A Normative Account of the Influence of Contextual Familiarity and Novelty on Episodic Memory Policy

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Summary

- Empirically, a familiar/novel stimulus triggers a lingering retrieval/encoding mode, even if this stimulus is incidental (Duncan et al. 2012, 2016, 2019). However, it is unclear why this is the case from a normative standpoint.
- A neural network model that learns an episodic memory (**EM**) policy in an autocorrelated environment can capture human data (Duncan et al. 2016, 2019), suggesting that these lingering EM modes are an optimal adaptation to environment statistics (see also Anderson & Schooler, 1991, and Honey et al., 2023), which is consistent with the neuromodulation account (e.g. Hasselmo et al., 1996)

Familiarity/novelty trigger lingering EM modes

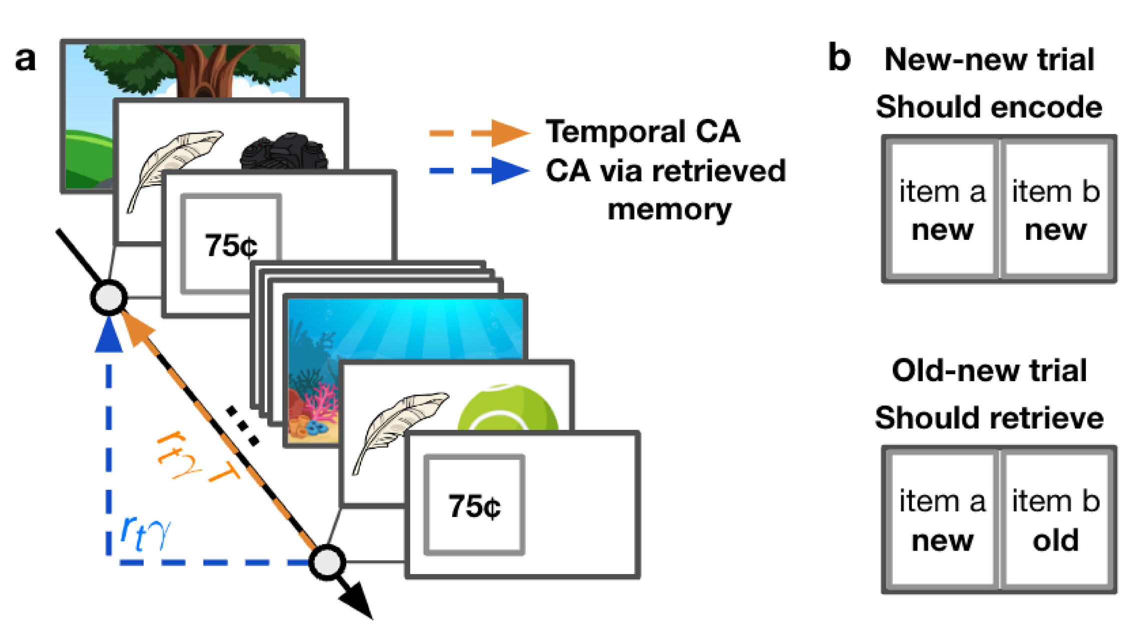

Figure 1: a) The task paradigm of Duncan et al. (2016) and an illustration of credit assignment (CA) via retrieved memory. b) Participants either choose between two new items or a new versus an old item.

- In Duncan et al. (2016; Fig.1a), subjects were instructed to choose the higher value item between two new items or an old versus a new item (Fig.1b; note that items had consistent values over time). It is optimal to encode in new-new trials and recall in old-new trials.
- Before every choice, a context image, either familiar or novel, was presented (Fig.1a).
- The findings show that choices were more influenced by past EMs in a familiar context, and EM encoding was better in a novel context.

A neural net model of EM policy

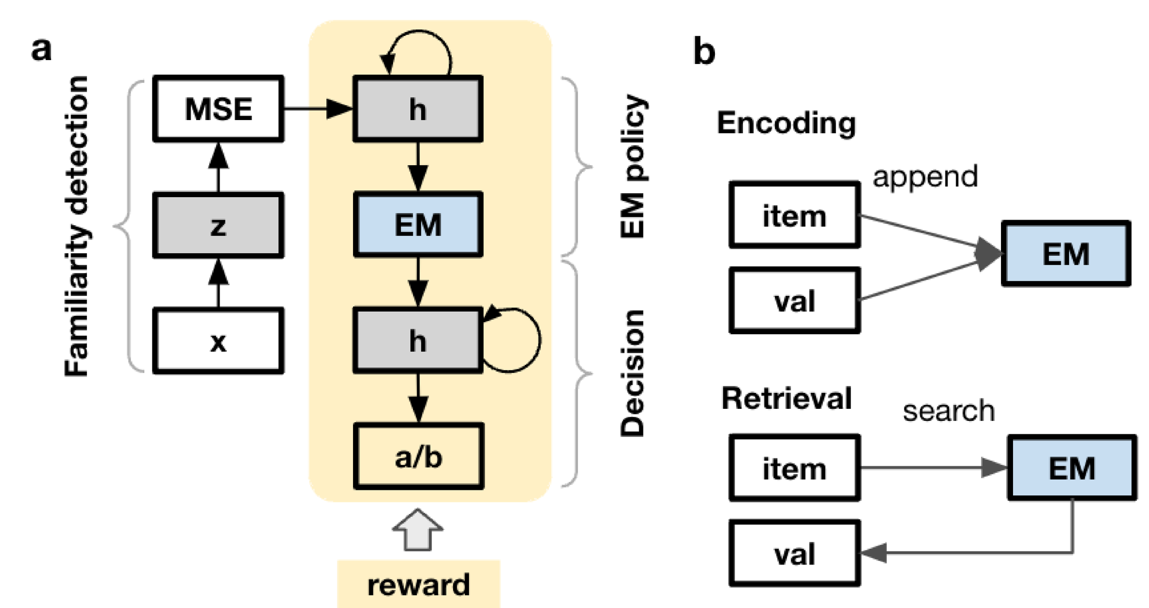

Figure 2: a) A neural net model of EM policy trained with RL. b) Episodic encoding and retrieval.

- Familiarity detector: an autoencoder that minimizes reconstruction mean squared error (MSE) so that lower MSE for experienced stimuli indicates greater familiarity.
- EM policy layer: an RNN that takes familiarity signal as input, outputs binary action – retrieve or encode (Fig. 2b); it learned to recall/encode when the stimulus is familiar/novel (Fig.3a).
- Decision layer: an RNN that takes the retrieved value to produce choices; it learned to choose higher-valued items (Fig. 3b).
- Learning: The EM policy and the decision layer were trained with RL. CA via retrieved memory reinforces encoding actions retrospectively when retrieval leads to rewards (Fig.1a); this is critical for learning an optimal encoding policy, as learning to encode involves long-range CA.

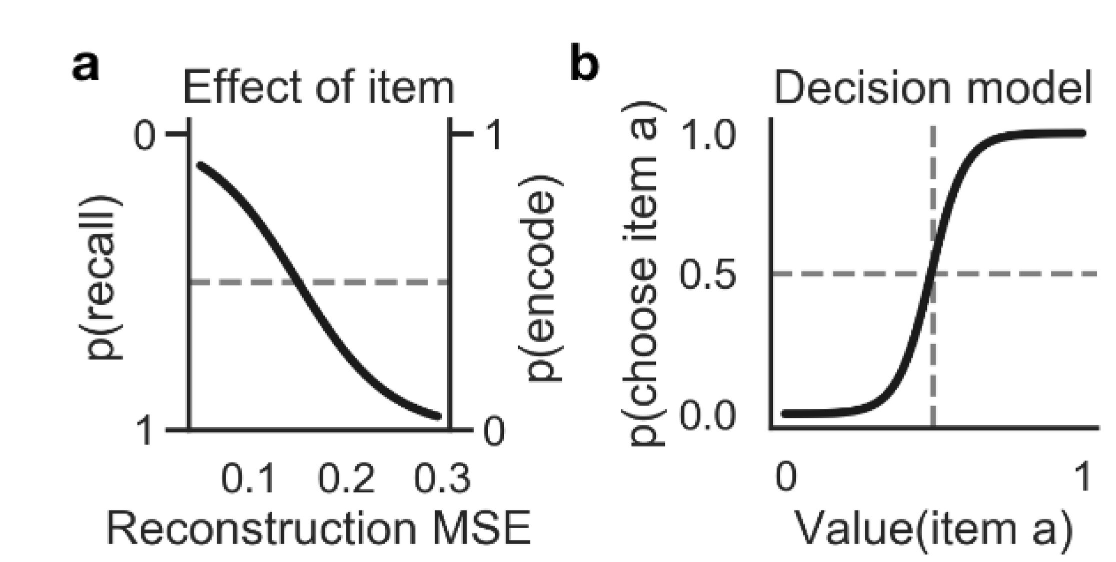

Figure 3: The probability of a) recall/encoding as a function of stimulus familiarity and b) choosing an item as a function of its value of trained models.

Model: Duncan et al. (2016)

- Hypothesis: Context familiarity/novelty biases are adaptations to environmental autocorrelation.
- Method: To test the hypothesis, models were either trained in i) an autocorrelated environment, where familiar/novel stimuli precede other familiar/novel stimuli or ii) a non-autocorrelated environment.

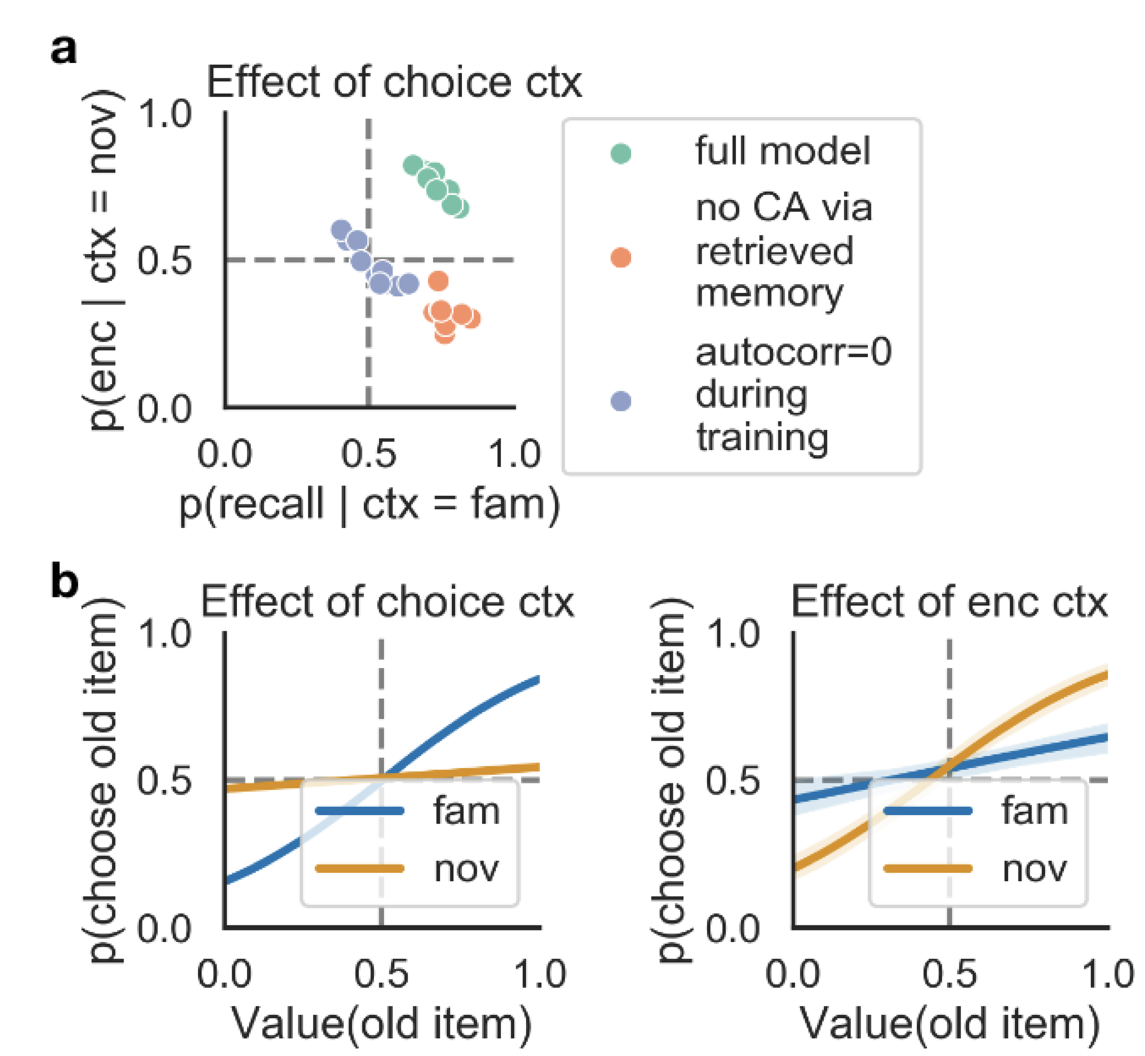

Figure 4: The influence of the familiarity/novelty of the preceding context on a) EM policy and b) decision policy.

Models trained in the autocorrelated environment ...

- ... were more likely to recall/encode when the preceding context was familiar/novel (Fig.4a); this was not the case for models trained in non-autocorrelated environment or models without CA via retrieved memory.
- ... captured the human data (Duncan et al. 2016; Fig.4b) – the level of influence of retrieved value was stronger i) when the preceding context was familiar and ii) when a novel context was presented at encoding, right before the value of the item was initially observed.

Models trained in the non-autocorrelated environment were not sensitive to context familiarity.

Model: Duncan & Shohamy (2019)

- In Duncan & Shohamy (2019), subjects had to coordinate between episodic and incremental values to make optimal decisions (Fig. 5a).
- Again, models trained in the autocorrelated environment qualitatively captured the human data (Fig. 5b), showing that choices in a familiar/novel context were more/less episodic-dependent.

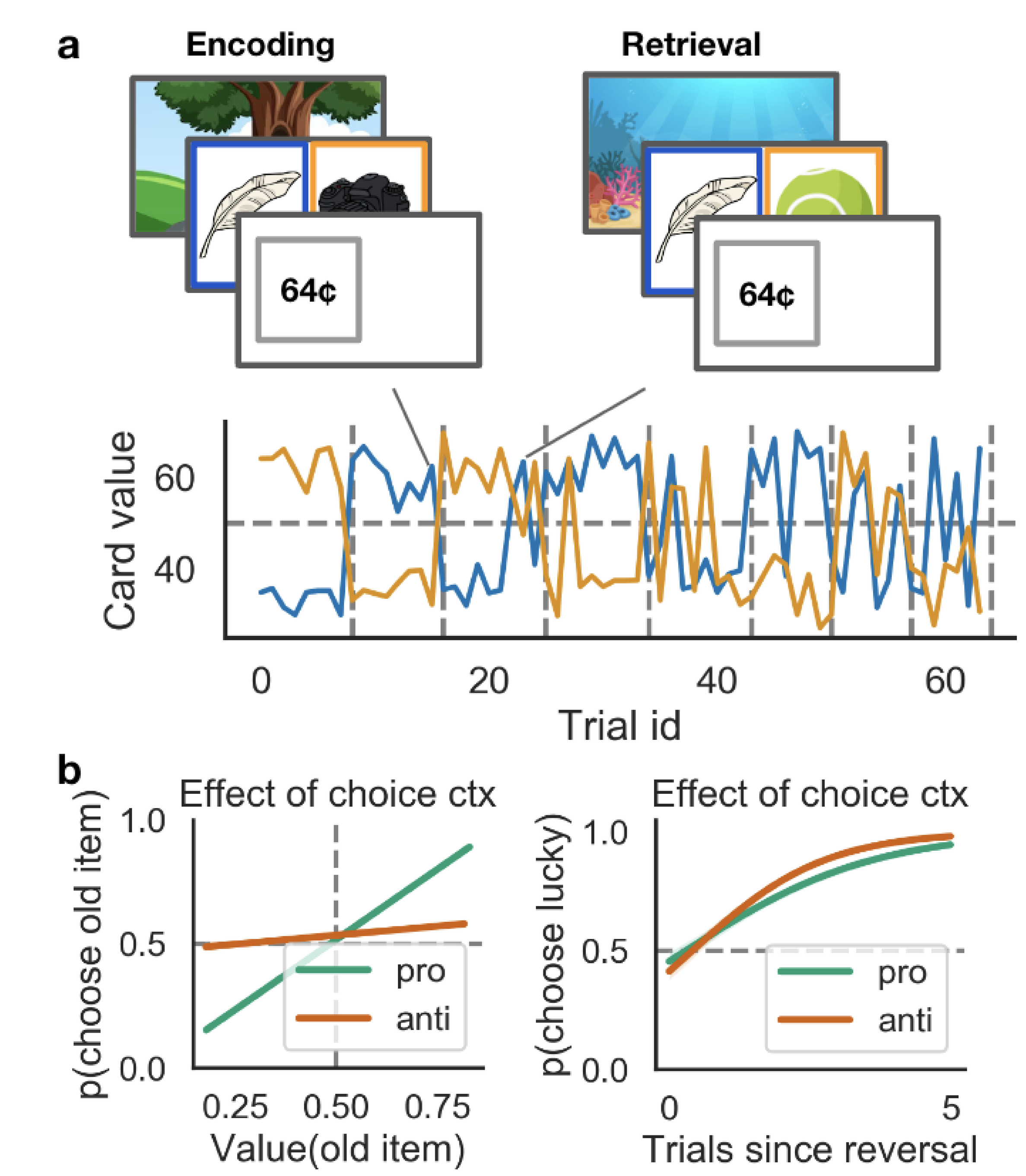

Figure 5: a) In the Duncan & Shohamy (2019) task, each card has a color (blue or orange). At any moment, cards from one of the colors have a higher mean value (the "lucky deck"). b) The modeling results. *pro: familiar context -> old-new trial, novel context -> new-new trial; anti: novel context -> old-new trial, familiar context => new-new trial.

References & Acknowledgement

References: [1] Duncan et al. (2012). Science; [2] Duncan et al. (2016). J Cog Neuro; [3] Duncan & Shohamy (2019). JEP.G; [4] Anderson & Schooler (1991). Psych Science; [5] Honey et al. (2023). Current Direction in Psych Science; [6] Hasselmo et al. (1996). Hippocampus

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