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Alternative UAV Sensor Control: Leveraging Gaming Skill

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The U.S. Army Aeroflightdynamics Directorate (AFDD) conducted a study on alternative unmanned aerial vehicle (UAV) sensor operator input devices for next generation operators and assessed the gamer skill set as it related to advantages in UAV operations. Six highly rated pilots and six experienced video game players were tested while utilizing three different operator sensor control devices. Participants flew UAV reconnaissance missions on pre-set routes, identifying all targets and distractors. Subjective ratings were collected to determine any variances in operator workload between devices. Results showed performance advantages in both skill sets when using an alternative sensor control design, favoring reduced mental translation for operator input. Overall, possessing the gamer skill set enhanced mission performance and mitigated perceived workload.

Introduction

UAVs are increasing in use and capabilities. As they do so, Human Systems Integration (HSI) issues related to the operator-vehicle interface become increasingly important. This is especially true if the operator is already engaged in a high workload environment. The following study evaluates HSI issues that emerged when a UAV was controlled from a helicopter cockpit.

The US Army project, Airborne Manned-Unmanned Systems Technology – Demonstration (AMUST-D) demonstrated control of a tactical, fixed-wing Hunter UAV from an Apache Longbow helicopter (Boeing, 2006). AMUST-D successfully demonstrated level 4 control (airborne control of both the sensor and the platform). The Hunter UAV was under control of the co-pilot gunner, who was not flying the helicopter, but performing normal mission management tasks. The UAV sensor imagery was displayed on the Optical Relay Tube (ORT) and was operated with the same controls that were used to control the helicopter's own sensors. A thumb force controller was used to slew the UAV imaging sensor. This caused the motion of the sensor to be very sensitive, resulting in many overshot targets.

Control Devices

This study began as a follow up to AMUST-D to look at alternative operator input devices for UAV image sensor control. Several types of operator control devices were considered. The sensor control task is essentially a cursor control task. This task has been studied in the context of data entry (Shively, 1985) and text editing (Garrison, 1993). These studies have evaluated devices including light pens, touch-screens, keyboards, as well as different types of mouse control. One common finding among these studies was that the more translation required from one reference system to another, the more difficult the device was to use. For example, touch screens needed no translation and so have reduced errors and faster reaction times. Likewise, a mouse control device can be quite useful since it has a straightforward translation from horizontal to vertical planes. In the right context, each control device may have beneficial application. In this investigation, an attempt was made to reduce the device to display translation. Thus, a 3D Connexion SpaceBall was selected because it hypothetically required less mental translation. Specifically, operators placed his/her hand on the SpaceBall and moved it in a manner physically analogous to the payload camera gimbaled motion. In this way, translation was minimal due to the direct analogy of hand movement on the SpaceBall to actual payload movement.

Current military pilot training is finding some inspiration from the video game community (Bourge & McGonigle, 2006; Gomes, 2002; and Pappalardo, 2004). In fact, the Marine Corps Warfighting Lab has modeled some of their robotic devices after the PlayStation 2 controller "because that is what these 18-20 [something] soldiers have been playing with pretty much all of their lives" (Gomes, 2002). Similar to UAS operations, many video games require players to understand objects in the viewed environment and to perform fast-paced activities that require efficient interaction (Richer & Drury, 2006). For these reasons, along with the understanding that current Army UAV operators are exposed very early to video games, a Sony PlayStation 2 controller was also selected for evaluation.

A standard joystick, very familiar to pilots, was selected as the "baseline" condition. The researchers did not have access to the ORT thumb force controllers from the Apache in the AMUST-D study, however this was chosen as reasonable emulation of the baseline controller. The joystick is also similar to controllers used in UAV ground stations. These three controllers; SpaceBall, PlayStation 2 and a joystick were evaluated as UAV sensor controllers in the present study.

Skill Set

The video game industry is extremely large and active in today's economy, accounting for investments of almost $2 billion by 2008 according to the Strategic Research Institute (SRI, 2007). A large portion of this investment is made by teenage boys and girls (which is essentially the same population from which the Army draws its UAV operators). Initial purchases are typically followed by hours and hours of practice or what could be called training on these systems, and specifically on the controllers which develop specific skill sets on video games.

Given apparent similarity between today's UAV ground stations and many video games, the question becomes: Can this gaming skill set be leveraged when designing UAV control stations? To begin to answer this question, participants with considerable video game experience (gamer skill set) were compared with experienced pilots (pilotage skill set).

The following study evaluated sensor control devices and the potential of leveraging video game skill sets in the context of a UAV reconnaissance mission.

Method

Participants

Participants were recruited on the basis of skill set: Pilot or Gamer. A total of 12 participants were tested in this study. Six of the 12 participants were pilots (5 U.S. Army pilots and 1 commercial pilot). The pilot population (M = 48.7 yrs.) averaged over 3,000 hours of commercial flight time and over 3,200 hours in military flight operations. The other 6 participants (M = 34.2 yrs.) were highly skilled gamers who averaged at least 10 hours of video game playing per week.

Simulation Equipment

The UAV Simulator (USIM) residing in the U.S. Army AFDD laboratory was used for this study. The USIM was modeled after the U.S. Army's Shadow tactical UAV. The simulation was generated with a Dual Pentium Processor with a BFG Technologies GeForce 7800 graphics card and 3 GB RAM. USIM consists of the sensor view, a mapview (the top-down view of the map showing the aircraft and all the waypoints), and the operator interface containing standard UAV controls and displays.

Sensor Control Devices

Three sensor control input devices were evaluated in this study (Figure 1). The current mode of sensor control was used as a baseline (joystick) for the experiment. Additionally, two alternative input devices were evaluated as possible candidate solutions for sensor control (Playstation and SpaceBall). A description of each device follows.

Joystick. Currently used in U.S. Army UAV ground control stations, the joystick has been the default solution for sensor payload control. Specifically, joystick movement controlled the sensor pan and camera depression angle. For this evaluation, the thumb lever located on a BG Systems Flybox joystick controlled zoom capability. The joystick trigger was used for designating targets. Yellow buttons located on the flybox base were used for marking distractors and performing the secondary task.

Figure 1. Joystick, 3D Connexion SpaceBall 5000, Sony Playstation 2 Dualshock Controller (left to right)

SpaceBall 5000. Utilizing digital 3D sensing technology, the 3D Connexion SpaceBall 5000 was evaluated as an alternative sensor control device. This device is used primarily in 3D computer-aided design and some advanced gaming. The SpaceBall is pressure sensitive and requires right/left and up/down twisting motions to control the position of the sensor camera. Forward/backward control inputs actuated changes in the camera field of view (FOV). For this experiment, left hand inputs to buttons located on the base of the SpaceBall effected target designation, distractor designation, and secondary task performance.

PlayStation 2. Borrowing from current gaming technologies, the Sony PlayStation 2 Dualshock Controller was evaluated as a candidate sensor control input device. It was hypothesized that synergy between Playstation device and gaming expertise might impact speed of sensor control, possibly yielding faster searches across the UAV center line. For this experiment, left thumb input to the "hat" control on the Playstation moved the sensor camera in elevation and azimuth, while the R1 and L1 buttons were used for increasing and decreasing FOV (zoom). The "X" button was used to designate the targets. The "o" button was used to mark distractors. Lastly, participants used the "m" for acknowledgements on the secondary task.

Evaluation Scenarios

The primary task for each participant was to conduct a reconnaissance-like mission, accurately and rapidly detecting and designating all vehicles encountered. Each scenario had 120 vehicles randomly located along a prerecorded flight path. The participant's task as mission payload operator was to manipulate the UAV sensor in order to detect and classify vehicles, marking each as an enemy or distractor. Two buttons on each control device were dedicated to the classification of enemy and distractor vehicles. Once the participant marked an enemy vehicle, a red circle appeared around the target vehicle. Alternately, a white circle appeared around vehicles marked as distractors. Figure 2 shows an example of one of the three enemy vehicles types and one of the six distractor vehicle types. Perfect performance on the primary task was not expected due to limitations in the vehicle sensor range, targeting opportunity, and time limits given.

Figure 2. Enemy and distractor vehicle examples.

In addition, a secondary task was incorporated into the simulation to measure operator workload. Performance on a secondary task is commonly used as a workload measure to provide insight to any potential spare capacity beyond what is required for the primary task. (Cummings & Guerlain, 2004) Excelling on a secondary task when testing with a particular control device might suggest greater spare capacity and therefore infer lower operator workload when utilizing that device. In fact, variances in secondary task performances may support use of one control device over another in order to facilitate lower operator workload. A secondary task was embedded within the primary task of this experiment. Primarily, operators scanned the sensor view looking for vehicles as they secondarily monitored a visual "alarm" that flashed at randomly timed intervals. When the alarm occurred (15 times per mission), they pressed a button on the control device in acknowledgement. Reaction time and accuracy was recorded.

Experimental Design

A 2 x 3 x 2 (Skill x Device Type x Trial) mixed factorial design with repeated measures was conducted. Participants from both Pilot and Gamer skill sets used each of the three control devices in two mission trials. The devices used in each mission trial were randomly assigned to one of three nominal reconnaissance scenarios.

Test Procedure

All participants were trained on the three control device types and required to fly a ten-minute practice mission with each device. After training criteria were achieved, each participant completed six 10-minute missions. At the end of each 10-minute mission, the NASA-TLX was administered to assess the workload pressure felt while using each of the three control devices (see Hart & Staveland, 1988). Upon completion of the evaluation, participants were asked to answer a detailed subjective questionnaire referencing each control device.

Data Collection

Quantitative data and subjective measures were collected for all primary and secondary tasks. Primary task data collection included: cumulative correct and incorrect target/distractor designation, target/distractor designation misses, and frequency of sensor oscillations across the UAV center line. Secondary task data collection included: mean reaction time and mean frequency of secondary tasks completed. In addition, participants' subjective workload ratings were collected and analyzed using the NASA-TLX. Lastly, subjective comments and preferences on all experimental conditions were collected in a post-simulation questionnaire.

Results

A 2 x 3 x 2 mixed factorial two-way ANOVA (Skill x Device x Trial) was conducted separately on associated primary and secondary task data. Performance analyses for both primary and secondary tasks follow.

Performance Effects of Skill

Primary task. Analyses of targeting designation performance revealed an interaction between skill and device on the number of correctly identified targets and distractors (hits) throughout a mission, $F(2,20) = 10.44$, $p < .01$ (Figure 3). Further analyses showed performance differences by device across skill sets, only when using a Playstation device for targeting ($M_{Gamer} = 62$ hits > $M_{Pilot} = 29$ hits, $t(10) = 3.33$, $p < .05$. Number of correctly and precisely designated targets doubled when gamers used the familiar Playstation control device. No statistically significant differences existed between gamers and pilots in the baseline joystick or SpaceBall conditions, although gamers accumulated more average hits for each condition.

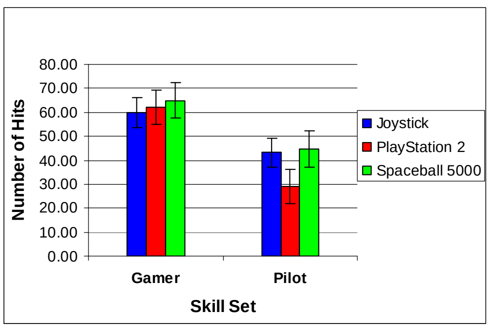

Figure 3. Mission hits: Skill x Device interaction

In addition, a significant main effect of skill (Figure 4) was found in the number of cumulative hits throughout a mission, $F(1,10) = 6.04$, $p < .05$. Specifically, gamers achieved higher numbers of hits across control device conditions than pilots, $M_{Gamer} = 62.31$ hits > $M_{Pilot} = 39.00$ hits.

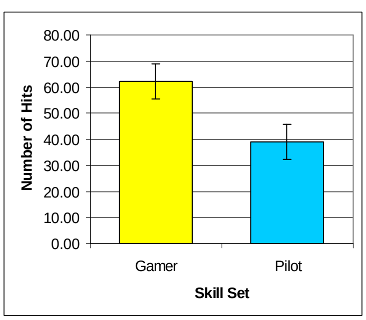

Figure 4. Mission hits: Skill main effect

In a review of target "miss" data and sensor oscillations, no significant effect of skill was found. Thus, in the primary task, peak performance in precise target designation was associated with gaming expertise, regardless of control device. Whereas, targeting performance was most impeded when a Playstation control input device was used by the pilot skill group.

Secondary task. No significant effects of skill were found in the secondary task data. Reaction time and frequency of secondary tasks attended was not statistically different for either skill set.

Performance Effects of Sensor Control Device

Primary task. In addition to the previously discussed skill x device interaction, a device main effect was found in target designation performance, $F(2,20) = 10.44$, $p < .01$ (Figure 5). In particular, missions flown using a Playstation control device ($M = 45.54$ hits) yielded significantly lower average hits than when a SpaceBall control device ($M = 54.92$) was used, $t(11) = 3.28$, $p < .01$. In planned pairwise comparisons, no performance differences were found between missions with sensors controlled by joystick versus SpaceBall or joystick versus Playstation, regardless of skill set.

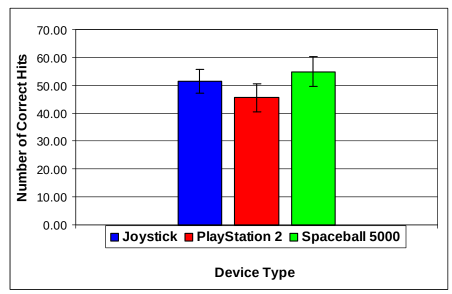

Figure 5. Mission hits: Device main effect

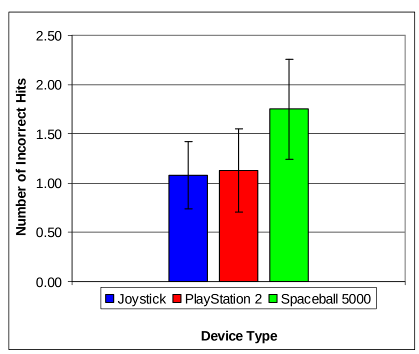

Figure 6. Device main effect on incorrect hits per mission

Analyses of targets misidentified, but precisely targeted ("incorrect hits") showed a main effect of device $F(2,20) = 3.70$, $p < .05$. Missions flown with sensor control by SpaceBall ($M = 1.7$ hits) yielded significantly larger incorrect hits than joystick ($M = 1.08$ hits) or Playstation ($M = 1.13$ hits) (Figure 6). Statistical significance between devices was found, however operational impact is unknown at this time. It is important to note that precise targeting must occur to register an incorrect hit. The operator failure is in identification, not targeting precision. Thus, targeting precision was supported with a SpaceBall control device, even if target identification was incorrect. Analyses of target "miss" data showed no significant effect of device.

In a review of sensor oscillation data, a device main effect was also found, $F(2,20) = 6.10$, $p < .01$ (Figure 7). Both pilots and gamers crossed the UAV centerline significantly fewer times when using a joystick for sensor control than either Playstation or SpaceBall ($M_{Joystick} = 14.38 < M_{SpaceBall} = 18.25 < M_{Playstation} = 19.75$). Conversely, pilots and gamers showed a greater number of scanning oscillations when joystick-alternative control devices were used.

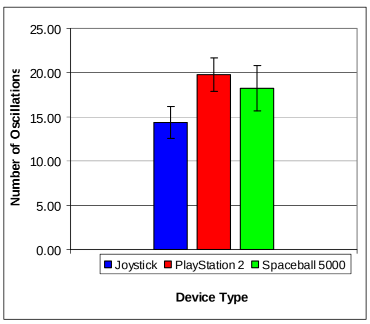

Figure 7. Sensor control oscillations: Device main effect

To summarize, for the primary targeting task, performance decrements were found when controlling the sensor with the Playstation. Also, participants had slightly more incorrect hits with the SpaceBall control device than joystick or Playstation. Lastly, control of sensor by both Playstation and SpaceBall was associated with more frequent sensor oscillations than the baseline joystick.

Secondary task. Results from the secondary task revealed a device main effect on participant reaction time to random alarms $F(2,20) = 5.14$, $p < .05$ (Figure 8). Participants showed significantly faster reaction times to the secondary task when using a joystick than Playstation, $t(11) = 3.12$, $p < .05$ or SpaceBall, $t(11) = 3.22$, $p < .01$. Secondary task reaction times did not significantly vary between Playstation and SpaceBall sensor control. When reviewing Playstation control across primary and secondary task performance, rapid reaction to secondary alarms using Playstation was moderated by lower average hits. It should be noted that design features of Playstation in the context of this experiment may have contributed to this performance tradeoff. Further details will follow in the Discussion section. No significant differences were found in the frequency of secondary tasks attended as a result of device manipulation.

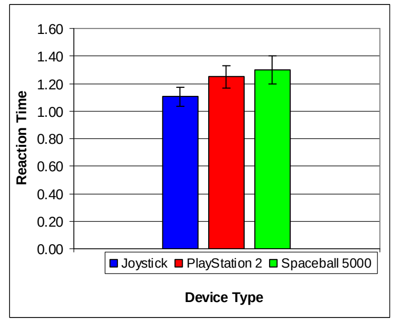

Figure 8. Reaction time to secondary task: Device main effect

Subjective Ratings

Workload ratings. In a comparison of means calculated from NASA-TLX ratings, collapsed across subscales, a significant skill by device interaction was found, $F(2,20) = 8.57$, $p < .01$ (Figure 9). Comparisons showed significant variance between the pilots' and gamers' ratings of the Playstation control device $t(10) = 5.75$, $p < .05$. Not unexpectedly, gamers rated the familiar Playstation device as less demanding than pilots did ($M_{\text{Gamer}} = 3.75 < M_{\text{Pilot}} = 7.48$). All other devices yielded statistically similar workload ratings across skill sets.

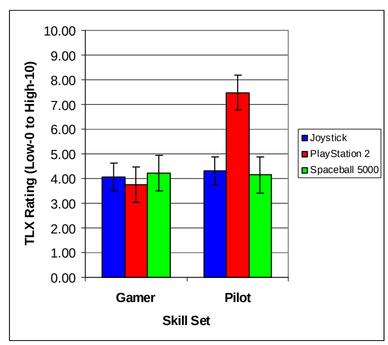

Figure 9. Workload ratings reveal skill x device interaction

Analysis of workload ratings also showed a device main effect $F(2,20) = 5.30$, $p < .05$ (Figure 10). Participants perceived workload demand was significantly higher when controlling the sensor with a Playstation device ($M = 5.62$) than joystick ($M = 4.18$) or SpaceBall ($M = 4.18$), $t(11) = 1.43$, $p < .01$; $t(11) = 1.43$, $p < .05$, respectively. Overall, both skill sets assigned lower demand ratings to joystick and

SpaceBall. By exception, the pilots' perception of workload demand with the Playstation device was consistently high.

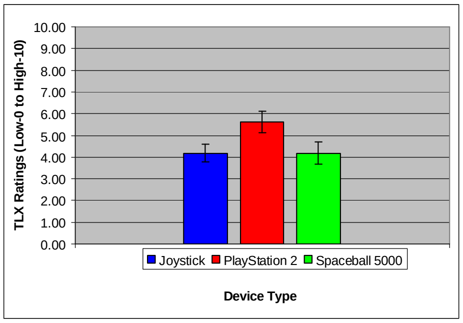

Figure 10. Workload ratings show device main effect

Subjective questionnaire. Ratings of device preference collected from participant questionnaires revealed half of the participants preferred the less familiar SpaceBall device for sensor control over other devices. Primary preference for the SpaceBall device was reported by both skill sets. A review of pilots' device preferences showed individual variability with the exception that pilots consistently ranked the Playstation device as the least desirable for sensor manipulation. In conclusion, primary and secondary preference ratings (1 and 2) were given by both skill sets for joystick and SpaceBall sensor control. Pilots unanimously assigned lowest preference to Playstation sensor control, while gamers had mixed primary and secondary preference ratings for the Playstation device.

Discussion

In summary, consistent with previous studies on control devices, these findings showed mission performance advantages when the sensor controller required less mental translation. Initially, the SpaceBall was identified for having movement characteristics that appeared analogous to sensor payload movement, thus supporting facile mental translations. In fact, both pilots and gamers showed increased precision, reduced operator workload, and favorable subjective ratings when using the SpaceBall in nominal reconnaissance missions. In addition, both skill sets were able to complete more scans across the field of regard with the SpaceBall than the current baseline joystick. Although missions utilizing Playstation control yielded high numbers of scans, associated workload increase for pilots excludes this device from recommendation.

Secondary task performance showed some increased reaction time when utilizing the SpaceBall and the Playstation. These findings come with a caveat because noted increases may have occurred due to an experimental artifact. In both alternative sensor control devices, secondary task acknowledgements were not exclusively accomplished by the left hand. The alternative sensor control devices required that the left hand execute other control inputs, whereas the joystick required a left hand exclusively dedicated to the secondary task. For this reason, no conclusive evidence of impacted cognitive spare capacity was found to impact favor of one device over another.

Conclusions

1. Skill set can favorably affect UAV sensor control performance when it includes experience with video games.

2. The alternative SpaceBall control device showed preferable operator performance with no associated workload tradeoff, when compared with other devices.

3. Future design of replacement UAV sensor control devices should consider requiring operator inputs that mirror payload movement, thus requiring low levels of mental translation.

Acknowledgements

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