Impact of Instructional Strategies on Motivation and Engagement for Simulation-Based Training of Robot-Aided ISR Tasks

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The U.S. Army projects a considerable increase in the number of operational Unmanned Ground Systems (UGS) within the next ten years. There is a need to enhance UGS capabilities to support remote Intelligence, Surveillance, Reconnaissance (ISR) operations involving the identification of High-Value Individuals (HVI). Emerging UGS capability requirements will inevitably result in new or revised training requirements. The U.S. Army identifies Simulation-Based Training (SBT) as a required training platform for robot-aided ISR tasks utilizing UGSs. In order to implement an effective SBT system, there are several factors to consider related to training systems design and trainee needs. Factors addressed in this study include the selection of effective SBT instructional strategies and the impact on trainee motivation and engagement. Results from this study contribute to design and future research recommendations regarding SBT for robot-aided ISR tasks.

INTRODUCTION

Intelligence, Surveillance, Reconnaissance (ISR) consists of gathering, analyzing, and dispensing information regarding the current and anticipated state of the combat environment (U.S. Army, 2012). The U.S. Army desires to improve ISR ground operations by enhancing Unmanned Ground System (UGS) camera and sensing capabilities to support remotely executed ISR operations, hereafter referred to as robot-aided ISR (U.S. Army, 2008). The specific ISR task addressed in the present experiment was the identification of a High Value Individual (HVI), which is a target whose presence is required for an enemy’s attack to be successful, through behavior cue analysis, which involves the detection and classification of behavioral indicators to determine the HVI’s affective state or potential intent. Robot-aided ISR demands stress the importance of enabling the detection of suspicious individuals from safe distances, remote classification of behavioral indicators, and utilization of cultural and behavioral cues to identify suspicious or malicious activities (U.S. Army, 2008).

These capability demands necessitate the development of training recommendations to meet the perceptual skill needs of robot-aided ISR tasks, such as behavior cue analysis. The U.S. Army has identified Simulation-Based Training (SBT) as a necessary method to train robot-aided ISR tasks (U.S. Army, 2008). However, early SBT research found that SBT lacking appropriate instructional strategies that support training objectives often contributed to negative training (Oser, Gualtieri, Cannon-Bowers, & Salas, 1999). Therefore, one goal of the present experiment was to contribute to informed development of SBT instructional strategy recommendations for robot-aided ISR.

Instructional Strategies

A critical instructional design concern for SBT is the selection of appropriate instructional strategies for a given skill set. Perceptual skills required for behavior cue analysis include attentional focus, visual acuity, and pattern recognition. Carroll, Milham, and Champney (2009) conducted a review of training and education literature to identify effective instructional strategies for military perceptual skills training. Two of the identified strategies, Highlighting and Massed Exposure, were applied to behavior cue analysis training scenarios in the present experiment. Highlighting involves explicitly signaling the appearance of important training content or events (Carroll, Milham, & Champney, 2009). The Massed Exposure strategy attempts to increase sensitivity to specific training content or events by presenting opportunities for practice more frequently (Hirumi & Stapleton, 2009). Prior research related suggests that Massed Exposure promotes earlier detection of targets compared to the Highlighting strategy (Lackey & Salcedo, 2014). Presumably, performance is the most critical aspect of training; however, the potential impact of the instructional design on intrinsic motivation and engagement may impact the effectiveness of training. To further compare the two strategies, the present experiment investigated their impact on intrinsic motivation and engagement, which have both been shown to impact performance in SBT.

Intrinsic Motivation and Engagement

Intrinsic motivation is an affective state involving interest and self-efficacy, and is often impacted by a learner’s level of engagement, a cognitive state related to focused attention and involvement in a task (Carroll, Kokini, Champney, Sottilare, & Goldberg, 2011; McNamara, Jackson, & Graesser, 2009). Both motivation and engagement may positively impact transfer of training (Oskarsson, Nährlander, & Svensson, 2010; Salcedo, Maraj, Lackey, Ortiz, Hudson, & Martinez, 2013). Lack of interest has been correlated with lower levels of engagement (Carroll, Kokini, Champney, Sottilare, & Goldberg, 2011; Craig, Graesser, Sullins, & Gholson, 2004). Further, higher levels of engagement or involvement have shown to increase learning and training transfer (Csikszentmihalyi, 1990; McNamara, Jackson, & Graesser, 2009).

Hypotheses

There is presently a gap in the instructional design research addressing the impact of the Highlighting and Massed Exposure strategies on intrinsic motivation and engagement. Therefore, to address this gap, the aim for the present experiment was to empirically assess the effect of the Highlighting and Massed Exposure instructional strategies on intrinsic motivation and engagement during SBT for behavior cue analysis. To gain a
thorough understanding of the impact, the relationships between intrinsic motivation, engagement, and performance were also assessed.

METHODS

Participants

Participants included 90 volunteers (44 males, 46 females), ages 18 to 38 ($M = 21.57$, $SD = 3.25$), recruited from the University of Central Florida campus and affiliated organizations. Participants were compensated ten dollars per hour of participation. Inclusion in the experiment was restricted to U.S. citizens between ages 18 and 40 with normal or corrected to normal vision and no signs of color blindness.

Conditions

The scenario event rate remained constant across all conditions (Table 1). Thirty events per minute has been identified to elicit a medium level of workload in threat detection tasks (Abich, Taylor, & Reinerman-Jones, 2013).

Signal probability varied between conditions (Table 1). In the Control and Highlighting conditions, the probability of a target cue was 33% (Mogg & Bradley, 1999; Mogg & Bradley, 2002). Additionally, in the Highlighting condition, cues were highlighted by a translucent blue box over each target (Gold, Bennett, & Sekuler, 1999; Mogg & Bradley, 1999; Mogg & Bradley, 2002). In the Massed Exposure condition, the signal probability was doubled (Mogg & Bradley, 2002).

Experimental Testbed

The experimental testbed was developed with the Virtual Battlespace 2 (VBS2) version 2.0 software. VBS2 is currently utilized by the U.S. Army to develop virtual environments for SBT and mission rehearsal exercises (Ortiz, Maraj, Salcedo, Lackey, & Hudson, 2013). During the experiment, scenarios were displayed on a 22 inch (16:10 aspect ratio) widescreen computer monitor. The display during scenarios simulated a video-feed from an autonomous UGS conducting surveillance while on patrol.

Content of the experimental task leveraged concepts from Combat Profiling, which involves the assessment of factors related to the human terrain within a combat setting (Ross, Bencaz, & Militello, 2010). In Combat Profiling, human behaviors are interpreted across six distinct domains including: atmospherics, biometrics, geographics, heuristics, kinesics, and proxemics (Gideons, Padilla, & Lethin, 2008). The present experiment applied the kinesics domain to support the behavior cue analysis task. Critical features of human behavior analyzed in the kinesics domain include body language and gestures (Ross, Bencaz, & Militello, 2010). The experimental task required participants to monitor the video displayed by the UGS, and detect and classify targets as exhibiting aggressive or nervous behavior using classification buttons (Figure 1).

Sixteen behavioral agents, representing fair, light, medium, and dark skin tones, displayed the experimental stimuli. Fair, light, and dark skin tone categories consisted of two male and two female agents. The medium skin tone category included four males only because face, arms, and trunk of the available female models were veiled. Behavioral agents exhibited one of four target cues or one of seven non-target behavior cues selected from the VBS2 animation library (Table 2).

<table>
<thead>
<tr>
<th>Type</th>
<th>Behavior Cue</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target</td>
<td>Slapping the Hands</td>
<td>Aggressiveness</td>
</tr>
<tr>
<td></td>
<td>Clenched Fists</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wringing the Hands</td>
<td>Nervousness</td>
</tr>
<tr>
<td></td>
<td>Check Six</td>
<td></td>
</tr>
<tr>
<td>Non-Target</td>
<td>Rubbing Neck</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Coughing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pointing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waving Arm</td>
<td></td>
</tr>
</tbody>
</table>

Target cues were applied to the behavioral agents using the Autodesk® MotionBuilder® software for custom animation. Non-target behavior cues were selected from the existing VBS2 2.0 animations catalog. The sequence of agents was randomized and counterbalanced with an equal number of each skin tone represented. During the training vignettes, participants detected target behavior cues and classified each as a sign of aggressiveness or nervousness.
Measures

The individually validated subscales selected for the Intrinsic Motivation Inventory (IMI) included: Effort and Improvement, Pressure and Tension, Perceived Competence, and Interest and Enjoyment (McAuley, Duncan, & Tammen, 1989). The Engagement Measure comprised items related to perceived levels of involvement while using the SBT platform (Charlton & Danforth, 2005).

Performance data collected during experimental scenarios included detection accuracy, classification accuracy, and median response time.

Procedure

Upon arrival, the experimenter screened the participant for color blindness using the Ishihara Test for Color Blindness (Ishihara, 2013). Due to the need to see the highlighting feature and differentiate visual stimuli on screen, participant were dismissed if they did not pass the color blindness test. Next, the participant completed informed consent procedures.

To become familiar with the devices and controls, the participant completed an interface training scenario to practice clicking on targets and classification buttons in the VE. To avoid any priming effects, the stimuli in the interface training scenario were unrelated to those in the content practice scenarios. The interface training task required the participant to detect, select, and classify red and yellow barrels by color.

Next, the participant completed the pre-test scenario, which consisted of 180 behavioral agents, 60 detecting and selecting red and yellow barrels by color. The autonomous UGS navigated along a predefined route, and randomized order of target behaviors depended on the participant’s assigned condition (Table 1). After all four training vignettes concluded, the participant completed the Engagement Measure.

Following the pre-test phase, the participant completed the post-test scenario which included the same balance and distribution of behavioral agents as the pre-test only the route was reversed. Finally, the IMI was administered after the post-test scenario.

RESULTS

A one-way between subjects ANOVA was conducted to compare the effect of instructional strategy on intrinsic motivation and engagement. The results showed no significant differences in intrinsic motivation, assessed by the IMI, or engagement, assessed by the Engagement Measure, between instructional strategy conditions.

Pearson correlation coefficients were computed per condition to assess the relationship between intrinsic motivation measured by the IMI subscales and overall training vignette performance (Table 3). There were moderate positive correlations between Perceived Competence and detection accuracy in the Control and Highlighting conditions. In the Highlighting condition, there was a strong negative correlation between Perceived Competence and median response time. There were moderate negative correlations between Pressure and Tension and classification accuracy and Highlighting conditions. The Massed Exposure condition did not reveal any significant correlations between performance and intrinsic motivation.

Table 3
Pearson correlation coefficients of Effort and Improvement (EI), Perceived Competence (PC), Pressure Tension (PT), and Interest Enjoyment (IE) IMI subscales with Detection Accuracy (DA), Classification Accuracy (CA), and Median Response Time (MRT).

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Highlighting</th>
<th>Massed Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DA</td>
<td>CA</td>
<td>MRT</td>
</tr>
<tr>
<td>EI</td>
<td>-.020</td>
<td>-.212</td>
<td>.177</td>
</tr>
<tr>
<td>PC</td>
<td>.458*</td>
<td>.342</td>
<td>-.132</td>
</tr>
<tr>
<td>PT</td>
<td>-.345</td>
<td>-.540**</td>
<td>.327</td>
</tr>
<tr>
<td>IE</td>
<td>.103</td>
<td>.035</td>
<td>.029</td>
</tr>
</tbody>
</table>

*p < 0.05; **p < 0.01

The relationship between Engagement Measure scores and overall training vignette performance were also assessed using correlation analysis. Across all conditions, there was a weak negative correlation between the Engagement Measure and classification accuracy \(r = -.215, n = 90, p = .042\). However, results between conditions revealed no significant correlations among performance and the Engagement Measure.
Finally, correlations were computed to analyze the relationship between the IMI subscales and the Engagement Measure both across and between conditions (Table 4). Across conditions, there was a moderate positive correlation between Effort and Improvement and the Engagement Measure, but the correlation was not significant between conditions. There was a slightly weaker correlation between Pressure and Tension and the Engagement Measure across conditions and for the Highlighting condition only. The strongest positive correlations were revealed between Interest and Enjoyment and the Engagement Measure, which were consistent both across and between conditions.

<table>
<thead>
<tr>
<th></th>
<th>Across Conditions</th>
<th>Control</th>
<th>Highlighting</th>
<th>Massed Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EI</strong></td>
<td>.305**</td>
<td>.249</td>
<td>.338</td>
<td>.260</td>
</tr>
<tr>
<td><strong>PC</strong></td>
<td>.176</td>
<td>.000</td>
<td>.247</td>
<td>.278</td>
</tr>
<tr>
<td><strong>PT</strong></td>
<td>.298**</td>
<td>.190</td>
<td>.363*</td>
<td>.294</td>
</tr>
<tr>
<td><strong>IE</strong></td>
<td>.781**</td>
<td>.789*</td>
<td>.753*</td>
<td>.795*</td>
</tr>
</tbody>
</table>

*p < 0.05; **p < 0.01

**LIMITATIONS**

Presently, there is a lack of specific system requirements for robot-aided ISR interfaces, such as system speed, camera height, and field-of-view. Therefore, the experimental testbed design was aligned with recommendations from current UGS research and development literature, which may limit the realism of the simulation compared to future real-world systems. However, there was no evidence from this experiment indicating that the experimental design and results may not be applicable to emerging UGS training technologies for similar tasks.

Waypoints for the virtual UGS route during each scenario were placed along predefined roadways included in the selected VBS2.0 terrains. While this method reduced development time, it also affected the proper balance and distribution of the behavioral agents, animation triggers, and left versus right turns along the route. This limitation is currently being addressed in follow-on experimentation by plotting routes independent of the terrain and then properly balancing the presentation of behavioral agents, animation triggers, and turns using customized software scripts.

**DISCUSSION**

The ANOVA results did not support H1, suggesting that the Highlighting, Massed Exposure, and Control conditions were equally as motivating and engaging according to the scales used. Perhaps the presentation of behavioral agents individually and positioned separately from other behavioral agents provided a limited level of challenge during the training vignettes. This simplicity may have reduced the impact on intrinsic motivation and engagement, regardless of the instructional strategy employed. Theories related to flow state suggest that tasks considered too simple or too difficult may impact intrinsic motivation and engagement (Carroll, Kokini, Champney, Sottilare, & Goldberg, 2011; Csikszentmihalyi, 1990; Csikszentmihalyi & Nakamura, 1989). Future planned experimentation will increase the complexity of the task to include groups of targets and will investigate the effect of instructional strategy on flow state and the impact of flow on intrinsic motivation and engagement.

H2 predicted there was a significant relationship between intrinsic motivation and behavior cue analysis performance. The correlation results revealed that in the Control and Highlighting conditions, increased levels of Perceived Competence correlated to higher accuracy in detection, reduced response time, and greater distances between detected targets and the UGS. Additionally in the Control and Highlighting conditions, lower levels of Pressure and Tension correlated to higher accuracy in target classification. These results suggest that a lower signal probability and the use of a non-content feature to orient attention to targets contribute to successful execution, a greater perception of one’s competence, and lower stress during the training task. Perhaps the lack of intrinsic motivation and performance correlations in the Massed Exposure condition suggests that the higher signal probability decreased the impact of intrinsic motivation on performance. Perceived Competence and Pressure and Tension may be closely related to perceived levels of stress. Therefore, additional research will further investigate the impact of instructional strategy on stress state.

There was not enough evidence to support H3, which predicted a significant relationship between engagement and performance for the behavior cue analysis training task. Interestingly, although the relationship was weak, lower engagement was correlated to greater accuracy in target classification. Assuming humans are more likely to engage with other humans, it was expected that engagement would be greater during the behavior cue analysis task and result in higher performance because the task involved detection of human-like targets. Perhaps an unanticipated limitation in the Engagement Measure affected participants’ interpretation of the questionnaire items. Future SBT research may consider a
more exhaustive approach to assessing engagement by comparing scores from a variety of other validated measures of engagement. The intrinsic motivation and engagement correlation results support the H₁ prediction of a significant relationship between the two constructs. Increased Effort and Improvement on the IMI was correlated to increased engagement suggesting that an individual is more engaged when greater effort is expended to improve performance on a task. Interestingly, there was a slight indication that decreases in Pressure and Tension correlated to higher engagement which may suggest that the more difficult or stressful a task, engagement tends to increase. Further research investigating the impact of workload or stress state may provide more insight into these relationships.

Also in support of H₂, the Interest and Enjoyment IMI subscale was strongly correlated with engagement and emerged as a substantial contributor to the level of engagement during the behavior cue analysis training task. As interest and enjoyment increased, the level of engagement was greater. These findings are consistent with prior engagement and intrinsic motivation research revealing a positive relationship between changes in the level of interest and engagement (Carroll, Kokini, Champney, Sottilare, & Goldberg, 2011; Craig, Graesser, Sullins, & Gholson, 2004).

CONCLUSION

This experiment sought to provide a deeper understanding of intrinsic motivation and engagement in the context of SBT for robot-aided ISR tasks involving the analysis of human behavior. It appears the relationships between intrinsic motivation, engagement, and performance align with previous research. While the results presented herein may not support a definitive recommendation for a SBT instructional strategy selection, it is important to note that neither the Highlighting nor Massed Exposure strategies appeared to significantly hinder or dampen intrinsic motivation or engagement. Experimentation and analysis for further investigation are currently in progress and will explore additional design factors, such as flow, stress state, immersion, and workload.

ACKNOWLEDGEMENT

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REFERENCES


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