Exploring the impact of augmented night vision systems on cognitive workload and situational awareness for dismounted soldiers.

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***Abstract*—.** Augmented Reality (AR) helmet-mounted displays (HMD) provide the opportunity to improve task performance but also pose a cognitive burden risk. Several studies were conducted to assess the impact of number and type of HMD iconography on dismounted soldier performance. Study 1 was a pilot study involving field and simulation based assessments to compare cognitive workload for participants with and without an AR system. Studies 2 and 3 manipulated the simulation environment with number and type of icons. (*Abstract)*

Keywords—Augmented reality, night vision, cognitive workload

I. INTRODUCTION

Augmented Reality (AR) helmet-mounted displays (HMD) are able to supplement real-world vision by providing users with additional information such as navigation icons, information about tasks to be completed, and location of relevant resources. Supplementing real-world vision has the potential to improve task performance for a range of users, including military personnel conducting dismounted operations. The ADF enhanced Night Fighting Equipment Project L53-1BR is currently considering AR supplemented Night Vision Devices (NVDs). However, there is a risk with these devices that too much information may increase cognitive workload and adversely affect situational awareness and subsequently task performance.

The work presented is part of a broader research program that aims to understand the extent to which AR enhanced HMD would be beneficial to dismounted soldiers, and what limitations exist for operator performance (e.g. whether operators are at risk of cognitive overload or distraction due to the amount or type of information presented). The limitations on operator performance have been termed "cognitive burden". This is an umbrella term including attention, workload, situational awareness, memory, and other cognitive factors. The broad aims of this research are to-:

1. Conduct simulation exercises to understand the cognitive burden of dismounted combatants using AR HMDs,
2. Conduct field exercises to understand cognitive burden of dismounted combatant operations using current and future NVGs,
3. Conduct field and simulation exercises to compare the effectiveness of different types of iconology and information displays, and
4. Compare performance in simulation and field exercises to understand the differences in simulation versus real world trials, and make decisions about future studies accordingly.

The goal for the field exercises was to create a baseline for the current performance of an infantry Section, and to understand what aspects of the field exercise were not able to be replicated in a virtual environment. Comparisons in virtual reality (VR) were subsequently conducted in 3 studies to assess and contrast the effectiveness of participants to completing the simulated task under the various AR conditions:

- Study 1 - Field with no AR HMD, simulation with no AR HMD, and simulation with full AR HMD (comprising detailed blueforce tracking and navigation aids)
- Study 2 – Simulation with no AR HMD, Simulation with AR HMD-lite (low number and type of information displayed) and Simulation with full AR HMD (detailed navigation and blue force tracking icons)
- Study 3 – This study aimed to adjust the amount of information displayed to determine the nature of the information display's effect on task performance; whether there is exponential performance decay or if there is a critical point at which performance drastically drops. Six simulation conditions for individuals that had between 2-7 icons presented, and 12 team based conditions with variations of 3 different blue force tracking icons and 4 different navigation aids.

Study hypotheses included:

1. Participants would complete tasks significantly faster with an AR HMD
   a. Participants' will complete the task slower as more information is displayed on the overlay
2. Participants will notice more targets and more details about the targets with an AR HMD
   a. Participants' target and detail recognition will lower as more information is displayed on the HMD

3. Participants will find the AR HMD conditions easier to complete
    a. Participants will find the task more difficult to complete when more information is displayed on the HMD
4. Participants will be less stressed during the AR HMD conditions
    a. Participants will be more stressed when more information is displayed on the HMD
5. Participants will perform better with and prefer using some overlay elements over others.

II. METHOD

A. Participants

Study 1 involved one section (eight participants) with the assistance of two SMEs, all of whom were from 1RAR. Study 2 involved one section (eight participants) from 7RAR. Study 3 involved eight fire-teams (32 participants) for the individual trials, and 13 fire-teams (52 participants) for the team trials. These participants were from a variety of units. In Study 3 each fire-team was accompanied by an SME, and all participants who participated in the individual trial also participated in the team trial. Fire-team Commanders for all activities were the senior person in the team, and all participants were male except for two participants in Study 3.

B. Procedure and equipment

1) Field exercises:

A field exercise took place at Line Creek Junction, High Range Training Area, QLD. Participants undertook a typical night-time dismounted combatant operation that included clearing patrols, navigation, and building clearance. Field exercises were conducted in accordance with existing doctrine and standard operating procedures. During field exercises, participants wore current PVS31A NVGs.

2) Simulation exercises:

Simulation exercises used Virtual Battlespace 3 (VBS3) displayed using an Occulus Rift Virtual Reality Head-Mounted Display (VR HMD), or on a flatscreen display. In Study 1 participants completed simulated missions that replicated the field mission. Study 2 participants completed missions representative of typical dismounted combatant patrol and urban clearance. Study 3 participants completed a standard observation lane task as defined by military Subject Matter Experts.

During the simulation exercises, participants experiencing the AR HMD conditions had icons presented on the HMD which varied between experimental conditions and experiments, but were typically information relating to navigation, location of friendly and opposing forces, and mission objectives. The design of the AR HMD conditions used the findings from Oostergo, Temby, and Coombs (2017) and a follow-up study which elicited the information requirements for dismounted night patrol related tasks, for varying ranks and roles. For example, Fig. **1** shows a sample simulated HMD (from Study 2) used for a navigation and patrol task. The HMD includes information on direction, location and identity of friendly forces (names have been obscured for participant privacy, but were visible to participants during the study), and waypoints for the patrol.

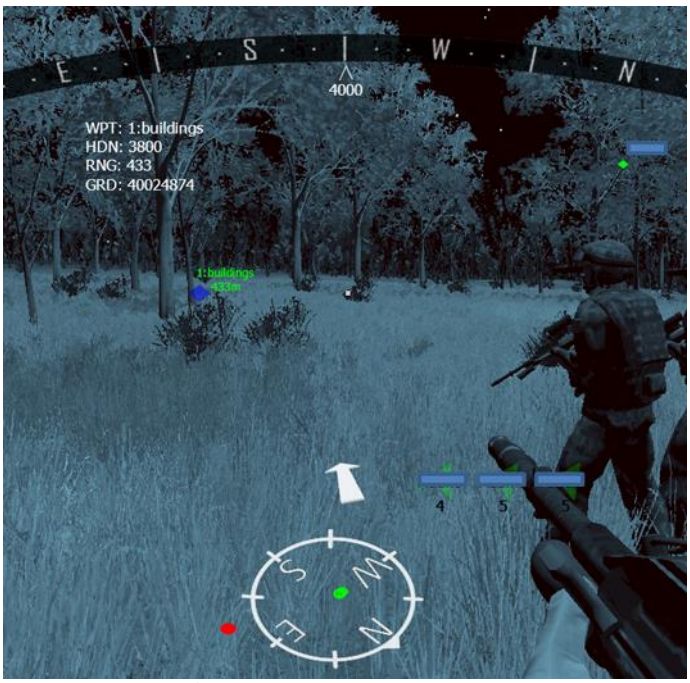

Fig. 1. Example of the simulated AR HMD

C. Measures:

Field and simulation tasks incorporated both quantitative and qualitative data collection.

Quantitative data was collected via questionnaires, including:

- Demographic Questions
- Perceived Effort – Collected through the NASA-TLX, administered at the end of the scenario

Data were also collected within the simulation including:

- Performance Criteria – How quickly and effectively did the participant complete the task, how many of the markers did they notice throughout the task, how many SME judged mistakes were made.
- Situational Awareness - Situational reports to 'headquarters' that the participant is required to give at certain points and when noticing in-simulation markers (Kaber et al., 2013) were recorded. Study 3 included Detection Response Task (DRT) measures (Young, Hsieh, & Seaman, 2013).

Qualitative methods were used to inform the quantitative results after the completion of each scenario:

- Structured individual interviews with participants containing questions designed to elicit explanations

concerning the participant's performance, system assessment, and operational viability.

The studies were approved under ethics protocol LD 12-17 and simulation sickness was carefully managed in accordance with the ethical approvals.

*D. **Analysis***

1) *Quantitative Results:* Quantitative results were compiled and graphed for visual analysis with 95% confidence intervals calculated and provided as visual error bars. Statistical analyses included one-way repeated measures Analysis of Variance (ANOVA) and Generalised Linear Mixed Models (GLMM) using SPSS.

2) *Qualitative Results:* Interview responses were compiled, tabulated, and coded according to theme. These codes were then used for a comparison of response frequency and to compare with the quantitative results for trends.

III. RESULTS & DISCUSSION

Overall the findings illustrated the potential usefulness of AR HMDs for improving task performance while simultaneously highlighting the potential for information overload having a detriment on task performance.

A. Study 1

Error! Reference source not found. highlights that the HMD was able to drastically improve the speed of navigation to a new waypoint, with the teams demonstrating a 54% and 25% reduction in navigation time respectively. The large difference between these percentage speed improvements is likely due to learning effects and lack of novel stimuli. This meant that while both groups navigated to the point much more quickly with the HMD than without it, the group who was already familiar with the task were able to navigate even more quickly because they had already completed a similar task.

TABLE I. STUDY 1 TASK COMPLETION TIMES

Team	Total Task Time [a]	Building Clearance	Point Navigation
Field	1h 50m 00s	15m 27s	32m 34s
1 (HMD to No-HMD)	20m 47s (-22s) *2% faster*	1m 49s (+13s) *2% slower*	5m 45s (-3m 6s) *54% faster*
2 (No-HMD to HMD)	35m 6s (-17m 56s) *49% faster*	2m 58s (-1m 48s) *60% faster*	6m 20s (-1m 35s) *25% faster*

[a.] Timings displayed as time to complete without HMD, followed by time difference with the HMD and percentage of HMD speed relative to No-HMD speed

Both teams failed to identify one specific target during the HMD condition which was identified in both the field and No-HMD conditions. Paired with the improvement in navigation performance, this study demonstrates an aid-related performance improvement based on HMD use, with potentially reduced non-aid-related performance.

Participants also rated their performance in the HMD condition as much closer to their performance in the field than their performance in the No-HMD condition, suggesting that the participants noticed the benefits of the HMD aiding their navigation, but did not feel as though it was having a negative impact on their SA. This contrast highlighted the importance of investigating the potential impact of an HMD on non-aid-related task performance during representative tasks in greater detail, and informed the subsequent design of Study 3.

B. Study 2

Study 2 introduced an urban patrol simulation and a third HMD condition, a streamlined version of the HMD which displayed no extra information beyond what was deemed necessary to complete the task. No significant results for the effect of HMD condition on cognitive burden was found. There are a number of possible reasons why this was the case including the method used and complexity of the task. It is suggested that this study be replicated on a larger scale with a more difficult set of simulations. By increasing the baseline complexity of the task, positive and negative changes in cognitive burden would be demonstrable if present, whereas the simplicity of the simulation in Study 2 meant that it was not possible to detect a decrease in cognitive burden. Several methods were identified during interviews to how this may be accomplished , including;

- Increasing the planning and decision making requirements for the commander
- Requiring a more complex set of additional actions to be completed, or increasing the number of concurrent tasks to be undertaken
- Increase time pressure, making it difficult to achieve the task within the given timeframe
- Increase participant fatigue, stress or motivation levels.

C. Study 3

The results of Study 3 are still being analysed, and as such only the results from the individual runs are discussed below.

Participants were found to respond more slowly and to fewer prompts of the DRT when a greater amount of information was present on the HMD, suggesting that more information on an AR HMD impedes situational awareness. The results also indicated that the progression (rate) of the DRT hit rate was stepped, suggesting that while responses gradually decayed with more information, the nature of the rate of change depended on the type information being presented. A notable decrease in hit rate was observed when the aid was not task-related, while there was a minor increase in hit rate when the aid was task-related. This suggests that whilst having more information on an HMD causes users to become cognitively burdened, the nature of these aids may be an important factor. Having aids that reduce cognitive burden by simplifying other tasks may lead to a net gain in available cognitive resources.

A significant effect on navigational performance was also found, illustrating that one particular navigation element, a waypoint marker that floated in virtual space above the waypoint, had a significant impact on improving navigation performance.

Finally, those participants with greater levels of digital literacy were better at using the HMD elements to navigate, and on average responded to more DRT prompts. This has a significant implication for system training, as it indicates that those soldiers who have less experience with digital systems and HMDs may suffer both on aid-related and non-aid-related task performance, including an impedance on their situational awareness.

These studies have shown that the use of an AR HMD for dismounted soldiers may be a double-edged sword. The availability of additional information such as navigational and blueforce tracking aids can lead to significant performance improvements for these tasks. However, they can also reduce the soldier's situational awareness and performance on tasks that don't utilise the HMD aids. In order to maximise soldiers' lethality and survivability while using an AR HMD, it will be necessary to understand when and how particular information types should be displayed, the ease with which that information can be understood and acted upon, and how much information is shown at any given time.

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