Project 1:
Computational Simulation of Human Display Monitoring

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September 15, 2022, Human Operation of Aerospace Vehicles (ASEN 6216)

Introduction / Background

In many environments, human operators are presented with a wide array of information, dynamic in nature, in differing work areas which can be described as Areas of Interest (AOI). Since most work areas, or AOIs, are much larger than the limited field of view (~4 degrees, only slightly larger than the fovea) of the human eye, scanning behavior is important to human factors engineers. For example, if an AOI takes up a large amount of scan time, these can be taken as a sign of poor workspace or display design. Prediction of visual supervision can be made through models of visual scanning. An additive of expectancy, salience, effort, and value provide an accurate prediction of noticing times, the N-SEEV model, which deals with specific events in time while monitoring a dynamic workspace, display or environment [1]. For the notional Mars base mission presented in Project 1, the N-SEEV model is proposed to predict the visual attention and performance of the operator monitoring a set of displays and identifying abnormalities.

Methods

MATLAB was used to obtain results and generate graphs for this project. The information provided in the project statement was used to define the constants required for the N-SEEV model associated with each display. These constants were used to obtain the absolute probability of viewing a given AOI and this value was normalized to obtain the relative probability that a given AOI is viewed next. A lognormal distribution was used with the values provided to account for the fixation time and a normal distribution with the values provided to account for the saccadic eye movements.

For problem 1, we did not consider the probability of looking at a display and staying in that same display for the following fixation. An iteration loop was used to populate the display scan pattern array based on the relative probability associated with each possible display, starting with display A. We used the display pattern array along with the total time array, which is a summation of the fixed and saccadic eye movement, to create our plot (see Figure 1). For problem 2, we leveraged the code from problem 1 and added an iteration loop for the 1,000 scan sequences simulation and updated the value to reflect 100 total display fixations per simulation. We used the total fixation time for each display to obtain a percentage of fixation time per display and plotted these values along with the average fixation time per display for the 1,000 scan sequences.

For problem 3, we assumed that we are looking at display D when we are detecting display D. We used the code from problem 2 and added a conditional statement to account for the situation where 10 seconds have elapsed, and the scan pattern is at display D with an 80% chance of detecting the alert during that fixation. For problem 4, we used the same code from problem 3 and updated the salience value to be 5. For problem 5, we leveraged the code from problem 4 and used the median value of detection time from problem 4 along with a tolerance of 0.001 to converge to new Effort values for display D. To obtain the new Effort values, we iterated them by stepping down by .0001 for each Effort value (D to A, D to C, and D to B) to represent positioning display D closer to the other displays.

Results

Problem 1) Figure 1 shows a trial simulation of 10 fixations. The results show the display that was selected for a specific fixation based on the relative probabilities of each display. The display scan pattern is shown by the y-axis and the x-axis shows the total time in seconds. Even though 10 fixations were used, the total simulation time was around 13 seconds. This additional time is accounted for by the variability in fixation time and saccadic eye movement.

Problem 2) To determine the percentage that each display is viewed, the number of fixations was increased to 100 and 1000 Monte Carlo simulations were performed. The distribution of results for these simulations along with the average viewing time for each display (shown as a straight line) is represented in Figure 1. Display A, B, C, D's viewing percentages were 38.97%, 20.5%, 19.55%, and 18.4% respectively. The remaining percentage of viewing time can be attributed to saccadic eye movements as the operator transitioned between each display.

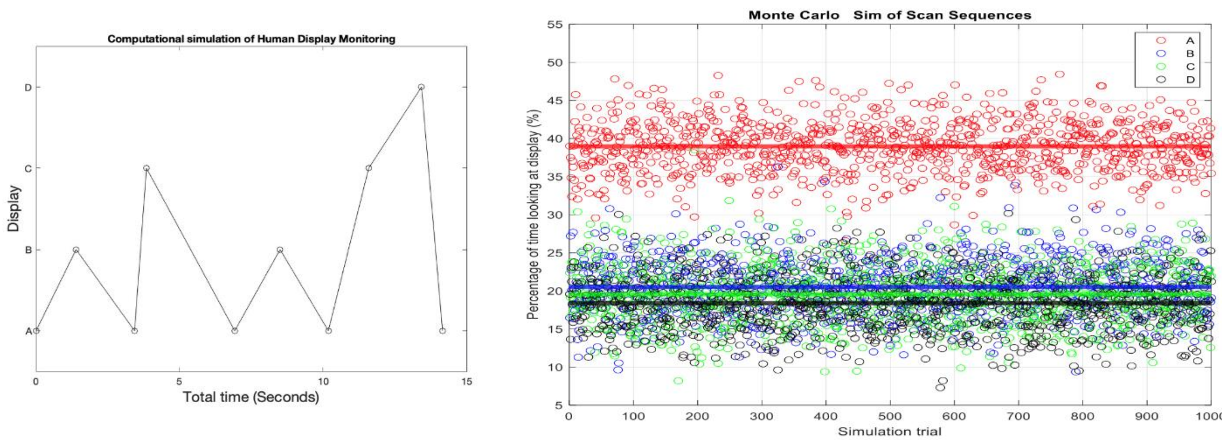

Figure 1 – Left: Display Scan Pattern for 10 fixations. Right: Monte Carlo Simulation of 1000 scan sequences

Problem 3) The left histogram in Figure 2 shows the distribution of time it took for the operator to look at display D and notice the windstorm alert. The median of the distribution was 5.84 seconds to detection, the 95th percentile was 19.73 seconds to detection, and the 5th Percentile was 1.58 seconds to detection.

Problem 4) In this scenario, an auditory alert was added to increase the salience value of display D from 2 to 5. With this added assumption, the simulation was run again with the following results: The median is 3.89 seconds to detection, the 95th percentile is 12.40 seconds, and the 5th percentile is 1.19 seconds to detection. Histogram shown in the right section of Figure 2.

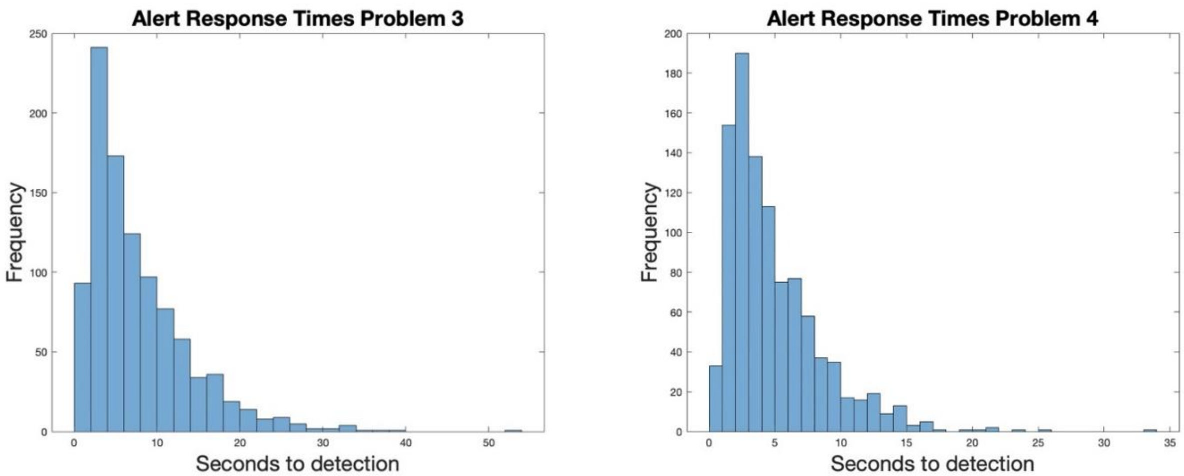

Figure 1 – Left: Alert Response Time for Display D. Right: Alert Response Time for Display D (Increased Salience)

Problem 5) The Effort values for display D were lowered to produce a median response time that would be equivalent to the median response time found in problem 4 (3.89 seconds) where the auditory alert was added. These updated effort values were found by programmatically stepping through different effort values and averaging the values of four program runs (Values obtained of 100 simulations with 100 fixations and a 3-digit accuracy tolerance and an effort value step of $-1e^{-4}$). The effort values are as follows: $Ef_{ad} = 1.86$, $Ef_{bd} = 2.86$, $Ef_{cd} = 1.36$

Discussion

The change in salience for display D between problem 3 and 4 showed a decrease of 33.39% in the response time from the operator in noticing the windstorm alert. This was achieved by an increase in the salience of display D from S=2 to S=5. In comparison, the changes to Effort values to achieve the same reduction in response time were on average, a decrease of 3.14 across each display in relation to display D. This larger change to the Effort values can be seen as a more significant change with moving the display rather than adding an alert tone. To further this conclusion, the initial display design of the windstorm alert for the operator is unknown. Given that the salience of the windstorm alert display (display D) is equal to the salience of the primary display (S = 2), it may be reasonable to assume that the 20 % chance of a missed signal could be caused by inattentional blindness in which the change in displays for the unexpected event was not significant enough to draw the attention away from the primary task in time to address the issue [2]. This would not change with a decrease in the Effort value associated with seeing display D and could result in an even higher degree of inattentional blindness depending on how similar the alert is represented relative to the data shown on the primary display. Therefore, the preferable display design change made to reduce the percentage of missed signals and reduce the response time would be to incorporate the auditory alarm presented in problem 4, over repositioning display D. With respect to the concern of hearing the alarm over the wind, further analysis can be performed to determine a particular tone frequency or volume that can cut through the external noise. This also falls in line with the team's industry experience with respect to making hardware changes, i.e., moving the location of a display, vs. software changes, such as changing frequencies or tones within the audio control unit aboard the vehicle. It is significantly more expensive and schedule prohibitive to modify hardware than to adjust particular software parameters.

References:

[1] Wickens, C. D. (2015). Noticing events in the visual workplace: The SEEV and NSEEV models. In R. Hoffman & R. Parasuraman (Eds.), Handbook of applied perception (pp. 749–768). Cambridge University Press.

[2] Simons, D. Chabris C. (1999). Gorillas in Our Midst: Sustained Inattentional Blindness for Dynamic Events. Journal of Perception.