

HUMAN PERFORMANCE ISSUES IN BATTLEFIELD VISUALIZATION

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SUMMARY

Visualizing future battlefields is an important objective for the 21st century Army. Technological advances promise a knowledge rich battlefield with virtual planning, multi-modal visualizations, disbursed operations, and highly intelligent automated systems. Too often the role of the future soldier and in particular the commander is ignored (Barnes, 1997). Visualization technologies are being developed to aid the commander in understanding future battlespaces including battle trends and possible end states. Obviously, the effects of visualization will cascade over the entire battlefield and influence both the common and specialized views of the battle at all echelons. Yet the demand for improved technology outpaces our understanding of the benefits of the various techniques (Barnes & Wickens, 1998). The objective of this research program is to investigate the effects of important visualization issues on soldier awareness and decision making in areas that we expect to impact future operations. Areas that we have investigated include soldier performance in immersed and three-dimensional (3-D) map related tasks, visualizing uncertainty in highly automated environments, combining machine intelligence with visualization tools, and trust issues for automated environments. The purpose of the visualization research is to develop a cognitive engineering architecture that will help guide the development of visualization systems based on behavioral and operational considerations rather than being based solely on the promise of new technologies. The key to our effort is to develop and use cognitive models of human visualization performance and verify them in the laboratory using important military problem sets and subjects to establish general concepts. These concepts will be used to develop realistic visualization tools that can be evaluated in appropriate field experiments as part of a more general Cognitive Engineering Science and Technology Objective (STO).

Terrain Visualization: As part of the program, researchers from the University of Illinois investigated a variety of military map tasks using United States Military

Academy cadre as test subjects. The research purpose was to investigate visualization variables using Silicon Graphics generated synthetic terrain. The initial experiment varied viewing conditions and display dimensionality. The cadre performed better using two-dimensional (2-D) vice 3-D displays for map distance measurement and equally well for mobility assessment. The 3-D displays showed some advantage when the cadres could immerse themselves in the terrain allowing them to make more accurate LOS judgments. Subsequent research indicated serious situation awareness issues with being immersed in the terrain. The cadre became fixated on the immediate environment and would lose track of threats behind them even when the threats were annotated on their display (Wickens, Thomas, & Young, in press). This on-going research points to serious limitations of both 3-D and immersed display formats; cognitive engineering solutions are suggested to utilize the considerable advantages of these formats without being constrained by their limitations.

Visualizing Uncertainty: An ubiquitous battlefield problem is risk management in uncertain environments. The question we addressed is how to best display uncertainty when operators are defending against missile attacks during a national missile defense (NMD) simulation. We compared displaying abstract probabilities of mission success to displaying concrete representations based on expected loss frequencies and found an advantage to the latter for improving display search and visualization memory but we found no effect of format on the trained NMD operators' actual decisions (Barnes, Wickens, & Smith, 2000). In the second experiment, there was evidence of a decision bias related to the sequence of hits and misses of shooting down incoming missiles. The results imply that the operators' visualization of trend effects was primarily influenced by their perception of whether the situation was deteriorating as opposed to their understanding of the natural fluctuation of independent probabilities. The results influenced new NMD display concepts and caused us to design a series of experiments to evaluate risk visualization concepts whose purpose is to improve the

operators missile defense decisions using target value and risk as trade-off criteria.

Visualizing Automated Systems: Because of the importance of reacting before the enemy does and also the extreme complexity of combat system of systems, automation is becoming a pervasive component of modern battlefields. However, the human performance issues are not well understood and threaten to interfere with the efficacy of future systems. At least in the near future, human decision-makers will have the final authority for execution and in many cases data interpretation. However, our research into these issues has confirmed that soldiers mistrust the systems when they should not (Dzindolet, Pierce, Beck, & Dawe, in press) and over rely on systems when they should override them. Our on-going research will attempt to develop general principles of displaying information to ensure that the soldiers' battlefield awareness is sufficient to allow understanding of both the state of the system and also the state of battlefield. Improved visualization tools and a more thorough understanding of the cognitive issues involved should allow the human to know when to trust and when to override automated systems.

Models, Architectures, and Field Validations: We will present interim models of battlefield visualization derived from our empirical research and indicate how these models are driving our future research. The inter-relationship of the various efforts is their investigation of transformation of battlefield information into images that decision-makers can use to understand their combat environments. Our research results indicate that more than pretty pictures are involved: cognitive biases are pervasive in all areas investigated. Soldiers can become fixated in immersive terrains; too conservative or not conservative enough in missile defense, over and under reliant using automated systems. Research is continuing into the precise relationship between different data views and the amelioration of these biases. However, our initial results suggest that training as well as the proper type of visualization is crucial to overcoming these biases. This does not limit the utility of visualization concepts but rather broadens the practical applications. Successful visualization techniques will allow the soldier and the commander to understand the implications of various decisions using realistic animated environments that can be used for both embedded training and for battle management. We are in the process of developing a general visualization architecture that is generic enough to investigate these concepts in Support and Stability Operations (SASO) and other non-conventional operations as well as mid intensity combat in order to generalize the results to the expected venues of future conflicts. The general architecture is the initial step into transforming these general models and principles from the scientific to the applications domain.

Results from this research will be used to create specific concepts that are being designed to investigate

our results and possible applications as part of realistic field exercises. We discuss the importance of a phased research project that start with well controlled laboratory experiments and simple models and progresses to realistic validations. We point out the advantages and disadvantages of controlled experiments and closed loop simulations and exercises. Our conclusion is the synergy of both results in the understanding of causality and the ability to generalize to complex environments.

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