on the left keyboard.

ALTITUDE----The last two digits of the altitude are always omitted.
e.g. 19 means 1900ft., 120 means 12,000ft.

HEADING-----To turn to a specific number of degrees use two digits.
e.g. 20 means alter heading twenty degrees.
To turn to a specific heading use three digits.
e.g. 020 means heading Zero Two Zero degrees.

HOW TO TAKE A RADAR HAND-OFF AND RELEASE A DEPARTURE AIRCRAFT.

This process only requires two steps.

Step One----Select the aircraft and hit the ENTER KEY
Step two----Depress the ENTER KEY for the second time.

OTHER INFORMATION KEYBOARD ENTRIES.

These entries are provided for your information and are useful to obtain additional information.

ALT+F----- To gain access to the TRACON menu.
ARROWS---- To move left or right, up or down in the menu.
TAB------- To move the cursor into a different field.
ESC------- To cancel last entry.
CTRL+F---- To show the aircrafts flight plan route.
CTRL+T--- To show the Airport information.
CTRL+A---- To show aircraft performance characteristics.

TO ACTIVATE ANY INFORMATION REQUESTS YOU MUST FOLLOW-UP BY DEPRESSING THE ENTER KEY.

HOW TO MAXIMIZE YOUR SCORING.

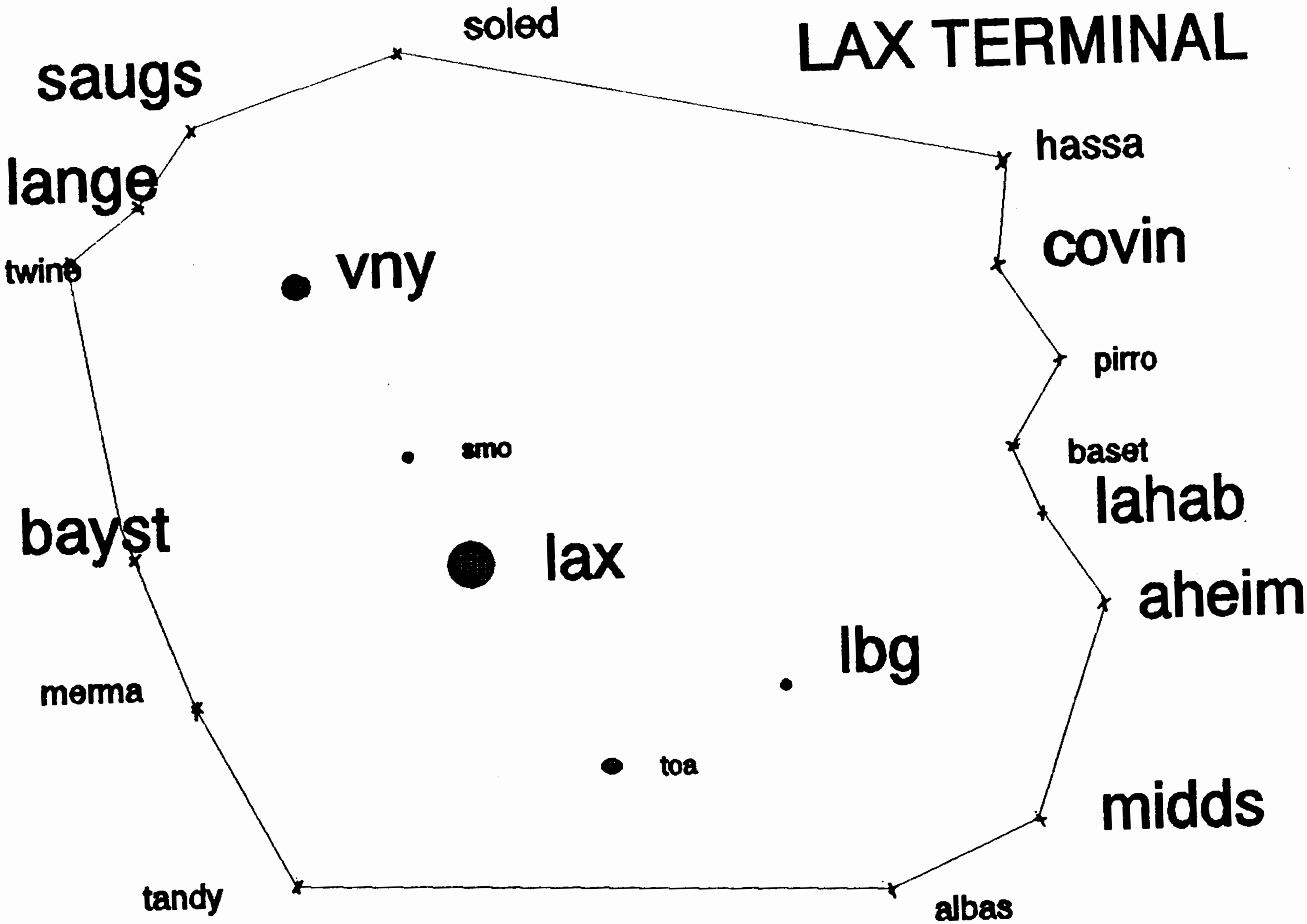
1) Take hand-off's as soon as possible.
2) Keep all aircraft at the same altitude at least 3 miles or 1,000 feet away from each other.
3) Turn aircraft on to the final approach course outside of the approach gate or course indicator.
4) Hand-off aircraft no sooner than 5 miles from the sector boundary.
5) Don't turn or maneuver aircraft unnecessarily.
6) Don't forget to make hand-off's to the next center controller.
7) Turn aircraft onto the approach course at the proper altitude and at a heading that does not differ by more than thirty degrees from the heading on your chart.
8) Release departure aircraft as soon as possible.
9) Try to issue multiple commands using the (;) to allow you to control the frequency.
10) DON'T AIM TWO AIRCRAFT AT EACH OTHER. A COLLISION IS AN AUTOMATIC EXIT FROM THE TEST.

This testing material will be fully explained to you by your instructor who was a qualified Air Traffic Controller. Feel free to ask any questions about the information hand-out, Air Traffic Control in general, or memory strategies we hope to teach you.

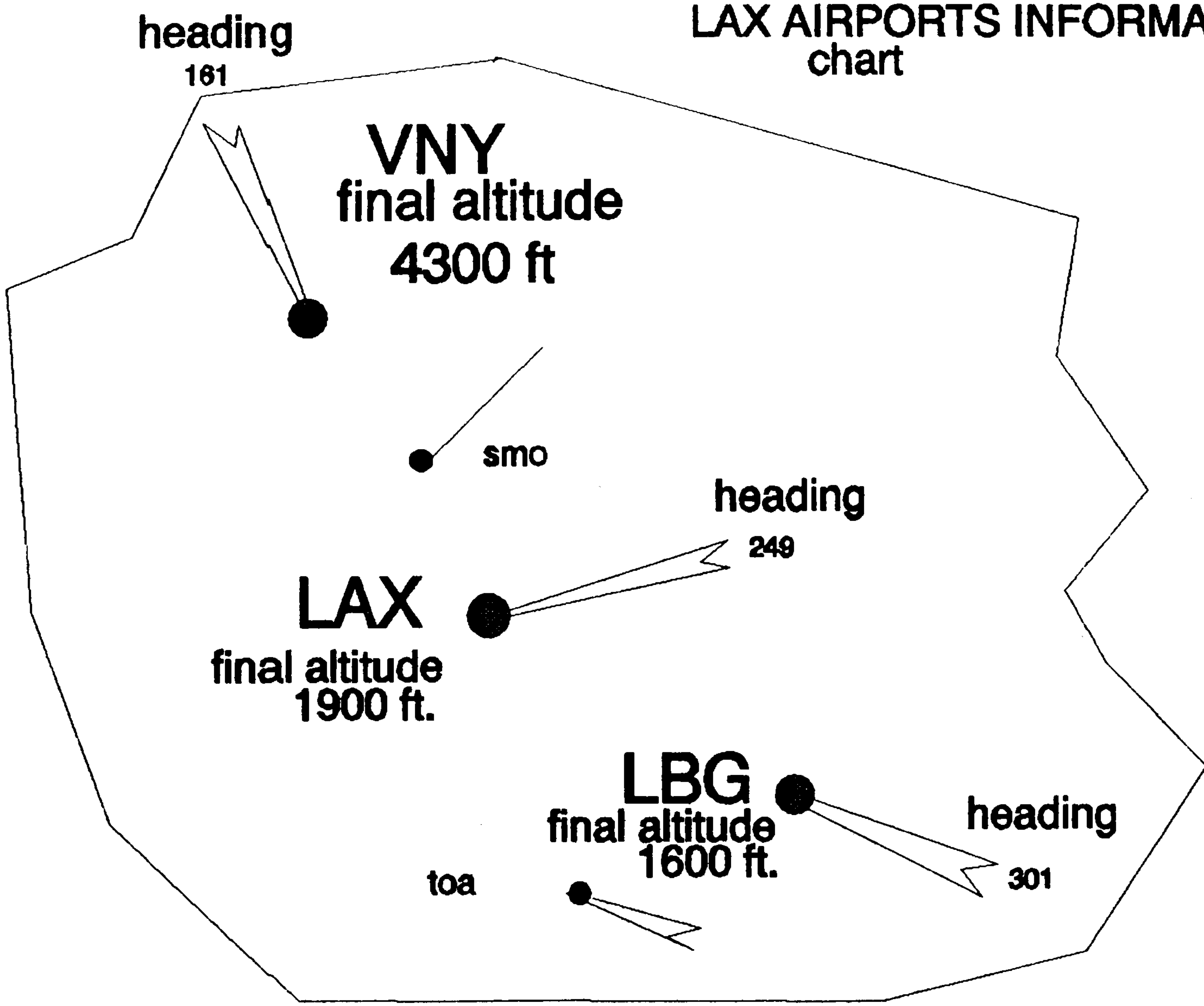
Remember, we expect you to make mistakes. We want you to have "FUN". Try to do your best but don't worry if you get behind or can't remember everything. You are not expected to become Air Traffic controller after this experiment.

Thanks again for your volunteer participation.

The staff at PERI.


LAX TERMINAL
soled
saugs
lange
twine
vny
hassa
covin
pirro
smo
baset
lahab
bayst
lax
aheim
lbg
memma
toa
midds
tandy
albas

LAX AIRPORTS INFORMATION chart



function commands

(insert)

[redacted]

(home)

[redacted]

(page-up)

[redacted]

(delete)

[redacted]

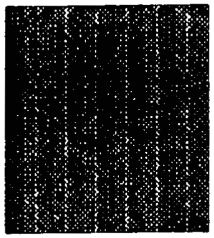
(end)

[redacted]

(page down)

[redacted]

control instruction commands



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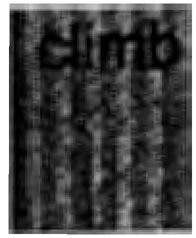

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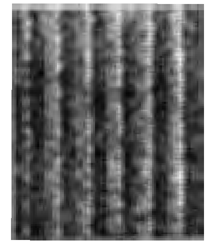

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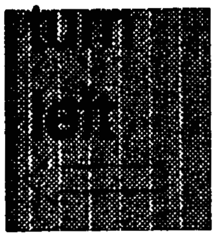

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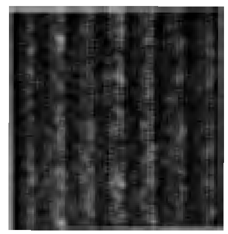

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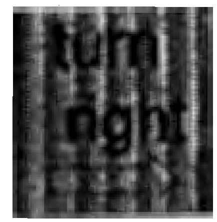

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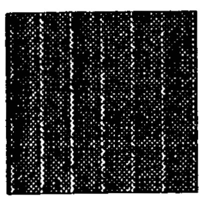

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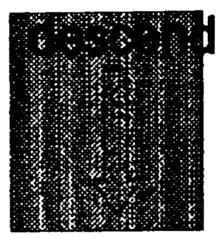

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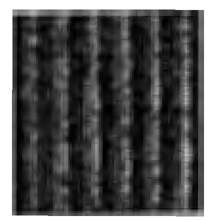


3

KEY PAD CONTROL COMMANDS

COMMAND	KEYPAD
Turn Right	→
Turn left	←
Degrees	00
Heading	000
Climb and Maintain	↑
Descend and Maintain	↓
Change Speed to..	SPEED
Resume Nrml Nav...	RESUME NORMAL
Cleared Direct to..	DIRECT TO
Hold at...	HOLD AT
Handoff to Twr/Ctr..	HAND-OFF
Say Heading and Speed..	SAY HEADING
Release Twr Depts.. Take Ctr Hand-offs..	ENTER
Make Multiple Commands..	(;)
Move Leader to....	(/)

IMPORTANT FLIGHT STRIP INFORMATION

CTR... OVERFLIGHT e.g. (MIDDS)

TWR... ARRIVAL e.g. (LAX)

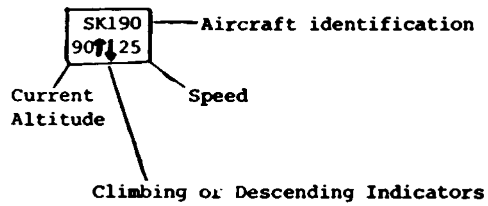
T/O... DEPARTURE FROM......

(*)... AIRCRAFT IS READY FOR YOU TO TAKE IMMEDIATE ACTION

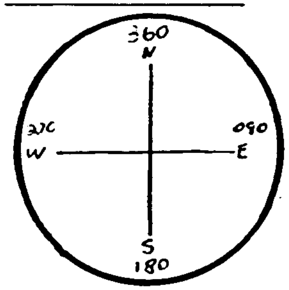
AIRPORT INFORMATION

ID	NAME	FINAL HEADING	FINAL ALTITUDE
LAX	Los Angeles	249	1900
VNY	Van Nuys	161	4300
LGB	Long Beach	301	1600

DATA BLOCK INFORMATION



COMPASS ORIENTATION



MOST IMPORTANT

YOU MUST ALWAYS USE "ENTER" after you type your command otherwise the command will not be processed.

HOW TO COMMUNICATE TO AIRCRAFT

STEP ONE..Highlight the strip (ENTER)

STEP TWO.. Issue the Command (ENTER) (if necessary)

STEP THREE.. Define the parameters (ENTER)

KEYBOARD INFORMATION ENTRIES

REQUEST	KEYPAD
Access Menu	ALT+F
Move in menu	ARROWS
Different field	TAB
Cancel or Delete	ESC or BACKSPACE
Flight plan Info.	CTRL+F
Airport Info.	CTRL+T
Aircraft Info.	CTRL+A

MUSTS

Take hand-offs A.S.A.P.

Keep aircraft ¼ to ½ inch apart (3 miles)

Make hand-offs no sooner than 5 miles (½) inch from boundary

Use proper altitudes for Arrival approach clearances

Only clear one aircraft for Take-off at a time. Let the second one wait. one minute.

APPENDIX B

EXPERIMENTS 1 AND 2 MATERIALS

Name : ____________

CODE : __________

N16FG TB-20	146K	00^{01}	80		LANGE-MIDDS	CTR
N9565G C-402	220K	00^{01}	90		SAUGS-LGB	TWR
N1EQ L-24	250K	00^{01}	50		COVIN-LAX	TWR
AA123 727	210K	00^{02}	100		AHEIM-LAX	TWR
SK190 747	210K	00^{02}	90		LAX-COVIN	T/O

PRACTICE SESSION:

Part 1. Based on the advance information you now have from the flightplans of the aircraft in the upcoming scenario, what actions can you preplan that will be useful for you in managing the air traffic flow?

Part 2. Now write out specific instructions next to each aircraft's flightstrip to use as reminders during the session. For example, reminders to change altitude, or speed or route. Write your instructions in the appropriate columns of the flightstrips.

In a few moments the practice session will begin and you will be asked to manage the aircraft, making as few errors as possible. To remind yourself of the aircraft's flightplan during the session, use the FLIGHTPLAN command (ALT D then F).

Experiment 1 -- < PLANNING >.
General instructions (Practice session).

Before beginning the upcoming scenario, you will be provided with the flightstrips for all the aircraft that will come under your control during the session. You will then have about 10 minutes to use this information to your best advantage:
to plan strategies for handling these aircraft in advance so that your errors can be minimized.

To give you a feel for how this can be done effectively, you will now have an opportunity to practice with the following. The flightstrips presented on the handout describe the aircraft that will enter your airspace in a short session. In the third column of the flightstrip is the time that you can expect that aircraft to look to come under your control. For example, N16FG, N9565G, and N1EQ will look to make contact within 1 minute of the start of the scenario. AA123 and SK190 will look to make contact within 2 minutes.

Before you begin actually directing this traffic, think about the way things will look at different points in the scenario and how you would anticipate handling any potential problems.

(a) N16FG will enter first. It is entering at LANGE (find this location on the map). It is going to go from here to MIDDS center (check location). Note that it will be travelling at 146 knots at an altitude of 8000 feet when it enters your airspace.

(b) Now, look at N9565G. It will enter your airspace just at about the same time as N16FG. It is entering at SAUGS and will be landing at Long Beach airport. It will initially be travelling at a speed of 220 knots at an altitude of 9000 feet. If you haven't done so already, locate SAUGS on the map. You will see that LANGE and SAUGS are very close to one another.

(c) Now check the flightpaths of both aircraft. The way things are set up, FG and 5G will be travelling along almost parallel paths, close to one another. You now know that you will need to be continuously aware of the 2 aircraft's proximity to one another. This lets you plan in advance how you will keep them separated during the scenario. Keep in mind that you must control the aircraft as efficiently as possible. For example, having them deviate a long way from their intended routes is not the most efficient strategy and you will see that points will be deducted from your score.

Now work with some of the other information. What do the flightpaths look like? Are there any potential conflicts that you can forsee?

EXPT1 a   code: ______

N999V C-23	95 K	00^{01}	100		SAUGS - LAX	TWR
N3586C PA31	200 K	00^{01}	70		LGB - SAUGS	T/O
N47A CH25	185 K	00^{02}	40		LAHAB - LGB	TWR
N460W PA42	215 K	00^{03}	80		VNY - COVIN	T/O
N19N LA250	100 K	00^{06}	80		COVIN - BAYST	CTR
N79WG BE400	220 K	00^{09}	90		AHEIM - LGB	TWR
DL923 72S	250 K	00^{12}	120		LAX - AHEIM	T/O

AS49 727	250K	00^{15}	120		COVIN -LAX	TWR
UA595 L10	250K	00^{21}	110		LAX- LANGE	T/O
N11H C310	200 K	00^{24}	70		MIDDS- LAX	TWR
N716H C402	215 K	00^{27}	100		MIDDS- VNY	TWR
N1J TB-20	180 K	00^{29}	60		SAUGS -MIDDS	CTR

CODE: ______________________

PERFORMANCE CHECK LIST

CRASH	SEPERATION CONFLICT	AIRCRAFT VECTORED OF SCOPE	MISSED APPROACH	HANDOFF AT WRONG ALTITUDE	HANDOFF NOT MADE TO CENTER

END OF SESSION SUMMARY (TOTALS)

CATEGORY	NUMBER
SEPARATION CONFLICTS	________
MISSED APPROACHED	________
HANDOFF ERRORS	________
PILOT REQUESTS granted/total	___ /____

SCORE: ________________

CONTROLLER SIMULATION QUESTIONNAIRE

PLEASE COMPLETE THE FOLLOWING QUESTIONS AS SOON AS YOU HAVE COMPLETED THE SESSION. YOUR RESPONSES SHOULD FOCUS ON ONLY THE WORK THAT YOU HAVE JUST COMPLETED IN THE LAST CONTROL PERIOD.

ALL CONTROLLERS EXPERIENCE A WIDE VARIETY OF ACTIVITY AND RESULTANT WORKLOAD DURING THEIR CAREERS. IT DOES NOT DETRACT FROM YOUR PROFESSIONALISM IF FOR A GIVEN PERIOD YOU REPORT VERY HIGH OR VERY LOW WORKLOAD. ON ALL THE QUESTIONS WHICH FOLLOW FEEL FREE TO USE THE ENTIRE NUMERICAL SCALE FOR EACH ANSWER. BE AS HONEST AND AS ACCURATE AS YOU CAN. YOUR NAME IS NOT RECORDED ON THIS OR ANY OTHER FORM, AND NO ATTEMPT WILL BE MADE TO ASSOCIATE YOUR RESPONSES WITH YOU AS AN INDIVIDUAL. DATA COLLECTED WILL BE FOR RESEARCH PURPOSES ONLY.

Participant code: ________

1. Choose the one number below which best describes how hard you were working during this period:

DESCRIPTION OF WORKLOAD CATEGORY	RATING (CIRCLE ONE)
VERY LOW WORKLOAD - All tasks were accomplished quickly and easily	1 2 3
MODERATE WORKLOAD - The chances for errors or omissions were low	4 5 6
RELATIVELY HIGH WORKLOAD - The chances for some errors or omissions were relatively high	7 8 9
VERY HIGH WORKLOAD - It was barely possible to accomplish all tasks properly	10 11 12

2. Rate your performance controlling traffic during the past session. Circle the number which best describes how well you think you did.

1	2	3	4	5	6	7	8	9	10
average									excellent

3. What fraction of the time were you busy during the period you were controlling?

1	2	3	4	5	6	7	8	9	10
seldom had much to do									fully occupied at all times

4. How much did you have to think during this period?

1	2	3	4	5	6	7	8	9	10
minimal thinking and concentration required									a great deal of thinking and concentration required

5. Rate the degree to which you found this control period stressful.

1	2	3	4	5	6	7	8	9	10
low									high

6. I am feeling tired.

1	2	3	4	5	6	7	8	9	10
strongly disagree									strongly agree

]7. Briefly describe your strategy for working traffic during this control period.

8. If you have a choice of separating aircraft vertically or horizontally, which do you prefer to do and why?

9. Is there anything else that happened this past session which you feel might help us understand the results? Any comments you have at this point would be very welcome.

APPENDIX C

EXPERIMENT 3 MATERIALS

SCENC

NAME

N634S L-24	240K	00 11	90		LAX-HASSA	T/O
N99H L-24	180K	00 13	100		AHEIM-LAX	TWR
UA354 M80	225K	00 15	90		LAHAB-LAX	TWR
CO35 747	245K	00 18	90		BAYST-LAX	TWR
N92F C-310	180K	00 19	70		BAYST-VNY	TWR
WN854 757	250K	00 22	120		LAX-SAUGS	T/O
AA362 727	230K	00 24	100		LAHAB-LAX	TWR
N324K C-402	215K	00 27	100		AHEIM-VNY	TWR

SCENE

NAME

N94KL C402	220K	00 01	60		HASSA-LGB	TWR
AA61 72S	250K	00 01	120		LAX-AHEIM	T/O
N2R PA42	250K	00 02	110		AHEIM-LAX	TWR
N27PT BE400	220K	00 04	90		AHEIM-LGB	TWR
N895C PA44	155K	00 05	80		BAYST-LGB	TWR
KE960 737	250K	00 06	100		COVIN-LAX	TWR
N84S C425	185K	00 08	40		LAHAB-LAX	TWR
N417L C-310	175K	00 09	90		AHEIM-LAX	TWR

EXP-3 SCENC

NAME ____________________

CONTROL INSTRUCTIONS ISSUED

AIRCRAFT I.D.	TURNS/ HEADING	DIRECT CLEAR	HAND OFFS	CLIMBS/ DESCENTS	SPEED RSTRNS	CLEAR APC.	HOLD/ OTHER
N634S							
N99H							
GA354							
CO35							
N92F							
WN854							
AA362							
N324K							

NAME________________________

EX. 3 SCENC

CONTROL INSTRUCTIONS ISSUED

AIRCRAFT I.D.	TURNS/ HEADING	DIRECT CLEAR	HAND OFFS	CLIMBS/ DESCENTS	SPEED RSTRNS	CLEAR APC.	HOLD/ OTHER
N94KL							
AA61							
N2R							
N27PT							
N895C							
KE960							
N84S							
N417L							

FXP3 Name: ________

CONTROL INSTRUCTIONS ISSUED

AIRCRAFT I.D.	
N634S	
N99H	
UA354	
CO35	
N92F	
WN854	
AA362	
N324K	

FXP3 Name. ______________

CONTROL INSTRUCTIONS ISSUED

AIRCRAFT I.D.	
N94KL	
AA61	
N2R	
N27PT	
N895C	
KE960	
N845	
N417L	

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