Appendix – 1

Changepoint condition:

The probability that a changepoint has occurred in the current trial is computed as the likelihood of current trial observation coming from a new helicopter position, which is randomly chosen from a uniform distribution between 0 and 300, over the sum of the likelihoods of the current observation coming from a non-changepoint distribution (Gaussian distribution centered around the most recent belief about helicopter positions) and changepoint distribution:

$$\text{CPP} = \Omega_t = \frac{U(X_t|0.300)\, H}{U(X_t|0.300)H + N(\delta_t; 0.\sigma_\mu^2 + \sigma_N^2)(1-H)}$$

Where Ω_t is changepoint probability, H is the hazard rate and is the same hazard rate used in the generative process for simulating outcomes, δ_t is the difference between the predicted and actual outcome, σ_N^2 is the variance of the distribution of bags around the helicopter, and σ_μ^2 is the variance on predictive distribution (estimation uncertainty) and is computed recursively after observing an outcome and using the changepoint probability of the current trial:

$$\sigma_\mu^2 = \Omega_t \sigma_N^2 + (1-\Omega_t)\, \tau_t \sigma_N^2 + \Omega_t(1-\Omega_t)(\tau_t + B_t(1-\tau_t) - X_t)$$

Where B_t is the current belief about helicopter position and X_t is the current trial outcome and τ_t is the relative uncertainty.

Relative uncertainty is computed as estimation uncertainty about bag locations as a fraction of total uncertainty that is sum the of estimated uncertainty and noise.

$$RU = \tau_{t+1} = \frac{\sigma_\mu^2}{\sigma_\mu^2 + \sigma_N^2}$$

Oddball condition:

The probability of an observation being an oddball is computed in a similar manner using the prediction error of the model on each trial:

$$\text{OBP} = \Omega_t = \frac{U(X_t|0.300)\, H}{U(X_t|0.300)H + N(\delta_t; 0.\sigma_\mu^2 + \sigma_N^2)(1-H)}$$

Where H is the hazard rate of the oddball condition. Here, the numerator is the likelihood of current outcome being an oddball and the second term in the denominator is the likelihood of current outcome coming from a normal distribution with the mean of predicted outcome and variance of total uncertainty.

The estimation uncertainty is computed similar to change point condition, albeit with a few modifications:

$$\sigma_{\mu}^{2} = \Omega_t \frac{\sigma_N^2 \tau_t}{1-\tau_t} + (1-\Omega_t)\, \tau_t \sigma_N^2 + \Omega_t (1-\Omega_t)(\delta_t \tau_t)^2 + \sigma_{drift}^2$$

Where the first term represents the contribution of an oddball observation to the uncertainty, the second term is the contribution of a nonoddball observation to the uncertainty, the third term is uncertainty proportional to the prediction error received from either an oddball or a nonodball trial and the last term reflects the uncertainty expected from the drift rate of the helicopter in between two trials.

Again similar to changepoint condition, relative uncertainty is computed as estimation uncertainty over total uncertainty:

$$RU = \tau_{t+1} = \frac{\sigma_{\mu}^2}{\sigma_{\mu}^2 + \sigma_N^2}$$