Cognitive Processing Considerations of the Small Unmanned Ground Vehicle

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ABSTRACT

Unmanned and robotic systems provide great promise and benefit in a variety of military applications. Although each of the varieties of systems have their own capabilities, one common operational challenge is the cognitive demands placed on operators who must make sense out of information presented to them by the system and communicate that information to others while controlling the system. For example, effective operation of the U.S. Army's Small Unmanned Ground Vehicle (SUGV) requires both procedural skill (e.g., use the hand controller buttons, know the menu options) and tactical skill (e.g., know how to use the system to accomplish the tactical mission, such as searching a room). The purpose of this paper is to document the cognitive demands placed on SUGV operators that impact training. The Task Analysis by Problem Solving method of cognitive task analysis was used to identify the categories of knowledge needed to operate and employ the SUGV and to understand how those categories interact. The analysis indicated that SUGV operators must simultaneously operate the vehicle, execute goals and subgoals, apply military knowledge, apply non-military knowledge, and communicate with leaders. The results suggest various recommendations to improve SUGV training. For example, to better estimate the size and shape of a room, the operator must choose to rotate the vehicle or robot head to view the entire space. Such steps are unique to human-robotic interactions and can substantially increase the mental demands placed on the operator. The need for such deliberate, compensating decisions must be understood and addressed through training to avoid compromised information gathering and to minimize cognitive load. By using the SUGV as a model, lessons learned can be generalized to the training of other unmanned and robotic systems in order to minimize cognitive demands and increase tactical effectiveness.

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Richard L. Wampler is a senior training analyst with 40 years of experience, including more than 20 years of active Army service. He has assessed training performance, determined shortfalls in meeting requirements, and designed/developed a multitude of cutting-edge training programs and materials to satisfy Army needs. A recent project entailed the development of a handbook so leaders and Master Trainers can more effectively train their SUGV operators.

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INTRODUCTION

The value of ground-based robots has been proven as a wartime asset. The U.S. Army has developed a 30-year plan to coordinate and synchronize Unmanned Ground System (UGS) research, development, testing and evaluation efforts. The goals of the plan are to provide manned-unmanned teams with leader persistence, protection, and endurance while decreasing physical and cognitive workloads on Soldiers and increasing their combat capabilities. The outcome will be a manned-unmanned team with improved movement and maneuverability, protection, intelligence, and sustainment (DoD, 2014). This paper provides an overview of the complex nature of the cognitive processes that developers, trainers, and operators need to consider when fielding new teleoperated ground vehicle systems.

Background

There has been an increase of robotic equipment being fielded that capitalizes on complex reconnaissance, security, and survivability tasks. One of these new systems is a small unmanned ground vehicle (SUGV). This vehicle is lightweight, remotely controlled, self-propelled, tracked, and can be used in multiple tactical situations to increase the safety of personnel. The SUGV enhances the small combat unit's ability to conduct military operations in urban terrain, confined access areas (e.g., tunnels, sewers, and caves), and over hazardous terrain. It also increases options and supports the execution of manpower-intensive and high-risk functions, tasks, and missions (Wampler, Lipinski, Mabry, Blankenbeckler, & Dlubac, In Preparation). SUGVs are designed to minimize direct exposure of Soldiers to hazards, direct fire, and observation. The system consists of a SUGV Operator Control Interface, a SUGV chassis platform with video capability (Figure 1), digital communications with audio relay modules (i.e., plug in/out), and advanced sensors/mission modules.

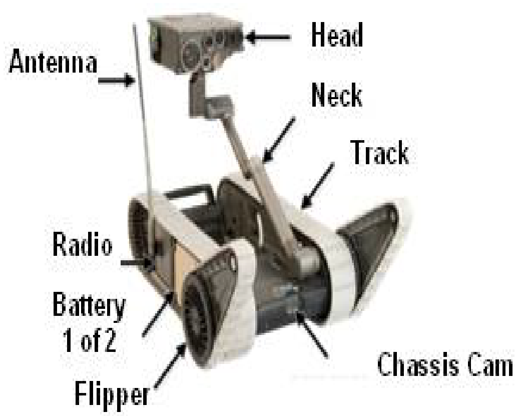

Figure 1. An Example of a Typical SUGV Chassis and its Parts

SUGVs provide sensor data and imagery to the operator in real time. Mobility features include the ability to climb stairs, negotiate obstacles, and maneuver in rough terrain. Early versions of small robotic vehicles have produced positive mission results, saved lives and equipment, and provided valuable lessons learned. The SUGV will be fielded at various Army units to support a multitude of tactical missions. The SUGV is challenging to operate (Wampler et al.), especially when time, decision-making, and reporting requirements are critical. There are no dedicated or specialized operators; unit members will have an additional duty to operate the system. Selected individuals in the unit will be trained with the requisite skills to enable efficient and effective operation, maintenance, and employment of the SUGV. Units are to sustain these skills and be ready to support tactical missions.

However, there are challenges to overcome if the maximum benefit is to be gained from the introduction of these unmanned systems. An operator must know how to control the SUGV both *procedurally* (e.g., use the hand controller buttons, know the menu options) and *tactically* (e.g., understand what the SUGV can and cannot do in various situations). Learning SUGV operational skills imposes a cognitive load beyond other military, perceptual decision-making, and communication skills that need to be utilized. Therefore, system and course developers, trainers and leaders must understand the cognitive demands placed on operators and how cognitive load impacts an operator's performance. Training materials must be designed and developed so that operators can effectively and efficiently take advantage of the capabilities offered by the SUGV.

Previous Observations of Cognitive Requirements

The Army Research Institute (ARI) recently identified challenges in training SUGV operators to perform operational tasks (Wampler et al.) and developed SUGV operator training materials. ARI has examined training materials from a pilot SUGV Master Trainer Course and from the Future Combat System programs, observed multiple iterations of SUGV Master Trainers instructing students in how to operate a ground unmanned robotic system, and interviewed the trainers at various points throughout the research effort. The trainers identified tactical missions and situations where a robotic system could be used, analyzed how the robotic system might be employed, and identified robotic operator requirements. Further, ARI conducted structured exercises where SUGV Master Trainers had to perform two typical missions that required operating the robot, and to gain detailed feedback from the operators, observed and recorded these exercises, asked clarifying questions of the operators while the missions were being performed. Anticipating an increase in cognitive load, the intent was to develop training materials that focused on the cognitive challenges of operating SUGVs. Specific psychomotor and cognitive tasks and skills needed to operate the SUGV system were identified, such as interpreting images and verbally communicating what is being seen. Four major areas for training were acknowledged. The first is having the operator skilled enough to smoothly manipulate the SUGV to the desired location to support the mission demands. The second is developing the operators' ability to accurately and quickly interpret the scenes observed through the SUGV optic devices. The third is being able to apply the skills rapidly within a time-pressure situation. The fourth is gaining the experience to effectively communicate (verbally) information that is being seen through the robotic system. A handbook was developed that contains an assortment of materials to assist unit leaders in training SUGV operators. Some of these materials were designed with the intent to address the operators' cognitive load.

Cognitive Demands on Operators

The operation of a SUGV presents some unique challenges. A core challenge is with regard to the physical separation of the robotic sensor from the operator. Foundational approaches to cognition have emphasized the limited capacity of a human being to process abstract, symbolic information while using perceptual and motor processes as a means of operating in the world through input/output relations. Subsequent research across a host of domains has shifted this focus to one whose physical embodiment and sensorimotor processing is fundamental to cognition, action, and communication (Wilson, 2002). The relevant research to consider when analyzing the challenges of operating a SUGV is those that address divided attention, the allocation of mental resources, the relationship between vision and spatial cognition, and performance in cognitively "noisy" environments.

Divided Attention

When a person attempts multiple tasks simultaneously, there is a decrement in performance in one or more of those tasks. This occurs when the SUGV operator uses mental resources to communicate with his leader to report what he is seeing and doing while also trying to make decisions about how to achieve some goal with the robot such as determining the distance of some object from the robot. This is related to the notion of "divided attention" that leads to "load stress" (Conrad, 1951). Load stress is observable in the SUGV operator's tasks and might cause operators to make errors in perceiving and interpreting information from the robot screen, while at the same time trying to move the robot and provide verbal reports. Load stress is likely increased by perceived physical danger (i.e., under fire).

Allocation of Mental Resources

It is difficult to multitask if the similarity of the mental resources used in each task overlap. This is because individuals have only a limited set of mental resources to execute cognitive tasks ("Multiple Resource Theory"; Wickens, 1984). A SUGV operator's job requires that the operator perform two activities that use both visual and auditory/visual resources. The operator must communicate information to his leader (verbal resources) that requires him to perceive and analyze information from a heads-up display (visual). Simultaneously, the operator must listen to the leader's instructions (auditory/verbal) and then translate those instructions and apply them operationally. This simultaneous use of limited resources can lead to an array of cognitive and perceptual errors.

Visual and Spatial Cognition Relationship

One of the most difficult perceptual tasks is related to dimensionality. Visual processing involves the perceptual cues of height, width, and depth, called 3D. When processing information from 2D (without depth), there are time consuming steps that occur as one cognitively translates an image into 3D (i.e., asynchronous processing). Due to peripheral vision limitations of the vehicle, the SUGV operator must perform extra camera actions, such as rotation and multiple viewing angles, to better understand what is being observed; thus, adding processing time. Visual cognition depends on the "richness of the action interface" (Gottesman & Gronlund, 2001). Motoric and perceptual systems are both dynamic systems (Vernon, 2006). They are mutually informative; vision informs action and action informs vision. When one system is constrained, it alters perceptual and motoric dynamics and impairs cognitive processing and subsequent communication.

Performing Tasks in Cognitively "Noisy" Environments

In general, as reaction time decreases, the number of errors a person makes increases. This presents a challenge for SUGV operators with regard to the speed at which they have to do their job. Extreme pressure to execute tasks quickly can lead a person to make more errors. This has been shown in studies of air traffic controllers (ATCs; Rantanen & Levinthal, 2005). To offset inaccuracies and error rates for ACTs, controllers often work in pairs, thus sharing the cognitive load and increasing their situational awareness. Further, there is evidence that people are unaware that their performance might be decreasing due to cognitive overload (Lesch & Hancock, 2004). Hence, SUGV operators might not be aware that their attempts to perform more rapidly will lead to a corresponding drop in accuracy. The effect on performance due to these deleterious factors is complex (Gawron, 1982). Emergency room (ER) physicians also perform in cognitively noisy environments. Expertise influences cognitive load because the more experienced SUGV operators will have more skills and automatic processing abilities, and thus will experience reduced cognitive workload and stress. Therefore, it is important that SUGV operators develop a high level of procedural and tactical skills (approaching automaticity) so that they have more resources available to address the novel aspects of each situation they encounter.

Cognitive Load and Memory

One's working memory is limited (e.g., Baddeley, 2002). The learning cognition literature shows that working memory is used heavily during the learning process to construct new knowledge and to integrate new information with existing knowledge (Gyselinck, Ehrlich, Cornoldi, de Beni, & Dubois, 2000; Mayer & Moreno, 2003). Cognitive load is an evolving and dynamic cognitive state. It is part of a past, current and future interactive system in which time pressures and social consequences of performance shapes the processing of information, the interactions with the environment, and communications regarding that information. Consequently, a SUGV operator cannot reach out and manipulate the environment, leading to additional investigation that requires considerably more moves (and time) by the SUGV. In contrast, when physically present, it is easier to act more quickly, to interact physically with greater efficiency, and to interpret the environment differently.

Using Task Analysis to Guide Training

An expert is very good at performing the tasks in that domain. However, experts are often unable to describe *how* and *why* they do the various steps that make up a task. This is due to the fact that many of these tasks have become automated and the cues that guide an expert's choice of steps and the task itself often cannot be articulated well. The task analysis approach developed by Catrambone (2011) aims to uncover the knowledge of an expert. The value of ascertaining expert knowledge is that it can inform the development and integration of instructional materials for all levels of learners. Many task analysis techniques exist (for a review see Schraagen, Chipman, &

Shalin, 2000). The merits and pitfalls of these techniques have been considered. Some pitfalls are unneeded complexity and a narrow application (Schraagen et al., 2000). Performing a task analysis is different than developing "learning objectives." For example, an instructor might have a learning objective that students should be able to solve relevant problems. However, the learning objective says nothing about the procedural content the learner needs to know in order to solve those problems.

The development of successful training systems (e.g., text instructions, images, animations, simulations, multimedia learning environments) requires the instructional designer to first identify what the learner needs to know. This is problematic because the subject matter experts (SMEs) involved in the development of training materials have automated and chunked many aspects of their knowledge. As a result, they fail to thoroughly identify the knowledge that a novice needs to learn. Thus, a task analysis is performed to identify the missing information. Task Analysis by Problem Solving (TAPS) is one approach to task analysis (Catrambone, 2011). Once a task analysis such as TAPS has been performed, the results can be used to guide the development of training materials. TAPS can determine what knowledge and skills should be instructed.

Task Analysis by Problem Solving

The Task Analysis by Problem Solving (Catrambone, 2011) approach requires collaboration between an SME and a knowledge extraction expert (KEE) who is a novice to the domain. Using TAPS, the SME identifies a set of typical problems, tasks, and scenarios that are performed within a certain domain. These tasks are ones that someone who "understands" the domain should be able to execute. Then, the SME carries out the tasks with the KEE observing. The KEE's job is to require the SME to verbally explain the SME’s problem solving process. The aim is to identify the steps, create detailed notes that explain *why* each step is being carried out (or not) and, any subgoals/sub-steps. The KEE edits the notes in order to extract procedures, decision rules, facts, etc. Next, the SME repeats the process to allow the KEE to check and edit the notes for accuracy. The KEE then executes the tasks allowing for the KEE to verify the accuracy and, if needed, to elaborate on the notes. The KEE will also solve new problems provided by the SME. Usually, there will be an impasse for the KEE for both old and new problems. When this occurs the KEE consults with the SME which leads the SME to recall and supply some missing information. This allows the KEE to adjust the notes. The TAPS process continues until the KEE can successfully execute all the tasks provided by the SME. The KEE is relying on the notes to execute the tasks; the intent is to develop complete notes and not to train the KEE. Depending on the domain and intent of the TAPS process, notes might be organized into subgoals, steps, facts, rules, definitions, implications, and conventions. There is evidence that subgoals have psychological validity for predicting problem solving transfer (Catrambone, 1996, 1998), the other categories aid in the organization of the information. This iterative knowledge elicitation process allows the KEE to conclude that all of the needed information has been identified.

METHOD

Participants

The SMEs for this report were three SUGV Master Trainer Course instructors from Fort Benning, GA.

Procedure

The research team consisted of three retired military personnel and the KEE who executed the TAPS process with the SMEs to identify the steps and requirements for operating the ground robot vehicle. The SMEs performed various tasks (system operation, driving, buttonology, maneuvering stairs, searching rooms and crossing varied terrain) and provided details about the SUGV operations and they provided first-hand insights of operating a SUGV in combat situations that enhanced the TAPS output.

Materials

One SUGV system was used. All tasks were executed inside and outside of a facility with stairs and multiple rooms where the lighting conditions could be varied (inside) and provided different terrain conditions (outside--paved parking lot, grass and dirt areas) where mobility considerations were demonstrated and discussed.

RESULTS

Our aim was to identify the cognitive demands placed on SUGV operators using TAPS. This process supported the information from previous observations (Wampler et al.) and provided more categorical details. The TAPS analysis confirmed and captured additional details about the cognitive loads that are placed on SUGV operators. ARI researchers identified five categories of knowledge pertaining to the operation of the SUGV. The first category addressed the “procedural skills” or buttonology of the hand controller (Figure 2)—knowing what each of the buttons and toggle switches controls, as well as, menu structure knowledge. This knowledge category includes robot movement—how to control the SUGV to do certain maneuvers such as descending or ascending stairs and "peeking" over an object. The second category addressed knowledge of how to use the SUGV to “achieving task goals and subgoals” to include SUGV camera operations. This example includes knowledge regarding the situations for which each of the cameras is best suited. The third and forth categories addressed the knowledge that is necessary to properly and effectively employ the robotic system. This knowledge includes both specific “military knowledge” (e.g., recognizing and identifying weapons and explosives) and worldly “general knowledge” not unique to the military (e.g., typical components one would expect to see in and on different types of vehicles). The fifth category addressed knowledge required to communicate and conveying information to leaders who are not able to view what the SUGV operator is seeing.

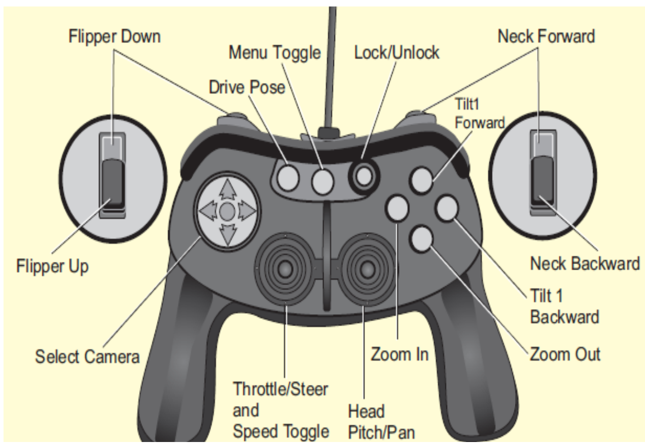

Figure 2. The Display of a Typical SUGV Operator Control Interface

These five identified categories of knowledge are not mutually exclusive; they may heavily interact. For instance, while one might know the buttons to push to make the robot more forward, to operate the flippers, and to switch among cameras, there are interactive strategies for *how* to approach an incline, *how* to make sure the robot is in a stable position, and *how* to be sure the robot has moved past an obstacle before attempting the next movement. These strategies require that the operator has the knowledge to press the correct buttons and choose the correct menu selections, and they also require the operator to have knowledge of the correct goals and subgoals for executing a strategy. These strategies depend on the operator's military knowledge and the ability to correctly interpret the information conveyed by the cameras. The SUGV operator has multiple competitors for cognitive resources. These include forming a plan for achieving some goal (i.e., climbing stairs), dividing the goal into a set of subgoals (approaching the stairs, "squaring up", etc.), determining the appropriate buttons to press and menus to access to achieve each subgoal, making decisions based on camera images, and reporting the information to, and listening for directions from, leaders who are remotely aware. SUGV operations might be performed under high stress (e.g., time pressure or high risk) and physical danger. From the SUGV TAPS analysis, the following categories were derived that demonstrate how an operator’s attention and mental resources compete with each other.

Procedural Skills

This category addressed knowledge concerning how to drive the SUGV, manipulate and choose cameras, access the various menus, etc. For instance, consider camera operation. In order to use the infrared (IR) camera, one must select that camera from a menu and recognize that the "IR illuminator" is on. However, one must also know how to access the main menu and then how to get to the appropriate submenu for cameras and how to check that the IR illuminator is on. Tasks can be represented as goals that can be decomposed into smaller and smaller subgoals. Steps for achieving these subgoals essentially take the form of subroutines that can be applied in a variety of cases. The short subroutine for accessing the main menu using the hand controller is an instance of a subgoal and method that can be used in many different circumstances.

Achieving Task Goals and Subgoals

This category addressed knowledge about the judgments operators must make as they drive and manipulate the SUGV. For instance, suppose the operator wants the SUGV to go down stairs. The operator needs to know how to drive the SUGV to the stairs and put it into the “descend pose”; this sort of knowledge should be well-learned and, therefore, trivial to recall. The operator needs to know how to use the cameras to look down the stairs to assess the slope, depth and width of each step, potential obstacles, etc. The operator also has to make judgments such as whether the SUGV is "squared up" to the stairs, how close to get to the stairs before lowering the flippers for stability, and when to move the neck forward to get a front view. These judgments and decisions are not issues of *how* to do things, but rather forming and knowing the right subgoals for *when* to do things in a particular situation. If operators are fumbling with the procedural details of making the robot move, they will have fewer resources available to recall the strategy for approaching the stairs and for making judgments about the SUGV’s position relative to the stairs, and fewer resources will be available for forming new subgoals to adapt to the situation if it changes.

Military Knowledge

This category addressed the SUGV operator’s knowledge pertaining to robots and soldiering. As an example, when entering a potentially dangerous room, certain things need to occur such as, checking for booby traps across the doorway and once through the doorway, to scan left and right. This knowledge is well-learned prior to a Soldier becoming a SUGV operator, and it needs to be practiced by the Soldier-operator and applied *to the SUGV*.

General Knowledge

This category addressed general world knowledge that might affect how the SUGV is used or how to interpret the information it is providing. For instance, suppose the operator is using the SUGV to check under vehicles and encounters a truck with two mufflers. If the operator knows that a particular truck model comes with one muffler, or if the operator knows that there should be a tailpipe for each muffler but sees only one tailpipe, then the operator could have reason to be suspicious about whether one of those mufflers might be an improvised explosive device.

Communicating with Leaders

This category addressed how an operator relays information to leaders. With the current SUGV system, only the operator can view the visual displays, and provide a verbal report to leaders. The effort to interpret what is seen by the operator requires mental resources and provides another source of cognitive load that competes for resources. Ultimately, *all* these tasks are competing for finite mental resources. The greater extent to which some of these tasks are automated, the less cognitive load they will generate and more cognitive resources will be available for the other tasks. For instance, someone who is an expert with buttonology will be able to devote more of the limited cognitive resources to interpreting what is seen and communicating that information to a leader.

DISCUSSION

It is clear that operating any type of vehicle requires a great deal of cognitive resources and competition for those resources. An experienced SUGV operator has probably automated some of the procedural knowledge (buttonology) and military knowledge. Yet, the operational demands remain high--the operator must interpret visual information and listen to directions from, and provide reports to, leaders. These tasks increase cognitive load on the operator making the performance of tasks more difficult. Moreover, a Soldier’s cognitive abilities are part of a transactional, dynamic system, as evidenced by the challenges of orientation with the SUGV. A Soldier who is physically inspecting a car is continually provided information about his orientation. This is not the case with using a SUGV and therefore presents training implications. The cognitive issues are not solely internal to the Soldier but rather in the collective, interactive Soldier-robot system. The Soldier functions as an active interface between the leaders and the robot. The cognitive limitations of that Soldier impact the information provided to leaders. However, if the Soldier has more information about the goals and aims of leaders, they will be better able to meet leader needs. Everything requires effortful action: limited sensor capabilities, unknown places, spatial orientation and reference frames are all off. For example, using the SUGV for climbing or inspection adds considerable cognitive load on the operator.

RECOMMENDATIONS

The following recommendations are directed toward the challenges of training the trainers, operators and leaders about divided attention, the allocation of mental resources, the relationship between visual and spatial cognition and the performance of tasks in a noisy environment. Effective trainers are able to teach and develop skills quickly. It is critical that they understand the cognitive demands placed on the learner. The following recommendations outline the major concepts emerging from previous research (Wampler et al.) and the outcomes from using the TAPS approach. These recommendations are derived from SUGV operators and might be applicable to other robotic vehicles and systems.

Divided Attention

With regard to the challenges of divided attention, the following two recommendations are offered: 1) enhance and extend procedural skills training: A well-trained operator can focus on things that require more attention. If the operator struggles with moving the robot, then the mission will take longer and will accomplish less due to the cognitive effort applied to operating the robot; and 2) communications with leaders: trainers must consider the impact of an operator's communication with leaders and their ability to simultaneously operate the vehicle in the context of extremely challenging terrain, poor visibility, or increased time pressure. The operator is the only person that can see the visual information coming from the sensors; it is not shared through any network connection. So, an operator's experience and communication skills must meet the needs of the mission and leaders. Specific considerations include: a more experienced operator will attend to relevant details and identify "patterns of life" that are relevant for leaders and decision makers; leaders, trainers, and operators must establish standard operating procedures for describing what is observed—if not, mission delays and mistakes will result; and, communicating with leaders during SUGV operations places additional mental demands on the operator.

Allocation of Mental Resources

With regard to the challenges of the allocation of mental resources, the following two recommendations are offered: 1) Best use of time: Trainers should help the operator make the best use of time to ensure that the highest priority actions are performed within the allotted time. The operator needs to know shortcuts and the risks of those shortcuts, and to ensure the leader understands the risks imposed, as well as when to speed-up certain tasks. A high cognitive load will slow task execution, so training some time-saving alternatives is helpful and 2) when to use certain capabilities: Trainers must convey *when* it is appropriate to use certain capabilities. There is a selection of cameras on the SUGV. The operator should know which camera to use under differing circumstances. Further, operators should know the total system capabilities and under what circumstances they should be used.

Visual and Spatial Cognition Relationship

With regard to the visual and spatial cognition relationship, the following two recommendations are offered: 1) alternate training and operations between pairs of operators: Due to the high cognitive demands and visual processing, operator pairing might reduce overall stress. Most operators report that fatigue and eye strain occurs in about an hour. To offset the extended battery life of the robotic system, have two operators switch off and relieve each other; and 2) time to perceive: Trainers must allow the operators to become skilled in visually translating an observed 2D image into a 3D perception of that image. When physically entering a room, Soldiers use natural visual and motor system cues to interpret a scene and to maintain spatial orientation. By contrast, operators need additional processing time to compensate for the lack of natural information. Therefore, the need to make deliberate and compensating decisions that ultimately reduce cognitive load must be addressed through training.

Performing Tasks in Cognitively "Noisy" Environments

Experienced Soldiers interpret scenes differently than a novice. They will use the SUGV to explore different aspects of the scene with a more dynamic approach, will have a higher degree of automaticity, and experience reduced load and stress. Prior experience dictates what information to attend to, the resulting actions of the SUGV, and what is communicated. Repetition decreases cognitive load. People use what they know to shape what they do; all operators are not the same and not all are equal. With regard to performing tasks in a cognitively "noisy" environment, to include the concept of automaticity, the following two recommendations are offered: 1) a thorough understanding of the user interface and buttonology: Trainers need to train the operator with regard to the multiple functions, buttons, directional arrows, knobs, etc. on hand controllers and interface functions. While operators will eventually learn to physically operate the SUGV in an automatic fashion (as with driving a car), the novice operator requires deliberate thought and effort. The novel operations require remembering basic controller buttonology, anticipating impacts on vehicle stability, and determining the best way to maneuver the robot. Trainers need to be cognizant of the operator's ability to physically manipulate the vehicle before attempting to train more mentally complex tasks; and 2) training repetition: Trainers need to ensure operators are well practiced. Automaticity is valuable for two reasons: automaticity reduces the cognitive demands of a task, which increases the availability of resources for attention and promotes effective communications. Also, Wilson (2002) suggests that automaticity allows for finer-grained control over a given action. Limited skills in driving taxes a person's cognition, attention, and working memory.

CONCLUSION

A proficient operator is one that will have well honed and automatic skills, making available cognitive resources for more demanding tasks. Further, task analyses can help identify, improve and develop training exercises and materials. Robotic systems will mature and provide more capabilities for the users, begging the question, how will these new capabilities impact the operator's cognitive load? The recommendations from this study might impact operator selection. Perhaps, operators should team up and distribute the high cognitive loads similar to the way ATCs team up. With the forecasted reduction in the number of forces, researchers should take advantage of this opportunity to improve training efforts and develop training requirements across all robotic platforms—aerial, ground and sea. In addition, the designers of Soldier operated robotic systems and the trainers of those systems need to consider the cognitive impacts on training and performance by considering the recommendations as reported in this paper. Well-developed robotic systems and proper training of these systems will lead to successful Soldier-robot synchronization.

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