MODELING INDIVIDUAL CONCEPTS AS GRAPH THEORETICAL NETWORKS

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BUILDING MODELS

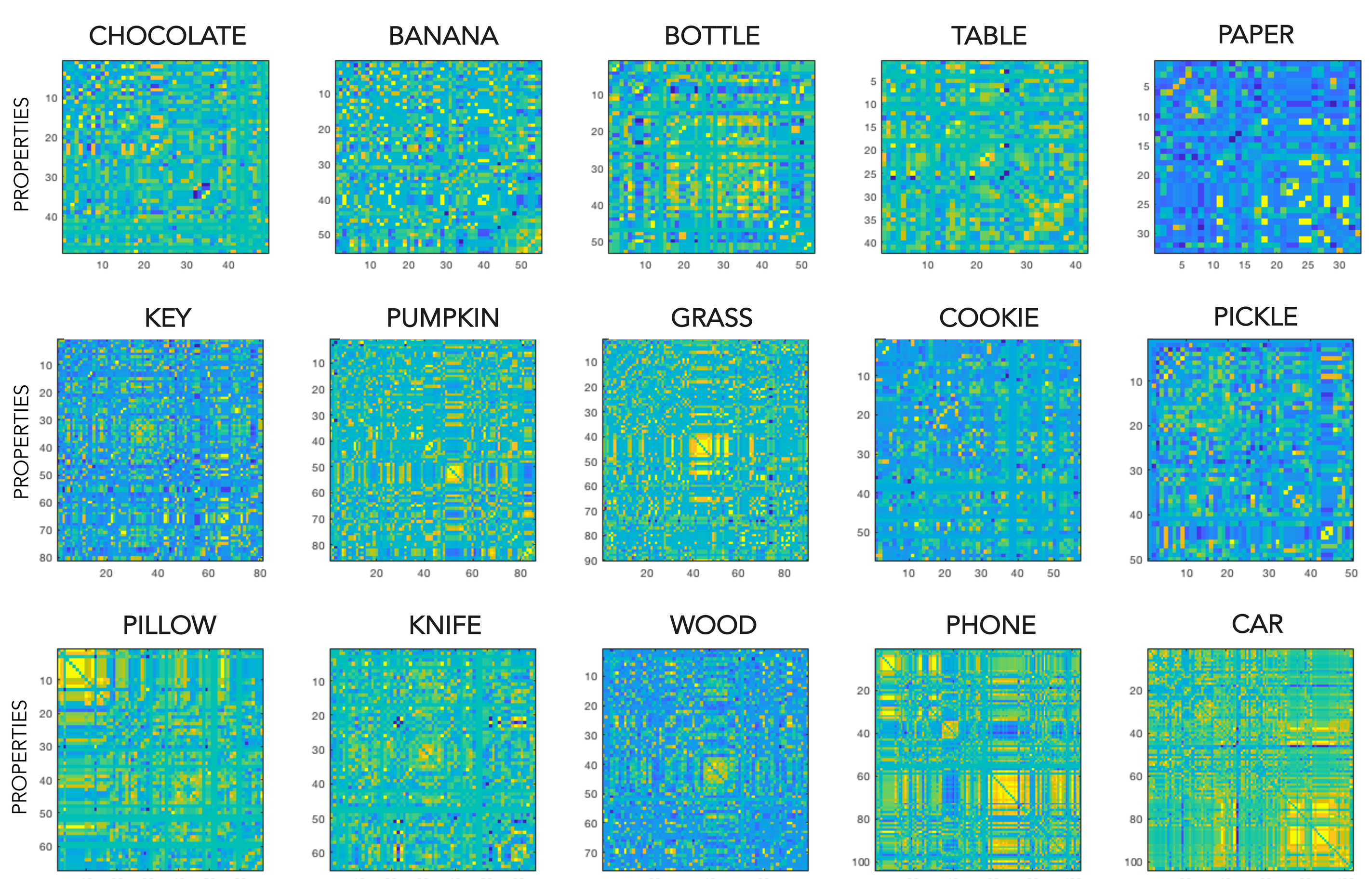
Data Set 1 (5 concepts)
CHOCOLATE, BANANA, BOTTLE, TABLE, PAPER

Data Set 2 (10 concepts)
KEY, PUMPKIN, GRASS, COOKIE, PICKLE, PILLOW, KNIFE, WOOD, PHONE, CAR

For each data set:

1. Construct a **set of properties** with which to define concepts. *(n=66; 60)*
   BLACK, BLUE, SWEET, SOUR, SMOOTH, ROUGH, HAS-BATTERIES
2. For each concept, **define various sub-kinds**. *(n=66; 60)*
   WHITE CHOCOLATE, ROTTEN PUMPKIN, CHEESE KNIFE, SUGAR COOKIE
3. Measure **property strengths for each subkind** for each concept. *(n=198; 108)*
   "Which properties are true of WHITE CHOCOLATE?"
4. Create **network models** for each concept by calculating within-concept property correlations across sub-kinds.
5. Create **standard models** for each concept that contain mean property strengths.

Concept networks contain within-concept property covariation information for properties that are true of at least one of that concept's sub-kinds



CONCLUSIONS

Concept network models are successful at classifying individual exemplars, suggesting that within-concept property covariations may help structure basic-level concepts.

When only a small number of properties are included in the model, the network model outperforms standard models that simply capture property strength.

Network models appear to be beneficial for more flexible concepts, whereas standard models appear to be beneficial for stable concepts.

Using networks to model concepts enables the use of many network science measures to help us model and understand the conceptual system.

REFERENCES & ACKNOWLEDGEMENTS

1. Tyler, Moss, Durrant-Peatfield, & Levy (2000). Brain and Language.
2. Medaglia, Huang, Karuza, Thompson-Schill, Ribeiro, & Bassett (2016). arXiv preprint: 1611.08751
3. Hoffman, Lambon Ralph, Rogers (2012). Behavior Research Methods.

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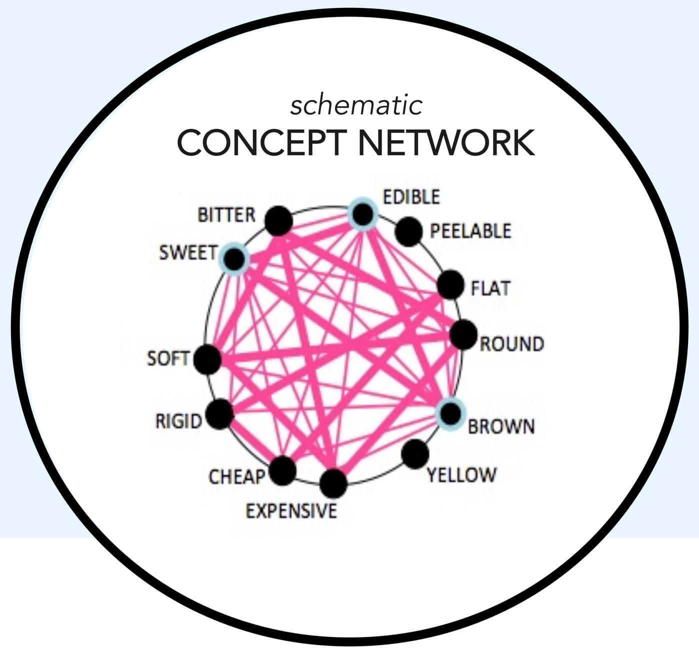
MOTIVATION

Concepts (e.g. CHOCOLATE) can be instantiated in many different forms (e.g., bar, truffle), and our **conceptual system must be flexible** enough to capture this variation.

We use graph-theoretical network models to capture the within-concept statistics that reflect **how properties correlate with each other across instances of a concept**. In these networks, properties are represented as nodes and their associations as edges.

Whereas traditional models[1] define concepts as static structures, we aim to model concepts in a way that can **accommodate the variation of conceptual information** across instances.

We **test these models** in order to see whether the correlations of properties with each other play a role in the structure of basic-level concepts, and **show the validity of this approach** in the study of conceptual knowledge.

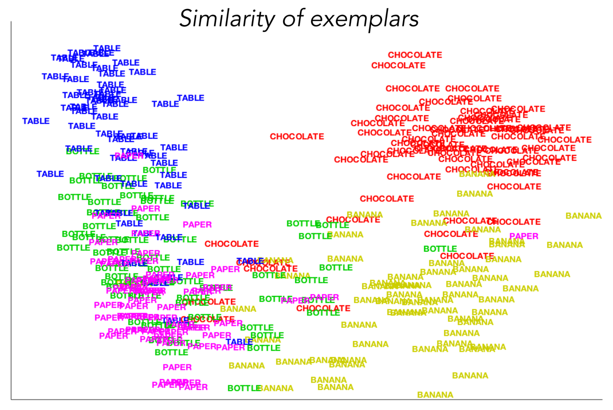


TESTING DATA

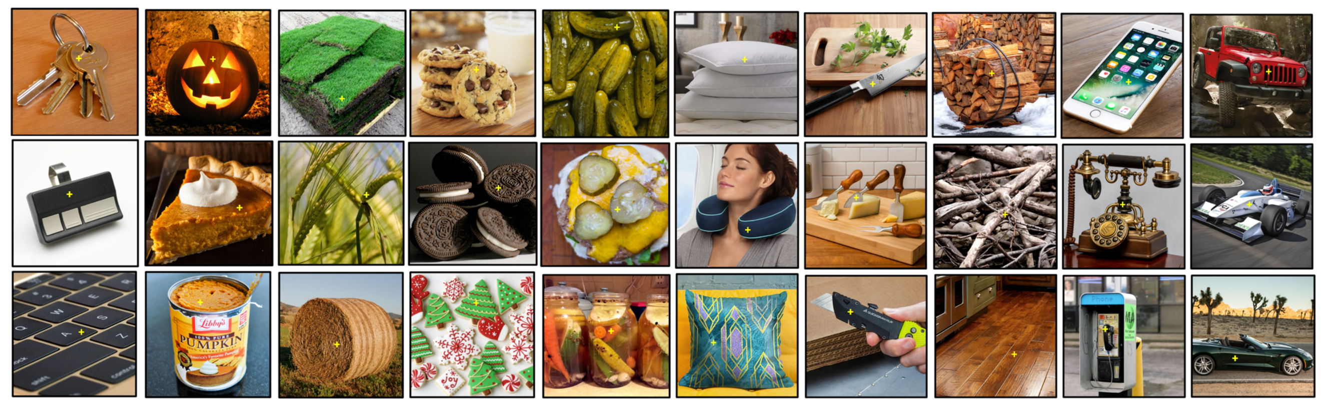
We collected property data for a range of exemplars for each concept, representing each of the concept sub-kinds

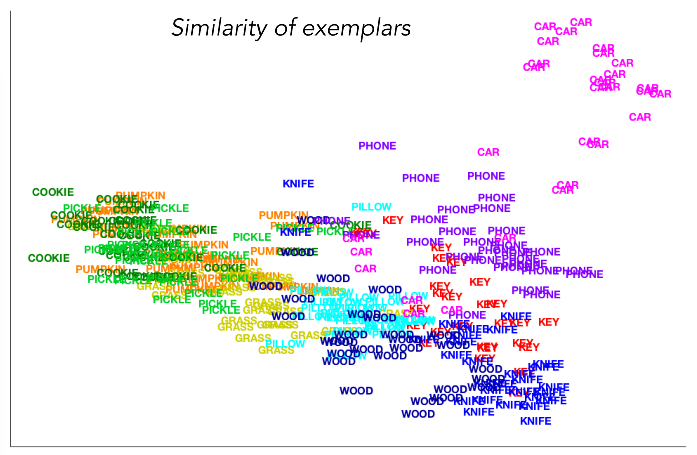
"Which properties are true of the object in the image?"

DATA SET 1 *300 exemplars, 60 per concept*



DATA SET 2 *300 exemplars, 30 per concept*





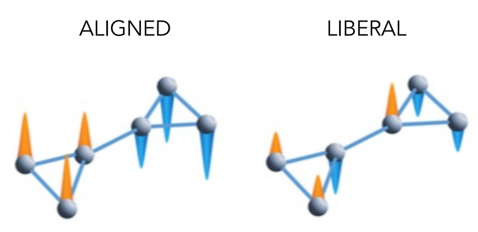
Our goal was to use our network models to classify each of our exemplars as the correct concept

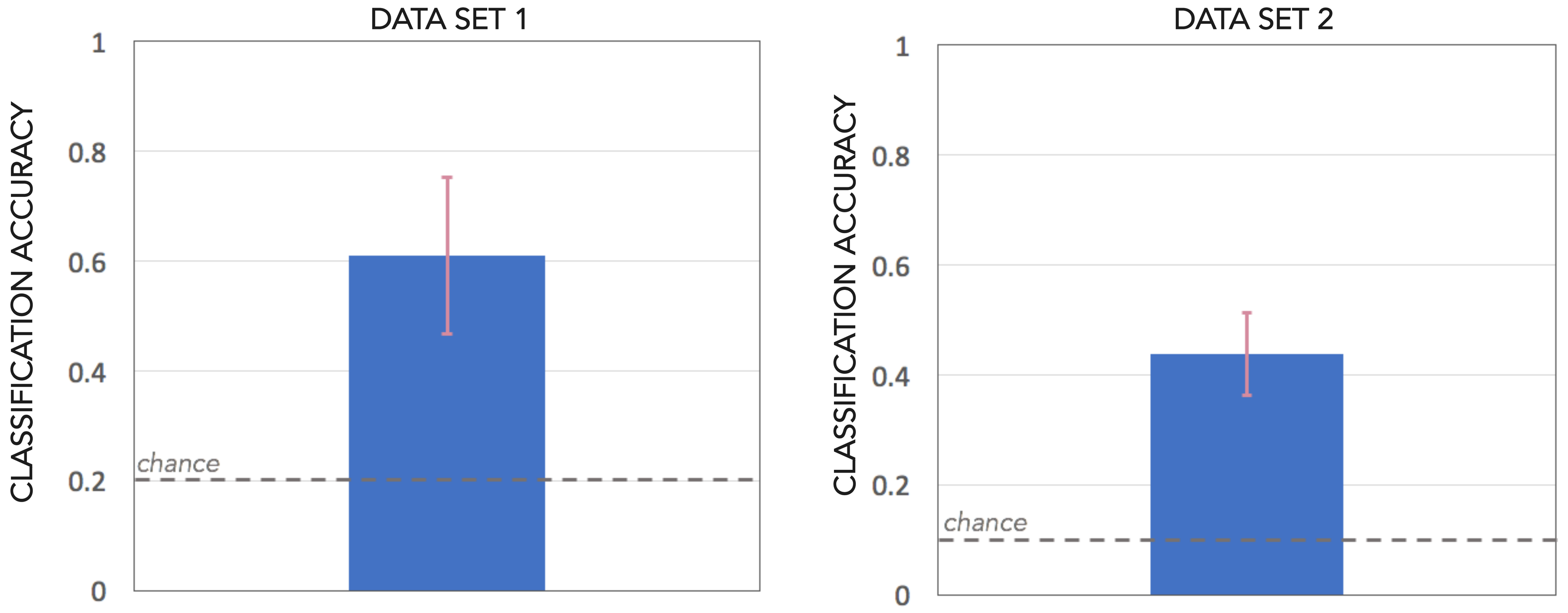
Network models: graph alignment classification
Standard models: correlation classification

CONCEPT CLASSIFICATION

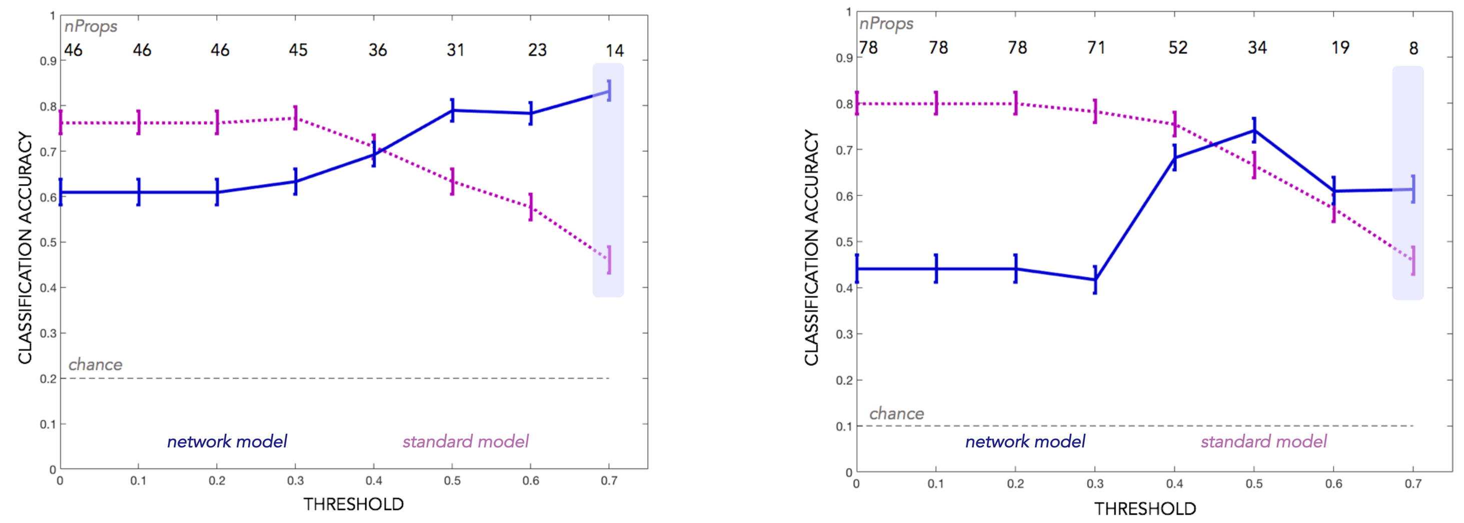
Graph Alignment

The graph alignment technique can be used to assess the degree to which a signal (*vector*) aligns with a network (*graph*). A signal is highly aligned if the magnitude of the nodes corresponds tightly to that expected by the network's organization.[2] In our case, the concept networks define what kind of signals we expect from individual exemplars.





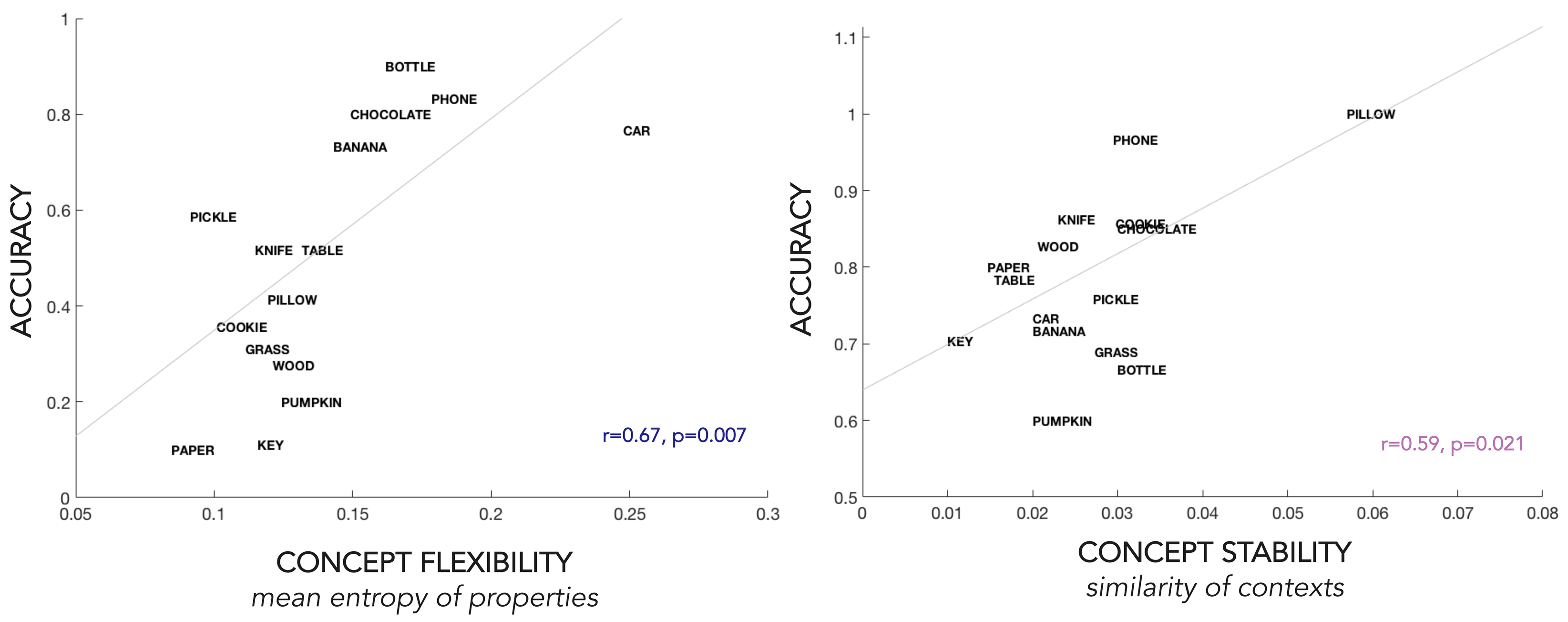
Concept network models, which only contain concept-specific property covariation statistics, are able to successfully discriminate between concepts. *(thresh=0)*



Increasing the threshold shrinks the network to include only the strongest properties. Concept networks that have only a few properties can still successfully discriminate between objects, and outperform standard vector models.

CONCEPTUAL FLEXIBILITY

One goal of the concept network models is to capture conceptual flexibility, unlike standard models which capture stable conceptual information. We use mean property entropy to capture conceptual flexibility, and mean cosine similarity[3] of a concept's various contexts to capture conceptual stability.



Network models perform better on flexible concepts

Standard models perform better on stable concepts