How do we estimate average magnitudes?

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Introduction

- Representing numbers on a “number line" [1] allows us to more quickly and accurately estimate average magnitudes.

- Empirical evidence suggests magnitudes may be abstractly represented along a “mental number line” which is in some cases logarithmic or nonlinearly compressive [2], and which may be thought of as a generalized magnitude system common to time, space, and quantity [3].

- We propose an iterative algorithm which estimates the average spatial location of a set of points by making noisy distance measurements from each point to an imagined reference point, where sensory noise scales with distance.

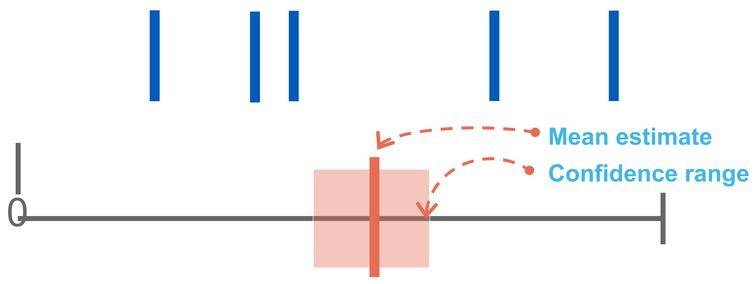
- We ask whether subjects leverage this distance-based representational schema to make estimates of numeric averages

Experimental design

10 subjects were asked to estimate the spatial or numeric average of a set of items.

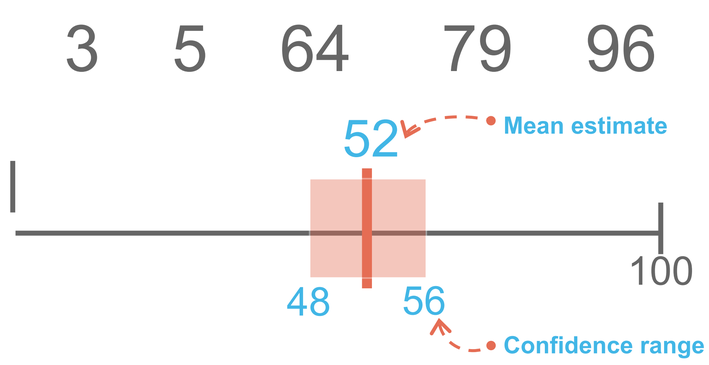
① Spatial averaging task

- Subjects were asked to find the average position of 2-6 vertical lines on a horizontal axis.



② Numeric averaging task

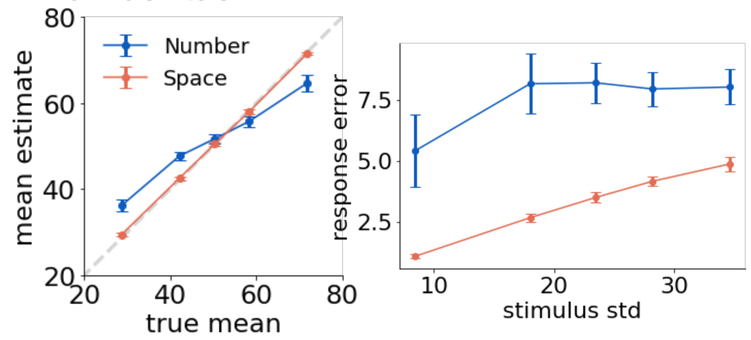
- Subjects were asked to report a “quick and dirty” estimate of the average of 2-6 numbers presented simultaneously.



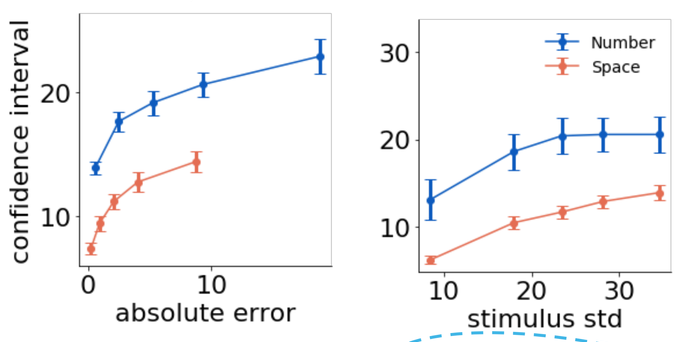
Subjects receive a reward if the true mean falls within the confidence range, but reward magnitude decreases exponentially with range size.

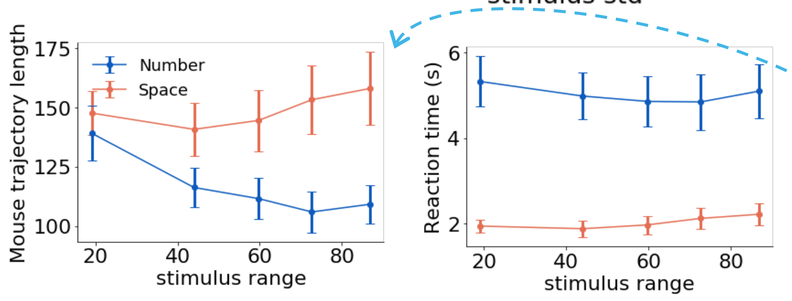
Results

- Error increases over stimulus variance on both tasks, with larger errors on the number task



- Confidence reflects error, stimulus variance, and number of elements



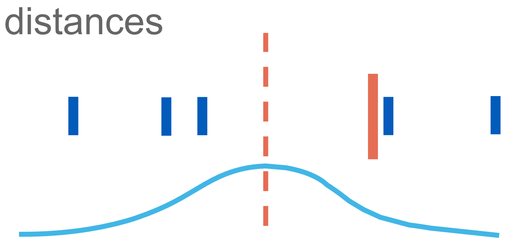


Proposed algorithm

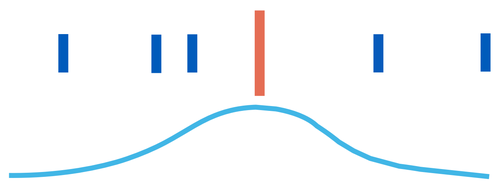
We test an iterative “distance”-based algorithm where the subject…

1) Makes a noisy estimate of the **distance** of each observation with respect to a **reference point**, where **sensory noise scales with distance (Weber’s law)**

2) Infers the posterior of the average of those distances



3) Updates the reference point to the new posterior mean

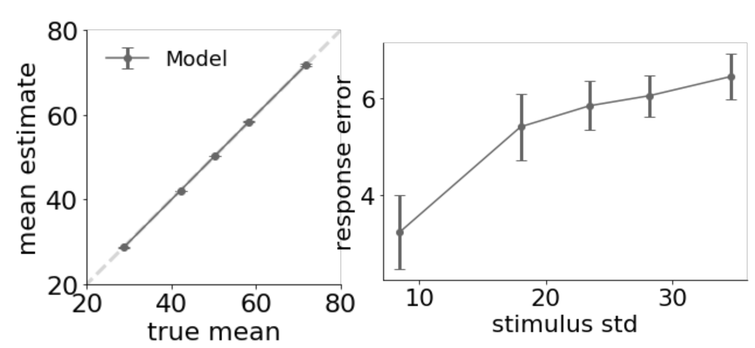


4) Repeats (1-3) until a convergence criterion is met

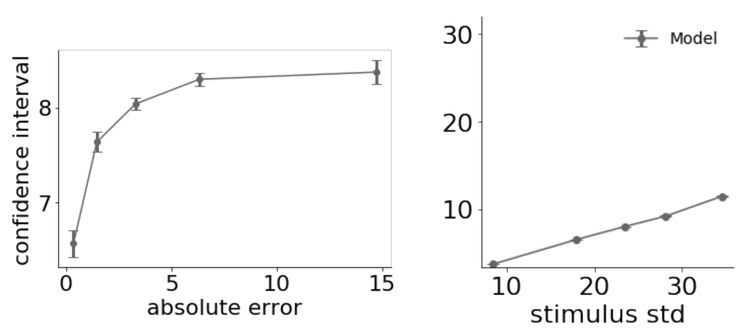
5) Picks a confidence range that maximizes expected utility, depending on both expected reward and the probability of catching the stimulus in that range

Preliminary modelling

- The proposed algorithm can reproduce similar trends in mean estimates…



- … and confidence intervals



- Mouse-tracking trajectory lengths suggest there may be utility in iteratively updating a visual reference point for the spatial (but not numeric) task

Discussion & next steps

- An iterative distance-based algorithm might account for the mental operations involved in quick averaging
- Weber’s law is a perceptual phenomenon operating over stimulus space— but mental representations may also obey Weber’s law in performing further cognitive operations like averaging

- Aim to make a common distance-based algorithm which can be parameterized to account for both spatial and numeric averaging tasks
- Compare mouse trajectory length (on the spatial task) and reaction times (on the numeric task) as possible model explananda

References

1.Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of experimental psychology: General*, *122*(3), 371. Mauris orci mi, varius id diam id, egestas auctor enim

2.Longo, M. R., & Lourenco, S. F. (2007). Spatial attention and the mental number line: Evidence for characteristic biases and compression. *Neuropsychologia*, *45*(7), 1400-1407.

3.Walsh, V. (2003). A theory of magnitude: common cortical metrics of time, space and quantity. *Trends in cognitive sciences*, *7*(11), 483-488. Aenean et est sem. Phasellus nec lectus bibendum, posuere