

Modeling search guidance: Three parameters for characterizing performance in different types of visual search

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BACKGROUND

- The accuracy of search guidance is reflected in the probability of fixating distractors within a search display as a function of their similarity to the target (e.g., Motter & Belky, 1998; Stroud et al., 2012).
- Strong search guidance produces high fixation rates to distractors that match the target on a given dimension (e.g., color), and low fixation rates to distractors that do not match the target.
- When guidance is absent, fixation rates are equal across all distractors, regardless of similarity to target.

Color guidance in search for one target versus two targets versus search-plus-working-memory

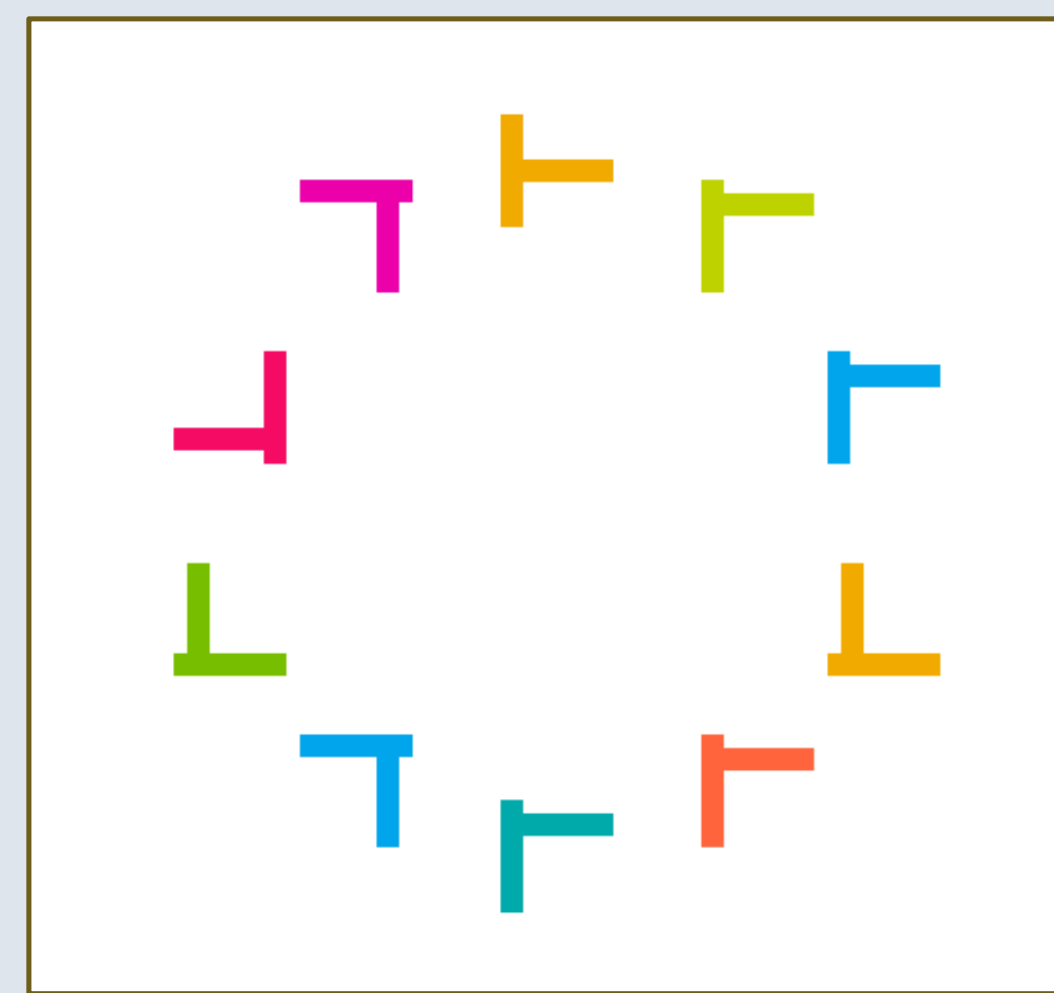


Figure 1: Example search array for three search types:

- Search for a T of a single color;
- Search for a T of one of two colors;
- Search for a T of a single color while remembering a second color.

Search targets were consistent throughout the experiment, while the color-to-remember varied.

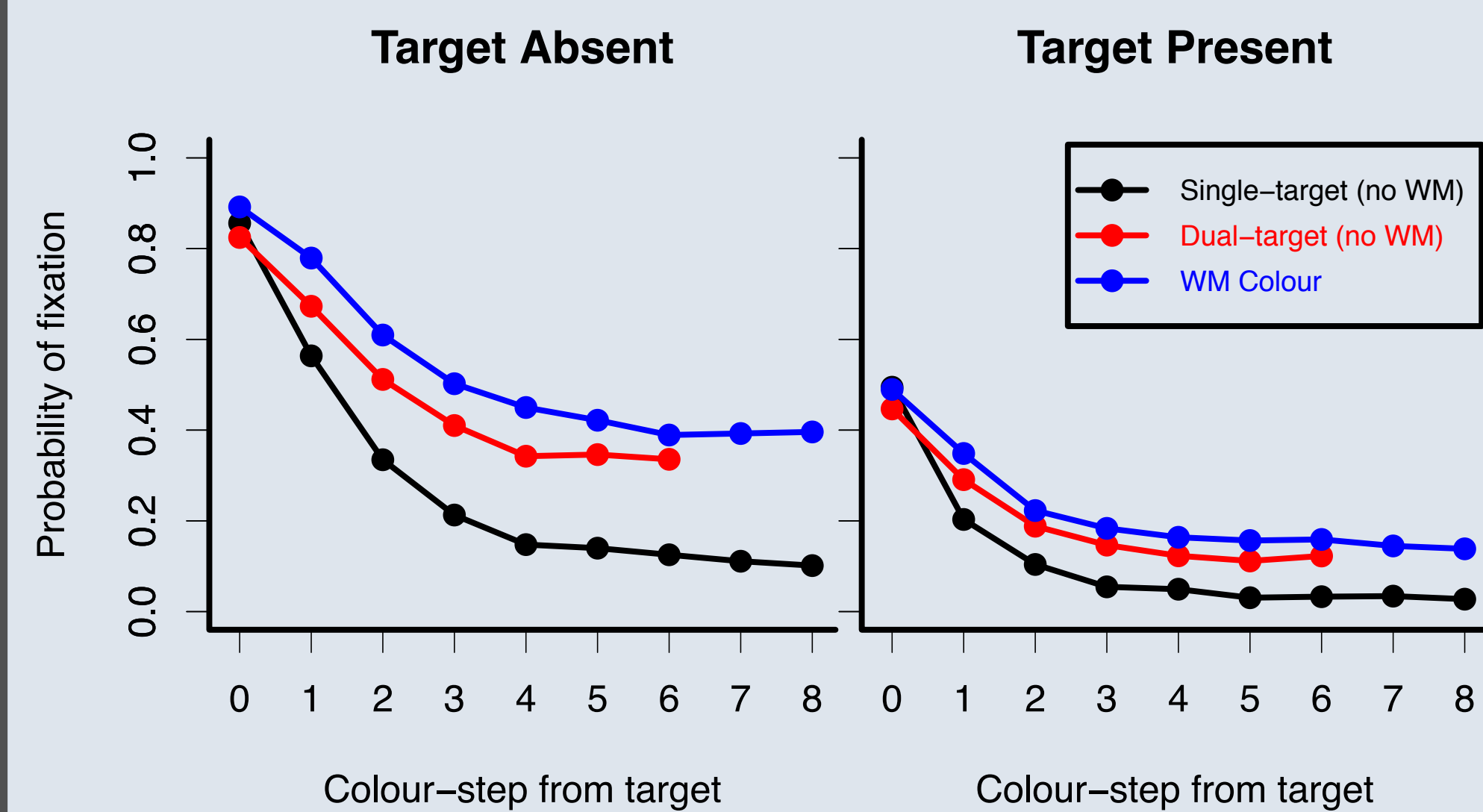


Figure 2: Probability of fixating distractors as a function of similarity to target, for three search types.

- The curve drops off less for dual-target search than single-target search.
 - Guidance is reduced, producing a dual-target cost in response accuracy (Stroud et al., 2012).
- The curve drops off less when holding a color in working memory during search.
 - Color guidance is affected by holding a color in working memory (Stroud et al., 2011; Menneer et al., 2014).

RESEARCH PURPOSE

- To develop a model
 - that fits these fixation-rate functions for the three types of search;
 - that affords interpretable parameters by which differences between the search types can be understood.

THE MODEL

- A sigmoid function is appropriate for the shape of these curves.
- Three parameters are necessary and sufficient to fit the function across a range of color-search tasks:

$$f = u + (1 - u) \left(\frac{1}{e^{sc-t}} \right)$$

where c is the color defined in steps from the target color.

Unguided fixation rate (u)

- Even in guided search, participants exhibit a baseline fixation rate to distractors that are maximally different to the target.
- u defines the ratio of unguided fixations to guided fixations.

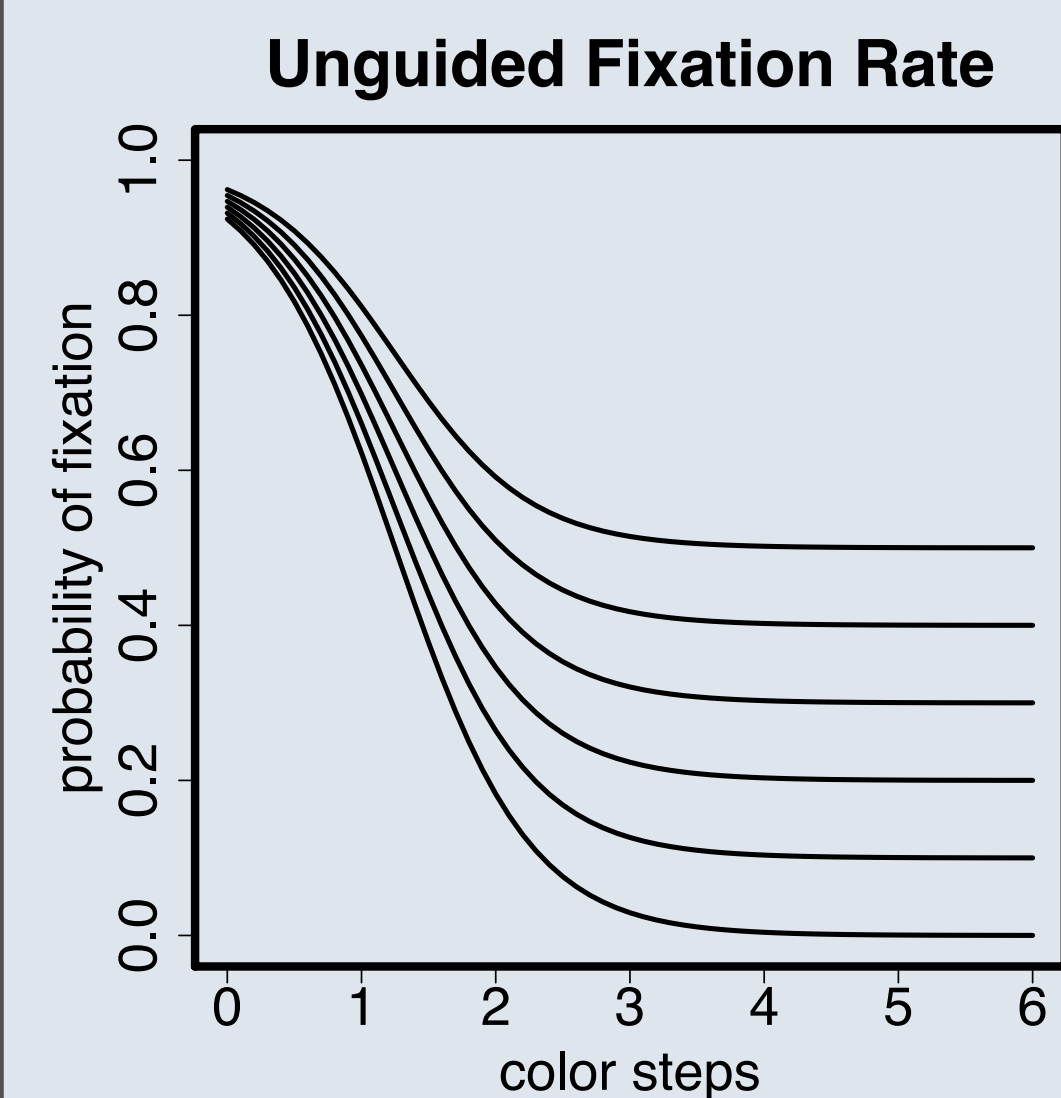


Figure 3: As u increases, the guided part of the function is compressed

Selectivity (s):

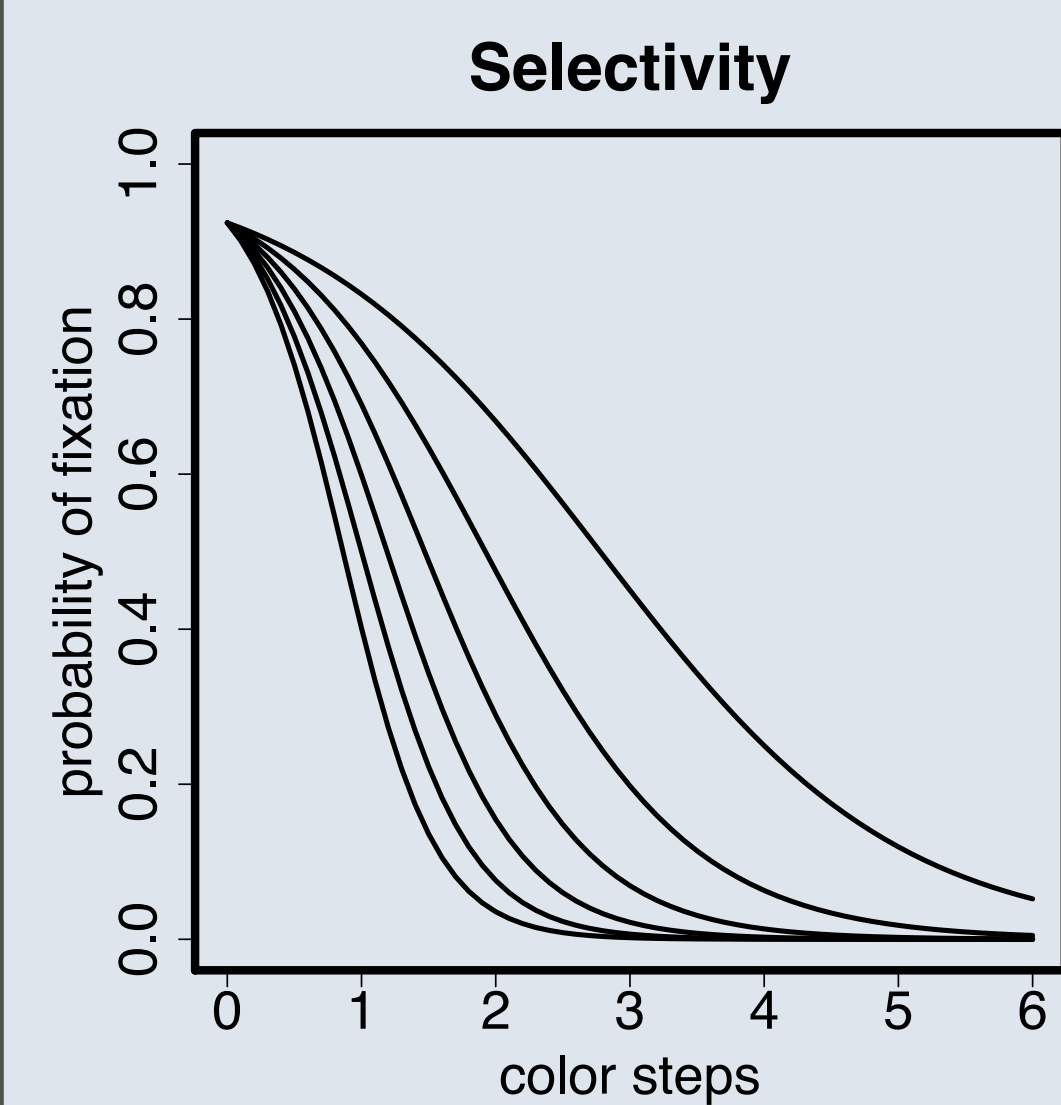


Figure 4: High selectivity (e.g., for target-similar colors) produces a guidance curve that drops off steeply. Low selectivity produces a shallow drop-off.

Target region (t):

- Some tasks produce high fixation rates to the target color only, but others produce high fixations rates to a range of colors similar to the target color.

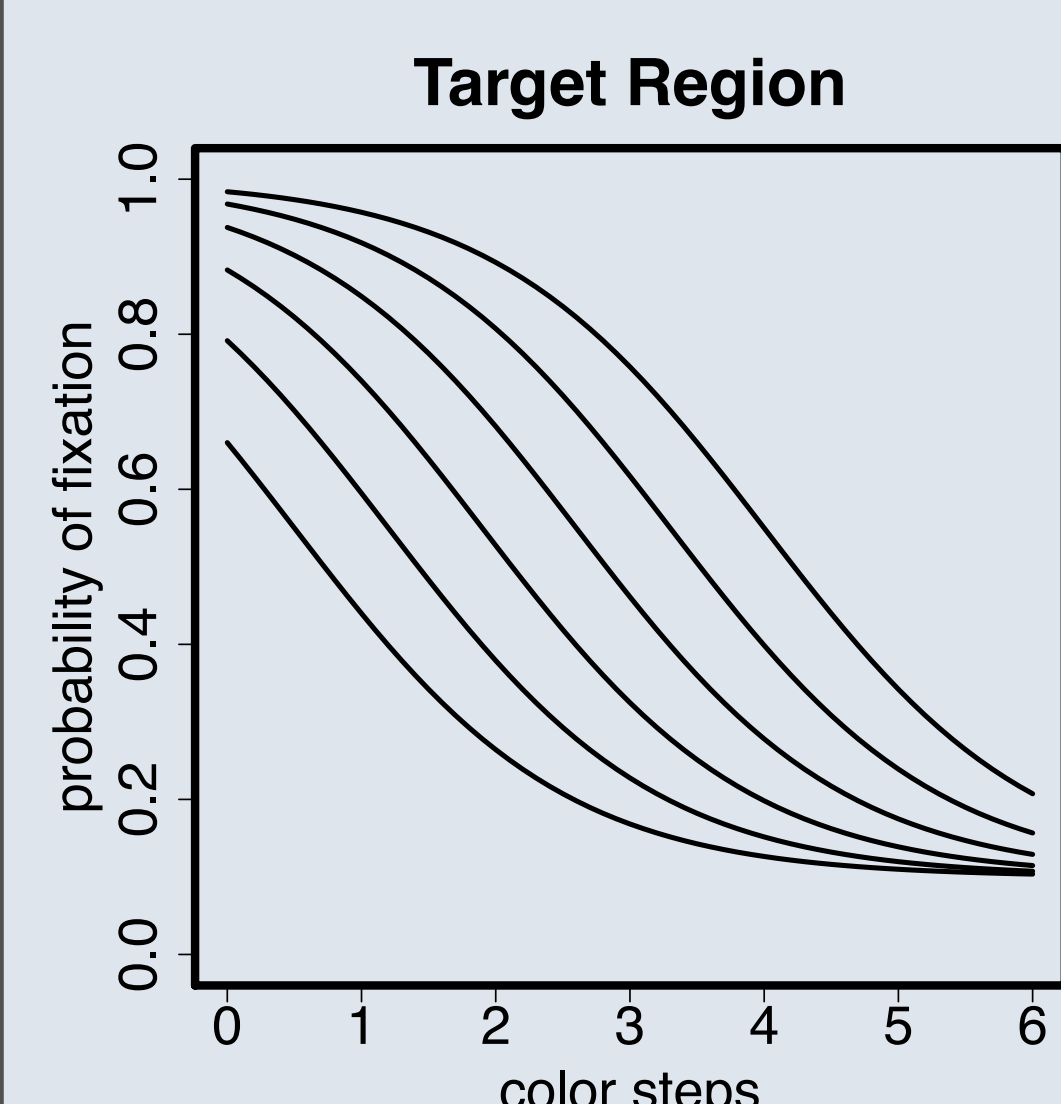


Figure 5: t allows adjustment of the region in color space that receives high fixation rates, and determines the level of dissimilarity at which the fixation rate begins to drop off steeply.

RESULTS: Modeling of individual data

Data for each participant were modeled to generate individual values for the three parameters (Figures 6 and 8).

Median values were then used to create an average model function for visualization only (Figure 7).

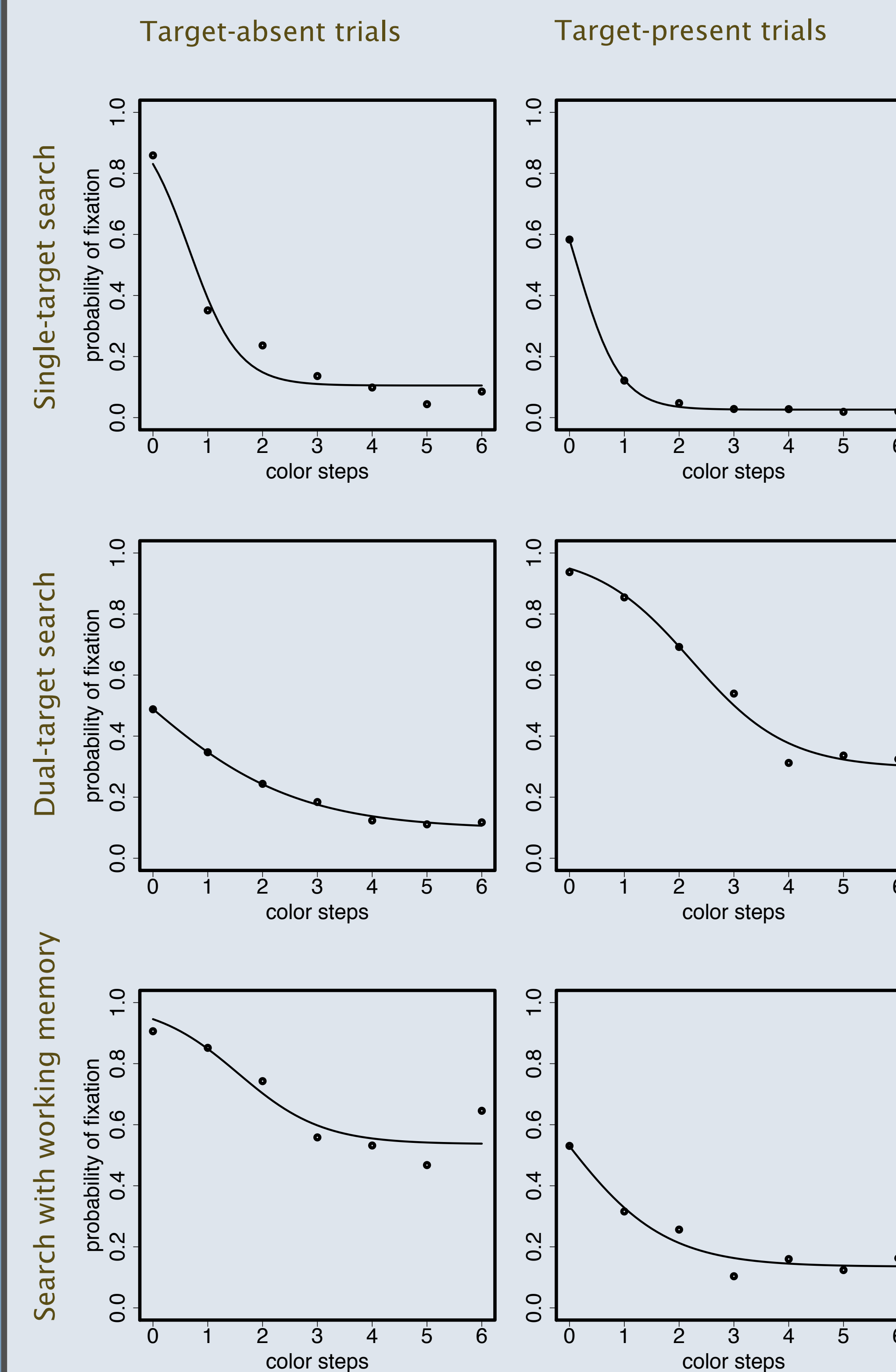


Figure 6: The modeled function (line) and empirical data (circles) for example participant values for each of the three search types.

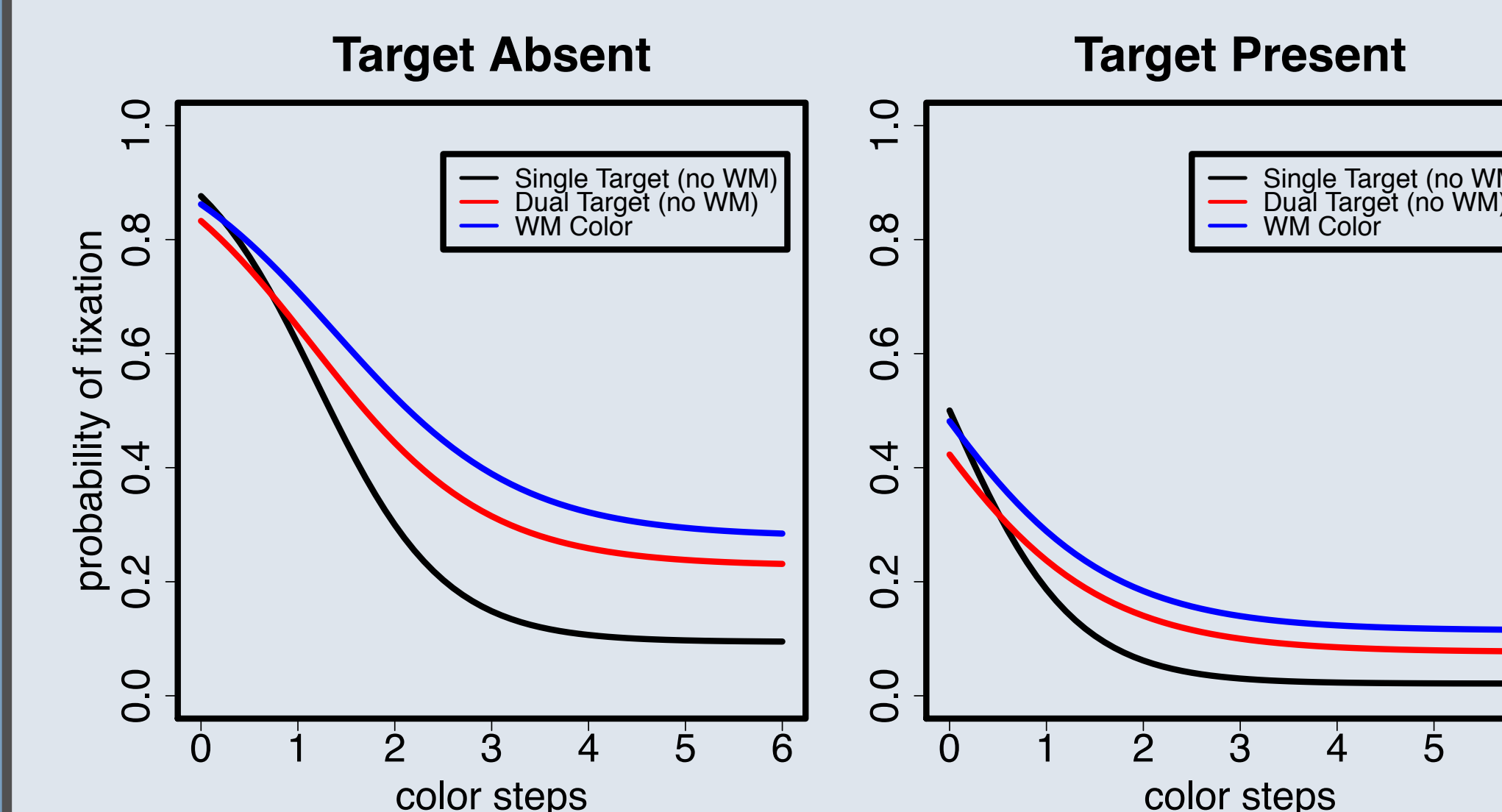


Figure 7: The modeled function for the median participant values for each of the three search types.

RESULTS: Comparing parameters

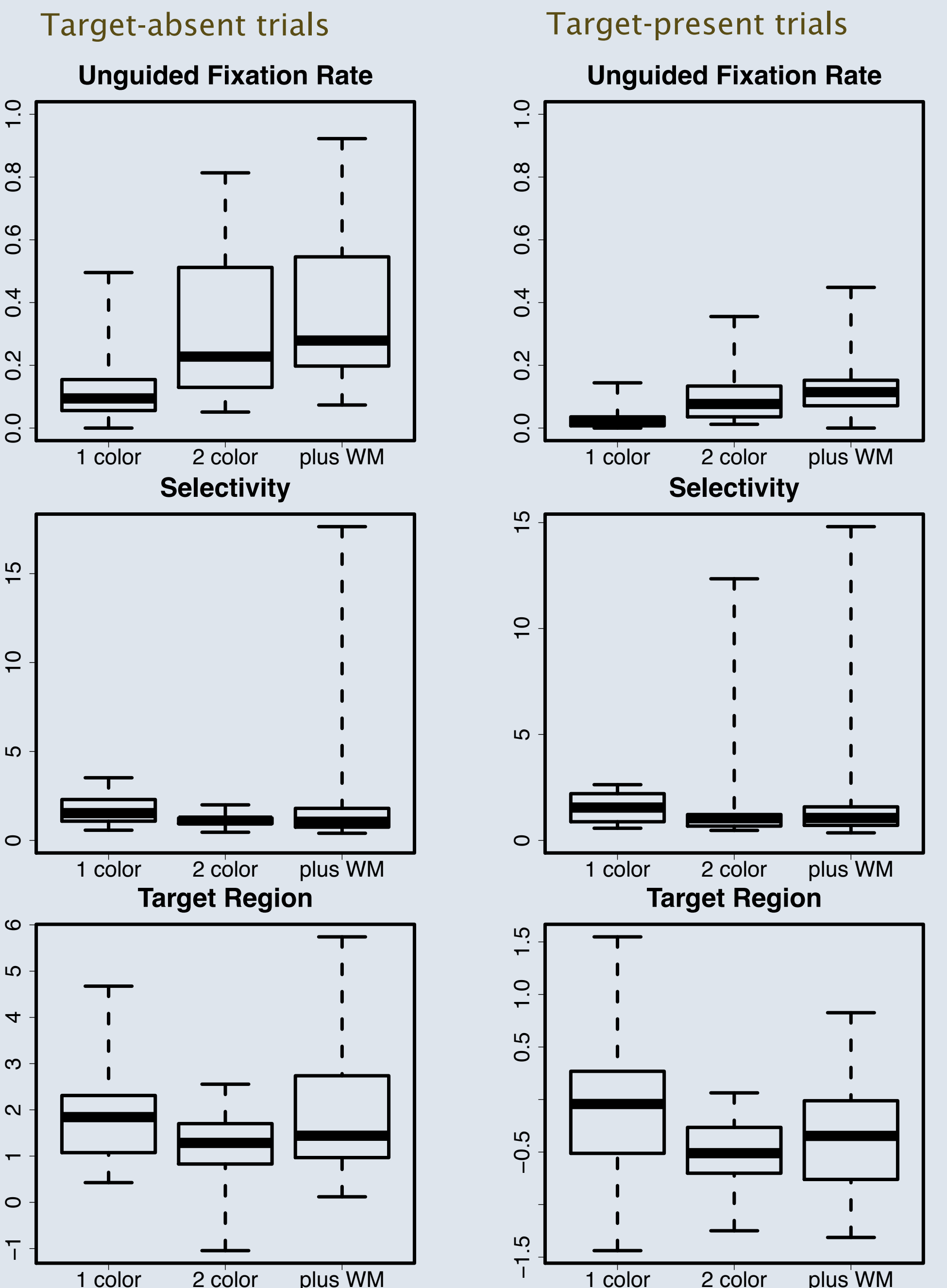


Figure 8: The values for each of the three parameters for each of the three search types.

- u is smaller in single-target search than in dual-target search and search-plus-working-memory.
- s in target-absent trials is larger for single-target search than dual-target search.
- t is larger in single-target than dual-target search.
- No significant differences between dual-target search and search-plus-working-memory, except a trend towards smaller t in dual-target search for target-absent trials.
- Guidance is weakest in dual-target search and search-plus-working-memory and strongest in single-target search.

SUMMARY AND CONCLUSIONS

Three parameters (unguided fixation rate, selectivity, target region) can be used to model the guidance function in visual search.

The three parameters can be interpreted in terms of search guidance and target representations.

Estimates for the three parameters can be used to demonstrate and understand how guidance changes across different types of search.

Search for two targets is less efficient mainly because of an increase in the number of unguided fixations (u). This pattern also occurs when a color is held in working memory during search.

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