F107

Response Time Distributions Constrain Models of Visual Search

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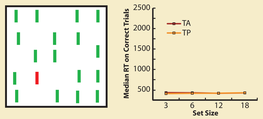
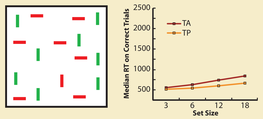
What Are The Tasks We Are Trying To Explain?

Feature Search



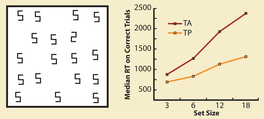
Target: Red Vertical Rectangle
Distractors: Green Vertical Rectangles

Conjunction Search



Target: Red Vertical Rectangle
Distractors: Green Vertical & Red Horizontal Rectangles

Spatial Configuration Search



Target: Digital 2
Distractors: Digital 5s

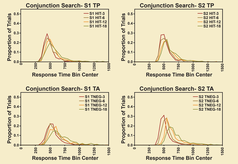
General Methods:
Participants: 10 different paid volunteers in each study.
Design: 4000 trials per subject (4 set sizes x 2 TA/TP x 500 trials).
Displays: Stimuli presented at random locations within a 5 x 5 jittered grid.

What Do RT Distributions Really Look Like?

Feature Search-- 2 of 10 Subjects

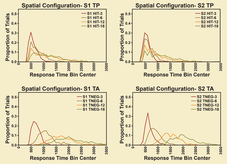
(Bins = 50 ms)

Conjunction Search-- 2 of 10 Subjects



(Bins = 50 ms)

Spatial Configuration Search-- 2 of 10 Subjects



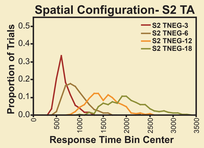
(Bins = 100 ms)

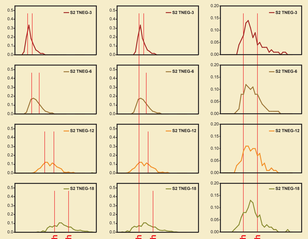
These Response Time Distributions:
- Are positively skewed.
- Change shape, position and spread as a function of set size in spatial configuration search, less so in conjunction search, and not at all in feature search.
- Appear to change shape (become more normal) as the effective set size increases.
- Suggest that participants are doing something different at small vs. large effective set sizes.
- Have different shapes for TA and TP trials, especially for the spatial configuration search.

Problems with analyzing raw RT distributions:
- Can't average RT distributions across different subjects without normalizing.
- Normalizing with Z-scores is problematic because the variance is extremely sensitive to outliers.

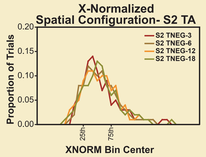
They Vary Over Task & Set Size.

How Can We Average RT Distributions? The X-Normalization Technique



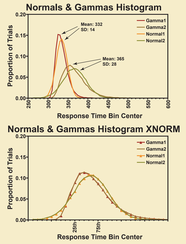


Identify 25th & 75th Percentiles | Align 25th Percentiles | Align 75th Percentiles.



Bin sizes are defined by choosing some number of bins between the 25th & 75th percentiles for all subjects and conditions. In all of the XNORM graphs presented here, there are 5 bins between the 25th and 75th percentiles.

X-Normalization Isolates The Shape of RT Distributions

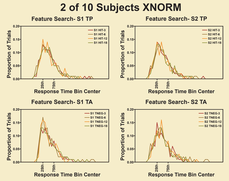


Two Normal and two Gamma distributions, with two different means and variances. Before X-Normalization, all distributions are significantly different from each other.

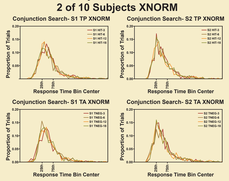
The X-Normalization technique pulls together distributions of the same type, despite the fact that they have different means and variances. After X-Normalization, the two Gamma distributions are statistically identical and significantly different than the two Normal distributions, which in turn are statistically identical.

What Do X-Normalized RT Distributions Look Like?

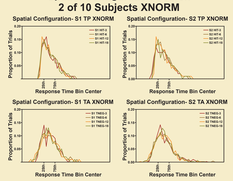
Feature Search 2 of 10 Subjects XNORM



Conjunction Search 2 of 10 Subjects XNORM



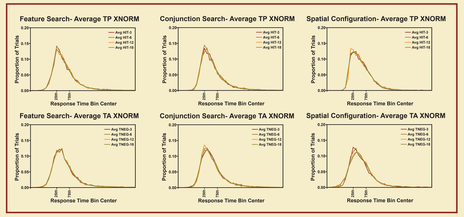
Spatial Configuration Search 2 of 10 Subjects XNORM

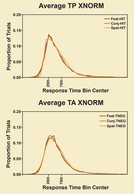


These X-Normalized Response Time Distributions:
- Are still positively skewed.
- Do not vary as a function of the effective set size.
- Do not change shape as the effective set size increases.
- Suggest that participants are doing the same thing at small vs. large set sizes and for Feature & Conjunction searches.
- Have the same shape for TA and TP trials, except for spatial configuration search.

They Don't Seem To Vary Much.

Different Tasks And Different Set Sizes Often Produce The Same Normalized Distribution

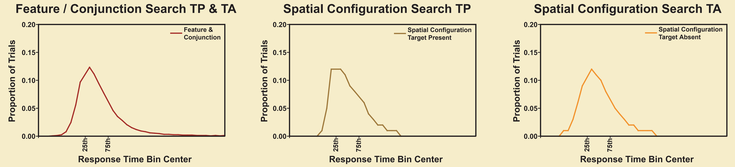




We compared RT distributions using the Kolmogorov-Smirnov test at the $p < .001$ level.

- **No significant difference between set sizes.**
- **No significant difference between TP and TA trials.**
- **No significant difference between Feature & Conjunction search data.**

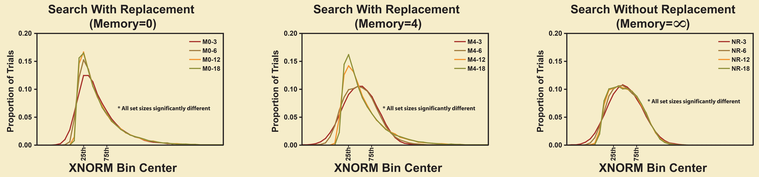
There Were Just 3 RT Distributions Found In Our Studies

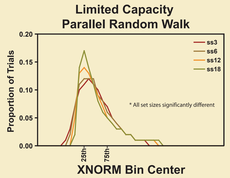


Feature and Conjunction Search share the same RT distribution. Spatial Configuration Search is qualitatively different.

For Feature and Conjunction Search, TP and TA distributions are identical while Spatial Configuration Search produces two distinct distributions.

We Simulated Several Serial And Parallel Models: They All Fail





"Search With Replacement" was modeled by checking a randomly selected item in the display every 50 ms until the target was found (normally distributed noise was added at each time step, mean=0 & sd=10ms). For the Memory=0 simulation, any item was eligible to be selected at each time step. For the Memory=4 simulation, any item was eligible to be selected except for items checked in the last 4 time steps.

For "Search Without Replacement", one item was checked at each time step, and no items were re-checked. This simulation corresponds to the classic self-terminating serial search model.

The "Parallel Random Walk" data was generated by assuming that all items in the display were processed at the same time and that data was accumulated at a rate of 1/set size, plus normally distributed noise (mean=0, sd=1).

- **Popular serial and parallel models of visual search predict changes in the shape of RT distributions as a function of set size.**
- **We did not observe any changes in RT distribution shape as a function of set size.**
- **Therefore, these models in their present form are unable to explain the observed data.**