Soldier Performance Issues in C2 "On the Move"

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ABSTRACT

For several years, the need for increased mobility for command and control (C2) assets in U.S. ground forces has been apparent. However, increased use of automated information systems in moving vehicles does incur a price in Soldier performance. There are many Soldier performance issues associated with the performance of tasks while the vehicle is moving, that is, "on the move." This paper presents some of the issues related to the effects of vehicle motion on Soldier performance. The issues include vibration, visual displays, manual control, interactions among Soldiers, cognitive functions, and workload. Four areas of mitigation for vehicle motion effects are identified and briefly discussed.

BACKGROUND

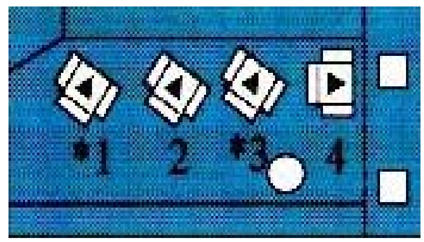
For several years, the need for increased mobility for command and control (C2) assets in U.S. ground forces has been apparent. The Army's command and control vehicle (C2V), proposed in the early 1990s, was in response to the inability of tactical operation centers (TOCs) to keep pace with advancing ground forces during Operation Desert Storm. Currently, the Mounted Battle Command On-the-Move (MBCOTM) program is being developed to provide the commander and some of his staff with the ability to monitor the battle and influence events during periods when the commander is away from the TOC. This trend will be extended by the Future Combat Systems (FCS) in which stationary locations will be replaced by multi-functional, highly mobile, distributed vehicles. In the FCS concept, the C2 function will be achieved by increased mobility and will provide information dominance. However, this increased use of automated information systems in moving vehicles does affect Soldier performance.

This paper discusses some of the issues involved in Soldier performance in moving vehicles. There are technological challenges to ensuring communications and data exchange among moving vehicles in addition to challenges in Soldier performance. Soldier performance issues should be at the forefront as future systems are designed.

To assist in understanding the Soldier performance "on the move" issues, first some background on studies where performance was degraded by vehicle motion is provided. Then what we mean by "on the move" and why it is important for future Army systems is discussed. Issues related to Soldier performance effects resulting from vehicle motion are discussed as well as potential solutions to help manage and overcome these effects.

In the early 1990's, a system called the C2V was developed in response to experiences in the Operation Desert Storm. These experiences showed that the battle moved more quickly than the TOCs. The tracked C2V was built on an M558 chassis, with four work stations in the back (see figure 1). A series of studies of Soldier performance in the original C2V in the 1990s showed that vehicle movement produced substantial degradation in individual and group task performance (Cowings, Toscano, DeRoshia, & Tauson, 1999; Beck & Pierce, 1998).

(a)



(b)

Figure 1. (a) The C2V from the 1990's, built on an M558 chassis; (b) The positions of the four work stations within the back of the C2V.

Other studies of performance in moving vehicles have shown performance decrements and sometimes motion sickness symptoms. For example, in a modified M113, cognitive task performance was less accurate (7 to 46%) and slower (7 to 40%) during moving operations (Schipani et al., 1998). Another study showed that, in a moving amphibious assault vehicle, 74% of the Marines tested reported moderate to severe motion sickness symptoms after working at computer workstations (Rickert, 2000).

Studies such as these, as well as anecdotal information received from the field, suggest that Soldier performance will be affected by motion and this issue should be examined and resolved to an acceptable level.

WHAT DO WE MEAN BY "ON THE MOVE"?

There are many Soldier issues associated with the performance of tasks while the vehicle is moving. For example, performing a computer-based task in the rear compartment of a moving vehicle presents multiple challenges for the Soldier, including seeing the displayed text and graphics (perception), understanding the display (cognition), communicating and collaborating with others (team performance), and using input or control devices (motor activities). In addition to these challenges, some proportion of the Soldier population will be susceptible to motion sickness.

Often the phrase "C2 on the move" is used to describe issues related to the ability of technology to be networked and successfully used within and across moving vehicles. The role of the Soldiers using that equipment and the challenges that Soldiers face in this environment will be emphasized in this paper. It is a mistake to believe that total system performance, including both technology and the Soldiers who use it, will not be affected by vehicle motion. The U.S. Army Research Laboratory, Human Research and Engineering Directorate, and others are working to identify procedural and materiel solutions to reduce the performance loss associated with vehicle movement. The effects of vehicle motion across a variety of tasks, including C2, are being examined.

HUMAN PERFORMANCE ISSUES RELATED TO ON THE MOVE

This paper presents a list of issues related to the effects of vehicle motion on Soldier performance. Some of these issues have previously been studied and information published about the effects and possible mitigation approaches. Other issues have not been previously addressed and need additional study to understand the phenomena and identify potential solutions.

There are two major aspects to vehicle motion effects on Soldier performance. The first aspect concerns the effects of movement on perceptual and psychomotor performance. The experience of movement, with the attendant vibration and noise, affects the ability to see and the ability to perform some physical movement tasks. A second, separate aspect is motion sickness. The degree to which motion sickness affects performance (as well as approaches to mitigate motion sickness) is not fully understood. What is important to recognize is that whether a person experiences discomfort or sickness from motion, a human's ability to see or control physical movement is affected to some degree. A number of potential human performance issues are presented here. While all answers are not yet known, it is important to recognize that there are additional factors to be considered when Soldiers will be performing tasks during moving conditions.

Vibration

The effect of vibration on the human has been an issue across many application areas. Subjecting the human to vibration can result in complex responses. Vibration can be defined in terms of both acceleration (magnitude of vibration) and frequency (number of motion cycles per second). The duration of vibration exposure is also important. For individuals inside vehicles, the primarily interest is in whole-body vibration, where the body is seated on a vibrating surface, in this case, a vehicle. Various levels of vibration can have different effects on humans. The frequencies of interest for effect on humans are in the 0.5-Hz to 100-Hz range. Very low frequencies (below 0.5-Hz range) are the range at which motion sickness occurs. At higher frequencies, other responses occur. For example, at 4 to 8 Hz, human performance is greatly disrupted; at 30 Hz, the resonant frequency of the eyes within the head and vision is greatly disrupted. Duration exposure is less well understood and depends on many factors. ISO Standard 2631, *Mechanical vibration and shock -- Evaluation of human exposure to whole-body vibration -- Part 1: General requirements* (1997), is used to determine time-dependent effects of vibration on health, performance, and comfort. However, there is some controversy regarding the validity and applicability of the standard (e.g, Griffin, 1990; Oborne, 1983).

Designers need to consider the potential effects of vibration on human performance and design to eliminate or lessen the effects. MIL-STD 1472F (Department of Defense, 1999) contains standards on vibration.

Visual Displays

Vision is affected by the vibration of moving vehicles. Discussions of the effects of vibration on vision are contained in several reviews (Moseley & Griffin, 1986b; Lewis & Griffin, 1980; Griffin & Lewis, 1978). Also, Moseley and Griffin (1986a) present some guidance on designing visual displays in vibration environments.

There are a number of issues related to visual displays, which do not yet have definitive answers. For example, the size of text, spacing, and symbols for various tasks in motion environments have not yet been fully explored. The idea of adaptive displays, where the display changes, depending on conditions or the state of the operator, have been conceptualized as a possible way to address the ability to see displays while moving. The use of animation is another area that might be explored to see under what circumstances it is a useful element and if it is differentially effective in motion versus stationary conditions. For some individuals, viewing a moving, animated display while physically experiencing a different motion could affect performance.

The use of multi-modal displays in motion should be explored. Vision is the primary input sense in many circumstances, so the question becomes to what degree the other senses can be used to receive data. In particular, the use of auditory displays has been explored for stationary environments but has not been fully explored for motion environments. The same is true for speech input and output. Another area of current research is in tactile displays, where the sense of touch is used to convey information. If, and how best, multi-modal displays can be used in moving vehicles is an open area for research.

Manual Control

Manual control movements by humans also become more difficult in moving environments. Discussions of the effects of vibration on manual control are contained in several reviews (McLeod & Griffin, 1989; Lewis & Griffin, 1978). Also, McLeod and Griffin (1986) present some guidance on designing visual displays in vibration environments.

The ability to use various input devices is affected by motion. Designers need to recognize the effects of motion and choose devices that account for those effects. Input tasks, such as cursor control, sketching, and using touch buttons, are affected by motion. It should not be assumed that because there is successful performance in stationary conditions that the same performance will occur within moving conditions.

Interactions Among Soldiers

An important component of C2 is the ability to communicate to seek or share information between and among people. This is one aspect of teamwork. This may be in collaboration with others or it may be more hierarchical communication. The communication and collaboration may be among peers or among commanders and subordinates. The communications and collaboration can take place in a variety of settings, such as face-to-face discussion or via computer tools. The timing of the communication and collaboration may take place in the same time frame, such as a face-to-face discussion or "live chat" (sometimes called synchronous communication) or across time, such as conversations or e-mail delayed by time (sometimes called asynchronous communication).

It is of interest to know if interactions among people are affected by the performance of those interaction tasks in moving vehicles. Is communication among people affected or changed by a moving environment? Are various media or tools more or less effective during motion? Does a vehicle need to stop for some period of time in order for its crew to accomplish certain tasks? These are all questions that have not yet been examined systematically.

Cognitive Functions

There is some evidence that movement, particularly vibration, affects cognitive functions. Sherwood and Griffin (1992) found some differences in the rates of learning between two groups, a vibration group and a static group. Schipani et al. (1998) found differences in a cognitive battery performance in areas such as time sharing, selective attention, inductive reasoning, memorization, and spatial orientation after exposure to rides in a modified M113. The effect of ride motion on cognitive functioning is an area where more information is needed.

Workload

Workload can be considered the psychological cost of doing work. It is the amount of the available resources that an individual uses to accomplish a task. In general, as workload increases, performance decreases. So, does operating in moving vehicles increase workload, adding to other possible factors in causing performance degradation? Certainly, anecdotal information suggests that, at the least, more physical work is done just to "hold on tight" in a moving vehicle, especially as the ride becomes bumpier. The question of cognitive workload is similarly of interest; do tasks take more effort cognitively because they are performed in moving vehicles?

Issues related to human performance and the ability to successfully accomplish tasks while moving appear in many areas such as physically performing tasks, cognitively (i.e., mentally) performing tasks, and interactions among individuals and teams.

POTENTIAL AREAS FOR MITIGATION

Our approach to performance degradation in moving vehicles is to suggest ways to mitigate the potential degradations in performance, not just identify the problem areas. Similarly, Rolnick and Gordon (1991), in their discussion of motion sickness and military performance, identify various prevention and treatment approaches. From that and other published literature, four primary areas where mitigations for vehicle motion effects may be explored were identified: vehicle design, personnel selection, personnel training, and other interventions, including medical.

As human factors engineers, our perspective is to start with vehicle design as a way to affect performance and address the vehicle motion effects. A potential area to address is the design of the vehicle to reduce vibrations known to affect performance. Other vehicle design issues include air quality (such as air flow and filters) and direct versus indirect external views. Similarly, the design of the work station, including the seating, computers, displays and control, may be changed to minimize vehicle motion effects on performance. Vibration dampeners and vibration coupling of observer and display and controls are also of interest.

Choosing personnel who are minimally affected is another potential approach to mitigation of motion effects. However, having personnel meet particular motion effects criteria will reduce the flexibility of assignments. Currently, people self-select for some jobs. If it is a job that requires performance that they believe they will not perform adequately, the individuals will not request that job or will ask to be moved. For selection, we must also have good predictors of future performance; the ability to predict motion effects would need to be enhanced for this approach to be successful.

Training is another approach that has been used to mitigate motion effects. As an example of training for the motion sickness part of motion effects, Dr. P. Cowings and colleagues, NASA-Ames, have developed an autogenic feedback approach for astronauts. They have found that the Autogenic Feedback Training Exercise (AFTE) is better than some medical interventions for motion sickness for space travel (e.g., Cowings & Toscano, 2000). Whether the AFTE would apply equally to Soldiers in Army ground vehicles is open to question. Other possible training solutions might be in desensitization or habituation training for individuals. The applicability of these latter approaches to ground vehicles is not established.

Another example of training is providing information that "trains" people in phenomenon of vehicle motion effects, how to identify them, and what to do about it. For example, the Navy published information about simulator sickness (Simulator Sickness Field Manual Mod 4, Naval Training Systems Center, Orlando, FL, 1989) to familiarize personnel with the phenomenon. At a minimum, this kind of information might be useful for Soldiers when they are performing operations on the move, so they know what is happening and what to do about it.

There are other interventions, such as pharmaceuticals or other medical devices, that may prove effective in dealing with the motion sickness portion of the motion effects issues. These interventions are within the purview of the Army medical community and are outside the scope of our work.

SUMMARY

This paper has identified some issues related to Soldier performance in moving vehicles. We need to consider how performance is affected when designing systems and tasks for moving environments. Information is available about this topic, but more needs to be known in order to answer specific questions about how to mitigate degradation caused by vehicle and task design.

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