Set-Size Effects in Identification and Localization

Theory and Data

Tom Busey
Indiana University
Bloomington

John Palmer
University of Washington
Divided Attention in Search

Are set-size effects in search for simple features due to:

• Limited capacity in perception,
  (e.g. Posner, Snyder & Davidson, 1980)
• Noisy integration in decision.
  (e.g. Shaw, 1980)

Recent studies of accuracy search are consistent with the noisy integration hypothesis and unlimited capacity in perception. (e.g. Palmer, 1994)

Question: Can this noisy integration hypothesis be extended to both identification and localization?
Yes/No Identification: Is There a Left-Leaning Target?
Yes/No Identification: Is There a Left-Leaning Target?
Yes/No Identification: Is There a Left-Leaning Target?
Example Localization Task: Always a Target. Where is it?
n-Alternative Localization: Always a Target. Where is it?
Identification and Localization

Is there unlimited capacity in perception of simple features for both identity and location information?

- Unlimited capacity for identity but not location. (e.g. Treisman & Gelade, 1980)
- Unlimited capacity for location but not identity. (e.g. Sagi & Julesz, 1985)
- Unlimited capacity for both location and identity. (e.g. Johnston & Pashler, 1990; Swensson & Judy, 1981)
Our Approach

• Measure accuracy in orientation search.

• Manipulate set size.

• Manipulate discriminability by varying the angle between targets and distractors to find a threshold.

• Compare observed and predicted magnitudes of set-size effects for a variety of identification and localization tasks.
Example Psychometric Functions
Yes/No- ID, Subject MR

Set Size 2
Set Size 8

Proportion Correct

Angle Difference (degrees)

SS2 Threshold 3.7°
SS8 Threshold 5.3°
Example Psychometric Functions

n-Localization, Subject MR

![Graph showing psychometric functions for set sizes 2 and 8. The graph plots proportion correct against angle difference in degrees. The thresholds for set sizes 2 and 8 are marked as SS2 Threshold 2.3° and SS8 Threshold 4.9°.](image)
Yes/No- ID, Subject MR

Set Size 2

Set Size 8

SS2 Threshold 3.7°

SS8 Threshold 5.3°

n-Localization, Subject MR

Set Size 2

Set Size 8

SS2 Threshold 2.3°

SS8 Threshold 4.9°

Subject MR

Set Size

Angle Threshold (Degrees)

Yes/No Identification
log-log slope = 0.26

n-Localization
log-log slope = 0.55
Measure of Set-Size Effect
Mean of 6 Subjects

Angle Threshold (Degrees)

Set Size

Yes/No Identification
log-log slope
0.32 ± 0.08

n-Localization
log-log slope
0.57 ± 0.09
How do we compare these tasks?

They have different response rules:

• Yes/No: Respond 'yes' if any stimulus is tilted to the left more than some criterion amount.

• Localization: Respond with the location that appears tilted most to the left.

• Requires a model of the different response rules.
Models Based on Signal Detection Theory

- Unidimensional random variable (angle)

- Two independence properties:
  - Unlimited Capacity
  - Statistical independence

- Task differences:
  - Independent decision rule for identification and maximum rule for localization

Key point: processing of individual stimuli does not change as items are added to the display.
Set Size 2 Representations:

Target Absent

Target Present
Set Size 8 Reduces Performance:

Target Absent

Target Present

8 distractors

7 distractors

1 target
Set Size 2 Representations:

For localization, pick the location with the greatest value on the stimulus representation axis (i.e. tilted to the left).
Set Size 8 Reduces Performance:

For localization, pick the location with the greatest value on the stimulus representation axis (i.e. tilted to the left).
Data verses Theory

Log-Log Slope: Data vs. Log-Log Slope: Theory

n-Localization

yes/no- ID
Experiment 1 Summary

- Localization has a larger set-size effect than identification in this experiment.
- The models can account for this qualitatively.
- Does localization always have a larger set-size effect than identification?
2-Target Tasks: Decision Rules

Distractors are vertical

2 Target Identification: Left or Right?
2 Target Localization: Where is it?
Data verses Theory

![Graph showing data points and labels involving n-localization, yes/no ID, and 2-target localization and identification.](image-url)
Data verses Theory

Log-Log Slope: Data

Log-Log Slope: Theory

n-Localization

2 Target Loc

yes/no- ID

2 Target ID

2-Target Localization

2-Target Identification
Measure of Set-Size Effect

Yes/No ID and n-Localization

- Yes/No Identification
  - log-log slope: 0.32 ± 0.08
- n-Localization
  - log-log slope: 0.57 ± 0.09

2-Target ID and Localization

- 2-Target Localization
  - log-log slope: 0.29 ± 0.03

- 2-Target Identification
  - log-log slope: 0.57 ± 0.10
Experiment 2 Summary

- Theory predicts a change in the order between localization and identification set size effects: localization is now predicted to have a smaller set-size effect than the corresponding identification task.

- This order reversal is observed in the data.

- This rejects any model in which localization is predicted to have always larger or always smaller set-size effects than identification (e.g. Sagi & Julesz, 1985; Treisman & Gelade, 1980).
Control Experiments

• Is set-size 8 harder due to lateral interactions and other sensory effects?
  – Always display 8 stimuli, but manipulate relevant set size by pre-cues.
  – No evidence for sensory effects.

• Is set-size 8 in localization harder because of increased number of responses?
  – Change task to a coarse localization task with 2 regions. Respond 'left' if the target appears on the left side of the screen, 'right' if on the right.
  – No evidence for response effects.
Summary of all Data vs. Theory

Best Fit:
Data = 0.0 + 1.4 Theory \( r^2 = .82 \)
Adjacent Errors in Localization

2-Target Localization: 5 Subjects

Error Probability vs. Relative Angle

- • Positions Adjacent to Target
- □ 2 Positions Away from Target
- □ 3 Positions Away from Target

Relative Angle

Error Probability
Mislocalizations

- Evidence for mislocalizations from previous studies (Johnson & Pashler, 1990; Solomon & Morgan, 2001).

- Suggests that information from nearby items is being assimilated.

- New Model: Assimilation Model
  - Blends information from nearby items
  - Happens only for relevant items
New value for target = \frac{1 + .5(.4) + .5(.4)}{1 + .5 + .5} = .7
Pick Value of Neighbor Weight from Mislocalization Data:

Errors for weight = 0.45  |  Errors for weight = 0.47  |  Errors for weight = 0.50  |  Errors for weight = 0.53
---|---|---|---
0.14 | 0.14 | 0.14 | 0.14
0.12 | 0.12 | 0.12 | 0.12
0.10 | 0.10 | 0.10 | 0.10
0.08 | 0.08 | 0.08 | 0.08
0.06 | 0.06 | 0.06 | 0.06
0.04 | 0.04 | 0.04 | 0.04
0.02 | 0.02 | 0.02 | 0.02
0.00 | 0.00 | 0.00 | 0.00

Errors for weight = 0.55  |  Errors for weight = 0.57  |  Errors for weight = 0.60  |  n-Loc Mislocalizations
---|---|---|---
0.14 | 0.14 | 0.14 | 0.14
0.12 | 0.12 | 0.12 | 0.12
0.10 | 0.10 | 0.10 | 0.10
0.08 | 0.08 | 0.08 | 0.08
0.06 | 0.06 | 0.06 | 0.06
0.04 | 0.04 | 0.04 | 0.04
0.02 | 0.02 | 0.02 | 0.02
0.00 | 0.00 | 0.00 | 0.00

Relative Angle

- Blue: Next to target
- Green: Two positions away
- Red: Three positions away
Pick Value of Neighbor Weight from 2-Target Mislocalization Data:

![Graph showing errors for different weights and relative angles.]

- Errors for weight = 0.45
- Errors for weight = 0.47
- Errors for weight = 0.50
- Errors for weight = 0.53
- Errors for weight = 0.55
- Errors for weight = 0.57
- Errors for weight = 0.60

Legend:
- Blue: Next to target
- Green: Two positions away
- Red: Three positions away

Relative Angle vs. Error Rate for 2-Target Loc Data:

- Relative Angle: $10^0$
- Error Rate: 0 to 0.12
Assimilation Model Predictions

Predictions for Log-Log Slope are still parameter free! 34
Conclusions

• Details of localization and identification tasks reverse the relative magnitude of the set-size effects.

• Rejects any simple account that proposes a special status for either localization or identification.

• Differences between identification and localization depend on the details of the task.
Conclusions from Modeling

• A model based on signal detection theory and specialized for each task accounts for the qualitative ordering of tasks.

• An extension based on assimilation of information from nearby tasks provides a quantitative account of all data, including that from identification tasks.
Where does this leave us?

• Success of models suggests that both identification and localization rely on the same underlying representation and apply different decision rules.

• Processing of this representation is unlimited capacity, with the exception of the capacity limitations brought on by the assimilation process (coarse coding or pooling across space).
Psychometric Functions - Yes/No and n-Loc

2-Target Identification and Localization

- SS2 2-Target ID
- SS2 2-Target Loc
- SS8 2-Target ID
- SS8 2-Target Loc
Psychometric Functions- 2 Target Conditions

Observer TB1

Observer WT

Observer EP

Observer MR

Observer KB

Observer HG

Yes/No ID and n-Localization

- SS2 Yes/No ID
- SS2 n-Loc
- SS8 Yes/No ID
- SS8 n-Loc
Threshold Ratios: At Set Size 2

Localization Threshold
Identification Threshold

![Graph showing threshold ratios for different conditions.](image)
## Threshold Ratios: Set Size 2

<table>
<thead>
<tr>
<th></th>
<th>Localization Threshold</th>
<th>Identification Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Localization vs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes/No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predicted Loc/ID ratio:</td>
<td>1.4</td>
<td>0.57</td>
</tr>
<tr>
<td>Obtained Loc/ID ratio:</td>
<td>1.6 ± 0.24</td>
<td>0.54 ± 0.03</td>
</tr>
<tr>
<td>2-Alt Localization vs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2AFC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We see a re-ordering of the ratios, which is again predicted by the theory.
Measure of Set-Size Effect

Mean of 5 Subjects

Angle Threshold (Degrees)

Set Size

2-Target
Localisation
log-log slope
0.29 ± 0.03

2-Target
Identification
log-log slope
0.57 ± 0.10
Experiment 1 Methods

- Measure performance in Yes/No and Localization tasks in separate blocks
- Two set sizes: 2 and 8 items
- Vary the angle between the target and distractors.
- Brief displays with no masks
- 4-6 observers per experiment
- 1152 trials per main condition
2 Target Identification: Always **one of two possible** Targets. Left or Right?
2 Alternative Localization: Always a Target. Where is it?
Theoretical Predictions

- 2AFC Identification: 0.42
  (verses 0.22 for 1 alternative yes/no)

- 2 Alternative Localization: 0.17
  (verses 0.34 for 1 alternative localization!)
2 Target Data- 5 Subjects

• 2AFC Identification: 0.57
  (Theory predicts 0.42)

• 2 Alternative Localization: 0.29
  (Theory predicts 0.17)
Unlimited Capacity Models Predict Non-Zero Set Size Effects

Predicted Log-Log Slopes:

• Yes/No: 0.224

• Localization: 0.34

*Predictions are parameter free
integrate these with previous slides*
Yes/No Decision Rule

Distribution of 1 distractor

Distribution of 1 target

Probability Density

Stimulus Representation (z)