Effects of Operator Spatial Ability on UAV-Guided Ground Navigation

Jessie Y.C. Chen
US Army Research Laboratory - HRED
Orlando, FL, USA
e-mail: jessie.chen@us.army.mil

Abstract— **We simulated a military reconnaissance environment and examined the performance of ground robotics operators who were instructed to utilize streaming video from an unmanned aerial vehicle to navigate his/her ground robot to the locations of the targets. We evaluated participants' spatial ability and examined if it affected their performance or perceived workload. Results showed that participants with higher spatial ability performed significantly better in target-mapping performance and reported less workload than those with lower spatial ability. Participants with poor sense-of-direction performed significantly worse in the target search task in the night condition compared with those with better sense-of-direction.**

Keywords- human-robot interaction, UAV, spatial ability, navigation, reconnaissance, military, individual differences

I. Introduction

Advances in robotics technologies have enabled soldiers to see the battlefield from multiple perspectives simultaneously via unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs). For example, soldiers can inspect potential targets at a closer range from the ground after they are detected by UAV operators. Additionally, ground fighting vehicles may take over control of a small UAV from its operator after targets are spotted, so the ground vehicle can use (and manipulate) the streaming video from the UAV as it moves toward the targets. In the current study, we sought to evaluate whether individual differences in spatial ability (SpA) might impact the operator's performance in ground robot navigation guided by video from a UAV. SpA has been found to be a significant factor in target search task using robots [1] and robot navigation task performance [2][3]. Lathan and Tracey [2] showed that people with higher SpA performed better (in both speed and accuracy) in a robot teleoperation task through a maze. In a more recent study, operators with higher SpA performed robot navigation tasks significantly better than those with lower SpA [3]. Besides SpA, we also tried to examine the effect of operator's self-assessed sense of direction (SOD) on his/her navigation performance. According to Balwin and Reagan [4], those with good SOD tend to rely more heavily on visuo-spatial working memory (e.g., using cardinal directions and map-like representations) when navigating in virtual environments; on the other hand, those with poor SOD tend to rely more on verbal working memory (e.g., using landmarks as references). Based on these findings, it is reasonable to expect that the lighting conditions (e.g., day vs. night) would have a greater impact on those with poor SOD, as objects in the environments would not be as useful to serve as landmarks in the night condition, due to the loss of color cues at night, compared to the day condition.

The overall design of the study was a 2 x 2 x 4 mixed design. The between-subject variable was Lighting (day vs. night-vision). The within-subject variables were Target (type of primary target, i.e., stationary vs. moving target) and type of UAV view (no UAV vs. micro UAV [MAV] vs. Large UAV-Fixed View vs. Large UAV- Orbiting View).

II. Method

A. Partcipants

Twenty-eight college students (10 females and 18 males, mean age = 23.4) participated in the study. They were compensated $15/hr and/or class credit for their participation.

B. Apparatus & Procedure

1) Apparatus: A first-person-shooter computer game, Half Life2®, was used to provide the simulation for the MAV and the UGV (with terrain database of U.S. Army McKenna Military Operations on Urban Terrain [MOUT], Ft. Benning, GA). The first-person-shooter perspective of Half Life2 was used to simulate the view from the UGV. Participants used voice commands (e.g., Forward, Backward, Turn Left/Right, Scan for Targets, Engage Target, etc.) to control the UGV's navigation. Half Life2 also provides a spectator's view, which was used to simulate the view from the MAV. Participants used a joystick to control the movement of the MAV. Another set of simulation (displayed on a second monitor) was used to provide the Large UAV views. The Large UAV with Fixed view was simulated as hovering above the MOUT at 100 meters. The Orbiting UAV was simulated as orbiting the MOUT at 15 mi/hr at the same altitude. Participants were able to see the entire MOUT site from the larger UAV video. However, with the MAV, they could only fly at a lower altitude (roughly the height of a 3-story building) and could not have a bird's eye view of the environment as good as the larger UAVs'. In each scenario, there were one primary target (an enemy vehicle, which was a sport utility vehicle [SUV]) and five secondary targets (stationary enemy soldiers) in the MOUT environment. In half of the scenarios, the SUV travelled at 10 mi/hr in the MOUT environment following a pre-designated route. In the other scenarios, the SUV was stationary throughout the scenarios. Night-vision condition was rendered by adjusting the color setting of the computer monitors to render scenes as though seen through night-vision goggles. Santa Barbara Sense of Direction Scale (SBSOD) [5] was used to assess participants' perceived SOD (i.e., navigation and wayfinding abilities).

Participants' workload was evaluated using the computer-based NASA-TLX questionnaire [6]. The Spatial Orientation Test (SOT) [7] was used to assess participants' SpA.

2) Procedure: Participants first completed the pre-experiment surveys and spatial tests and then received training by going through a PowerPoint®-based tutorial and practice on the tasks they would need to conduct. The training session lasted 1 hr. Participants then were randomly assigned to either the day or night-vision group. In the experimental session, the participants were asked to look for the targets (the SUV) by using the UAV first and s/he would then teleoperate his/her UGV (i.e., navigate by voice commands) to the location of the target to engage it. The voice commands were then executed by one of the experimenters. The video from the UAV was available when the participant navigated in the environment using the UGV. In the case of the baseline (No UAV) condition, the participant only used his/her UGV to locate the primary target. In the case of moving targets, the participants needed to ensure continuous monitoring of the targets. The large UAV could not be manipulated but the view covered the entire MOUT environment. Participants could request a change of view, in the case of the Fixed-view UAV, when targets were occluded by buildings. There were only 2 orthogonal views available. Participants were instructed to find and navigate to the primary target (i.e., SUV) first, before the five secondary targets (i.e., stationary enemy soldiers). There were also friendly civilians in the simulated environment to increase the visual noise for the target detection tasks. Participants marked the locations of the targets on a blank map after the UGV engaged the targets. Participants were instructed to do this without studying the video image of the UAV screen. Participants assessed their perceived workload (NASA-TLX) after each scenario. After the 8 scenarios, participants were administered a Landmark Location test. They were shown pictures of 5 buildings in the MOUT environment and were asked to mark the locations of these buildings on a blank map. The experimental session lasted about 1.5 hr.

III. RESULTS

The scores of map marking accuracy for both the primary and secondary targets were aggregated and so were the search time data for both types of targets. Participants with higher SpA (based on their SOT scores) performed significantly better on the map-marking task, especially when they used the larger UAVs, $F(1,26) = 7.2$, $p < 0.05$ (Fig. 1). Those with lower SpA, in contrast, did not appear to take advantage of the larger UAVs (compared to the other two conditions) as much as their higher-SpA counterparts. Those with higher SpA also performed significantly better in the Landmark test, $F(1,26) = 7.6$, $p < 0.05$, and had significantly lower workload than did those with lower SpA, $F(1,26) = 5.1$, $p < 0.05$. Those with poorer SOD (based on their SBSOD scores) performed significantly worse (i.e., longer search time) than those with better SOD in the Night condition; however, the two groups performed at similar levels in the Day condition, $F(2,21) = 8.4$, $p < 0.01$ (Fig. 2). This result is consistent with previous findings [4] that those with poor SOD tend to rely more on verbal working memory (e.g., using landmarks as references) when performing navigational tasks.

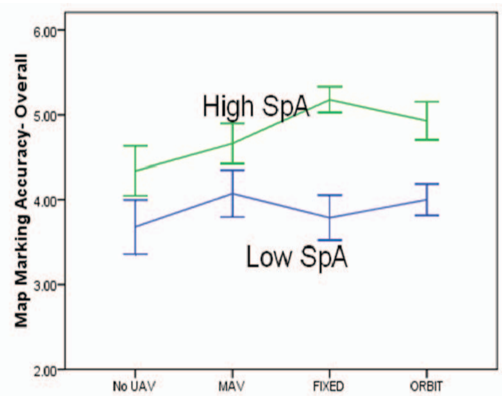

Figure 1. Map marking accuracy (all targets)

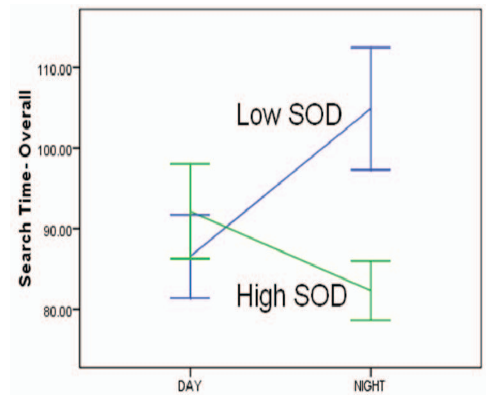

Figure 2. Target search time - Interaction between SOD and lighting.

REFERENCES

[1] J. Chen and M. Barnes, "Robotics operator performance in a military multi-tasking environment," Int. Conf. Human-Robot Interaction, pp. 279-286, Amsterdam, Mar 2008.

[2] C. Lathan and M. Tracey, "The effects of operator spatial perception and sensory feedback on human-robot teleoperation performance," Presence, vol. 11, pp. 368-377, Aug 2002

[3] D. Cassenti, T. Kelley, J. Swoboda, J., and D. Patton, "The effects of communication style on robot navigation performance," Human Factors & Ergonomics Soc Meeting, San Antonio, TX, Oct 2009.

[4] C. Baldwin and I Reagan, "Individual differences in route-learning strategy and associated working memory resources," Human Factors, vol. 51, pp. 368-377, Jun 2009

[5] M. Hegarty, A. Richardson, D. Montello, K. Lovelace, and I. Subbiah, "Development of a self-report measure of environmental spatial ability," Intelligence, vol. 30, pp. 425-447, Sep 2002.

[6] S. Hart and L. Staveland, "Development of NASA TLX (Task Load Index): Results of empirical and theoretical research," in Human Mental Workload, P. Hancock and N. Meshkati, Eds. Amsterdam: Elsevier, 1988, pp. 139-183.

[7] L. Gugerty and J. Brooks, "Reference-frame misalignment and cardinal direction judgments: Group differences and strategies," J Exp Psych: Applied, vol. 10, pp. 75-88. Mar 2004.