2006 YIA WINNER

Running head: UAV LANDING TACTILE FEEDBACK

19
18
37
:13
50

BRIAN SELF could accept for

Effects of Tactile and Visual Feedback on UAV Landings

Donald T. Aretz II B.S.
United States Air Force Academy

Human Factors

Top Grad Academy @

9481 Cedar Glade Cove
Cordova, TN 38016

c06donald.aretz@usafa.af.mil

C06DONALD.ARETZ@USAFA.AF.MIL

Very Good Presentation

Draft

BRIAN.SELF@USAFA.AF.MIL

Abstract

Currently the U.S. military has developed and employed unmanned aerial vehicles (UAVs) in various operations since the late 1990s. Feedback from the UAV operating station is vital for the pilot to control the UAV. The current UAV control setup has a monitor that shows the pilot a map and another monitor that displays a nose camera view combined with a heads-up display (HUD). Since operators control the UAV from a ground control station that is remote from the actual aircraft, the pilot is not provided with the normal auditory, vestibular, and proprioceptive feedback they would receive in the actual aircraft. Because of the remote operation of the UAV, they are also not immune to mishaps. In fact, the landing task alone contributes up to 22% of all UAV mishaps. The purpose of this study is to assess the potential for a vibrotactile vest to provide tactile feedback to UAV pilots while landing. This study will have two groups of participants. The first group will use the UAV simulator as it is currently employed with no tactile vest. The second group will use the UAV simulator while also using the tactile vest. We will examine the learning performance of each group by measuring the number of trials it takes to obtain a passing landing score for the initial condition each participant is assigned. After obtaining a passing score, the participant will switch to the other condition (vest or no vest) and complete an additional three trials. We will then use the root mean square (RMS) error from an optimal flight path to analyze the impact of initial training with and without the tactile vest. This study will include 30 participants (maximum of 40) with at least 15 participants assigned to each group. Participants will be drawn from the Beh Sci 110 subject pool. All tests will be performed on a UAV synthetic task environment (STE) simulator located in the Behavioral Sciences and Leadership Laboratory. The findings will help determine if a vibrotactile vest can help UAV pilots more accurately perform a landing.

Effects of Tactile and Visual Feedback on UAV Landings

As the Air Force moves toward the future there will be a greater utilization of unmanned aerial vehicles (UAVs) to support the full spectrum of missions. Pilots of UAVs are faced with a difficult task of controlling the aircraft from a remote ground control station. Feedback from the UAV operating station is vital for pilots to effectively control the UAV. The current UAV ground control station includes a monitor that shows the pilot a map and another monitor that displays a nose camera view combined with a heads-up display (HUD). Since operators control the UAV from a ground control station that is remote from the actual aircraft, the pilot is not provided with the normal auditory, vestibular, and proprioceptive feedback they would receive in the actual aircraft. Due to the "out of cockpit" experience while piloting UAVs there is a larger mishap occurrence than manned aircraft. UAVs have on average 141 mishaps per 100,000 flight hours, while manned aircraft have one mishap per 100,000 flight hours. 22% of those mishaps occur during the landing phase of UAV operation (Tvaryanas, Thompson, & Constable 2005). Tactile feedback may be a method to reduce the demand on a UAV pilot's visual load and provide the kind of feedback needed to effectively operate the UAV in all phases of its mission.

The project will investigate the potential training advantages of a vibrotactile vest that is used to give the pilot tactile cues concerning the altitude and direction heading in relation to an optimal landing pattern. The focus of our study is on the Predator UAV synthetic task environment (STE) simulator provided by the Air Force Research Laboratory. The UAV STE is similar to the actual trainer used by Predator RQ-1A pilots. In addition to the two monitors for the map and nose camera view, the UAV also includes a hands-on-throttle-and-stick (HOTAS) for control input. Other UAV control stations, like the one for the Global Hawk, do not utilize a HOTAS system. Instead, the flying is fully automated and the Global Hawk operator just has to enter commands though a keyboard. Since the Predator has a HOTAS system, it is important to develop a control system that allows the UAV pilot to control the UAV with the appropriate level of feedback.

Tactile feedback is a relatively new field of research and its potential applications have not yet fully been identified. Tactile feedback may be a great asset to many areas requiring users to divide their attention among different tasks. Christopher D. Wickens has proposed the multiple resource theory (MRT). The MRT states that there are multiple "pools" of cognitive resources, and if one of these resource pools is being completely used during a task, then no more information of the same resource will be processed. (Wickens, Lee, Liu, Becker 2004). Examples of these resources are audio and visual stimuli. In a given task, if you only display visual information then the user will become overwhelmed if too much visual information is displayed. To prevent the user from being overwhelmed, one would channel part of the information through auditory means. The MRT can be applied with tactile feedback, since there is not a current application of tactile feedback in UAVs the resource is not being used. If information can be channeled through tactile means, then the information overload to UAV pilots may be reduced.

Terrence, Brill, and Gilson (2005) measured the time it took for participants to indicate a perceived direction using auditory cues and tactile cues. The study used five body orientations (supine, kneeling, sitting, standing, and prone) and a 45 degree separation between directions being tested. The results from the study showed the tactile responses to be significantly faster than auditory responses. Absolute angle differences between perceived and presented cues were significantly smaller with the tactile feedback. If tactile feedback is faster and more accurate in stimuli detection, then UAVs would have much to gain by moving some of the control feedback into the tactile area.

Calhoun, Draper, Ruff, and Fontejon (2002) compared the performance of tactile feedback and visual feedback in a study using the UAV STE at Wright-Patterson AFB. The study had participants detect and identify system faults while completing a tracking task. The study found that the responses with tactile feedback were significantly faster than the visual response times. Another study by Calhoun, Draper, Fontejon, Guilfoos, and Ruff (2004) had participants respond to critical events while performing multiple tasks on a UAV STE. The critical events were alerted with aural or tactile cues. The study found no significant difference between aural and tactile cues, and may imply that portions of auditory cues used on UAV control stations can be moved to tactile cues with no performance loss, thus reducing the demand on auditory resources.

Another study performed by Cheung, Craig, Jennings, Rupert, and Schultz (2004) utilized a tactile situational awareness system (TSAS) to see whether tactors can help helicopter pilots in poor visual conditions. The study measured lateral (fore/aft) inputs from the pilots during good and poor visual conditions. There were two scenarios, one with TSAS off and another with TSAS on. Helicopter pilots landed on a simulated frigate at night with poor visual conditions. The study concluded that TSAS improves pilot performance in all areas.

van Erp, Veltman, and van Veen (2003) completed a study using tactile feedback on helicopter pilots and altitude monitoring. The study had helicopter pilots wear a torso tactile system on their torso, shoulders, and thighs. Two scenarios were presented to the pilots. One scenario was just a presentation of a direction and desired altitude. The second added current motion direction. A cognitive task was completed by each pilot during half of each scenario. The measured variables were the absolute altitude error and root mean altitude error. The results of the study showed that the tactile feedback reduced altitude error by half and also did not effect the mental effort rating. The tactile effect was the same in each scenario.

The question this study is investigating is whether the application of tactile feedback to a UAV monitoring station will help UAV pilots control their UAV better, leading to fewer mishaps. The first null hypothesis is that there will be no difference in number of trials for successful completion between participants utilizing the tactile vest and those not using the tactile vest. The first alternate hypothesis is that there will be a difference in number of trials for successful completion between participants utilizing the tactile vest and those not using the tactile vest, with those exposed to the tactile vest first performing better. A second null hypothesis is that there will be no difference in the average RMS error on the post-trials for both groups. The alternate hypothesis is that there will be a difference in the average RMS error on the post-trials. It is predicted that the results from the study will support both alternate hypothesis. The tactile vest participants will perform better than the participants with no vest. After switching roles (post-trials) it is predicted that the group wearing the vest will perform better than the group who took the vest off.

If the tactile vest does show to help performance for UAV pilots it may help reduce the number of UAV mishaps. Reducing the number of UAV mishaps will help save the Air Force money and improve mission effectiveness.

Method

Participants

The participants in this study consisted of cadets at the United States Air Force Academy who were enrolled in a core leadership class. 30 cadets were randomly assigned to one of two groups. All participants were volunteers and received extra credit for participation.

Materials

Equipment consisted of a Dell 3.2 GHz, Pentium 4 processor with two 19" liquid crystal display (LCD) monitors. Software used was the UAV STE provided by the Air Force Research Laboratory (see Figure 1). The vibrotactile vest is made by TNO, a company from Holland (see Figure 2). The vest contains 64 tactors that can be programmed to give specific low-frequency vibration feedback.

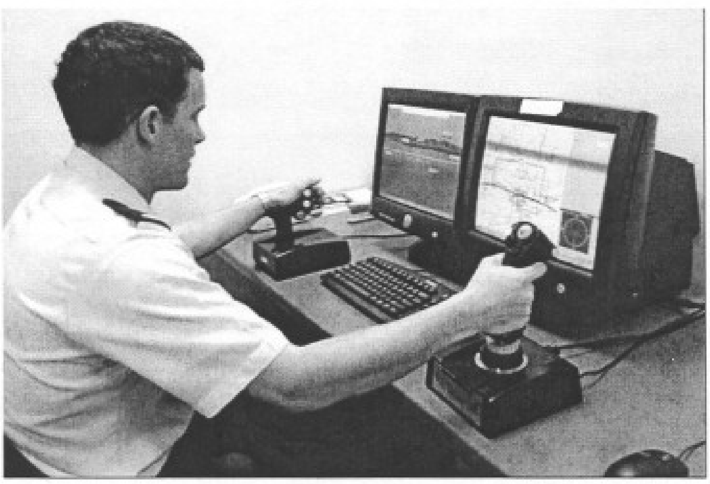

Figure 1. UAV STE with HOTAS flight controls.

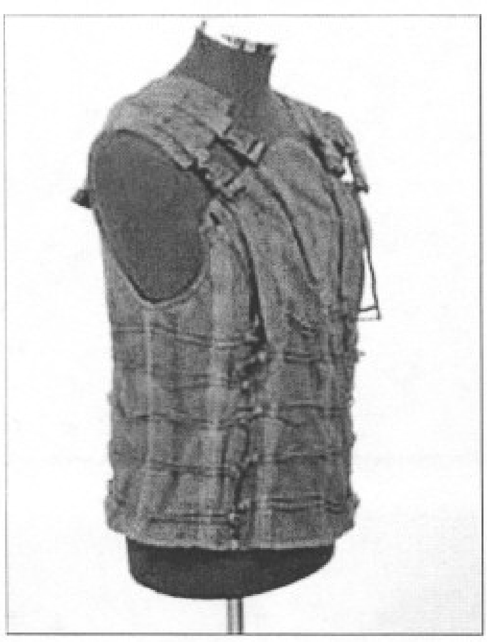

Figure 2. TNO tactile vest.

Procedures

Participants read and signed the informed consent document and received information on the study before beginning. Participants had to pass a basic maneuvering task (BMT) to a criterion. Specifically, participants learned how to: read the instrument displays on the monitor, feel how the tactile vest gives feedback, control the aircraft, and perform basic maneuvering tasks. Once the participant has passed all criteria of the BMT he/she will move to measured portion of the study.

The second part of the study involved the participant completing a landing task on the UAV STE. The landing task started the participant downwind from an airfield. The participant controlled the UAV form the downwind position until the UAV has landed. During this portion of the study two different groups of participants were used. The first group flew the UAV using a tactile vest, and landed the UAV using information from both the UAV STE and tactile vest. The second group flew the UAV without the tactile vest, and used the displays on the STE to land. The STE monitored the UAV's altitude and when the UAV flew outside the specified altitudes the tactile vest will vibrate. The vibrations alerted the participant that they need to return to the specified altitudes. Both groups flew the landing task until they achieved a passing score. The passing score was an RMS error of 20ft or less. The independent variable is the presence of the tactile vest during the completion of the landing task. The dependant variable is the number of trials it takes each participant to achieve a passing score on the landing task, which is measured by the STE software.

The third part of the study involved the participants completing the same landing task as in part 2, however, each group will switch roles. The group that did not wear the tactile vest will now wear it while completing the landing task. The group that wore the tactile vest will now complete the landing task without the vest. Each participant will only complete the landing task three times during this portion of the study. The root mean square (RMS) error from an optimal flight path will be used to determine the impact of initial training with and without the tactile vest.

Results

The primary outcome of this study indicates that using a tactile vest can help reduce the time it takes to train novice pilots.

Table 1

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
# of Trials	Vest	15	3.53	1.407	.363	2.75	4.31	2	7
	No Vest	15	7.13	2.722	.703	5.63	8.64	3	12
	Total	30	5.33	2.808	.513	4.28	6.38	2	12
Glide RMS	Vest	15	38.5721	12.17856	3.14449	31.8278	45.3163	21.17	59.51
	No Vest	15	54.5339	23.82316	6.15111	41.3411	67.7267	23.92	121.25
	Total	30	46.5530	20.28495	3.70351	38.9785	54.1275	21.17	121.25
Post Glide RMS	Vest	15	31.0395	10.40100	2.68553	25.2796	36.7993	19.07	61.35
	No Vest	15	25.8207	10.49363	2.70944	20.0095	31.6318	9.04	48.41
	Total	30	28.4301	10.60323	1.93588	24.4707	32.3894	9.04	61.35

An analysis of variance (ANOVA) was conducted to determine if any relationships were significant. Since there were not 3 conditions a post hoc was not used.

Table 2

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
# of Trials	Between Groups	97.200	1	97.200	20.702	.000
	Within Groups	131.467	28	4.695		
	Total	228.667	29			
Glide RMS	Between Groups	1910.849	1	1910.849	5.339	.028
	Within Groups	10022.043	28	357.930		
	Total	11932.892	29			
Post Glide RMS	Between Groups	204.269	1	204.269	1.871	.182
	Within Groups	3056.158	28	109.149		
	Total	3260.428	29			

A repeated measures analysis was used (between subjects) to compare the mean RMS error between the vest condition and no vest condition.

Table 3

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	84336.875	1	84336.875	347.257	.000
conditio	432.797	1	432.797	1.782	.193
Error	6800.251	28	242.866		

A paired samples t-test was used to compare the RMS error (within subjects) to determine if there is an effect from pre-condition to post-condition.

Table 4

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Glide RMS - Post Glide RMS	28.71325	25.07758	6.47500	14.82575	42.60075	4.434	14	.001

Table 5

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Glide RMS - Post Glide RMS	7.53262	16.36964	4.22662	-1.53258	16.59783	1.782	14	.096

The Statistical Package for the Social Sciences (SPSS) software was used to complete all statistical analysis. The ANOVA ($\alpha = .05$) resulted with a significant main effect between the number of trials needed to complete the landing task, $F(1,28) = 20.702$, p=.000. There is also a significance in the glide RMS error $F(1,28) = 5.339$, p=.028. The post-glide RMS error was not significant $F(1,28) = 1.871$, p=.182. The between subjects repeated measures analysis resulted in a semi-significant effect between condition 1 and condition 2, $F(1) = 1.782$, p=.193. The 2 t-tests resulted with a significant relationship between the pre and post glide RMS errors for condition 2, $t(14)$=4.434, p=.001, and a semi-significant relationship between the pre and post RMS errors for condition 1, $t(14)$=1.782, p=.096.

Discussion

The data collected in this study supported the primary hypothesis, trails until a passing score using the vest will be significantly fewer than not using the vest, and partly supported the secondary hypothesis, significant difference in RMS error scores with wearing vest performing better than not wearing vest.

The performance of the vest condition significantly outperformed that of the no vest condition in average trials until the landing task was completed. The performance of the vest condition supports the possibility that tactile feedback can be used in training novice pilots to fly UAVs.

The difference in the post condition's RMS error was not significant. This may be due to a learning effect gained from the vest condition, and the improvement of the no-vest condition can be attributed to putting the vest on. Even if the comparison between the two post condition RMS errors were not significant, further analyses showed a significant main effect between the pre and post no vest condition. This supports the idea that tactile feedback does improve pilot performance.

The study did not go without limitations.

- Cadet pool limits generizability
- Training time for each cadet varied from 15 minutes to 60 minutes – learning difference?

Future Research

More detailed feedback, horizontal and vertical

Command vs. Status Feedback

Differences in time required to train each cadet – variability

Visual representation of tactile feedback

Will tactile feedback have same effect on expert pilots as it did on novice pilots?

Conclusion

If training UAV pilots can be improved using the tactile vest, thus improving the quality of UAV pilots, and then the possibility to reduce UAV mishaps from pilot error can occur.

References

Calhoun, G., Draper, M., Fontejon, R., Guilfoos, B., & Ruff, H. (2004). Tactile versus aural redundant alert cues for UAV control applications. *Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting*, HFES, Santa Monica, CA, 137-141.

Calhoun, G., Draper, M., Ruff, H., & Fontejon, R. (2002). Utility of tactile display for cueing faults. *Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting*, HFES, Baltimore, MD, 2144-2148.

Cheung, B., Craig, G., Jennings, S., Rupert, A., & Schultz, K. (2004). Flight-test of a tactile situational awareness system in a land-based deck landing task. *Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting*, HFES, Santa Monica, CA, 142-146.

Terrence, P. I., Brill, J. C., & Gilson, R. D. (2005). Body orientation and the perception of spatial auditory and tactile cues. *Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting*, HFES, Orlando, FL, 1663-1667.

Tvaryanas, A. P., Thompson, B. T., & Constable, S. H. (2005). U.S. military unmanned aerial vehicle mishaps: Assessment of the role of human factors. *Unpublished Manuscript*, Brooks City-Base, TX.

Van Erp, J. B. F., Veltman, H. J. A., & van Veen, H. A. H. C. (2003). A tactile cockpit instrument to support altitude control. *Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting*, HFES, Denver, CO, 114-118.

Wickens, C. D., Lee, J. D., Liu, Y, & Gordon-Becker, S. E. (2004). *An introduction to human factors engineering* (2nd ed.). Upper Saddle River, NJ: Pearson Prentice Hall.