Graphic Representations of Uncertainty Within Sub-surface Environments

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Introduction

In submarine sonar, Schunn, Kirschenbaum and Trafton (2003) believe the major source of uncertainty arises because submariners attempt to compute the course, speed, and range to the noise source from a passive sonar signal, which provides measurements for only two parameters, bearing (direction) and bearing rate (rate of change in the bearings). As the passive sonar signal only directly measures these two parameters, it fails to provide operators any range-to-target information, which means an infinite number of course, range and speed combinations exist that are capable of producing the identical signal.

Using experienced naval submarine officers, Kirschenbaum and Arruda (1994) began to investigate sub-surface uncertainty by examining the performance effects of graphic and verbal representations of target position uncertainty in eight different uncertainty scenarios that varied in difficulty. Their research suggested that submarine operators provide more accurate range estimates when presented with a graphical representation of the uncertainty surrounding a target's spatial location.

The primary aim of the present study was to expand on Kirschenbaum and Arruda's (1994) findings by examining what sort of uncertainty representation leads to the best performance. In particular, we compared participants' decision-making performance when presented with graphical representations that varied across six different uncertainty ellipse conditions (50%, 75%, 95%, 99%, no ellipse and tabular non-graphical). The ellipse provided participants with a graphical display of the area of uncertainty (i.e., range x bearing probability distribution) associated with the target's spatial location. As scenarios progressed more target related information would be collated and analyzed, resulting in the uncertainty ellipse gradually decreasing in size over time.

Method

Twenty four university undergraduates (M = 27 years, SD = 9 years) were presented with each of the ellipse conditions in six different scenarios that were either all classified as easy or difficult based on standard objective tracking measures. In the no ellipse condition, only the target (via a green dot) was visualized. In the tabular non-graphical condition participants were not presented with any graphic visualization of the scenario, but were presented with time to next leg information, and estimates of the enemy submarine's course, range, speed, range rate and bearing rate.

Each generated scenario contained six possible stages, with participants instructed to use only as many as they felt necessary before giving the order to fire at the enemy submarine. Spatial knowledge was assessed at the completion of each scenario stage through range from own-ship to target estimates, own-ship to target maximum and minimum range estimates, confidence intervals and completion time measures.

Results and Discussion

Participants assigned to the easy scenarios consistently performed significantly better than participants in the difficult scenarios, indicating that the task complexity manipulation worked. Across most ellipse condition analyses there was little difference in performance between each of the six different ellipse conditions. However, when examining the proportion of correct maximum and minimum estimates (i.e., true position of enemy was within their bounds) against the mean width or difference of their maximum and minimum range estimates, the 99% and 95% ellipses were the two best performing conditions respectively in both task complexity conditions. This suggests that these two ellipse conditions lead to the best interpretation of the uncertainty as participants more frequently knew that the enemy was a certain minimum and maximum distance away from them, which is an important finding when confronted with uncertainty surrounding an enemy's position.

Further investigation into increasing the number of targets and their ellipses is proposed. Of particular interest is to examine how humans perform when required to track and monitor several overlapping and cluttered contacts across a variety of ellipse sizes.

References

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