Figure S1: ER and RT trade off comparisons for four models. The task is to discriminate targets or either 110° or 120° against 90° distractors. (a-c) ‘Continuous’ is SPRT that requires the support of the ‘softmax’ functionality and the transmission of continuous-valued membrane potentials. (a) ‘Continuous+max’ replaces the softmax module with a hard max (WTA). (b) ‘Spikified(τ)+Softmax’ encodes the membrane potential using spike trains thresholded at \( \{\tau_0 = -\tau, \tau_1 = \tau\} \), labeled as “Spikified(\( \tau \))”. The bold numbers next to the SPRT curve (green hollow) are the thresholds used for taking decisions. (c) ‘Spikified(\( \tau \))+Max’ uses both the hard max and spike train encoding. (d) Efficiency of spike train encoding (the average number of spikes to reach decision) using different decision thresholds \( \{\tau_0, \tau_1\} = (-\tau, \tau) \) is plotted against the risk. The bold numbers are the discretization thresholds \( \tau \).
Figure S2: Encoding quality of spiking networks. Two sender neurons communicate their membrane potential using spike trains to a receiver neuron. The receiver reassemble the spike trains and reconstruct the senders’ membrane potentials. The top half of each panel shows the spike trains of the senders. The bottom half compares the senders’ membrane potentials (thick lines) and the reconstructions from the receiver (thin lines). Each panel shows a different discretization threshold \( \tau^S_0 = -\tau^S, \tau^S_1 = \tau^S \).
Figure S3: Model fits to individual objects in the blocked experiment Exp. 1. This figure span multiple pages. Median RTs, ERs and RT histograms under all conditions (all combinations of set-size \( M \in \{3, 6, 12\} \) and orientation-difference \( \Delta \theta \in \{20^\circ, 30^\circ, 45^\circ\} \)) and for all subjects: bc (not the author), CH, ck, ER, gm, IM, LG, LO, MC and RG. This page shows the posteriors of model parameters from each of the subjects. The posterior is visualized for a pair of parameters at a time (e.g. the upper and lower thresholds). The posterior of the two parameters are approximated using a Gaussian and visualized as an ellipse. Pages below show fits to individual subjects (median RT, ER and RT histograms).
Subject bc

M = 3, $\Delta \theta = 20$

M = 3, $\Delta \theta = 30$

M = 3, $\Delta \theta = 45$

M = 6, $\Delta \theta = 20$

M = 6, $\Delta \theta = 30$

M = 6, $\Delta \theta = 45$

M = 12, $\Delta \theta = 20$

M = 12, $\Delta \theta = 30$

M = 12, $\Delta \theta = 45$
Subject CH

RT (ms) vs. M for different values of \( \Delta \theta \):
- \( \Delta \theta = 20 \) (left)
- \( \Delta \theta = 30 \) (middle)
- \( \Delta \theta = 45 \) (right)

ER vs. M for different values of \( \Delta \theta \):
- \( \Delta \theta = 20 \) (bottom left)
- \( \Delta \theta = 30 \) (bottom middle)
- \( \Delta \theta = 45 \) (bottom right)

TA, TP, FPR, and FNR for \( \Delta \theta \):
- TA (data) vs. fit (red)
- TP (data) vs. fit (green)
- FPR (data) vs. fit (black)
- FNR (data) vs. fit (dotted green)

TA and TP are shown in green and red, respectively, with shaded areas indicating standard deviation. FPR and FNR are shown in red and dotted green, respectively.
Subject CH

M=3, $\Delta \theta = 20$

M=3, $\Delta \theta = 30$

M=3, $\Delta \theta = 45$

M=6, $\Delta \theta = 20$

M=6, $\Delta \theta = 30$

M=6, $\Delta \theta = 45$

M=12, $\Delta \theta = 20$

M=12, $\Delta \theta = 30$

M=12, $\Delta \theta = 45$
Subject ck

$M=3, \Delta \theta = 20$

$M=6, \Delta \theta = 20$

$M=12, \Delta \theta = 20$

$M=3, \Delta \theta = 30$

$M=6, \Delta \theta = 30$

$M=12, \Delta \theta = 30$

$M=3, \Delta \theta = 45$

$M=6, \Delta \theta = 45$

$M=12, \Delta \theta = 45$

 freq

 RT (ms)

TA(data)

TA(fit)

TP(data)

TP(fit)
Subject gm

\[ M=3, \Delta \theta = 20 \]

\[ M=3, \Delta \theta = 30 \]

\[ M=3, \Delta \theta = 45 \]

\[ M=6, \Delta \theta = 20 \]

\[ M=6, \Delta \theta = 30 \]

\[ M=6, \Delta \theta = 45 \]

\[ M=12, \Delta \theta = 20 \]

\[ M=12, \Delta \theta = 30 \]

\[ M=12, \Delta \theta = 45 \]
Subject LO

- For $M=3$, $\Delta \theta = 20$
- For $M=6$, $\Delta \theta = 20$
- For $M=12$, $\Delta \theta = 20$

- For $M=3$, $\Delta \theta = 30$
- For $M=6$, $\Delta \theta = 30$
- For $M=12$, $\Delta \theta = 30$

- For $M=3$, $\Delta \theta = 45$
- For $M=6$, $\Delta \theta = 45$
- For $M=12$, $\Delta \theta = 45$

Legend:
- Red: TA(data)
- Dashed Red: TA(fit)
- Green: TP(data)
- Dashed Green: TP(fit)
Subject RG

- $M=3, \Delta \theta = 20$
- $M=3, \Delta \theta = 30$
- $M=3, \Delta \theta = 45$

- $M=6, \Delta \theta = 20$
- $M=6, \Delta \theta = 30$
- $M=6, \Delta \theta = 45$

- $M=12, \Delta \theta = 20$
- $M=12, \Delta \theta = 30$
- $M=12, \Delta \theta = 45$

Legend:
- TA(data)
- TA(fit)
- TP(data)
- TP(fit)
Figure S4: Model fits to individual objects in the mixed set-size experiment Exp. 2. This figure span multiple pages. This page shows the posteriors of the parameters. Pages below show median RT, ER and RT histogram under every set-size $M \in \{3, 6, 12\}$ and for every subject.
Subj=CH

\[ \Delta \theta = 30 \]

RT (ms)

\[ T_A (\text{data}) \]
\[ T_A (\text{fit}) \]
\[ T_P (\text{data}) \]
\[ T_P (\text{fit}) \]

\[ M = 3, \Delta \theta = 30 \]
\[ M = 6, \Delta \theta = 30 \]
\[ M = 12, \Delta \theta = 30 \]

freq

\[ \text{FPR} (\text{data}) \]
\[ \text{FPR} (\text{fit}) \]
\[ \text{FNR} (\text{data}) \]
\[ \text{FNR} (\text{fit}) \]

ER

\[ M = 3, \Delta \theta = 30 \]
\[ M = 6, \Delta \theta = 30 \]
\[ M = 12, \Delta \theta = 30 \]
Subj=ck

\[ \Delta \theta = 30 \]

- TA(data)
- TA(fit)
- TP(data)
- TP(fit)

\[ M = 3, \Delta \theta = 30 \]

- TA(data)
- TA(fit)
- TP(data)
- TP(fit)

\[ M = 6, \Delta \theta = 30 \]

- TA(data)
- TA(fit)
- TP(data)
- TP(fit)

\[ M = 12, \Delta \theta = 30 \]

- TA(data)
- TA(fit)
- TP(data)
- TP(fit)
Subj=ER

M=3, Δθ=30

M=6, Δθ=30

M=12, Δθ=30

Δθ=30

RT (ms)

FPR(data)

FPR(fit)

ER

FNR(data)

FNR(fit)

TA(data)

TA(fit)

TP(data)

TP(fit)
Subj=gm

$\Delta \theta = 30$

$M=3, \Delta \theta = 30$

$M=6, \Delta \theta = 30$

$M=12, \Delta \theta = 30$
Subj=IM

![Graph of RT vs M for different ∆θ values.](image)

- RT (ms)
- M: 4, 6, 8, 10, 12
- ∆θ: 30
- TA(data), TA(fit), TP(data), TP(fit)

![Graph of frequency vs RT for different M values.](image)

- M: 3, 6, 12
- ∆θ: 30
- FPR(data), FPR(fit), FNR(data), FNR(fit)

![Graph of ER vs M for different ∆θ values.](image)

- ER
- M: 4, 6, 8, 10, 12
- ∆θ: 30
- FPR(data), FPR(fit), FNR(data), FNR(fit)
Subj=LO

- RT (ms) vs. M
- ∆θ = 30
- TA (data), TA (fit), TP (data), TP (fit)

- FPR (data), FPR (fit), FNR (data), FNR (fit)
- freq vs. RT (ms)
- M = 3, ∆θ = 30
- M = 6, ∆θ = 30
- M = 12, ∆θ = 30
Subj=MC

- RT (ms)
  - $\Delta \theta =$ 30
  - TA (data)
  - TA (fit)
  - TP (data)
  - TP (fit)

- FPR (data)
  - FPR (fit)
  - FNR (data)
  - FNR (fit)

- M = 3, $\Delta \theta =$ 30

- M = 6, $\Delta \theta =$ 30

- M = 12, $\Delta \theta =$ 30
Figure S5: Model fits to individual objects in the mixed orientation-difference experiment Exp. 3. This figure span multiple pages. This page shows the posteriors of the parameters. Pages below show median RT, ER and RT histogram under every orientation-difference $\Delta \theta \in \{20^\circ, 30^\circ, 45^\circ\}$ and for every subject.
Subj=CH

- **RT (ms)**
  - M=12 TA(data)
  - M=12 TA(fit)
  - M=12 TP(data)
  - M=12 TP(fit)

- **Δθ (°)**
  - M=12, TC=20
  - M=12, TC=30
  - M=12, TC=45

- **ER**
  - M=12 FPR(data)
  - M=12 FPR(fit)
  - M=12 FNR(data)
  - M=12 FNR(fit)

- **freq**
  - M=12, TC=20
  - M=12, TC=30
  - M=12, TC=45
Subj=gm

\[ \Delta \theta (\degree) \]

RT (ms)

M=12

TA (data)

TA (fit)

TP (data)

TP (fit)

ER

FPR (data)

FPR (fit)

FNR (data)

FNR (fit)

Subj=gm

M=12, TC=20

M=12, TC=30

M=12, TC=45

freq

RT (ms)

10^3

10^3

10^3

10^3
Figure S6: Model fits to individual objects in the blocked experiment (Exp. 1) where a common cost of error is used across different conditions / blocks. Each page below is one subject. Each panel shows the RT and ER tradeoff for a condition (a pair of set-size and orientation-difference), and fits using two methods. The first ("Ind C(errors)") is the presented method where a pair of thresholds are fitted for each condition, totaling $2 \times 9 = 18$ free parameters. The second method ("shared C(errors)") fits two costs of errors $C_p$ and $C_n$ (2 free parameters) that are common to all conditions, assuming the subject is minimizing Bayes risk with the same cost parameters across conditions. The thresholds for each condition can be solved given $C_p$ and $C_n$. The tradeoff points with the three lowest Bayes risk are shown (redder means lower risk). The plot also presents the ideal tradeoff curve (blue) and the observed subject's tradeoff (green).
bc: $C_p = 0.2004$, $C_n = 0.4008$
CH: $C_p = 1.8036$, $C_n = 2.004$
ck: $C_p = 0.6012$, $C_n = 0.6012$
ER: $C_p = 0.8016$, $C_n = 0.6012$
$\text{gm: } C_p = 0.6012, C_n = 0.4008$
IM: $C_p = 0.6012, C_n = 0.8016$

**Human Shared C(errors)**

**Ind. C(errors)**
LG: $C_p = 4.2084$, $C_n = 6.2124$

- Human
- Shared C(errors)
- Ind. C(errors)

- Median RT (ms)
- ER
- $M=3$, $\Delta \theta = 30$
- $M=3$, $\Delta \theta = 45$
- $M=6$, $\Delta \theta = 20$
- $M=6$, $\Delta \theta = 30$
- $M=6$, $\Delta \theta = 45$
- $M=12$, $\Delta \theta = 20$
- $M=12$, $\Delta \theta = 30$
- $M=12$, $\Delta \theta = 45$
LO: $C_p=0.6012$, $C_n=0.6012$
Median RT (ms)

500 1000 1500

ER

0 0.1 0.2 0.3

M=3, ∆θ = 20

Human

Shared C(errors)

Ind. C(errors)

M=3, ∆θ = 30

M=3, ∆θ = 45

M=6, ∆θ = 20

M=6, ∆θ = 30

M=6, ∆θ = 45

M=12, ∆θ = 20

M=12, ∆θ = 30

M=12, ∆θ = 45

MC: $C_p = 0.8016$, $C_n = 0.6012$
RG: $C_p=0.6012$, $C_n=0.6012$