The Grass is not always Greener: Property integration in adjective-noun combinations

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BACKGROUND

① Concepts are rarely used in isolation: research examining the neural processes underlying conceptual combination will help reveal how concepts interact with one another, thus enabling us to reference a theoretically infinite number of objects[1,2,3,4].

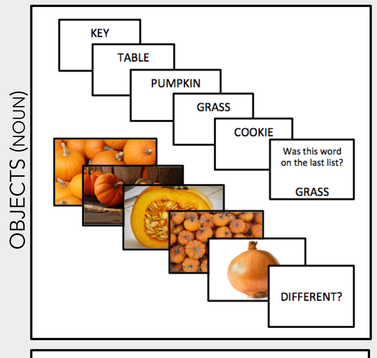
② In adjective-noun combinations (e.g. GREEN PUMPKIN), properties are directly ascribed to objects: here we explore if and how conceptual information is dynamically transformed online as new properties are integrated into concepts during comprehension.

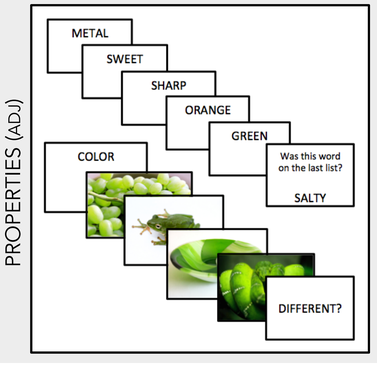
HYPOTHESIS

If a concept (e.g., PUMPKIN) is in part composed of its ensemble of properties (e.g., ORANGE, ROUND), and if a concept's information structure is dynamic, then we should be able to witness the integration of new properties (e.g., GREEN) during comprehension of adjective-noun combinations (e.g., GREEN PUMPKIN), and the amount of integration should be modulated by the strength of the property in the unmodified concept.

DESIGN

Subjects (*N*=10) completed 5 different runs while fMRI data were collected:
$\text{NOUN}_{\text{WORDS}}$, $\text{NOUN}_{\text{PICTURES}}$, $\text{ADJ}_{\text{PICTURES}}$, $\text{ADJ}_{\text{WORDS}}$, and $\text{ADJ-NOUN}_{\text{WORDS}}$



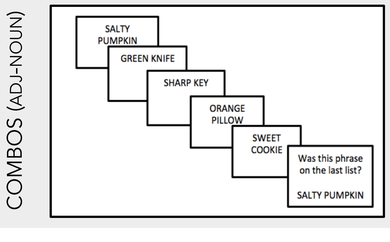


OBJECTS	PROPERTIES
KEY	METAL
TABLE	WOODEN
PUMPKIN	ORANGE
GRASS	GREEN
COOKIE	SWEET
PICKLE	SALTY
PILLOW	SOFT
KNIFE	SHARP

i. Each object was originally paired with a property with which it is strongly associated (TYPICAL PROPERTY)

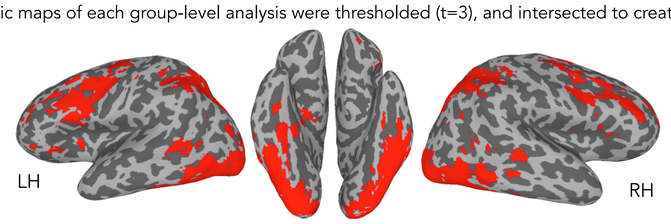
ii. Property Strength: We also collected ratings (*N*=50) on how strongly associated each property was with each object

iii. Each of the 8 nouns were crossed with each of the 8 adjectives, resulting in 64 combinations

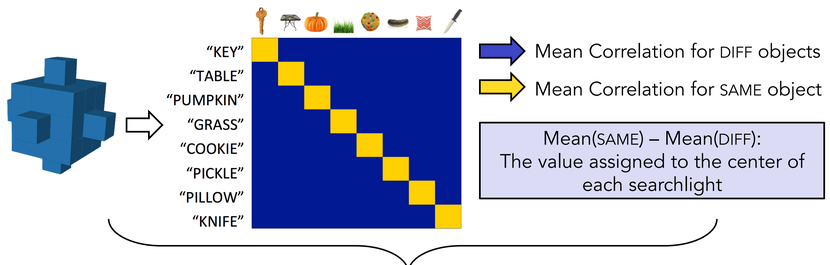


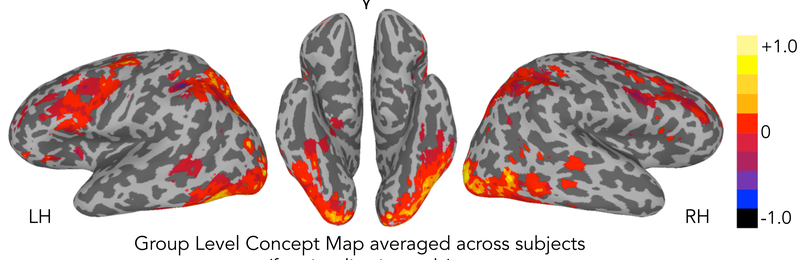
VOXEL SELECTION

① **Main Effect:** $\text{NOUN}_{\text{PICTURES}}$ and $\text{NOUN}_{\text{WORDS}}$ (both versus fixation baseline)
T-statistic maps of each group-level analysis were thresholded (t=3), and intersected to create a mask.



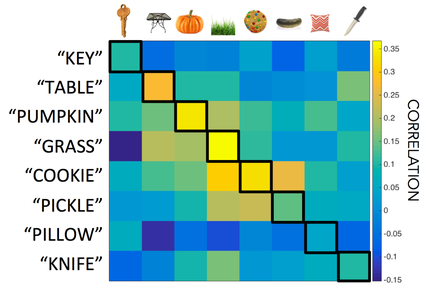
② **Searchlight analysis:** For each subject, find "conceptual voxels" within this mask by locating regions that show similar patterns for the same object across the $\text{NOUN}_{\text{PICTURES}}$ and $\text{NOUN}_{\text{WORDS}}$ runs.





Group Level Concept Map averaged across subjects
(for visualization only)

③ **Extract Conceptual Voxels:** For each subject, we extracted the top 100 concept-voxels, and used these for following analyses.



Validating Conceptual Voxels

Mean Correlation for DIFF objects

Mean Correlation for SAME object

We calculated Mean(SAME) and Mean(DIFF) for each subject, and performed a paired *t*-test across subjects to confirm that patterns in these voxels were more similar for the PICTURE and WORD patterns for the same object versus different objects.
$t(9)=3.76$, $p=0.005$

DYNAMIC PROPERTY INTEGRATION

If a property is integrated into a concept, then the pattern evoked by the ADJ-NOUN pattern should be more similar to the ADJ pattern than is the unmodified NOUN pattern.

$$\text{PROPERTY INTEGRATION} = \text{sim}(\text{ADJ-NOUN}_{\text{WORDS}}\ ,\ \text{ADJ}_{\text{PICTURES}}) - \text{sim}(\text{NOUN}_{\text{WORDS}}\ ,\ \text{ADJ}_{\text{PICTURES}})$$

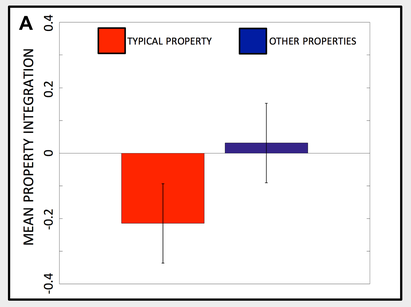
FOR EXAMPLE: $\text{sim}\{\text{"GREEN PUMPKIN"}, \text{<image>}\} - \text{sim}\{\text{"PUMPKIN"}, \text{<image>}\}$

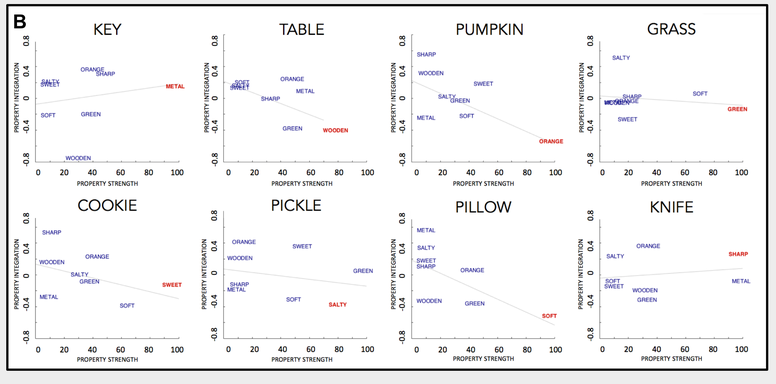
Prediction: If a concept's informational structure transformation reflects the integration of a new property, then there should be less property integration for strongly-associated properties because they were already present in the unmodified concept.

For each subject, the property integration measure was calculated for each of the 64 combinations; these values were z-scored within subjects, and then averaged across subjects. Item analyses were then run across the 8 objects.

A. Across the 8 object concepts, there was less property integration for the typical (M=-0.22) vs. other (M=0.03) property ($t(7)=2.02$, $p=0.08$)

B. Across the 8 object concepts, property strength was negatively correlated with property integration ($t(7)=2.4$,$p=0.04$)





CONCLUSION

During comprehension of adjective-noun combinations, the information contained in concept-sensitive voxels is transformed such that properties that were not included in the original concept are integrated into the neural representation.

REFERENCES

1. Sedivy (2003). *J. of Psycholinguistic Research*. 2. Westerlund & Pylkkanen (2014). *Neuropsychologia*. 3. Westerlund et al. (2015). *Brain & Language*. 4. Price et al. (2015). *Journal of Neuroscience*.

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