Display type effects in military operational tasks using Unmanned Vehicle (UV) video images: Comparison between color and B/W video feeds

Yaniv Minkov[1,2], Ronny Ophir-Arbelle[1] and Tal Oron-Gilad[1*]
[1] Dept. of industrial engineering and Management, Ben-Gurion University of the Negev,
P.O. Box 653 Beer-Sheva 84105, Israel, [2] IDF-Israeli Defense Forces *Corresponding Author

The increased use of unmanned vehicles (UVs) in military environments requires development of guidelines to enable maximal compatibility between those technologies and users' needs. Specifically, the way video feeds are delivered to dismounted soldiers may affect the utility of such information. This work follows previous studies on the type (e.g., size) of displays required by dismounted soldiers to process video feed from UVs in a variety of operational situations. Sixteen former infantry soldiers with no experience using UV video feed participated. Three display types were examined using color or B/W video feeds in three different operational tasks (identification, orientation and movement detection). Performance and subjective data were collected. Results showed some effects for display type, no significant effect for feed color and an interaction for display type and feed color only in response time.

INTRODUCTION

Technological forecasts point that the use of remote-controlled platforms will vastly increase in the next decades and will continue the trend of performing and controlling a variety of tasks from a distance. In military environments, Unmanned Vehicles (UVs) are already involved in a wide spectrum of tasks in the air (UAVs), on the ground (UGVs) and in the sea (USVs). The use of UV imagery in combat has become essential for mission success. In recent operations, dismounted soldiers relied on video from UAVs and UGVs to locate or to engage with targets. Since most of the future military operations will be held in and around urban environments, the military will have to promote the development of new doctrines, training structures and equipment specifically suited for urban operations (Collyer, 2003). Strategic and technological efforts are constantly being made to help soldiers confront uncertainty and increase situation awareness in those situations. Developing effective ways for integrating imagery from UVs into dismounted soldiers' operations are necessary for improving decision making during operations. Recent studies aimed to investigate and map the factors that affect the use of imagery from UVs. Factors as UV type (Chen and Clark, 2008, Oron-Gilad et al., 2011), display type, and type of task (Minkov, Perry & Oron-Gilad, 2007; Minkov & Oron-Gilad, 2009, Minkov et al., 2010) were among those factors. Another factor that may affect the ability and quality of UV video feeds utilization is the color and quality of the feed. The use of black and white feeds or colored ones is considered both from technical aspects (e.g., the communication bandwidth that is needed to transfer feed from vehicle to operator station) and cognitive aspects (e.g., operators' ability to interpret and understand the feed). Operationally, B/W is often used due to band width limitations, or payload selection. For example, average B&W cameras produce brighter images in low-light situations. While no particular study in this domain examined the use of color versus B/W video feeds per se, many use black and white feeds due to its robustness compared to color. Furthermore, color may be more affected by video quality and low contrasts.

The current study is part of an ongoing research effort focused on scalability of UV displays for dismounted warfighters. The scalability component concerns how best to accommodate presentation on smaller and lighter devices while maintaining accuracy and ease of use. Dismounted soldiers cannot carry the relatively large displays used in stationary environments or combat vehicles. Thus, smaller interfaces are needed. Equipment designers must consider not only the range of devices that soldiers will use, but also their context of use. Previous studies (e.g., Oron-Gilad, Redden & Minkov, 2011) have shown task dependent differences among display types with regard to soldiers' performances. The purpose of the current study was to further examine the effect of color versus B/W feed and to confer the hypothesis that display type affects performances and user workload in such situations.

METHOD

The experiment simulated a situation where the dismounted soldier performed a typical intelligence-gathering mission in an urban environment using operational data derived from either an aerial or ground UV, operated by remote mounted operators. No direct communication was available between soldiers and operators. Thus, participants could not directly control the UV or its payload. The method was similar to the one described in Component 2 of Oron-Gilad et al. (2011) with two modifications: two feed variations - color and B/W were used, and the inferior head mounted display (HMD) was replaced with a Hand held monocular display (HHMD) used previously in Minkov et al. (2009; 2010). In total, three display types were examined (Figure 1) using color or B/W UV feeds in, which were derived from two video feed sources (UAV or UGV) generating a (3X2X2) design. The feed color was a between subject factor while two other factors were within subjects.

Figure 1. Three displays were used: (Left) 12" Tablet, 7” hand held display (HHD) and hand held monocular display (HHMD).

Participants

Sixteen former Israeli defense forces (IDF) soldiers participated in the study for course credit or for monetary compensation. All had infantry urban experience and some navigation skills but no experience in operating UVs or using UV imagery. Age range was 25-30 years.

Experimental System

A dedicated testbed was used, as shown in Figure 2.

Figure 2. The experimental system interface: the UV video feed to the right (a), the aerial map to the left (b) and toolbars (c1+c2) that displayed information regarding the layout and direction of the map and were used by the participant to input information.

Equipment and Tasks

Participant’s station. The participant was seated in a 3X2 m^2 darkened room where a small table light was turned on. Upon each trial one of three possible displays was used in varying order, depending on the experimental condition. Display types were 12" Tablet, 7" hand held display (HHD) and the HHMD (Figure 1). All display devices could be placed according to each participant's own comfort. All devices had 600X800 screen resolution. Due to some practical constrains, only the first 8 participants used all three displays. The remaining 8 participants used only the 7" HHD and 12" Tablet displays. A mouse enabled the participants to manipulate the map (Figure 2- b) but not the video image (Figure 2- a). A 17-key keypad was used to enter numeric inputs when needed.

Scenarios and movie production. Scenarios were derived from Component 2 of Oron-Gilad et al. (2011). Four scenarios were used in order to allow eight within-participant trials (one for training and three conditional trials, in color and black and white). Each scenario consisted of: eight waypoints (WPs) which were marked using a three dimensional polygon (WP model); five moving elements consisting of vehicles, soldiers, or camels; and four static elements consisting of combinations of four parked vehicles (recreational vehicles (RVs), pickups and private vehicles. Figure 3 provides examples of scenario elements. In the color condition the WP model appeared as a light green sphere with purple markings. The parked vehicles appeared in yellow and two shades of blue. Moving soldiers were wearing camouflaged uniform. However, note that the operational tasks did not require any interpretation of color.

Figure 3. Example of scenario elements and tasks. Participants were asked to (left) navigate between waypoints, (center) identify static parked vehicles or (right) detect movements of soldiers from the UAV (top) or UGV (bottom) feeds.

Intelligence gathering task types. The video and digital map displayed an urban area. Elements of interest were divided into three task domains (see Figure 3): (a) Vehicle Identification. Participants were asked to identify parked vehicles, count their quantity, type this number using the keypad into the “Input” text box and press the “Send” button; (b) Orientation. Participants were asked to correlate a WP model in the video feed with a WP number on the digital map. The participant was required to locate the position of the WP model on the digital map, type in the WP number into the “Input” text box and press the “Send” button. Participants were allowed to correct their input by inputting a different WP number and pressing the send button again; and (c) Movement Detection. The participant was required to identify movement of a vehicle, a group of soldiers or a group of camels. Once motion was detected the participant was instructed to immediately press the “Motion” button.

Measuring Method

Performance measures. Performance was measured using response time and accuracy measures. With regard to response time, the difference between the participants' response and the master solution was used as an indication for speed of response. For example, if a movement appeared and therefore could be detected after an elapsed time of 50 seconds from the beginning of the scenario and the participant pressed the "Motion" button after 52 seconds, her relative performance compared to the master solution was a 2 seconds delay. With regard to accuracy, performances on each task were scored according to a predefined scoring index. For example, in the orientation task, the number assigned by the participant to the WP model was compared to the master solution. An exact answer credited the participant with the score of “4”, a deviation of one waypoint on the map was scored as “3”, a difference of two waypoints on the map was scored as “2” and any greater difference was graded as “0”. Credit of “1” was given if no answer was typed or the "not sure" option was selected from the combo-box (i.e., acknowledging that one could not determine the orientation of a WP was scored higher than a completely erroneous assignment). In the static element identification task a score of "4" was given if participants identified correctly the number of private vehicles in the cluster of parked vehicles. A deviation of one or two from the correct number resulted in the scores "3" and "2" respectively, no answer was "1" and larger deviations were "0". In the motion detection there were only two options "4" for detection and "0" for none.

Subjective measures. Mental workload was assessed using the raw NASA task load index (RTLX), an un-weighted average of the subscale values on a scale of 1-9 (with 9 being the highest). In addition, a post-trial questionnaire was presented after each trial referring to the satisfaction of use for a specific display (in terms of comfort, performance and appropriateness for the task). A closing questionnaire consisted of six questions related to the UAV and UGV scenarios. Participants had to specify for each scenario which display they thought was best in terms of: overall comfort, performance (i.e., generated best results), and appropriateness for the task.

Procedure

Participants arrived at the lab during day time one at a time and were instructed not to take caffeine or sugary intake for three hours prior to the experiment. After briefing, two training scenarios (one per type-UAV and UGV) were executed using the 12" Tablet. Once basic understanding of the mission was accomplished, the experiment began.

Three scenario trials were conducted with UAV or UGV feeds, according to the experimental condition, each paired with one of the three displays. Combinations were partially -counterbalanced over display type, and UV system. For example, a participant could complete the first part of the experiment in a certain order of displays (12", 7", HHMD) with UAV feed in color, and then complete the second half of the experiment in the same order of displays but with UGV feed in B/W. Analysis of data accounts for this not-fully balanced design. After completing three trials, a short break was administered. Then, the participant continued with a similar session, a training and three trials, this time using UGV feeds (or vice versa). After each scenario the participant was required to complete the RTLX and the sub-closing questionnaires. At the end of the experiment, the closing questionnaire was administered.

RESULTS

Performance

Accuracy. Accuracy scores on a scale of 0-4 were given for each task in each scenario (total of 1522 tasks across all participants). Since the dependent variable is multinomial distributed it was decided to use an ordinal logistic regression within the Generalized Estimation Equations (GEE) framework also suitable for unbalanced designs. To account for individual differences participant was included in the model as the random effect and the main effects were display type (3), UV type (2), task type (3) and color vs. B/W (2), all interactions were included in the model. Applying a backwards elimination procedure revealed that only the main effect of UV type and task type were statistically significant (Wald χ^2_1=14.5; p<0.001, and Wald χ^2_2=325.5; p<0.001). Accuracy with the UGV feed was higher than with the UAV feed (Mean=3.6, SE=.07 and Mean=3.3, SE=.07, respectively). The motion detection task scores were highest (Mean=3.8, SE=.08) followed by vehicle identification (Mean=3.5, SE=.09) and WP orientation (Mean=3.0, SE=.08). None of the interactions reached significance.

Response time. GLMM analysis for response time over display type (3), UV (2), and color (2) with participant as the random effect and all three-way interaction included revealed a significant effect for display type ($F_{2, 307}$=7.2, p<.001) with average time of 11.1 (8.3), 16.0 (10.8) and 16.2 (10.7) seconds respectively for the 12", HHMD and 7". A significant effect was also found for the type of UV feed ($F_{1,307}$=83.6, p<.0001), with the UGV feed generating faster responses than the UAV one (means of 13.09 seconds (SD=11.1) and 16.19 (SD=9.0), respectively). Feed color was not significant yet the interaction between display type and feed color was significant ($F_{2, 307}$=27.5, p<.0001). The combination of B/W feed with the HHMD generated longer response times (15.1 (1.0)) than the colored feed (13.0 (0.7)), an inverse trend was seen with the 12" Tablet (13.4 (0.5) and 14.5 (0.2)) and the 7" HHD (13.4 (0.4) and 16.8 (0.9)). The three-way interaction display type by UV by feed color was significant ($F_{2, 307}$=11.5, p<.0001), as shown in Figure 4.

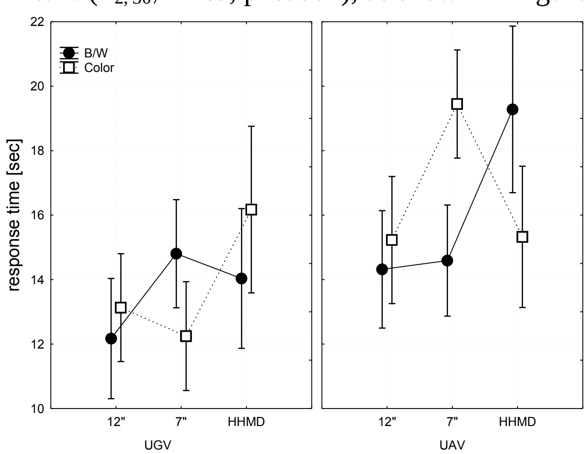

Figure 4. Three-way interaction in response time among Display type, UV type and feed color.

Mental Workload

RTLX ratings were analyzed by repeated-measures ANOVA using three factors: display type (3), feed color (2) and UV type (2). There was a significant main effect for display type ($F_{2, 12}$ =8.1, p<.001). The average RTLX ratings (on a scale of 1-9 with 9 being the highest score) were 5.9 (.5), 5.2 (.3) and 5.0 (.4) respectively for the HHMD, 12" Tablet and 7" HHD. Thus, workload estimates in general were moderate across all displays. There were no significant effects for the UV type or for the interaction display by UV type. No significant main effect was found for feed color, but an interaction ($F_{2,72}$=6.42, p<.012) between feed color and display type was found. Workload was higher when colored feed was presented on the 12" Tablet and HHMD than when B/W feeds were. The 7" HHD display generated the opposite outcome.

Preference and Closing Questionnaires

The preference questionnaire was administered after each trial. A repeated measures ANOVA was conducted, with display type (3) UV type (2) and color feed (2). Display type had a significant effect on preference ($F_{2, 71}$=6.4, p<.003) with 5.2 (SE=.34) 6.6 (SE=.27) and 6.6 (SE=.26) scores for the HHMD, 7" HHD and 12" Tablet. No effect for UV type was found. An interaction for feed color and display type emerged only from using the HHMD. For the HHMD, the use of colored imagery was favored over the use of B/W feed (5.5 (SE=.48), 5.0 (SE=.48) respectively).

At the end of each part of the experiment, participants were asked to choose a preferred display type while considering: performance, comfort and appropriateness for the task. Generally, the 12" Tablet was the most preferred display type. With regard to the UV system, as shown in Table 1, the 12" Tablet was perceived as most appropriate for the UAV feed but for the UGV feed the 7" HHD was more appropriate.

Table 1. Preferences rates for display type by UV type.

UV System	Parameter	HHMD	12"	7"
UAV	Comfort	0	12	4
	Performance	0	11	5
	Appropriateness	1	7	8
UGV	Comfort	0	8	8
	Performance	3	11	2
	Appropriateness	3	3	10

DISCUSSION

The results partially reconfirm our hypothesis that display device influences performance. While performance accuracy has not been directly affected, response times were significantly shorter using the 12" Tablet display than the 7" or HHMD. Looking to the other two experimental factors revealed varying effects: feed color did not directly affected performances or subjective workload evaluations, however it did interact with display type. Focusing on the interaction between display type and feed color showed that B/W feed generated longer response times in the HHMD, and shorter ones for the 7" and for the 12" Tablet. As discussed in previous studies (Minkov et al., 2007, Minkov & Oron-Gilad, 2009, Minkov et al., 2010) using the HHMD may be more problematic in complex tasks as navigation and orientation. Here, the effect of feed color may be another evidence for the need of more naturalistic vision (e.g. colored and not B/W) when using the HHMD, although in operational environments, using B/W feeds does not always disturb and even sometimes helps to improve user performance.

As for the UV type, the results showed priority for the UGV and revealed a significant priority for both accuracy and response times. Although consistent with our previous study (Oron-Gilad et al., 2011), in operational contexts in general, aerial vertical views are considered to be more informative and easy to understand than ground horizontal ones (Chadwick, 2008) due to their holistic view and similarity to aerial maps. Naturally, the experimental scenarios here may have contributed to the superiority of the UGV. If the task can be conducted from both ground and aerial perspective feeds then it is reasonable to assume that the ground view (which is more compatible and aligned with the soldier's point of view) will be preferred and superior. Nevertheless, one should keep in mind that oftentimes in operational settings the UGV is not capable of viewing the same exact information as the UAV and the two sources provide complementary but not identical feed (see for example Ophir-Arbelle, et al. in press).

CONCLUSIONS

Here, evidence had showed that for video and map based missions a larger display has its superiority, and that B/W feeds may be good enough to perform certain tasks in larger displays. The findings point again upon the complexity of using UVs feeds in military environments, how little is known and how many confounding variables need to be addressed when examining display configurations. Experimental design considerations may have influenced the results, e.g., the simulation conditions, the (high) quality of the simulated feeds, the lack of role for color in the operational tasks and scenarios, and the partial-balance of the experimental design. Amongst other factors, future studies should focus on how the cognitive state of the operator e.g., mental or physical fatigue and extreme stress affect performance.

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