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An Investigation of Sensory Information, Levels of Automation, and Piloting Experience on Unmanned Aircraft Pilot Performance

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16. Abstract
The current experiment was intended to examine the effect of sensory information on pilot reactions to system failures within a UAS control station simulation. This research also investigated the level of automation used in controlling the aircraft and the level of manned flight experience of the participants, since these also have been shown to influence pilot effectiveness. While the presence of sound did improve responses to engine failures, it did not improve responses to failures in heading control. The prediction that higher levels of automation would lead to complacency or vigilance decrements was not supported. The finding that pilots, in the manual conditions, flew significantly closer to the flight path than non-pilots was unexpected. The results suggest differences between those with manned aircraft experience and those without, but it is unclear whether these differences are due to manned aircraft training and flight experience or whether other factors, such as personality, may be evident.

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An Investigation of Sensory Information, Levels of Automation, and Piloting Experience on Unmanned Aircraft Pilot Performance

INTRODUCTION

A recent review of sensory information in Unmanned Aircraft Systems (UAS), compared to manned aircraft, documented the severe lack of information available to UAS pilots (Williams, 2008). The current research continues that review to find empirical support for the need to have multiple sources of sensory information available to pilots of UAS to enhance their ability to diagnose and respond to system failures.

Research looking at (UAS) accident causal factors has suggested that sensory deficiencies have played a role in UAS accidents (Tvaryanas, Thompson, & Constable, 2005). For example, Tvaryanas et al. stated that 10% of UAS accidents across all services were influenced by a misperception of the location and/or attitude of the aircraft. Additionally, they found that 26.5% of Predator UAS accidents they reviewed had problems associated with the instrumentation and sensory feedback systems.

However, other factors besides the types of sensory information available can influence the ability of a pilot to effectively manage a flight. UAS control, for many current systems, is highly automated. Automation-induced complacency, which is the tendency for humans to become less vigilant or focused on a task that is being performed by automation, is possible when automation replaces a task that occupies a human activity (Parasuraman, 1986; Warm, 1984). Automation-induced complacency has been documented as a cause or contributing factor in many manned aircraft accidents throughout the last two decades (Parasuraman, Molloy, & Singh, 1993; Singh, Molloy, & Parasuraman, 1993; Woods, Sarter, & Billings, 1997). A pilot's ability to respond to system failures, therefore, will be influenced not only by the sensory information available but also by the type and level of automation employed in the system and the control-interface requirements on the pilot.

Finally, there is an unresolved question regarding the need for manned aircraft experience for piloting a UAS (Fogel, Gill, Mout, Hulett, & Englund, 1973; Schreiber, Lyon, Martin, & Confer, 2002; Williams, 2007). Tvaryanas et al. (2005) found that, for other systems besides the Predator, the presence of sensory feedback as a factor in the accidents was not as readily apparent. They speculated that the difference could be that Air Force UAS pilots are more likely to notice the lack of sensory information available in the ground control station because of their greater experience with manned aircraft operations. UAS pilots in other military branches are not required to have experience flying manned aircraft. Currently, the Federal Aviation Administration (FAA) requires pilots of UAS to have a manned aircraft pilot certificate for most operations. However, the development of a UAS-specific pilot certification has been proposed.

The current experiment was intended to examine the effect of sensory information on pilot reactions to system failures within a UAS control station simulation. However, in addition to sensory information, this research also investigated the level of automation used in controlling the aircraft and the level of manned flight experience of the participants, since these also have been shown to influence pilot effectiveness. The design of the experiment was a 2x2x2 between-subjects design, manipulating two levels of sensory information (visual vs. visual/auditory), two levels of control automation (manual vs. automatic), and two levels of manned piloting experience (some vs. none). Participants were asked to pilot a UAS along a predetermined route of flight while responding to various system failures. They had to monitor traffic in the area and, at set times during the flight, determine the relative position of the aircraft to a specific location. It was expected that the visual/auditory level of sensory information would be superior to the visual-only level, and that participants would respond to system failures more quickly when they received both a visual and auditory failure cue. For the two levels of automation, it was expected that the more automated condition would lead to a certain level of complacency for the participants, thus inducing slower responses to system failures and perhaps poorer performance at monitoring traffic. Finally, participants with manned-aircraft experience were expected to be better at determining the relative position of the aircraft and, because of a more effective scan, detecting system failures in the visual-only condition.

METHOD

The study was conducted at the Federal Aviation Administration (FAA) Civil Aerospace Medical Institute (CAMI), Human Factors Laboratory in Oklahoma City, OK.

Table 1. Participant demographics by level of flight experience.

Flight Experience	Mean Total Flight Hours (Median)	Mean Flight Hours Last 90 Days	Mean Age (Median)	Gender: Males (Females)
Non-pilot	0	0	23.6 (23)	7 (9)
Pilot	675.2 (265)	22.5	28.4 (23)	12 (4)

Figure 1. UAS control station simulation used in the experiment.

Participants

Thirty-two participants were recruited from the local Oklahoma City metropolitan area. Of the 32 participants, 16 had flown as pilot-in-command (PIC) of a manned aircraft and held at least a private pilot certificate. The lowest level of manned flight experience was 73 hours; the highest was 3,000 hours. The other 16 participants had no flight experience. All participants were asked to fill out a demographics questionnaire prior to the start of the experiment. Table 1 summarizes these demographic data for each of the two groups.

In addition, participants were asked about their experience with UAS, radio-controlled aircraft, and computer gaming. None of the participants had any UAS experience. Four participants (three non-pilots, one pilot) had flown radio-controlled aircraft. However, the most experience for any one participant was 20 hours. The level of gaming experience was relatively low, with most participants (23) stating that they played games either "a few times a month" (14) or "none" (9).

Apparatus

An unmanned aircraft simulation was created using Microsoft Flight Simulator 2004© (MFS04) as the flight model. A separate, generic UAS pilot control station was developed using a commercial software package that allows flight variables to be read from and written to MFS04. This software package is the Flight Simulator Universal Inter-Process Communication (FSUIPC) package.

Using the Visual Basic 6.0 software development environment, a UAS control station simulation was developed that could control an aircraft within MFS04 through the FSUIPC software module. Any aircraft flight model that can be hosted within MFS04 can be controlled using the UAS simulation if the aircraft has an autopilot. However, for this experiment, we utilized a Cessna 172 flight model.

Figure 1 presents a picture of the control station. The control station simulation provides for three types of aircraft control. Manual control can be accomplished through use of the throttle and joystick. Vector control is done using the mouse and onscreen buttons for changing the altitude and heading of the aircraft. Waypoint control is accomplished by entering a series of waypoints on the moving-map display and establishing altitude settings for each leg of the flight. For this experiment, only vector and waypoint control schemes were used.

The ground control station display interface for the experiment consisted of a moving map display that depicted ownship, flight waypoints and segments, and air and ground traffic. Two check boxes were available to remove the air traffic and/or ground traffic from the display. Several boxes contained flight parameters and radio settings; two boxes indicated the commanded heading and altitude of the aircraft. There was also a box that indicated the datalink status and was color-coded as green, yellow, or red, with red indicating a failure of the datalink. The pilot/operator could change aircraft heading and altitude by using a mouse to click on command buttons. Heading and altitude values could also be entered using a keyboard, but this method of interaction was not shown to the pilot/operator for this experiment.

The interface indicated the current flight segment. When the aircraft came within 0.8 miles of the next waypoint, the flight segment number was increased by one. When the aircraft was being flown by waypoint control, new heading and altitude values were automatically placed in the command boxes by the system. Under vector control, the segment number increase prompted the pilot to input new heading and altitude values in the command boxes. Above the moving map display, there was a box labeled "Flight Technical Error," indicating the distance of the aircraft from the current flight segment. An increasing value in the box meant that the aircraft was flying away from the segment, and a decreasing value indicated the aircraft was flying toward the segment. The user could place the cursor on an object in the moving map display and two boxes depicted the distance of the object from ownship and the bearing to that object.

There were potentially four types of failures that could be introduced by the experimenter during a flight. These were a loss of datalink, an altitude control failure, a heading control failure, and an engine failure. For the current experiment, only two of the four failure types actually occurred. These were the heading control failure and engine failure. Each failure was accompanied by a visual warning. This warning, except for the datalink failure, was that the appropriate aircraft parameter readout numbers (altitude, heading, or engine revolutions per minute) turned red. A datalink failure was indicated by the datalink status box turning red. There could also be an auditory alarm. The same alarm (a continuous beeping sound) was used for each of the warnings. In addition, participants could also hear simulated engine noise at the discretion of the experimenter. Participants were given either a visual warning only or a visual warning accompanied by an auditory alarm. In addition, participants receiving the auditory alarm could also hear engine noise during the experiment.

For each failure, the proper response for the failure was to press a corresponding "recovery" button located below each flight parameter box (in the case of altitude, heading, or engine failures) or to the right of the datalink status box. After pressing one of the "recovery" buttons, a "recovering" message was displayed below the button to indicate that the system was recovering, even though the alarm might still be activated. The "recovering" message was needed because the system required several seconds to reduce the difference between the commanded heading or altitude and the actual heading or altitude. When heading or altitude changes were commanded, the alarm could be triggered, but the user was instructed that the presence of the "recovering" message indicated that no failure had occurred. Because of the trivial nature of failure recovery, this behavior was thought to add some complexity to the interface to make it more consistent with actual control station complexity.

Materials

Several items were developed for the experiment. A participant consent form was constructed explaining the experiment and the requirement to remain seated for approximately 1 hour during the experiment. An experimenter instruction page was developed to read to the participants. A demographics questionnaire was created to gather information regarding age, gender, flight experience, unmanned aircraft experience, radio-control aircraft experience, and computer-gaming experience. The experimenter instruction page and demographics questionnaire are reproduced in Appendix A. A page with an analog clock face was used to explain the designation of relative position information. For non-pilots, a heading indicator depiction was used to explain the concept of heading and what it meant to fly a heading. An experimenter checklist was developed to track experiment setup and conduct, including the introduction and order of failures, relative position responses, and sighting of traffic. Finally, a post-test questionnaire was created to gather workload estimates, subjective impressions of the display interface, and participant comments regarding the experiment. This questionnaire can be found in Appendix B.

Procedures

Participants were tested one at a time. Each participant was brought into the simulation lab and asked to read and sign the consent form. They were then asked to fill out the demographics questionnaire. After completing the questionnaire, participants were read a set of instructions regarding the experiment. Participants were told they would be the pilot of an unmanned aircraft. In the automated flight condition, their task would be to simply monitor the aircraft and potentially respond to failures. In the vector-control condition, their task would require making heading and altitude changes to the aircraft during the flight to maintain its progress along a predetermined route of flight and potentially respond to failures. Participants then received training regarding the control station interface and were briefed about potential failures and the appropriate responses to those failures. They were also told that they would be asked to indicate the relative position of locations from the aircraft. Finally, they were instructed to watch for air traffic and to call out traffic that came within 5 miles horizontally and 1,000 feet vertically of their aircraft.

After receiving their instructions, participants practiced a flight scenario. The practice scenario consisted of a flight of three waypoints, requiring one turn by the aircraft. Any confusion regarding the task or interaction with the control station was corrected, and the participants then flew the experimental scenario. The experimental scenario was a flight of four waypoints (three flight legs). The total length of the flight was approximately 60 miles and took approximately 40 minutes to complete. Both the practice and experimental scenarios began with the aircraft in the air and ended before reaching the final waypoint.

During the course of the experimental scenario, four failures were introduced. Two of the failures occurred during the second flight leg, and two failures occurred during the third flight leg. The only failures that occurred were a heading control failure and an engine failure. The order of the failures was counterbalanced across participants and conditions. Between each failure on each leg, the participant was asked to estimate the relative direction of the starting point of the flight.

After completing the experimental scenario, participants were asked to fill out a workload estimate based on the NASA TLX subjective workload scale (Hart & Staveland, 1988). NASA TLX is a six-item questionnaire measuring mental demand, physical demand, temporal pressure, perceived performance, total mental and physical effort, and frustration level. Participants scored their workload on two tasks, piloting the aircraft and responding to failures. Each scale was scored on a seven-point metric by marking a point along a line representing each scale. Participants also scored their subjective assessment of the complexity of the user interface and the difficulty of identifying a failure along the same seven-point metric. Participants were debriefed and released upon completing the questionnaire.

RESULTS

Responding to Failures

Two significant findings appeared in regard to responding to failures. First, the proportion of participants that failed to respond to an engine failure within 5 seconds was significantly greater when no sounds (auditory alarm or engine noise) were present in the control station, $\chi^2 = 4.57$, $p = .033$. Twenty-five percent of the participants failed to respond within the 5-second interval when no sounds were present in the control station as opposed to none when sounds (both auditory alarm and engine noise) were present. Neither the level of automation nor level of pilot experience had any significant effect on response to an engine failure.

The second significant finding was that the proportion of participants responding to a heading control failure before the visual failure warning occurred was significantly greater if the participant was an experienced pilot and no auditory warning was present, $\chi^2 = 9.93$, $p = .019$. Three of eight pilots in the no-sound condition (38%) pushed the heading failure recovery button before the failure warning had occurred, as opposed to zero pilots in the sound condition, and zero non-pilots in either the sound or no-sound conditions.

In regard to responding to heading control failures, participants received the following instructions: "If the heading control fails during the flight, the actual heading will begin to drift away from the commanded heading. Once the actual heading and commanded heading differ by 10 degrees or more, the actual heading numbers will turn red and an alarm will sound." Note that the auditory alarm instructions were provided only to those participants who were given both a visual and auditory failure warning.

Flight Control Accuracy

The initial heading of the aircraft at the beginning of the experimental scenario was approximately 3 degrees left of the heading required to fly directly to the second waypoint. If the pilot/operator did not make corrections to the heading, the aircraft would miss the second waypoint by approximately 0.8 miles. Somewhat unexpectedly, several of the non-pilot participants did not make any corrections to the heading of the aircraft during the initial leg of the flight. However, all of the pilots made the appropriate corrections. This led to a finding that the technical flight error for non-pilots was much higher than the technical flight error for pilots during the first leg of the flight, for those participants in the manual flight condition. Of course, for those participants in the automated flight condition, appropriate corrections to

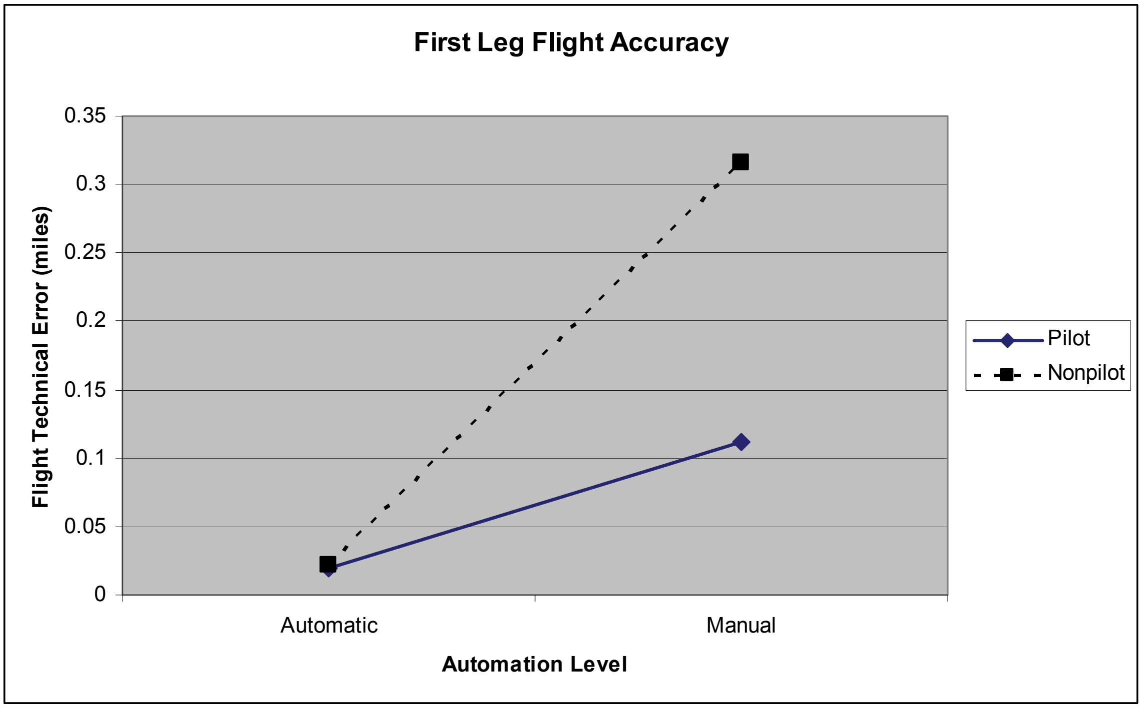

Figure 2. Flight technical error during the first flight leg.

the heading were accomplished by the system. These differences can be seen in a plot of the flight technical error measures for the first flight leg (Figure 2).

An analysis of variance of these data demonstrated a significant automation level by experience level interaction, $F(1,24) = 7.892$, $p = .01$. In addition, both the main effects for automation level and for pilot experience level were significant, $F(1, 24) = 29.24$, $p < .001$, and $F(1, 24) = 8.255$, $p = .008$, respectively. As can be seen in Figure 2, automated flight control was more accurate than manual flight control. In addition, for the manual flight control condition, pilot flight accuracy was better than non-pilot flight accuracy.

A similar finding appeared for the second leg of the flight as well. Several of the non-pilots did not make corrections to the heading of the aircraft after entering an initial heading change at the waypoint. In addition, after the heading control failure, and once the aircraft had recovered its commanded heading, many non-pilots made no corrections to account for the aircraft straying off course. None of the pilots exhibited this behavior.

A fairly simplistic algorithm was used for the automated flight mode. This algorithm triggered a turn to a new waypoint when the aircraft got to within 0.8 miles of the previous waypoint. For the second leg, because the turn to the leg was shallow, the automated flight mode was less accurate than the first leg. As can be seen in Figure 3, pilots flying manually were more accurate than the automated flight mode for the second leg. An analysis of variance of the flight technical error for the second leg found a significant automation level by experience level interaction, $F(1, 24) = 4.932$, $p = .036$. The main effect for pilot experience level was also significant, $F(1, 24) = 4.638$, $p = .042$. However, the main effect for automation level was not significant.

As can be seen in Figure 3, pilots flying in manual mode were significantly more accurate than the non-pilots. Of course, there was no difference between pilots and non-pilots in automatic mode. This accounts for the significant interaction effect that was found.

Interacting With the Display

Although display interaction was limited for all participants, especially those in the automated condition, it was possible to change the zoom level of the moving-map display during the flight. For each participant, an assessment was made of the level of zoom manipulation performed (high or low). Low levels of zoom manipulation meant that the zoom level was rarely changed during the flight or not at all. High levels of zoom manipulation occurred usually when the participant was attempting to fly the aircraft as close to the flight path as possible.

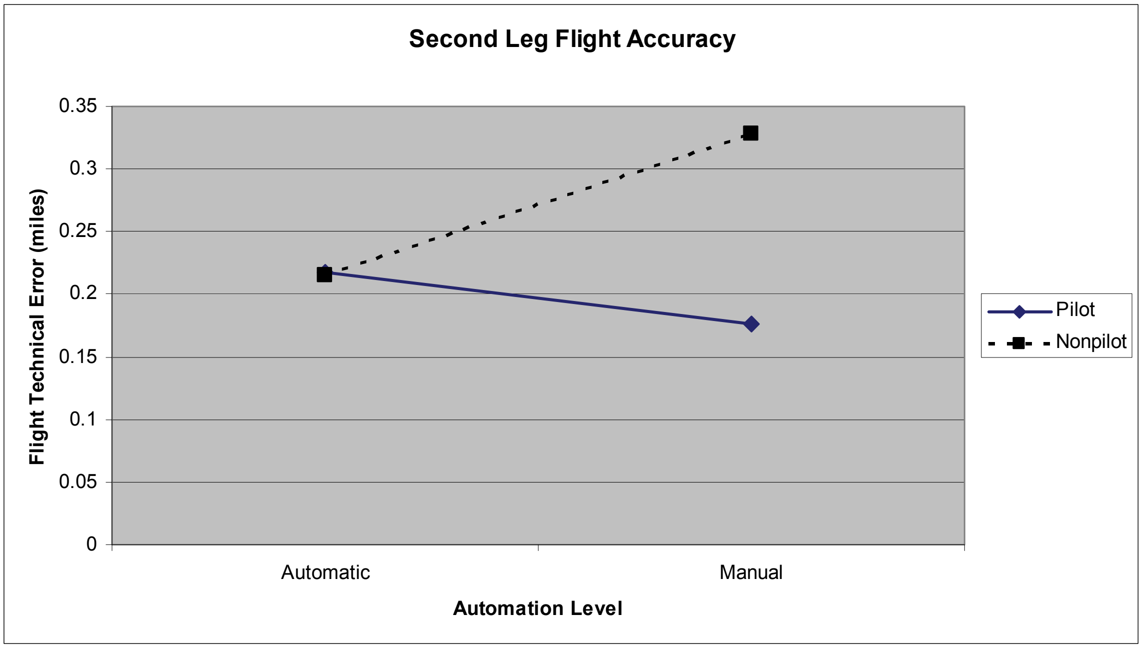

Figure 3. Flight technical error during the second flight leg.

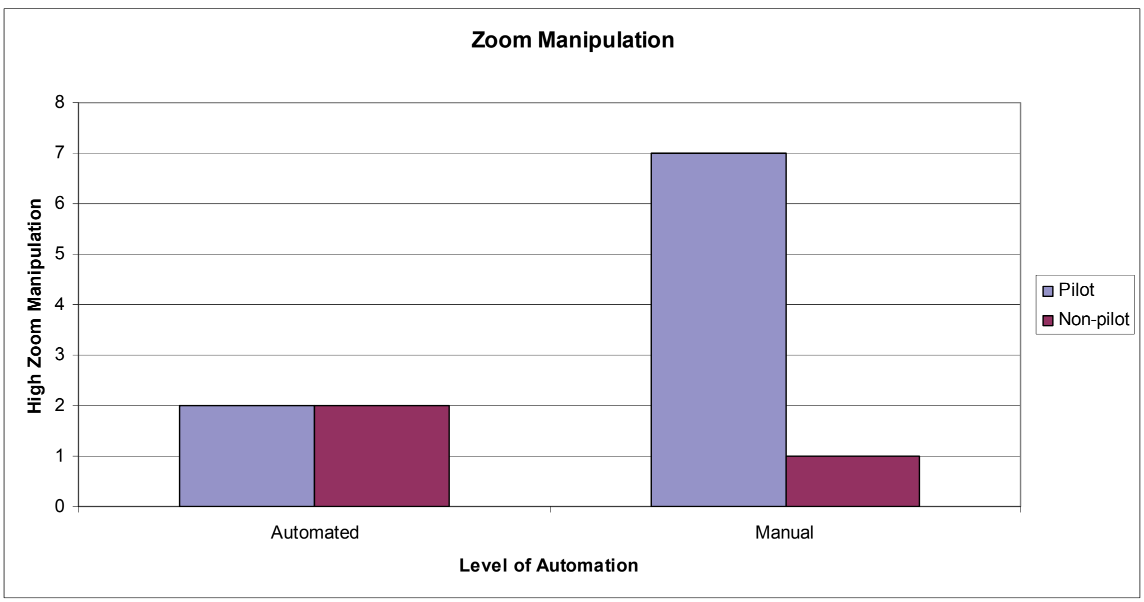

Figure 4. Number of participants with high levels of zoom manipulation.

Results, seen in Figure 4, show that pilots in the manual condition tended to manipulate the zoom more than participants in the other conditions, $\chi^2 = 11.73$, $p = .008$. This higher level of zoom manipulation was reflected in the lower flight technical error scores discussed above.

Monitoring Traffic

No statistical differences in the ability to monitor traffic were found. One pilot and one non-pilot failed to call out traffic that came within 5 miles horizontally and 1,000 feet vertically of the aircraft. In addition, one pilot and two non-pilots called out traffic that was outside the prescribed parameters. The pilot that failed to call out the traffic had set the zoom level of the moving map display to 1 mile (while attempting to reduce flight technical error) and failed to see the impinging traffic. The non-pilot, on the other hand, had the traffic visible on the moving-map display but was apparently focused on a different portion of the screen.

Awareness of Relative Position

No statistical differences in awareness of relative position were found. Participants, in general, understood the concept of "o'clock" position and could accurately estimate the direction to a specific location (starting waypoint) from the current position and heading of the aircraft.

Workload and Other Subjective Estimates

After completion of the flight, participants were asked to provide subjective estimates of workload related to piloting the UAS and responding to failures. In addition, they were asked the questions, "How complex was the user interface?" and "How difficult was it to identify a failure?" Responses were along a seven-point scale, with higher numbers indicating higher workload, complexity, or difficulty. Because the task was fairly simple, it was expected that many of the six workload scales used for the NASA TLX would not yield any differences across conditions. One exception was the scale for temporal demand. The description for the temporal demand rating scale is, "How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?"

Results showed a significant difference in temporal demand, both in piloting the UAS and in responding to failures due to a difference in the level of automation, $F(1, 24) = 6.744$, $p = .016$ and $F(1, 24) = 5.825$, $p = .024$, respectively. No other main effects or interactions reached significance.

An analysis of the responses to the question, "How difficult was it to identify a failure?" showed no significant differences for any of the factors or their interactions. However, an interesting pattern of responses was found for the question, "How complex was the user interface?" Both the main effects of type of sensory information and pilot experience level were significant, $F(1, 24) = 9.035$, $p = .006$ and $F(1, 24) = 4.271$, $p = .050$, respectively. That is, participants almost always judged the interface to be higher in complexity when there was no sound available. The interface was judged to be less complex when sound, including engine noise, was available. Also, non-pilots judged the interface to be more complex than pilots under most conditions. There was a significant experience level by sensory information interaction, $F(1, 24) = 4.271$, $p = .050$. Finally, there was also a significant three-way interaction as well with $F(1, 24) = 5.965$, $p = .022$. Figures 5a and 5b show this interaction.

A summary of this three-way interaction effect is as follows. Comparing Figure5a and 5b, we see that pilots generally rated the interface as less complex than did non-pilots, and that the presence of sound also reduced the complexity, except in the automated condition where the presence of sound reduced complexity only for the non-pilots. The presence or absence of sound had little effect on ratings of complexity for pilots in the automated condition.

DISCUSSION

Flight simulation experiments quite often introduce potentially confounding variables by requiring pilot actions and decisions beyond what is of interest in the experiment. This is especially true with simulations that duplicate the control interfaces of specific systems. Because of this lack of control, it is difficult to assign causal statements to many of the results.

The notion that simply adding a second type of sensory information (sound) would increase the ability of pilots to identify and respond to failures was not supported in the current study. While the presence of sound did improve responses to engine failures, it did not improve responses to failures in heading control. One difference between the engine failure cues and heading control failure cues was the presence, in the condition where sound was used, of engine noise in addition to the auditory warning. Unfortunately, it is not possible to determine whether this additional sound cue was the cause of the difference in responding to the failures. It is possible that one reason that differences in sensory information did not affect the ability to identify heading control failures is that much of the task involved making heading changes, at least in the manual condition, so participants were more focused on the heading information and more aware when the commanded and actual heading started to diverge. Nevertheless, the results of the experiment support the long-accepted notion that multiple modes of information are more effective than a single mode, especially for flight parameters that are not monitored constantly (e.g., Kantowitz & Sorkin, 1983).

In addition to its effect on responses to system failures, the presence of sound also had an effect on the subjective estimates of the complexity of the user interface. In general, participants had the impression that the interface was more complex when no sound was available. The exception was pilots in the automated condition, where the presence or absence of sound had no impact on their perceptions of complexity. Why this would affect perceptions of user-interface complexity is not clear. However, it could be that participants perceived the overall task to be more easily accomplished with the presence of sound, even though objective measures of performance only supported the response to engine failures.

The prediction that higher levels of automation would lead to complacency or vigilance decrements, that is, a lack of focus on the task, was not supported in the current experiment. Perhaps the relatively short flight used for the experiment (approximately 40 minutes) did not allow for an effect to occur. However, Parasuraman et

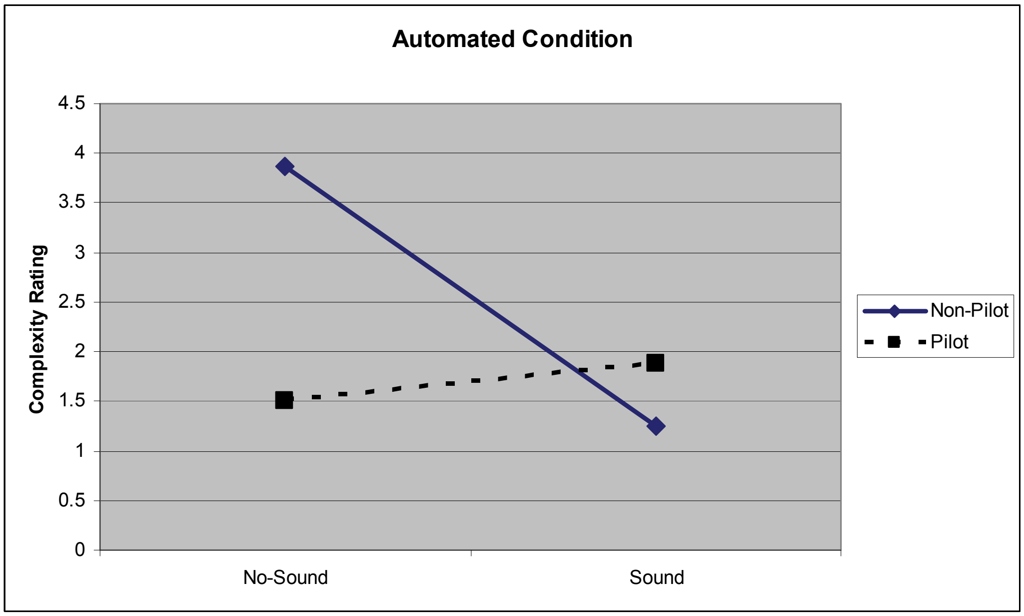

Figure 5a. Complexity rating as a function of experience level and sensory information for the automated condition.

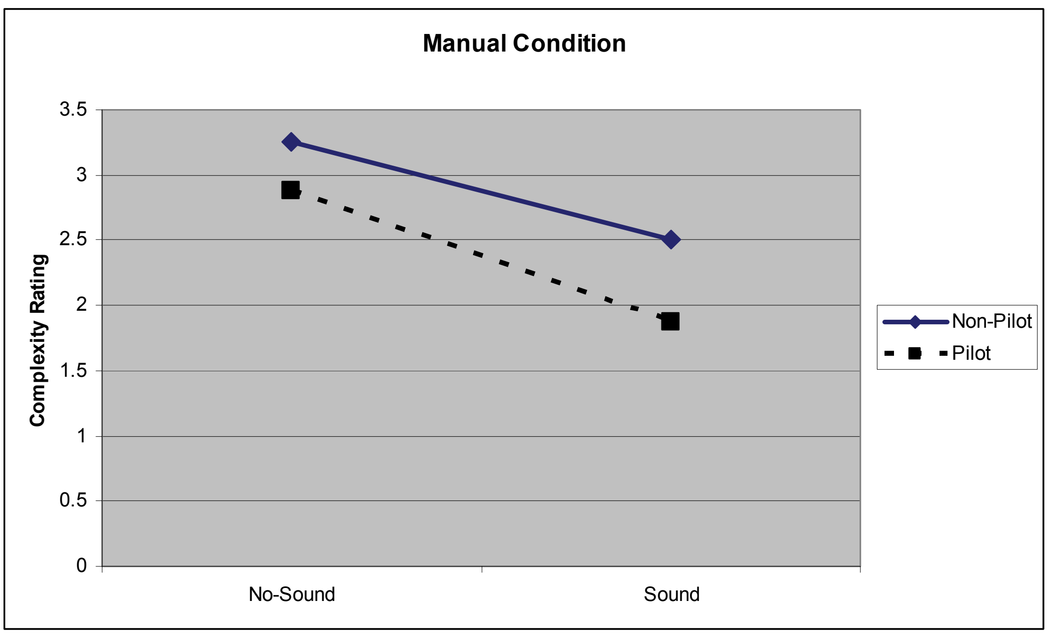

Figure 5b. Complexity rating as a function of experience level and sensory information for the manual condition.

al. (1993) suggest that complacency, at least, is not a function of time as much as it is a function of variability in automation reliability. In that study, complacency effects were evident after only 20 minutes of monitoring. Constant levels of automation reliability were shown by Parasuraman et al. to lead to higher levels of complacency. However, a constant level of automation reliability in the current experiment did not result in complacency effects. Perhaps the relatively simple nature of the task attenuated any effects due to differences in automation.

Although the predicted effects of automation in regard to complacency or vigilance decrements were not supported, other effects of differing levels of automation occurred. As expected, a higher level of automation led to lower estimates of subjective workload. This was reflected in the flight-technical-error performance findings that showed superior flight performance, in general, for participants in the high-automation condition.

The manipulation of manned aircraft experience levels resulted in some significant findings but not for the tasks where differences were expected. Participants with manned aircraft experience did not perform any better at monitoring traffic or in estimating relative direction than those without flight experience. However, there were some interesting differences between pilots and non-pilots that bear closer examination in the performance of the tasks.

The finding that pilots, in the manual conditions, flew significantly closer to the flight path than non-pilots was unexpected. It is difficult to believe that only the pilots noticed that the aircraft was deviating from the flight path during the first flight segment, so the question is why some of the non-pilots did not attempt to correct the deviation. Because it occurred suggests individual differences between the pilots and some of the non-pilots could be due to either training or are innate traits that contribute to success as a pilot. If manned aircraft training and/or experience leads to more responsive flight-path control, it would be important to identify what portion of the training was responsible. Interaction with onboard automated systems might have contributed. Unfortunately, pilots were not questioned regarding their experience with onboard automation. It would be interesting to see if the addition of a more manual mode of flight, such as joystick control, would still show these pilot/non-pilot differences.

One reviewer has suggested that the non-pilots were less responsive to flight path control because of their low level of gaming experience. However, the pilots also reported low levels of gaming experience. Even so, if a lack of gaming experience contributed to the behavior, there is still a question regarding how such experience is similar to manned flight training. The question is important in regard to whether or not manned aircraft training is important for the piloting of unmanned aircraft.

A second unexpected difference between pilots and non-pilots in the study was in the response to heading-control failures. A significant proportion of pilots responded to the heading failure before the warning for the failure was presented, based on a recognition of the actual heading drifting away from the commanded heading. However, this occurred only in the no-sound condition. The presence of an auditory warning for pilots actually seemed to inhibit a response to a heading failure. None of the non-pilots responded early to the heading control failure, regardless of the warning condition. For both pilots and non-pilots, it was clear that some of the participants noticed the heading failure early but waited for the warning by positioning the cursor over the heading recovery button. Again, there are questions of whether individual differences allowed some of the pilots to respond early, why the presence of a sound cue would prevent this response, and whether training or other factors were involved in the differences between the groups.

In conclusion, the presence of sound cues in addition to visual cues was helpful for the recognition of engine failures, but auditory warnings were not necessarily useful for information that was constantly being monitored by the pilot, like aircraft heading. In addition, more research is required in regard to the question of the effect of manned aircraft experience on the piloting of unmanned aircraft. The results of the current experiment suggest differences between those with manned aircraft experience and those without, but it is unclear whether these differences are due to manned aircraft training and flight experience or whether other factors, such as personality, may be evident. Identifying the cause of these differences could affect training and/or selection requirements for pilots of unmanned aircraft systems.

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Appendix A

Subject Instructions for UAS Experiment

Welcome. In this study you will be asked to be the pilot of an unmanned aircraft system. Your task is to monitor the flight and, unless the flight control is automated, make heading and altitude changes to the aircraft during the flight to maintain its progress along a predetermined route of flight. Monitoring the flight will consist of tracking heading, altitude, engine rpm, and datalink status of the aircraft. There are potentially four types of failures that could occur during the flight. If the datalink is lost for more than 5 seconds, an alarm will sound. If the altitude control fails during the flight and the altitude varies from the commanded altitude by more than 450 feet, an alarm will sound and the altitude readout numbers will turn red. If the heading control fails during the flight and the heading varies from the commanded heading by more than 10 degrees, an alarm will sound and the heading readout number will turn red. If the engine power fails during the flight and the engine rpm drops below 2000, an alarm will sound and the RPM readout number will turn red. For each of these failures, the proper response for that failure will be to press the corresponding "recovery" button.

In addition to this task, the experimenter will ask you to estimate your relative position to a specific location at various times during the flight. Your response to this request should be an "o'clock" position indicating the relative position from the aircraft to that location. To properly answer the question, you must take into account the direction that the aircraft is flying in addition to the location of the position. If the location is directly in front of the aircraft, the answer would be "12 o'clock." If the location is to the right of the aircraft's path of flight, the correct answer would be "3 o'clock." In each case the answer would be relative to someone actually flying in the aircraft. This task can be confusing because if the aircraft is flying south, left and right of the aircraft are reversed from someone looking at it from the outside. Keep that in mind as you answer the question.

Questions? If not, let's take a look at the control interface, and I will explain the details of what you will see on the screen.

Demographics Questionnaire

Participant Number ___________ **Date________**

Instructions: Indicate your response to the following questions by filling in the blank or checking the circle or square corresponding to the response option of your choice.

FLIGHT EXPERIENCE

1. Have you ever piloted an unmanned aircraft system (excluding radio-control hobby aircraft)?
___Yes ___No

2. If Yes, what systems have you flown (please list)

____

____

3. If Yes, what is your total flight time as pilot of unmanned aircraft in hours approximately?

____

4. Do you have any experience as pilot-in-command of a (manned) aircraft? ___Yes ___No
If no, please skip to the next section on radio-controlled aircraft (RC) experience.

5. How long have you been a certificated pilot? ____ *years*

6. What is the highest certificate you hold?

- Student
- Sport
- Recreational
- Private
- Commercial
- Airline Transport (ATP)

7. What ratings do you hold? *[Mark all that apply]*

- Single-engine Land or Sea
- Multi-engine Land or Sea
- Rotorcraft (helicopter/gyroplane)
- Lighter than air
- Flight Instructor (CFI, CFII, MEI)
- Instrument
- Other (please specify)

8. Please list your **Pilot-in-Command (PIC)** time (Estimate and round to the nearest whole hour.)

		PIC Flight Time (Hours)	
	Last 90 Days	**Instrument**	**Total PIC**
All aircraft....................................	______ Hrs	______ Hrs	______ Hrs

RADIO-CONTROLLED AIRCRAFT EXPERIENCE

9. Have you ever flown a radio-controlled aircraft? ____Yes ____No

10. If yes, how many hours of flight experience (approximately) do you have? ________

GAMING EXPERIENCE

11. How often do you play computer games? ____ every day ____ few times a week ____ few times a month ____ none

12. What types of games do you play (check all that apply) ____ first person shooter ____role playing

____ word or board games ____Other (please specify)

____

13. Age ____ 14. Gender ____ M ____ F

Appendix B
Post-test Questionnaire
Task – Piloting the UAS

MENTAL DEMAND

Low High

PHYSICAL DEMAND

Low High

TEMPORAL DEMAND

Low High

PERFORMANCE

Good Poor

EFFORT

Low High

FRUSTRATION

Low High

Appendix B (continued)

Task – Responding to Failures

MENTAL DEMAND

Low High

PHYSICAL DEMAND

Low High

TEMPORAL DEMAND

Low High

PERFORMANCE

Good Poor

EFFORT

Low High

FRUSTRATION

Low High

Rating Scale Definitions

Title	Endpoints	**Descriptions**
MENTAL DEMAND	**LOW/HIGH**	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	*LOW/HIGH*	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	**LOW/HIGH**	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
PERFORMANCE	*GOOD/POOR*	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
EFFORT	*LOW/HIGH*	How hard did you have to work (mentally and physically) to accomplish your level of performance?
FRUSTRATION LEVEL	*LOW/HIGH*	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

How complex was the user interface?

Low High

How difficult was it to identify a failure?

Easy
Difficult

Comments?

Thanks for your participation.