Stepping into the Same River Twice: Are Miss Errors in Visual Search Deterministic or Stochastic?

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Introduction

In any visual search task, individuals routinely make errors[1,2]. These errors can be categorized as deterministic or stochastic.

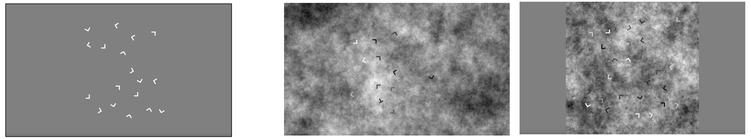
- **Deterministic error**: if you miss this target in this display once, you will definitely miss it again.
- **Stochastic error**: the error occurs randomly with some probability from trial to trial.

To empirically categorize errors in a simple search task, our observers searched for the letter "T" among "L" distractors, with each display presented twice.

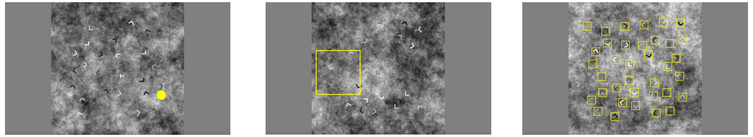
Methods

Exp 1: Visible letters (white letters on a uniform gray background).

Exp 2a & 2b: The visibility of letters was manipulated (letters of different gray levels on a noisy background).



Exp 3a, 3b & 3c: Cueing interventions (two groups: noCue – noCue, noCue - Cue).



Exp 3a (random cueing): A yellow dot jumped at random places in the search display.

Exp 3b (area cueing): An outline yellow square moved in a spiral fashion in the search display.

Exp 3c (item cueing): A set of static yellow squares highlighted the positions of all items .

In all the experiments, each stimulus was presented twice. The two copies of stimuli were randomly mixed during the experiment. Thus, the two copies of the same stimulus can be very close or very far from each other in each experiment.

Methods

P1: The proportion of miss errors on the 1st copy of stimuli.
P2: The proportion of miss errors on the 2nd copy of stimuli.
P12: The proportion of miss errors on both copies.

- If all errors are stochastic, $\boldsymbol{P12 = P1 * P2}$.
- If all errors in round 1 or round 2 are deterministic, $\boldsymbol{P12 = \min(P1, P2)}$.
- If errors are a mix of stochastic and deterministic, $\boldsymbol{P1 * P2 < P12 < \min(P1, P2)}$

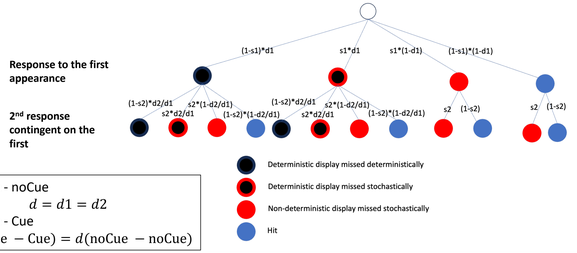
Parameters
$\boldsymbol{d1}$ **&** $\boldsymbol{d2}$: The proportion of deterministic errors relative to the total number of stimuli in round 1 and round 2.
$\boldsymbol{s1}$ **&** $\boldsymbol{s2}$: The stochastic error rates for a stimulus in round 1 and round 2.

$$P1 = d1 * (1 - s1) + s1$$
$$P2 = d2 + s2 * (d1 - d2) + (1 - d1) * s2$$
$$P12 = d2 + s2 * (d1 - d2) + s1 * (1 - d1) * s2$$

solve equations

$$d2 = \frac{P12 - P1 * P2}{1 - P1 - P2 + P12}$$
$$s2 = \frac{P2 - P12}{1 - P1}$$
$$s1 = \frac{P1 - d1}{1 - d1}$$

- noCue - noCue: $d = d1 = d2$
- noCue - Cue: $d1\ (\text{noCue} - \text{Cue}) = d(\text{noCue} - \text{noCue})$

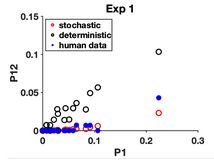


Discussion

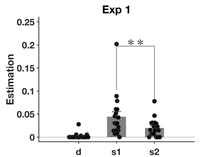
- **Exp 1**: When the letters were clearly visible, the errors were almost purely stochastic.
- **Exp 2a & 2b**: When the letters were of different grayscale values and were presented on a noisy background, the errors were a mix of deterministic errors and stochastic errors, with low contrast targets accounting for most deterministic errors.
- **Exp 3a, 3b & 3c**: Among the three different cueing interventions, only the item cueing intervention that included knowledge of item locations in Experiment 3c could effectively reduce errors and the reduced errors were mainly deterministic errors.

Results

Exp 1: Errors were stochastic

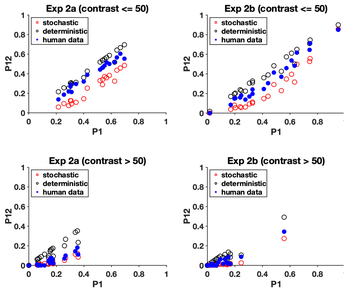


Observed $\boldsymbol{P12}$ almost overlapped with stochastic predictions.



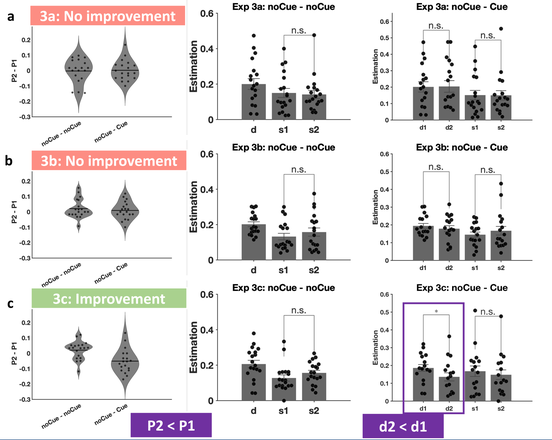
Estimated $\boldsymbol{d}$ was not significantly different from 0.

Exp 2: Errors were a mix



Deterministic errors were mostly from low-contrast targets.

Exp 3: Deterministic errors were reduced in Exp 3c



Conclusion

- When targets are clearly visible, errors are almost completely stochastic. Such errors may be hard to reduce by any method that does not come down to spending more time or adding a second observer.
- When targets are harder but not impossible to see, more of these hard-to-see targets appear to be missed in a deterministic manner. Deterministic errors due to low target contrast could be reduced by an appropriate intervention, e.g., image enhancing algorithms.

References

1. Berlin, L., & Hendrix, R. W. (1998). Perceptual errors and negligence. *AJR Ameri- can Journal of Roentgenology, 170*(4), 863–867.
2. Duszak, R., Jr., & Robinson, J. (2022). Malpractice litigation: The elephant in the reading room. *Journal of the American College of Radiology*.

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