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Learn to Fly: Instructor and Student Communications in Instrument Flight Instruction

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It is proposed that one-on-one human tutoring is the best way to learn. Several models of tutoring have been developed to tutor students in subjects such as LISP, Literacy, and Algebra. In this study we investigate how a key-tutoring model generalizes to tutoring 5 student pilots performing instrument flight in a simulator and in an airplane.

Introduction

Acquiring new knowledge or a new skill through instruction is an essential part of learning and mastery in any field. Learning through instruction can occur in multiple ways, which raises the question: What is the best way to learn? According to Chi (1996), "Human tutoring is a more effective means of instruction than classroom teaching, mastery learning, computer-aided or programmed instruction, and computer tutors" (p. 1). One reason one-on-one human tutoring seems to be so effective is because it quickly addresses and corrects each student's individual misunderstanding of the information. The other methods of tutoring mentioned above focus on presenting the student with new information with little emphasis on individual comprehension.

Tutoring Model

Graesser, Person and Magliano (1995) proposed a model that focuses on effective one-on-one human tutoring called the "tutoring frame." The tutoring frame consists of five key steps:

1. Tutor asks an initiating question
2. Student provides an answer
3. Tutor gives feedback on answer
4. Tutor improves quality of answer through a collaborative conversation
5. Tutor assesses student's understanding of answer

In the first step the tutor asks an initiating question which serves to narrow the focus of the material. Chi (1996) states, "The tutors' action of asking and initiating questions can be broadly construed to be effective at promoting learning of a template or material contained in a curriculum script" (p. 2). Thus, initiating a question is an ideal way of focusing the student's resources on learning the most important concepts contained within a certain domain.

In the second step, the student provides an answer, which allows the tutor to assess the student's knowledge of the problem. Depending on the answer, the tutor gives the appropriate response. For example, if the tutor asks the student, "What is the numerical value of (23+2) x 2 – 1?" and the student incorrectly responds by saying "25" the tutor might say, "Remember, order of operation matters". If the student still gets the answer wrong the tutor might say, "Start by solving the expression in the parentheses first." The response is gauged depending on the answer the student gives. The tutor works by first giving vague hints to the student if they make a mistake and progressively gives more specific hints if the student continues making mistakes.

In the third step the tutor's feedback to the student's answer is one of the main reasons that one-on-one human tutoring is so successful. According to Merrill, Reiser, and Landes (1992) tutors are very fast at giving feedback when a student makes an error. This immediate feedback helps the student correct any errors or gaps in knowledge needed to master the material quickly. Furthermore, research done by Anderson, Boyle, and Reiser (1985) showed that feedback is important because it decreases the likelihood of the student searching down the wrong path of a search space.

In the fourth step the tutor initiates a series of exchanges with the student taking 5-10 turns (Graesser et al., 1995). The tutor begins by giving the student suggestive hints, for example, the tutor might say “are you sure that’s right?” prompting the student to reconsider their answer. If the student continues making errors the tutor’s feedback becomes more specific.

In the final step the tutor asks a probing question that helps the tutor determine what the student understood. This comprehension-gauging question helps the tutor to assess whether or not the student needs more practice in the same line of questioning.

Model Generalizability

The above approach to tutoring has been successful in domains such as LISP (Anderson, Conrad and Corbett, 1989), Literacy (Juel, 1991) and Algebra (Koedinger, Anderson, Hadley, & Mark, 1997). Most of the tasks in these domains require problem solving to perform, for example, finding the solution to an algebraic expression like (23+2) x 2 – 1. Another characteristic these domains have in common is that they are usually governed by an ordered set of principles. So, to solve (23+2) x 2 – 1, the student must follow the order of operation by first calculating the expression in the brackets, then multiplying, and finally subtracting. A third characteristic these domains share is that the tasks are performed in a relatively stable environment where the problem does not change over time.

Many tasks that are learned through one-on-one human tutoring do not necessarily require problem solving. Learning how to drive, fly, or do surgery requires manual control rather than problem solving to perform. Moreover, driving, flying, and surgery are not completely governed by an ordered set of principles due to the unpredictability of the domains. For example, flying a plane effectively in windy weather is based more on skill rather than a fixed set of ordered principles. Lastly, driving, flying, and surgery are performed in volatile environments where the task changes spontaneously over time. This is in contrast to tasks performed in domains such as Algebra, Literacy, and LISP, where tasks remain stable despite any manipulation on behalf of the student.

Research by Donae & Sohn (2003) suggests that tasks presented during flight are complex and tax working memory capacity and long-term memory skills. Learning to fly requires participants to attend to multiple elements in the environment and thereby forces them to divide their attention among several tasks. A study by Anderson & Douglass (1997) shows that tasks that require divided attention are harder to perform. Driving and performing surgery also tax memory and divide attention making them difficult to perform. This raises two questions: 1) does the tutoring frame generalize to a wide array of tasks of varying difficulty? And 2) can the tutoring frame be used to teach a student how to drive, fly, or perform surgery?

Very little research has been done on how one-on-one tutoring works in domains like driving, flying, and surgery. To investigate the generality of the tutoring frame we examined how a certified flight instructor tutors student pilots to perform 9 instrument flight maneuvers.

Method

Participants. Five local student pilots and one instrument certified flight instructor pilot participated in the study. Student pilots had between 28-130 hours of experience flying and range in age from 18 to 40. Each student pilot received 50 dollars for their participation in the simulator session and 50 dollars for their participation in the airplane session. Student pilots were able to log one hour of flight experience for their time in the simulator and one hour for their time in the airplane.

Design. The study is observational and consists of one subject variable and two research variables. The subject variable is the student pilot’s level of skill, which is measured by the number of hours the student pilot has logged. Five student pilots participated in the study, three of whom had less than forty hours of flight experience and two had 100 or more hours of flight experience. The first research variable is the flight setting: a fixed sequence where students performed the same tasks, first in a computer simulator and then in a real airplane. Given the safety concerns of the IRB, the order of the flight settings (first the simulator then the airplane) was held constant across all participants. The second research variable is the difficulty of the tasks given to the students during the flight sessions. Nine tasks were given to each student pilot to perform, beginning with the easiest task and ending with the hardest in both sessions. The difficulty of the task is based on the complexity of control movements needed to complete a maneuver. For example a left/right turn in an airplane is harder to perform than a climb/descent or an acceleration/deceleration due to the number of axes involved. Furthermore, a task that requires more than one maneuver to be executed, for example turning left and climbing, posses even greater difficulty. The tasks were given from easiest to hardest in both flight settings (simulator then airplane). Since the two research variables were invariant across participants, we cannot separate treatment effects from history or practice effects, and so we cannot isolate treatment effects from these confounding factors. The study therefore is not a true experiment but rather an observation of how these variables affect tutoring.

Materials. Flyers were posted at a local flight school to recruit student pilots for the study. The flyer explained the basic flight requirements and the incentive for participating.

A consent form was given to the student pilot to fill out if they chose to volunteer for the study. The consent form outlined in more detail the study, the requirements, the incentives, and the student's right to withdraw at anytime.

A questionnaire was administered to the pilots before participating in both the simulator flight and the airplane flights. The questionnaire was designed to gather information about where the pilot learned to fly, how long the pilot had been flying, and what kind of planes they have flown.

The flight simulator is PCATD (Personal Computer-Based Aviation Training Device), which is a hardware and software unit that is certified by the FAA (Federal Aviation Administration) for flight instruction. The PCATD consists of a control box with a yoke and a throttle that is connected to a computer screen (Figure 1). The student pilot is presented with a screen showing the main instruments necessary for flight (Figure 2).

A video camera was placed behind the instructor and student in the simulator and airplane to capture audio and video data for later analysis.

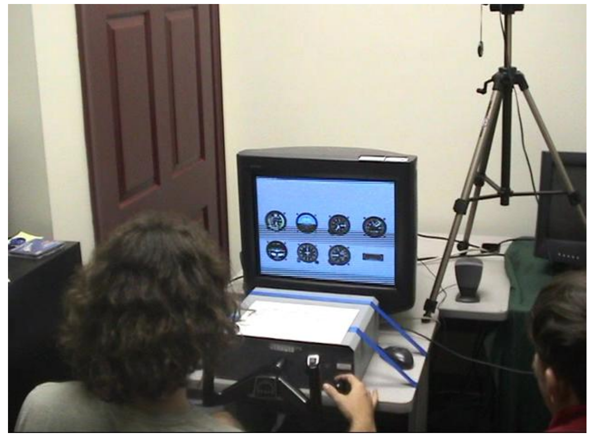

Figure 1. Student pilot performing a task on the PCATD

Figure 2. PCATD Instrument Panel

Procedure. Five student pilots were asked to perform nine tasks, in both a simulator and an airplane, that pose different levels of difficulty. A two-hour time commitment and a three-hour commitment were required for the flight simulator and airplane respectively. A consent form was given to each student to read and sign explaining the student's right to withdraw and discontinue participation at any time during the study.

In each case, the instructor pilot was present to give the student the task instructions and to help tutor them during the flight sessions. Each task was performed using seven instruments essential for instrument flight (Tachometer, Airspeed Indicator, Attitude Indicator, Altimeter, Turn Coordinator, Directional Gyro, and Vertical Speed Indicator). During airplane flights the student pilots wore "foggles" (e.g. goggles) that blocked any view outside the cockpit allowing only a view of the instruments and flight controls. Task one to four involved a single axis maneuver, task five to seven involved a double axis maneuver, task eight involved a triple axis maneuver, and task nine involved an instrument failure (See Table 1).

Progressive difficulty of the tasks was designed to examine how communication might be affected under more complex situations. Between each task the instructor pilot readjusted or reset the plane to prepare for the next task, allowing a short break for the participants.

Table 1. Task Instructions

Task	Instruction
1	Decrease airspeed to 80 knots while maintaining a heading of 3-6-0 and an altitude of 3000 feet.
2	Turn left (standard rate) to a heading of 1-8-0 while maintaining an airspeed of 90 knots and an altitude of 3000 feet.
3	Turn right (standard rate) to a heading of 1-8-0 while maintaining an airspeed of 90 knots and altitude of 3000 feet.
4	Climb to 4000 feet at 500 feet per minute while maintaining an airspeed of 90 knots and a heading of 3-6-0.
5	Increase airspeed to 100 knots while turning right (standard rate) to a heading of 1-8-0 and maintaining an altitude of 3000 feet.
6	Decrease airspeed to 80 knots while descending to 2500 feet at 500 feet per minute and maintaining a heading of 3-6-0.
7	Turn left to a heading of 0-niner-0 and climb to 4000 feet at 500 feet per minute while maintaining an airspeed of 90 knots.
8	Increase airspeed to 100 knots while turning right a heading of 1-8-0 and descending to 2000 feet at 500 feet per minute
9	Turn left (standard rate) to a heading of 1-8-0 while maintaining an airspeed of 90 knots and an altitude of 3000 feet.

The audio track of the video recording was transcribed for coding. Each utterance was broken into constituent clauses, for example the instructor might say, “Watch your heading, you need to pull up” as one utterance. In which case the utterance would be broken into “watch your heading” which would be coded as a warning and “you need to pull up” which would be coded separately as a command. Four main categories were defined: commands, warnings, comments, and explanations. Each of the four main categories was put into two main overarching categories: Coaching and Instructional. Coaching messages are messages given by the instructor to the student to help guide the student to take immediate and correct action. Instructional messages are messages given by the instructor to the student to help explain the mechanics or theory of flight. The goal of the coding system is to understand the purpose behind each utterance. Is the instructor trying to warn the student, tell the student what to do, or to teach the student about flight dynamics? The coding system was designed to answer those questions for us.

The simulator records and stores the airplane’s altitude, heading, and airspeed every 10 milliseconds during each simulator flight. Since each flight was also recorded using a video camera, the time from the simulator data and the time from the videotape were synchronized. Synchronizing the simulator flight data and the video tape recording is important in investigating what the state of the plane was (in terms of altitude, heading and airspeed) when the instruction was given by the instructor to the student.

Results

The first question we want to illuminate is how well does Grasser’s model of tutoring generalize to tutoring student pilots how to perform instrument flight? Preliminary results reveal that the instructor does nearly all of the talking during instrument flight instruction. The total number of utterances across all pilots and across both flight sessions (simulator and airplane) is 3831. The instructor makes 3756 utterances (98%) across all pilots and across both flight settings. In contrast, the students only make 75 utterances (2%) across flight settings. This is not consistent with a feedback model of tutoring where the tutor uses probing questions to determine the extent of student knowledge, then uses his understanding of problems in student knowledge to provide effective tutoring: Students simply aren’t talking enough to allow the tutor to determine what they do or do not know. Clearly the instrument flight instructor must be watching the *performance* of the flight as a primary source of information about student knowledge.

The second question we explored is: Does the tutoring process follow the same sequence of steps as Grasser’s model of tutoring? Examining the coded utterances reveals that the instructor never asks the student any questions during instrument flight. Furthermore, the student makes only 2% of the utterances during tutoring. Thus, the first two steps of the Grasser’s model of tutoring do not apply to instrument flight.

The third question we investigated is: Does the instrument flight instructor tailor his instruction to student pilots with different skill levels? The frequency of coded utterances reflects the instructor's sensitivity to the pilot's proficiency in instrument flight. Figure 3 below plots the frequency by pilot and utterance type: commands, warnings, comments, and instructions. The data reveals that lesser skilled pilots (e.g., Pilot 4) get more commands, instructions and warning messages than more skilled pilots. Pilots that are more skilled (e.g., Pilot 1) on the other hand get equal or more instructional messages about the dynamics of flight and messages commenting on the status of the plane (in both the simulator and airplane). A chi-squared test was performed using the five student pilot participants and four major code categories. The analysis revealed significant differences for these frequencies (. ˜ ..1 d.f., $p < .005$).

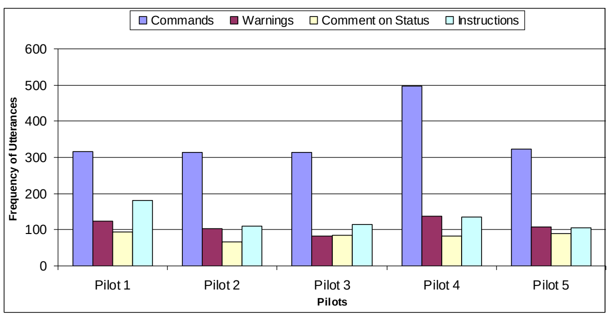

Figure 3. Frequency of utterances made by the instructor to each pilot across flight settings (simulator and airplane)

The fourth question we addressed is: what are the differences in how the instructor tutors students in a simulator flight compared with how the instructor tutors students in a real airplane flight? The difference between tutoring the student pilots in the simulator versus in the airplane is based on the frequency of utterances made by the instructor. Figure 4 plots the frequencies of commands, warnings, comments, and instructions given in the airplane and the simulator. The data shows that the instructor speaks more in the simulator than in the airplane, and also that a higher proportion of commands were given in the simulator than in the airplane. A chi-squared test was performed using the two flight settings and the 15 different code subcategories. Again the proportions differed significantly (. ˜ ..1 d.f., $p < .005$). Here we find a considerable sensitivity to the context, with richer instruction given in the simulator than in the airplane.

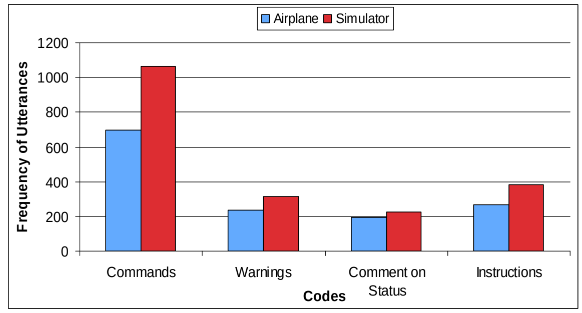

Figure 4. Frequency of utterances made by the instructor in the simulator and airplane across pilots

Discussion

The disproportionately large ratio of instructor-to-student utterances does not fit into Grasser's model of tutoring. Grasser's model of tutoring assumes that the instructor asks an initial question followed by a response by the student. However, based on our preliminary data the student rarely speaks during the simulator and airplane flight sessions. The primary utterances the students make are to repeat back the task instructions assigned by the instructor at the beginning of each task (Table 1). The instructor informs the student to repeat back the instruction before the simulator and airplane flight sessions begin. The poor level of generalizability of Grasser's model of tutoring to instrument flight shows a need to re-examine how tutoring works in volatile domains.

The data also shows that the instructor rarely asks an initiating question. Asking an initiating question is the cornerstone of Grasser's model of tutoring (see page 1). The instructor spends most of his time giving commands and warnings based on our coding of the utterances, especially to lesser skilled pilots. We believe this is due to the volatile nature of tutoring a student how to perform instrument flight. The instructor is more concerned with keeping the plane under control while tutoring the student.

Instrument flight tutoring does not follow the steps of the Grasser's model of tutoring. We believe this is, again due to the volatility of the domain being investigated. In addition, asking the students questions and getting responses would affect the student's ability to perform instrument flight. This is another reason why we believe the instructor never asks the student questions.

The instructor gives slightly more utterances in the simulator across pilots because the domain is less volatile than a real airplane. A second reason the instructor gives more utterances in the simulator is because there is no engine noise to interfere with the communication. A third reason we believe the instructor gives more utterances in the simulator is because the airplane uses an awkward voice-activated intercom that increases the difficulty of communication.

Future research on this project will focus on creating subcategories for each of the four main codes. Further parsing the categories will allow us to see if there are significant types of commands, warnings comments, and instructions given by the instructor. In addition, we will examine how much deviation the instructor allows each student pilot before giving certain kinds of messages. The amount of axial deviation for each task across pilots will only be done using the simulator flight sessions. The flight state (altitude, heading, and airspeed) was recorded every 10 milliseconds during the simulator flight. No such device was used to record the flight state for the real airplane flights that the students performed.

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