Table S1

A	Model Summary
Populations	Input: 4 excitatory stimuli (A, B, C, D); Associative Layer (AL): 1 inhibitory + 1 excitatory; Decision Layer (DL): 2 excitatory, 2 inhibitory
Connectivity	Input to Associative: random Input-E-to-E and Input-E-to-I Recurrent Associative: sparse-random E-to-E and I-to-E, all-to-all I-to-I, no E-to-I, Associative to Decision: all-to-all E(AL)-to-E(DL) Recurrent Decision: all-to-all within-pop E-to-E; all-to-all across pop E-to-I; all-to-all within-pop I-to-E; all-to-all I-to-I
Neuron model	Leaky integrate-and-fire (Iaf) with dynamic threshold and dynamic refractory conductance
Channel models	-
Synapse model	Excitatory AMPA + voltage-dependent NMDA, inhibitory GABA Conductances - step increase then exponential decay.
Plasticity	Input to associative and recurrent E-to-E synapses: triplet spike-timing-dependent plasticity (STDP). I-to-E synapses: long-term potentiation of inhibition (LTPi). Associative to decision-making output synapses: DA reward-based plasticity; short-term facilitation, depression.
Input	Independent fixed-rate Poisson spike trains from populations of Input cells.
Measurements	Spike trains & times, synaptic connections & weights, decision times.

B	Populations	
Name	**Elements**	**Size**
Input-E	Poisson trains	N_{In} = 2, 4, 6, 10, 20
Associative-E	laf neuron	$N_E = 4N_I$
Associative-I	laf neuron	N_I
Decision-E	laf neuron	2x200
Decision-I	laf neuron	2x50

C	Connectivity		
Name	**Source**	**Target**	**Pattern**
InE	Input-E	Associative-E	Random, p=[.05 - .5] plastic, initial weight InE_0
InI	Input-E	Associative-E	Random, p=[.05 -.5] plastic, initial weight InI_0
EE	Associative-E	Associative-E	Random, p=.10; plastic, initial weight WEE_0
I-to-E	Associative-I	Associative-E	Random, p=.25; plastic, initial weight WIE_0
I-to-I	Associative-I	Associative-I	All-to-all, weight WII
E-to-D	Associative-E	Decision-E	All-to-all; plastic, initial weight DW_0 Static or dynamic synapses
DE-to-DE	Decision-E	Same Decision-E	All-to-all, fixed weight DWEE
DE-to-DI	Decision-E	Opposite Decision-I	All-to-all, fixed weight DWEI

DI-to-DE	Decision-I	Same Decision-E	All-to-all, fixed weight DWIE
DI-to-DI	Decision-I	All Decision-I	All-to-all, fixed weight DWII

D	**Neuron and Synapse Model**
Name	laf neuron
Type	Leaky integrate-and-fire (laf) with dynamic threshold, dynamic refractory conductance, and exponential conductance input.
Subthreshold dynamics	$\tau_m \frac{dV}{dt} = \begin{matrix} g_L\left(V_L - V\right) + g_{GABA}(t)\left(V_{GABA} - V\right) + g_{AMPA}(t)\left(V_{AMPA} - V\right) \\ + g_{NMDA}(t)\left(V_{NMDA} - V\right) * NMDA(V) + g_{ref}(t)\left(V_{ref} - V\right) + g_{Poisson} \end{matrix}$ $\tau_{ref} \frac{dg_{ref}}{dt} = -g_{ref}$ And $\tau_{th} \frac{dV_{th}}{dt} = -\left(V_{th} - V_{th}^{0}\right)$
AMPA, GABA$_A$, NMDA synaptic conductance dynamics	$g_i(t) = \bar{g} \sum_j W_{ji} s_j(t)$ $\tau_s \frac{ds_j(t)}{dt} = -s_j + \sum_k \delta(t - t_k^{(j)})$ $NMDA(V) = 1/([\mathrm{Mg}_{ext}^{2+}]e^{(-0.062(V(t)/3.57\times10^{-3})})$ Where $[\mathrm{Mg}_{ext}^{2+}] = 1\mathrm{mM}$
Spiking	If $V(t-) \leq V_{th}(t-) \wedge V(t+) > V_{th}(t+)$ then (1) set $t^* = t$ (2) emit spike with time-stamp t^* (3) $g_{ref}\left(t\right) \mapsto g_{ref}\left(t^*\right) + \Delta g_{ref}$ (4) $V_{th}\left(t\right) \mapsto V_{th}^{\max}$

E	**Plasticity**	
Type	**Mechanism** (presynaptic cell i, postsynaptic cell j)	**Connections**
Triplet-STDP	if $t_{post} > t_{pre}$ then $\Delta W_{ij} = e^{\left(\frac{t_{pre} - t_{post}}{\tau_+}\right)}\left[A_2^+ + A_3^+ \sum_j e^{\left(\frac{t_j - t_{post}}{\tau_y}\right)}\right]$ if $t_{post} < t_{pre}$ then $\Delta W_{ij} = -e^{\left(\frac{t_{post} - t_{pre}}{\tau_-}\right)}\left[A_2^- + A_3^- \sum_k e^{\left(\frac{t_k - t_{pre}}{\tau_x}\right)}\right]$	E-to-E and In-to-E 1 synapse per spike-pair
LTPI	if $\left\lvert t_{post} - t_{pre}\right\rvert < \Delta T_{LTPi}$ or $V_{post} < -65mV$ then $\Delta W_{ij} = 0$ else $\Delta W_{ij} = \Delta W_{LTPI}$	I-to-E all presynaptic weights per Presynaptic spike
DA-reward	sublinear: $\Delta W_i^R = \varepsilon_R\left(\sqrt{R_i} - \left\langle\sqrt{R_i}\right\rangle\right)$; linear: $\Delta W_i^R = \varepsilon_R\left(R_i - \left\langle R_i\right\rangle\right)$; superlinear: $\Delta W_i^R = \varepsilon_R\left(R_i^2 - \left\langle R_i^2\right\rangle\right)$; If Reward=1, $\Delta W_{ij} = \Delta W_i^R$; if Reward=0, $\Delta W_{ij} = -\Delta W_i^R$	E-to-D synapses to winning pool, every trial

E-Homeo	$\Delta W_{ij} = \varepsilon_{EH} W_{ij} \left(r_{Egoal} - \overline{r_j(t)} \right)$	InE-to-E, E-to-E, all synapses every trial
IE-Homeo	$\Delta W_{ij} = \varepsilon_{IEH} W_{ij} \left(r_{IEgoal} - \overline{r_j(t)} \right)$	I-to-E all synapses every trial
Facilitation	$F_i(t) = 1 + (F_i(t) - 1) e^{(-dt/\tau_F)}$ $if\ V_i = V_i^{spike}\ F_i(t^+) = F_i(t^-) + f_F\left(F_{max} - F_i(t^-)\right)$	E-to-D, all synapses every trial
Depression	$D_i(t) = 1 - (1 - D_i(t)) e^{(-dt/\tau_D)}$ $if\ V_i = V_i^{spike} D_i(t^+) = D_i(t^-)\left(1 - D_{frac}\right)$	E-to-D, all synapses every trial

F	**Input**
Type	**Description**
Poisson generators	Fixed rate, $\nu_{In} = \nu_0 / N_{In}$ for $t_{on} \le t < t_{off}$ ($\nu_0 = 480$Hz) for selected Input populations

G **Measurements**
Spike activities: mean rate per cell & decision pool during stimulus presentation, spike times.
Reaction times: bin time when mean activity of one decision pool exceeds other by 20Hz
Connectivity: final distribution of AL-to-DL connections.

Table S1: A summary of the spiking neuron network model's structure, plasticity, and dynamics. (Nordlie et al., 2009).

Table S2

B: Populations		
Name	**Value**	**Description**
Nin	2, 4, 6, 10, 20	Number of Input Poisson spike trains per Stimulus
NE	320	Number of excitatory Associative layer neurons
NI	80	Number of inhibitory Associative layer neurons
DNE	2x100	Number of excitatory Decision layer neurons
DNI	2x25	Number of inhibitory Decision layer neurons

C: Connectivity		
Name	**Value**	**Description**
$\bar{r}$	480Hz/(Nin)	Mean Input rate
Input synE	7	Excitatory Input Synaptic Weight
Input synI	8	Excitatory Input Synaptic Weight
WEE	0.05 ± 0.025	Associative Excitatory-to-Excitatory base synaptic Weight
WIE	0.05 ± 0.025	Associative Inhibitory-to-Excitatory base synaptic Weight
WII	0.038 ± 0.019	Associative Inhibitory-to-Inhibitory fixed synaptic Weight
WEI	--	--
WED	0.088	Associative Excitatory-to-Decision base synaptic Weight
WDE-DE	0.02	Decision Excitatory-to-Excitatory fixed synaptic Weight
WDE-DI	1.0	Decision Excitatory-to-Inhibitory fixed synaptic Weight
WDI-DE	0.16	Decision Inhibitory-to-Excitatory fixed synaptic Weight
WDI-DI	0.04	Decision Inhibitory-to-Inhibitory fixed synaptic Weight

D1: Associative Layer Neuron & Synapse Model Parameters			
Name	**Excitatory value**	**Inhibitory value**	**Description**
V_L	-67.5mV ±1.25mV	-67.5mV ±1.25mV	Leak reversal potential
g_L	36μS ± 0.5μS	36μS ± 0.5μS	Leak conductance
τ_m	10ms ± 0.75ms	10ms ± 0.75ms	Membrane time constant
V_{reset}	-58mV ±1mV	-58mV ±1mV	Reset voltage
V_{th}	-48mV ± 1mV	-48mV ±1mV	Voltage threshold
V_{thmax}	150mV	150mV	Maximum voltage threshold
τ_{th}	2.25ms ± .125ms	1.25ms ± .125ms	Dynamic threshold time constant
τ_{ref}	2.25ms ± .125ms	1.25ms ± .125ms	Refractory conductance time constant
δ_{gref}	150μS	150μS	Refractory conductance step size
E_{AMPA}	0mV	0mV	AMPA reversal potential
E_{NMDA}	0mV	0mV	NMDA reversal potential
E_{GABAA}	-70mV	-70mV	$GABA_A$ Reversal Potential
$\bar{g}_{AMPA}$	3μS	3μS	AMPA maximal conductance
$\bar{g}_{NMDA}$	3μS	3μS	NMDA maximal conductance
$\bar{g}_{GABA_A}$	100μS	100μS	$GABA_A$ maximal conductance
τ_{AMPA}	2ms	2ms	AMPA synaptic time constant
τ_{NMDA}	100ms	100ms	NMDA synaptic time constant
τ_{GABA_A}	10ms	10ms	$GABA_A$ synaptic time constant

$[MG^{2+}_{ext}]$	1.0mM	1.0mM	External Magnesium concentration
σ_V	$40\,\mu V s^{-1/2}$	$40\,\mu V s^{-1/2}$	Voltage noise amplitude
σ_S	$1.2\,mS s^{-1/2}$	$1.2\,mS s^{-1/2}$	Conductance noise amplitude
D2: Decision Layer Neuron & Synapse Model Parameters			
Name	**Excitatory value**	**Inhibitory value**	**Description**
V_L	-70mV	-70mV	Leak reversal potential
g_L	35µS	30µS	Leak conductance
τ_m	20ms	10ms	Membrane time constant
V_{reset}	-55mV	-55mV	Reset voltage
V_{th}	-48mV	-50mV	Voltage threshold
τ_{th}	2.25ms ± .125ms	1.25ms ± .125ms	Dynamic threshold time constant
τ_{ref}	2.25ms ± .125ms	1.25ms ± .125ms	Refractory conductance time constant
δ_{gref}	150µS	150µS	Refractory conductance step size
E_{AMPA}	0mV	0mV	AMPA reversal potential
E_{NMDA}	0mV	0mV	NMDA reversal potential
E_{GABAA}	-70mV	-70mV	$GABA_A$ Reversal Potential
$\bar{g}_{AMPA}$	2µS	1µS	AMPA maximal conductance
$\bar{g}_{NMDA}$	6µS	1.5µS	NMDA maximal conductance
$\bar{g}_{GABA_A}$	100µS	100µS	$GABA_A$ maximal conductance
τ_{AMPA}	2ms	2ms	AMPA synaptic time constant
τ_{NMDA}	100ms	100ms	NMDA synaptic time constant
τ_{GABA_A}	10ms	10ms	$GABA_A$ synaptic time constant
$[MG^{2+}_{ext}]$	1.0mM	1.0mM	External Magnesium concentration
$g^{max}_{urgency}$	5µS	--	Maximum urgency signal conductance
σ_V	--	--	Voltage noise amplitude
σ_S	$4\,mS s^{-1/2}$	$4\,mS s^{-1/2}$	Conductance noise amplitude

E1	**Long-term Plasticity Parameters**	
Name	**Value**	**Description**
idW	0.001	LTPi potentiation per inhibitory spike
LTPi window	±20ms	Window for excitatory spike to 'veto' LTPi
V_{Thresh}	-65mV	Excitatory depolarization needed for LTPi
A_{2+}	$5*10^{-5}$	Amplitude – doublet LTP
A_{2-}	$7*10^{-3}$	Amplitude – doublet LTD
A_{3+}	$6.2*10^{-3}$	Amplitude – triplet LTP
A_{3-}	$2.3*10^{-4}$	Amplitude – triplet LTD
τ_{2+}	16.68ms	Time constant – doublet LTP
τ_{2-}	33.7ms	Time constant – triplet LTD
τ_y	125ms	Time constant – doublet LTP
τ_x	101ms	Time constant – triplet LTD
dW	0.005	3-STDP potentiation per excitatory spike
ε	0.001	Homeostatic rate constant

rg_E	4Hz	Input and recurrent excitatory goal rate
rg_{IE}	8Hz	Inhibitory-to-excitatory goal rate
ε_R	$1*10^{-4}$	DA-reward learning rate constant
E2	**Short-term Plasticity Parameters**	
f_F	1.0	Facilitation factor
F_{max}	4.0	Maximum facilitation variable value
τ_F	500ms	Facilitation variable time constant
D_0	1.0	Initial depression variable value
D_{min}	0.0	Minimum depression variable value
D_{frac}	0.4	Depression factor
τ_D	500ms	Depression variable time constant

Table S2: A summary of the neural, synaptic, and plasticity parameters in the spiking neuron model corresponding to their respective section in Table S1, which details the spiking neuron model layout (Nordlie et al., 2009). Each parameter is described by its name, value in units, and a brief description.