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Optimal Mission Task Assignment for Complex Military Simulator Operations

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Abstract

In Side-by-Side helicopter system, pilots and co-pilot occupy same place and make a community about instruments. So both pilots have a great interaction and communication compared with tandem helicopter. In our previous research, we found the TSD information is effected on mission conduction greatly. We also realized the new task assignment is required. To compensate for our previous research and find the optimal task assignment in side-by-side helicopter system, we set up the second experiment. We established the scenario and did some experiment. Measuring data is performance total time, killing rate, and pilot & gunner workload data similar to before experiment 1, and this project has a purpose about finding optimal task assignment and researching strong point than Tandem system using 1 & 2 experiment totally.

Keywords

Attack Helicopter, Task Assignment, Helicopter Simulator, Task Workload

1. Introduction

Despite its numerous advantages, such as small bombed area and large view range, the Tandem helicopter allows limited communication between the two pilots, a captain and a co-pilot, because they work in a different area of the helicopter. On the contrary, the Side-by-Side helicopter fully enables communication between the pilots, while its range of peripheral vision decreases. Since the advantages and disadvantages of the two helicopters are different, it was suggested that we should do another experiment according to their different attributes. In our previous research, we have presented the following solutions to improve our studies [1]. In order to fix our first problem, the TLX evaluation problem, we selected an experiment that could be our standards and did a relative evaluation using that experiment. Our second problem, fixed controls of the captain pilot, was solved by allowing the captain pilot and the co-pilot to switch their operation, as they would do in the Side-by-Side helicopter. Also, even when the pilots had assigned tasks, the co-pilot was allowed to take over and operate the helicopter when it was necessary. For the problem of task assignment, our third problem, we wanted to reflect reality (real-life situations) and effectively measure the difference among task assignments. Therefore, we

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divided the task into five new categories: The Missile attack (guided weapon), the Rocket & Gun attack (non-guided weapon), evasion flight, TADS operation (identifying targets), and radio communication (communication with command post). To fix the problem of the lack of repetitions, we randomly repeated ten different experiments fifty times. Our fifth problem, which was different level of proficiencies of the experimenters (human subjects), was solved by implementing additional flight training after the first experiment to decrease the gap among the proficiencies of the human subjects. Lastly, to fix the excess of flight duration, we reorganized and cut it down from thirty minutes to five minutes.

2. Research Methods

In this experiment, we allowed the pilot and the gunner to switch their operation including flight operation, as they would do in a Side-by-Side helicopter. Also, even when they all had assigned tasks, the gunner was allowed to manipulate the helicopter when necessary. In order to reflect reality and effectively measure the difference between each task assignment, we adopted five new categories: the Missile attack, the Rocket & Gun attack, evasion flight, TADS operation and radio communication. To solve the problem of the lack of repetitions, we set ten different experiments as one set and randomized the order of each set. Each set was done in different orders of the experiments, and it was repeated for five times. To reduce the gap between the proficiencies of the pilots, we implemented additional flight training after the first experiment. Lastly, to make the TLX evaluation more accurate, we selected a specific experiment as our standard that we could compare our results with relative evaluation [2] [3].

2.1. Scenario

It is necessary that the captain and the co-pilot are given appropriate tasks and that we design a proper scenario in order to measure the amount of workload for each task effectively. The scenario was carefully designed that a virtual opponent is occupying the flying field of our military forces. In addition, we made the instructor responsible for the Scout to add the task of operating radio and utilized a smart phone application that acted as a transceiver to communicate during the reenactment of the scenario. **Figure 1** represents experiment scenario and the attack helicopter simulator that used in this research.

We randomly create three targets on the flying field of our military forces that have been occupied by the enemy. The helicopter is on the NOE (Nap of the earth) mode and goes on reconnaissance while the captain and the co-pilot alternate. The one that is not operating the helicopter checks their flight path. The helicopter that is in the location of reconnaissance communicates with the scout using the radio, identifies the target, and hands over. The helicopter attacks our prioritized target, the tank, with missiles and evades according to the instructor, assuming that there are some counterattacks. To get the second and third target, the pilot goes to the enemy camp, attacks with Rocket and Gun respectively, and returns.

2.2. Research Methods

Several tasks that are necessary to complete the scenario were divided into five categories and considered a combination of categories as shown in **Table 1**.

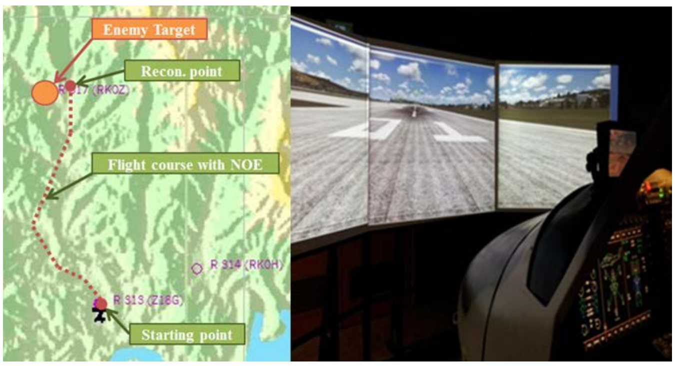

Figure 1. Experiment scenario and attack helicopter simulator.

Table 1. Categories and combination of mission.

No of experiment	Categories of mission				
	Operation a missile	Operation rocket, gun	Acquire a target and identification	Evasion flight	Operate a radio
1	P	P	G	G	G
2	P	G	P	G	G
3	P	G	G	P	G
4	P	G	G	G	P
5	G	P	P	G	G
6	G	P	G	P	G
7	G	P	G	G	P
8	G	G	P	P	G
9	G	G	P	G	P
10	G	G	G	P	P

The instructor randomly selects experiments, and the captain and the co-pilot perform their tasks accordingly. During the experiment, the instructor sends important information using the radio and measures how long it takes to finish the tasks with a stopwatch. After each experiment, the instructor tells the captain pilot and the co-pilot to NASA-TLX where they document their accuracy rate and time spent (duration). NASA-TLX is a workload measure tool uses six dimensions to assess mental workload. Using the five categories of tasks, the captain and the co-pilot did a total of ten different experiments and repeated each experiment five times. Regardless of its outcome, total performance time is one of the most significant factors related to survival in the battlefield out of all the other factors [4] [5].

3. Data Analysis

Setting the confidence level as 95% for all the analyses, we analyzed our data with MINITAB 16 and determined which experiment is the most effective and efficient in terms of workload using the normality validation and the ANOVA analysis. Through the principal component analysis, we compared all the experiments and found the three most effective experiments. Also, we examined what the three experiments have in common to find out the best combination of missions.

3.1. Performance Time Analysis

To find out the difference in performance time according to different types of experiments, the ANOVA analysis was performed. **Figure 2** is the confidence level displayed with a box plot. Since our P-value, 0.06, is greater than our significance level, 0.05, we cannot really conclude that it is significant; however, the difference was only 0.01. Also, the box plot indicates that the averages of experiment 3, 9, 10 are relatively lower than those of other experiments. **Table 2** is a result of grouping using the Fisher Method, we can conclude that experiment 3, 9, 10 are different from other experiments. Since our P-value, 0.06, is greater than our significance level, 0.05, we cannot really conclude that it is significant; however, the difference was only 0.01. Also, the box plot indicates that the averages of experiment 3, 9, 10 are relatively lower than those of other experiments. **Table 2** is a result of grouping using the Fisher Method, we can conclude that experiment 3, 9, 10 are different from other experiments. **Table 3** shows the task assignments of experiment 3, 9, 10. The similarity among the three experiments is that the co-pilot controls the Rocket and Gun. We also reversed the order of the data and analyzed the total amount of performance time when the pilot and the gunner had assigned work. This method allowed us to see the pattern and the difference between the performance time of the two pilots. We wanted to discover which task takes the shortest time for the pilots to complete.

It is shown by **Table 4** that the result is not significant since the p-value was less than the significance level. A possible cause for this may be interaction with other tasks. For example, when the pilot is responsible for

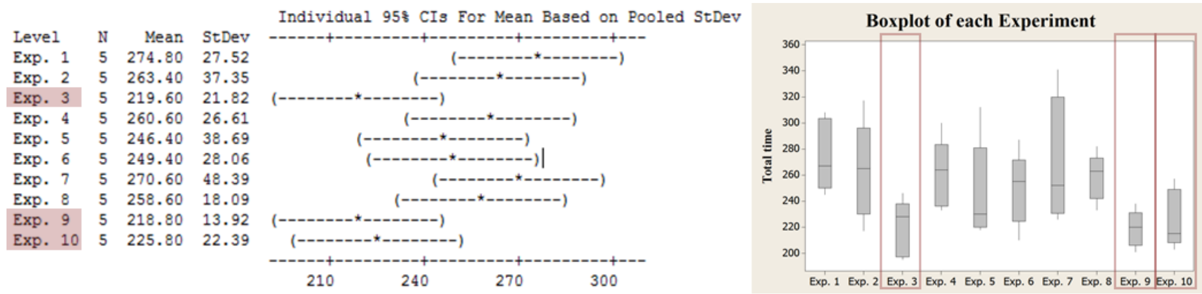

Figure 2. Confidence interval of each experiment and Boxplot of each experiment.

Table 2. Result of grouping using the fisher method.

# of experiment	N	Average	Result of grouping		
2	5	283.4	A		
7	5	279	A		
1	5	274.8	A	B	
6	5	259	A	B	C
5	5	258.8	A	B	C
8	5	255	A	B	C
4	5	253.8	A	B	C
10	5	2234		B	C
3	5	225.8			C
9	5	224.2			C

Table 3. Procedures of Exp. 3, 9, 10.

No. of experiment	Operation a missile	Operation rocket, gun	Acquire a target and identification	Evasion flight	Operate a radio
3	Captain Pilot	Co Pilot	Co Pilot	Captain Pilot	Co Pilot
9	Co Pilot	Co Pilot	Captain Pilot	Co Pilot	Captain Pilot
10	Co Pilot	Co Pilot	Co Pilot	Captain Pilot	Captain Pilot

Table 4. P-value of performance time of the two pilots.

No. of experiment	P-value	Criterion	Statistical significance
Captain pilot	0.249	>=0.05	**No**
Co Pilot	0.464	>=0.05	**No**

missiles, there is a possibility that he/she also has other tasks, such as controlling the radio or returning. Therefore, the result is not necessarily considered to be accurate because it may have been affected by other tasks. Also, further analysis cannot be done due to the fact that our experiment is designed to consider particular factors, not all the other potential factors.

3.2. TLX Data Analysis

The ANOVA analysis on the each pilot's TLX was performed to discover which type of experiment requires the least amount of workload. **Table 5** shows pilot's ANOVA results.

Table 5. Analysis of TLX data.

Scale	Captain pilot			Co-pilot		
	P-value	Criterion	Significance	P-value	Criterion	Significance
Mental demand	P < 0.001	<=0.05	Yes	P < 0.001	<=0.05	Yes
Physical demand	P < 0.001	<=0.05	Yes	P < 0.001	<=0.05	Yes
Temporal demand	0.002	<=0.05	Yes	P < 0.001	<=0.05	Yes
Performance	0.079	>0.05	No	P < 0.001	<=0.05	Yes
Frustration level	P < 0.001	<=0.05	Yes	P < 0.001	<=0.05	Yes
Effort	0.486	>0.05	No	P < 0.001	<=0.05	Yes

In the case of captain pilot, except for "own performance" and "frustration", every analysis is significant. And this indicates that there is a difference. There is no difference in the categories of "own performance" and "frustration". And in the case of co-pilot, all scales are significant. To find out the trend of TLX scores for each type of experiment, we use PCA (Principle component analysis). The reason why we performed the principal component analysis is that it enables us to consider particular mental pressure that affects the experiment the most. So we put principal component first than sum of variance. **Table 6** represents result of PCA.

In the case of captain pilot, the one variable represents 75%. And in the case of co-pilot, the one variable represents 93% as shown in above **Table 7**, we could compare with TLX score by PC1 score. Finally, we compared with sum of variance and PCA score and we chose 3 experiments based on each pilot's analyzed data as shown in **Table 7**.

Except for own performance and frustration, every analysis is significant for the captain pilot, which signifies that there is a difference according to the task procedures. There is no difference in own performance and frustration because the task is accomplished successfully, which leads to no difference in achievement and frustration. When it comes to the case of the co-pilot, the box plot shows that every TLX category is significant and that there is a similar pattern. Also, we learned an interesting fact that the type of experiment that involves high workload of the captain and the co-pilot and the type of experiment that requires low workload are almost complete opposites. According to the similarity between differences of highest and lowest TLX scores, we can ensure that the tasks were carefully and appropriately assigned. Experiment 3, 9, 10 had best results for the captain pilot, and experiment 1, 5, 7 required the highest workload. For the co-pilot, experiment 1, 5, 7 had best results, and experiment 8, 9, 10 had the lowest TLX scores. According to the TLX evaluation, it is suggested that the TADS manipulation is more suitable for the co-pilot. The data also shows that it is better for the co-pilot to take the responsibility of missile manipulation. Since the location of the allied forces is very likely to be revealed during the evasion flight, the pilots launch both the Chaff and Flare while managing the evasion flight. Among the six different types of experiments, Experiment number 3, 9, 5, 7 are similar in that Missile attack and evasion flight are maneuvered by one pilot continuously. According to the TLX evaluation, the rocket and gun manipulation set the common task and the TLX data shows that task is needed more effort than other task. Lastly, the radio manipulation set the common task is better.

4. Conclusion, Improvement

Using several criteria, mainly performance time and mission load, we deducted the optimal combination of missions as shown **Table 8**. Also, we reduced the workload in order to increase the efficiency of the execution of duty.

The TSD is a crucial measuring instrument in this experiment because it provides various information about the distance between the allied forces and enemy forces, direction, and route. Therefore, the main pilot and the co-pilot should be supplied with the TSD, so they can use this useful instrument for their own purposes. For example, the shared TSD monitor should be able to tell how well the main pilot is following his assigned route and provide information about the distance to their destination. Also, it would be a lot more effective if the TSD monitor had zoom-in features and aided the co-pilot with better target identification. Additionally, the workload should be measured at each step of the procedure during the LAH attack management to distribute the workload

Table 6. Result of PCA.

Captain pilot	Eigenvalue	713.63	107.55	66.03	47.29	11.18	5.61
	Ratio	0.75	0.113	0.069	0.05	0.012	0.006
	Accumulative value	0.75	0.863	0.933	0.982	0.994	1
Co-pilot	Eigenvalue	1721.6	42.1	35.7	20.8	15.8	12.7
	Ratio	0.931	0.023	0.019	0.011	0.009	0.007
	Accumulative value	0.931	0.954	0.973	0.985	0.993	1

Table 7. The selected experiments.

Pilot	# of experiment	Sum of variance	PCA score
Captain pilot	3	82.96	59.108
	9	107.336	60.3364
	10	0.16	41.6076
Co-pilot	1	0	35.2194
	5	15.808	41.7312
	7	162.008	61.8496

Table 8. The optimal task combination.

Task	
Captain pilot	Co-pilot
Set the flight path using TSD Gathering target information using TSD	Acquire a target and damage confirmation using TADS Missile manipulation
Common task	
Rocket & Gun manipulation/Radio manipulation/The evasion flight (Chaff and Flare)	

to the pilots more appropriately. Since the continuity at each step of the task procedures is very likely to affect their task performance time, the cause-and-effect relationship should be reanalyzed, considering this factor. In doing so, the task procedures should be more subdivided and reestablished. Since the two pilots are sharing the work space in the Side-by-Side helicopter, information delivery and communication are more accurate and detailed compared to the Tandem helicopter. Also, when unexpected incidents, such as the malfunction of the MFD and stick, occur, the Side-by-Side helicopter is a lot more flexible and offers various ways to handle such situation, in contrast to the Tandem helicopter. The establishment of the task procedure with these advantages and special features of the Side-by-Side helicopter will enable more improved and sophisticated helicopter management.

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