Semantic Neural Networks for Memory and Recall

PSYCH 209

Ari Beller — 3/18/21

Semantic Nets and Memory Structure

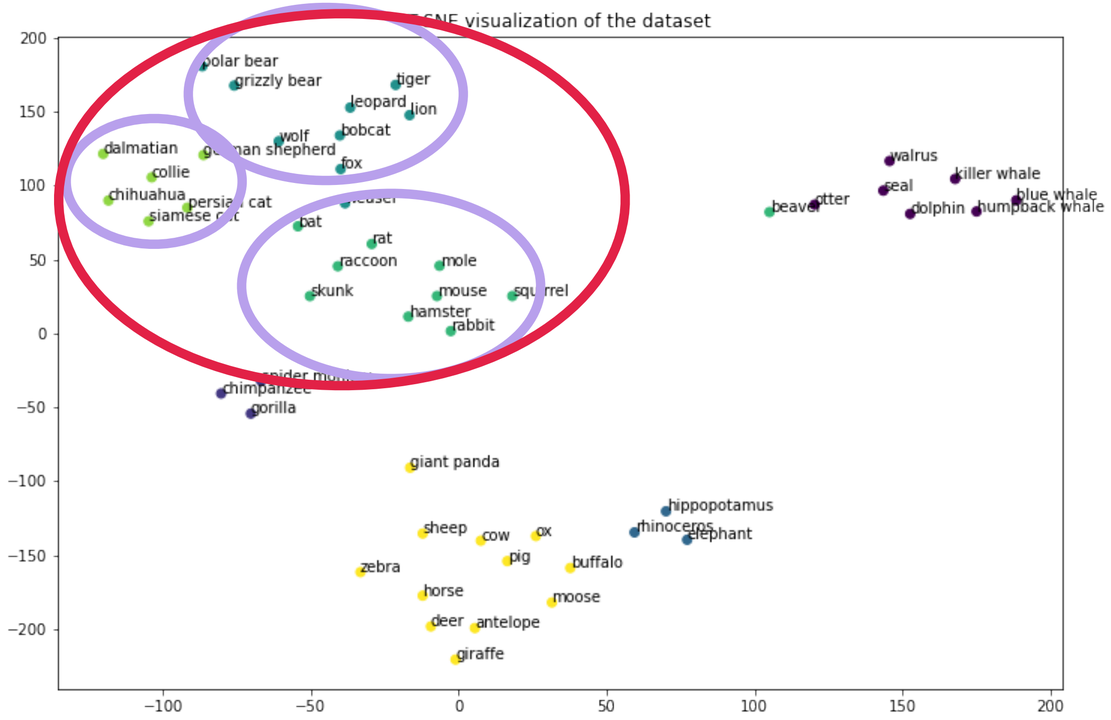
- Rogers and McClelland 2003 got me thinking about the Semantic Fluency Task (SFT)
- Free recall of category elements (usually animals)
- Semantically related clusters in participant response sequences
  - Farm animals…sea creatures…birds…etc
- Reminded me of cluster structure in the representation layers of the Semantic Networks based on coherent covariation in the data.
- Interested to explore Semantic Networks as a model of memory structure in this setting, and hypothesize about how that memory structure supports recall.

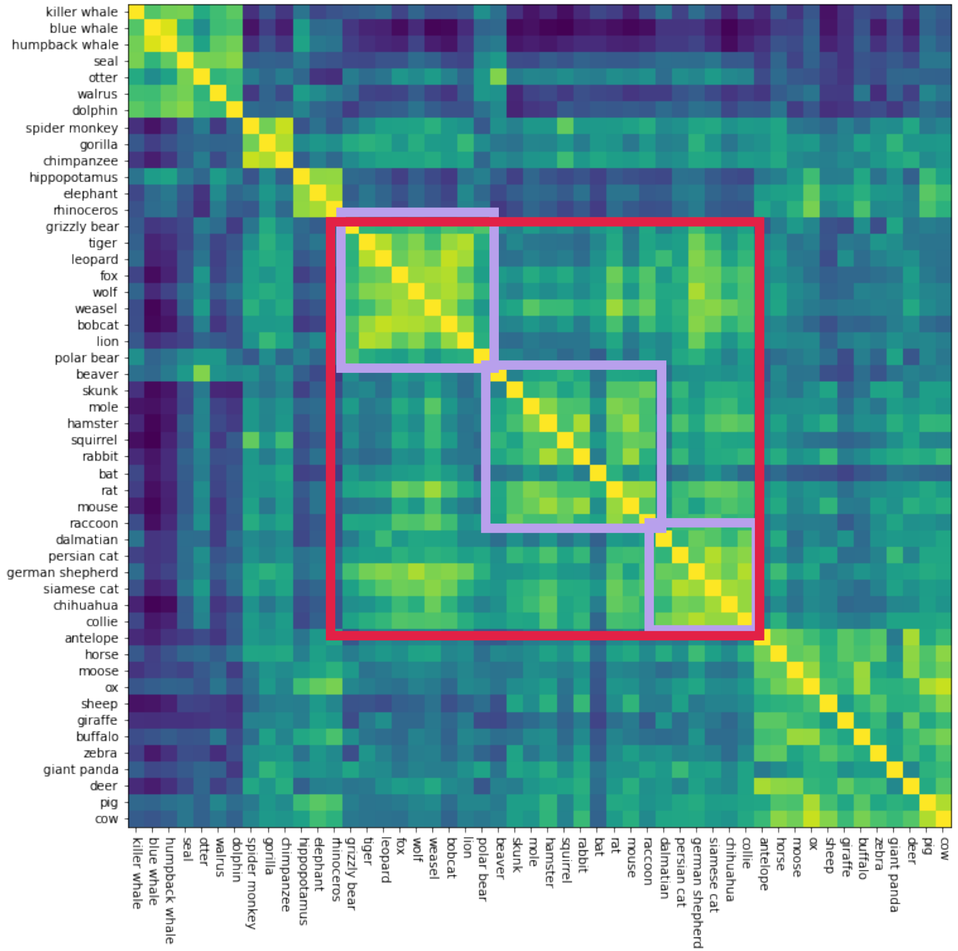
Mammals Dataset

- 50 mammals
  - Examples: Antelope, Blue Whale, Tiger
- 85 features each
  - Human ratings
  - Examples: Red, Solitary, Coastal
- I augmented the data with one-hot class labels. Each animal was represented by a 135-vector

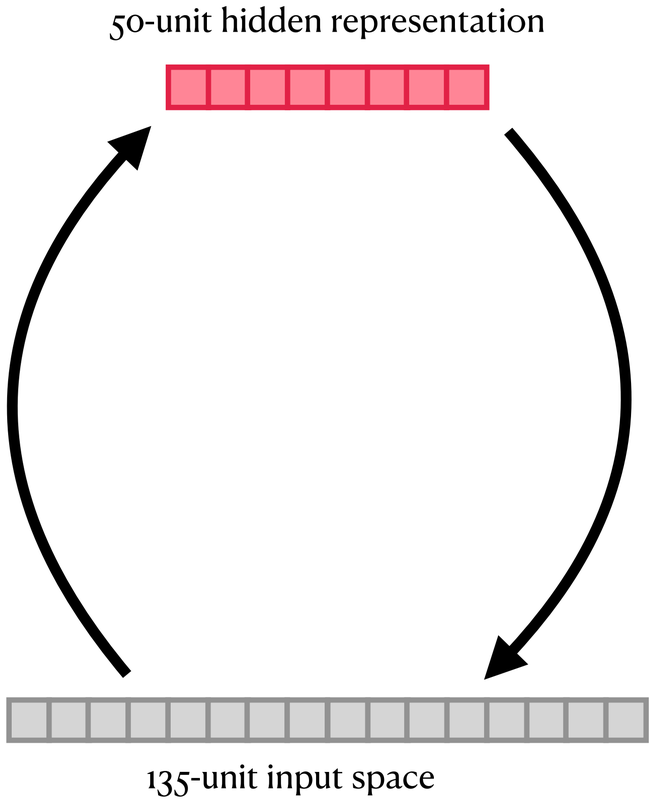
Structure in the data

Clustering by Affinity Propagation



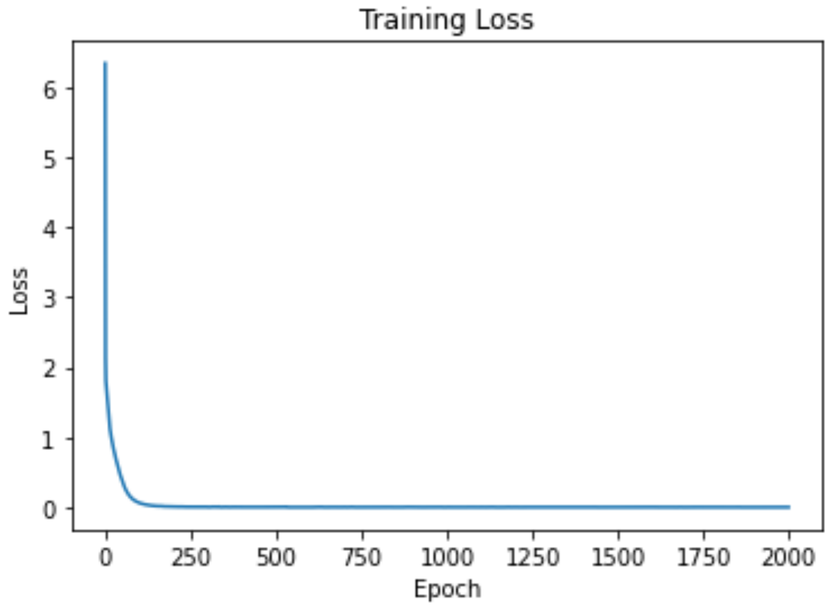


Semantic Memory Autoencoder



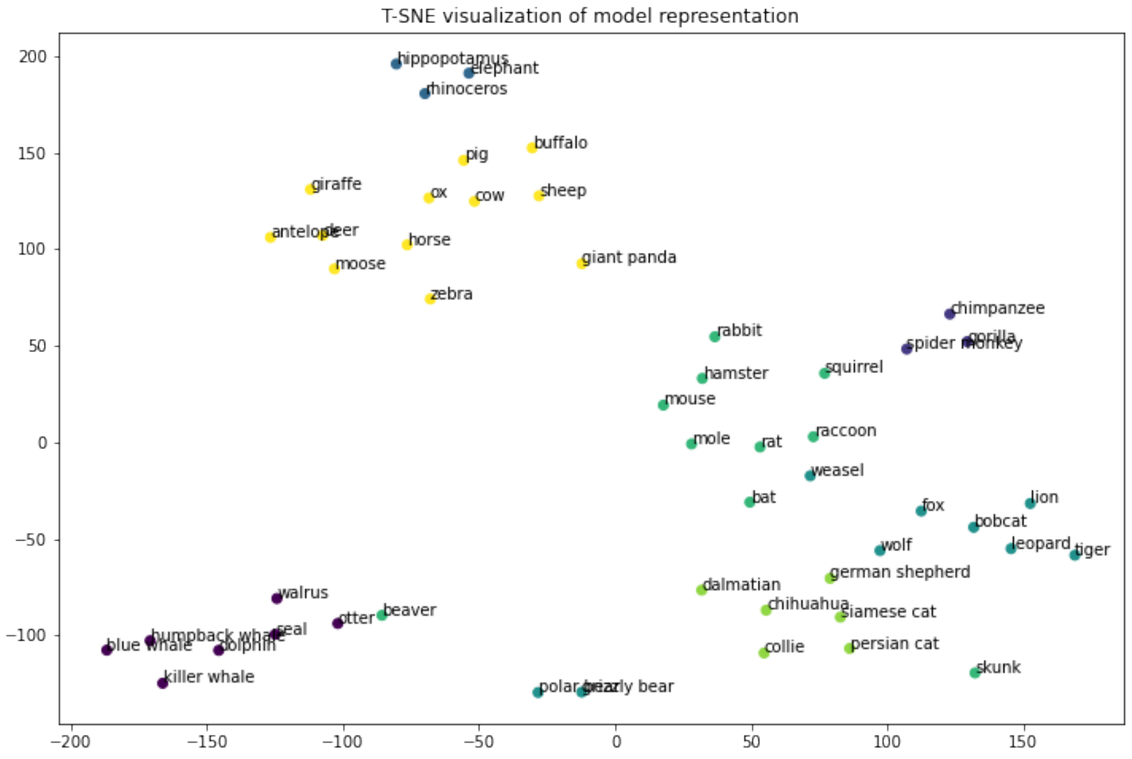
Training

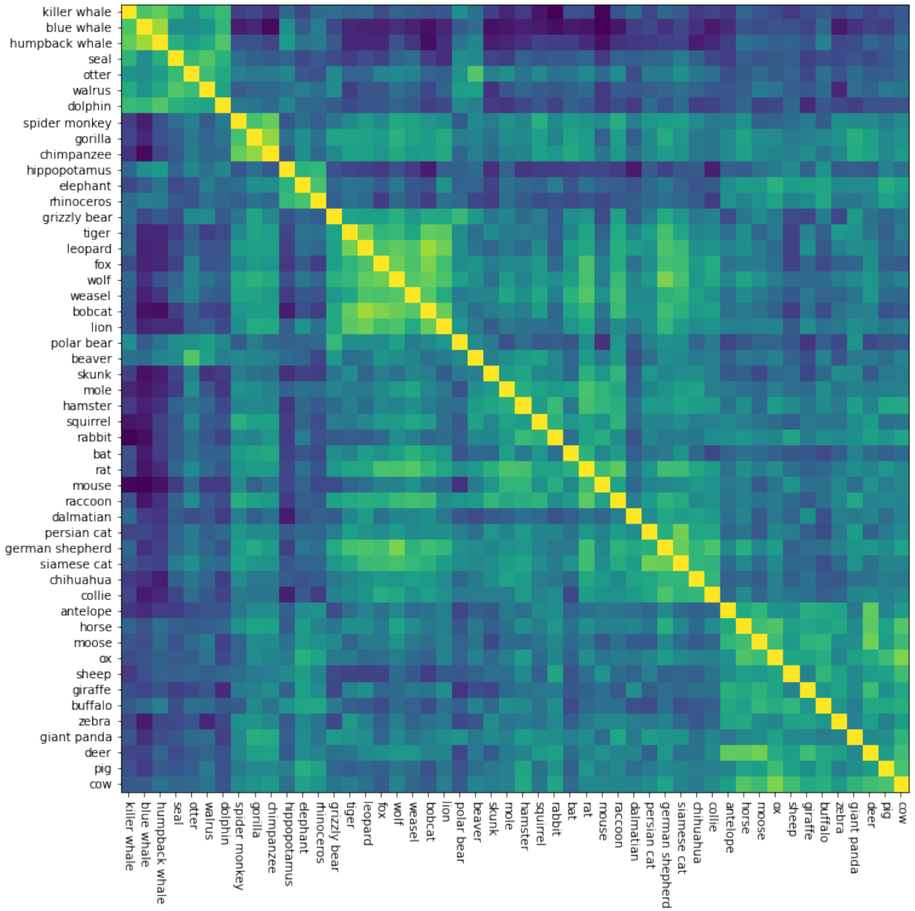
- Mean-Squared Reconstruction Loss
- Adam Optimizer
- 2000 Epochs



Model Reconstruction

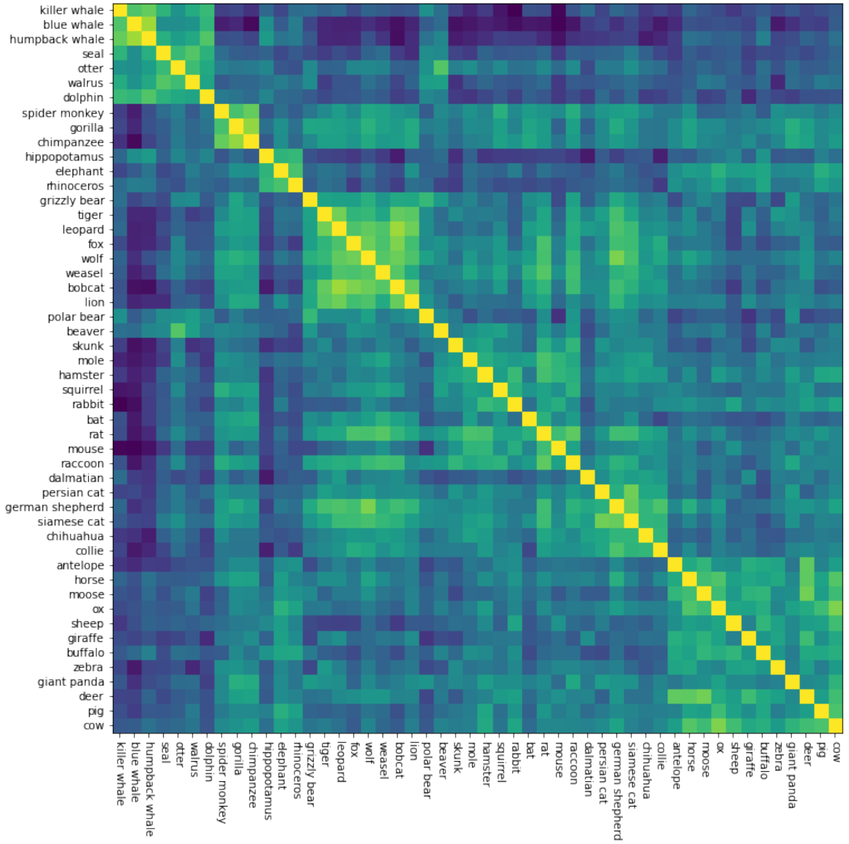
Similarity on hidden unit representations for each of the animals



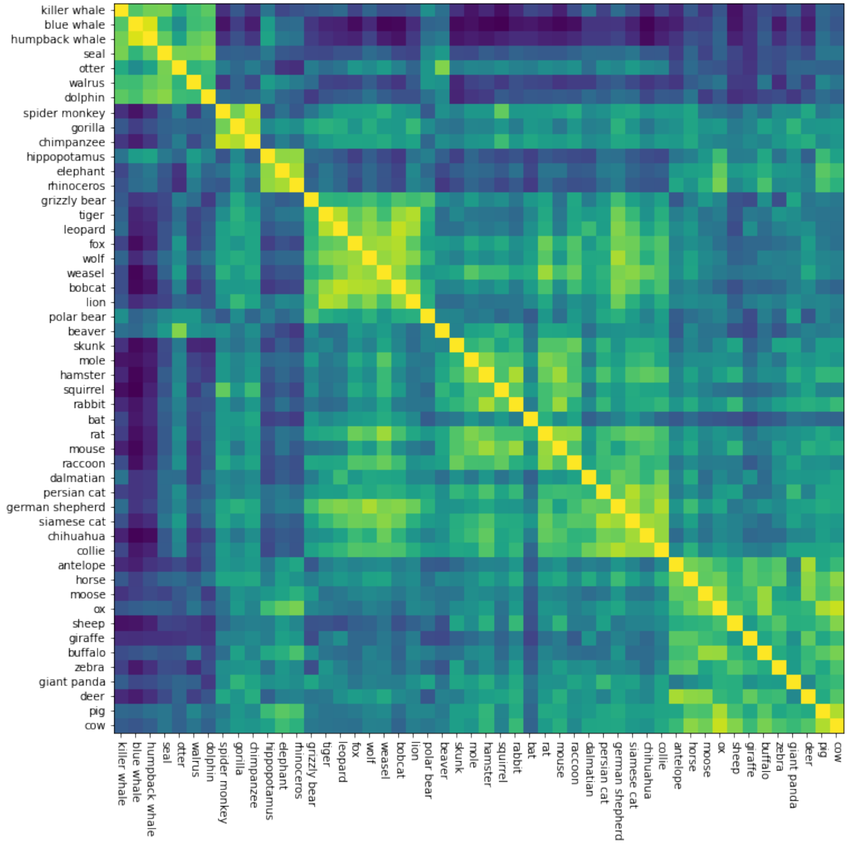


Model vs Data

Model

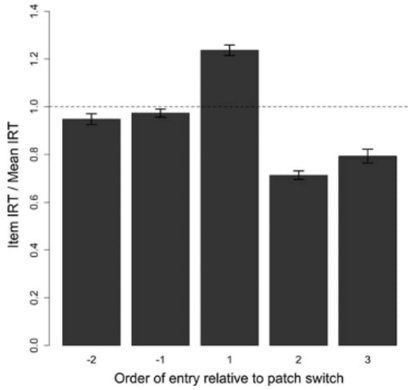


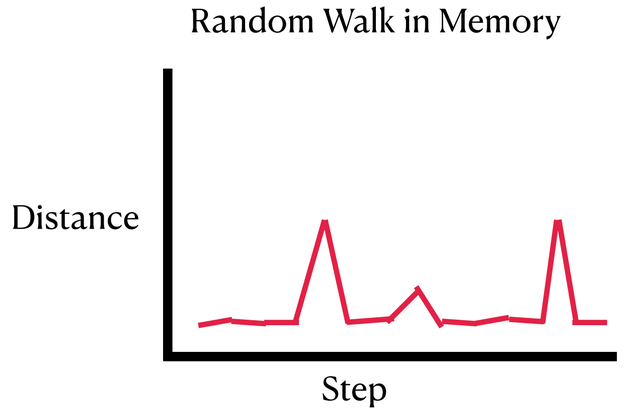
Data



Modeling SFT with a Random Walk

- If memory is structured in this clustered way, then one way to think about the retrieval process in SFT is as a random walk where the probability of transitioning from one item to another is inversely related to the distance between items in memory space.
- This idea builds on work first proposed in Hills, Jones, and Todd (2012), where the authors design a random walk in a memory space defined by a language model.





Define a Memory Random Walk

Distances

$$\begin{bmatrix} 0 & 1 & 2 \\ 1 & 0 & \frac{1}{2} \\ 2 & \frac{1}{2} & 0 \end{bmatrix}$$

Reciprocal Euclidean distance

Similarities

$$\begin{bmatrix} 0 & 1 & \frac{1}{2} \\ 1 & 0 & 2 \\ \frac{1}{2} & 2 & 0 \end{bmatrix}$$

Normalize by row. Peakiness parameter β

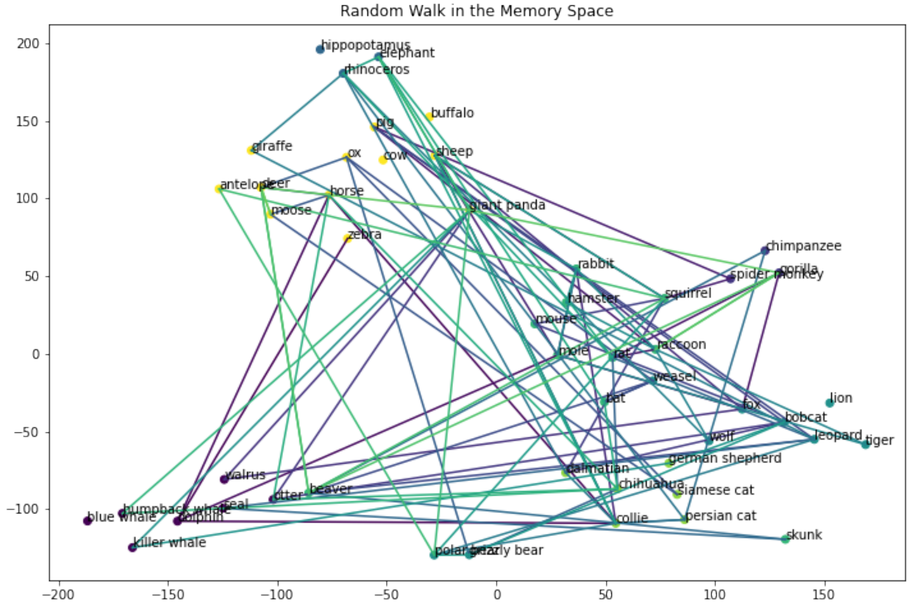
Markov Chain

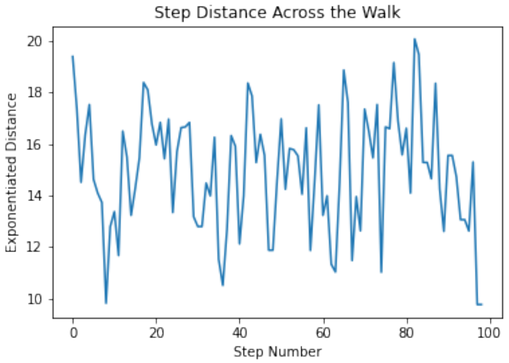
$$\begin{bmatrix} 0 & \frac{2}{3} & \frac{1}{3} \\ \frac{1}{3} & 0 & \frac{2}{3} \\ \frac{1}{3} & \frac{2}{3} & 0 \end{bmatrix}$$

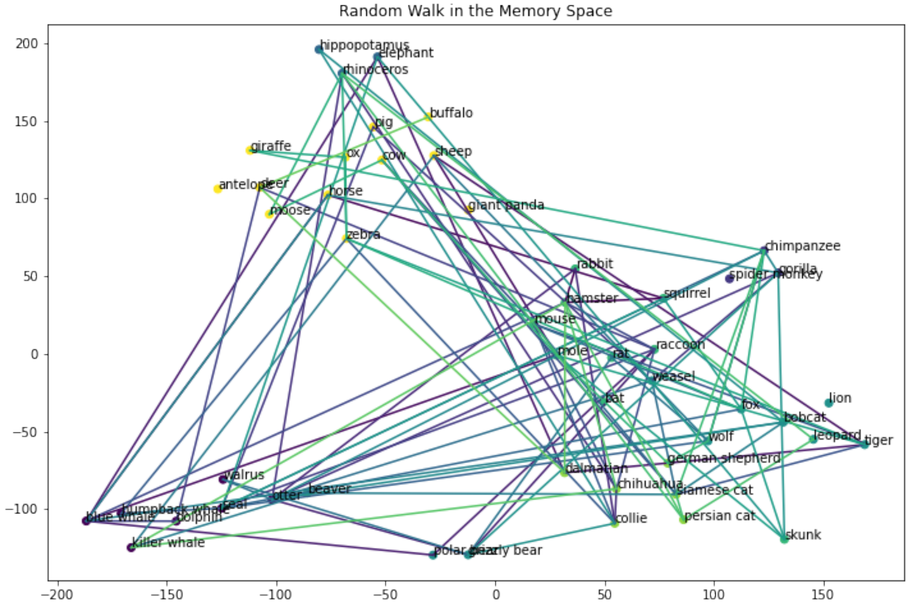
$$P(I_i|Q_1,Q_2,\ldots,Q_M) = \frac{\prod_{j=1}^{M} S(Q_j, I_i)^{\beta_j}}{\sum_{k=1}^{N} \prod_{j=1}^{M} S(Q_j, I_k)^{\beta_j}},$$

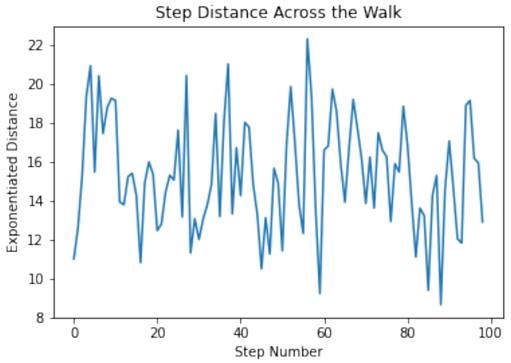
Unparameterized Walk

$\beta = 1$



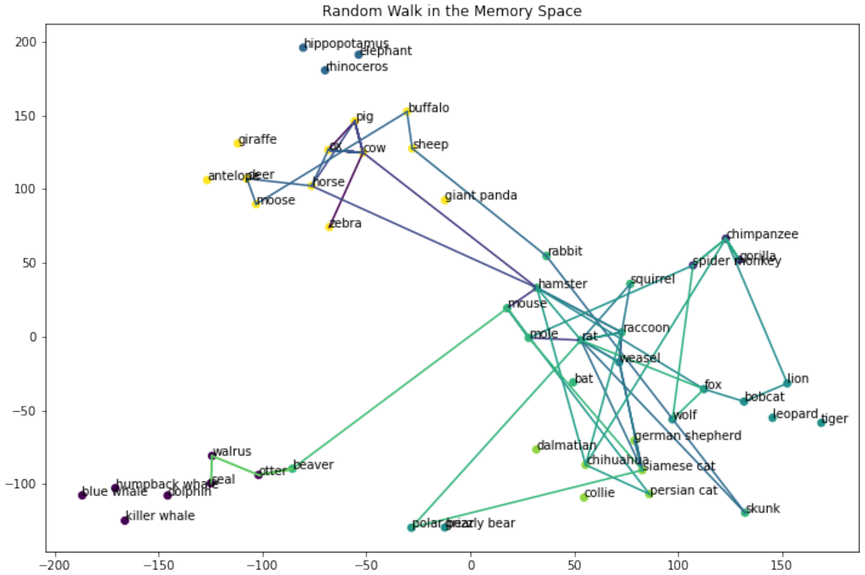


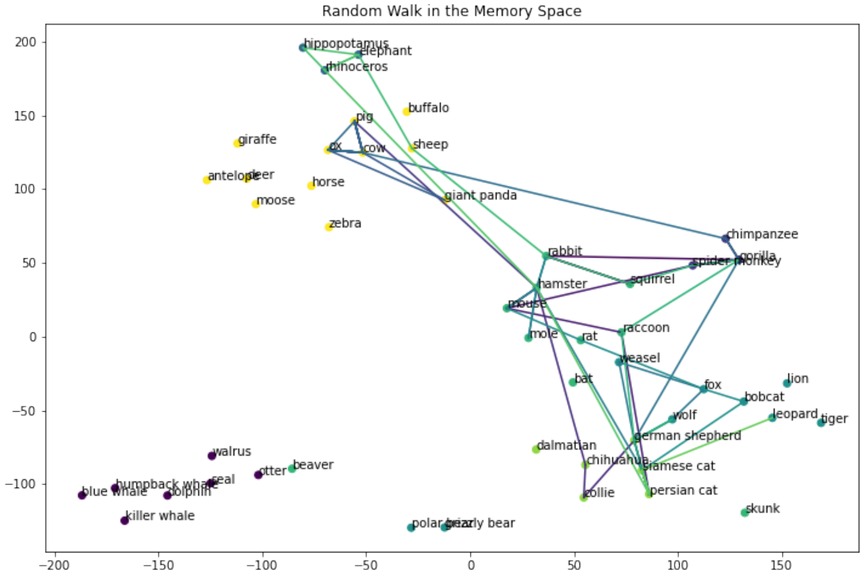


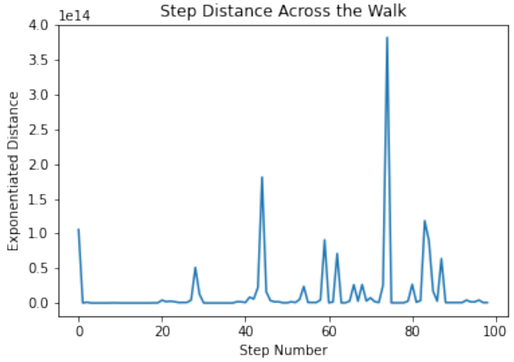


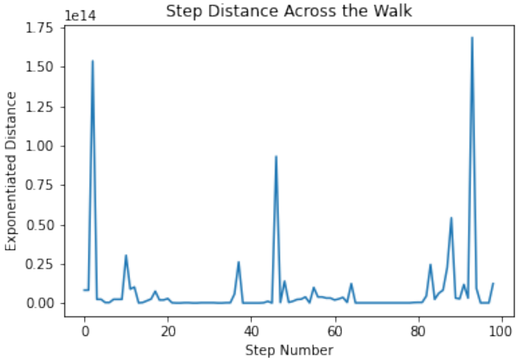
Parameterized Walk

$\beta = 12$









Summary

- A variant of the Semantic Network, the Semantic Autoencoder does a good job of capturing cluster structure in a human-elicited, animal feature dataset. This suggests it could be a good stand in for human memory representations in the Semantic Fluency Task.
- Random walks in the learned memory space offer a way to model the recall process. With tuning they capture response time characteristics exhibited by human participants.
- Going forward, will need to collect data from human participants to test and fine-tune a model that aims to capture the actual patterns of behavior that humans exhibit.

Thanks!
Questions?