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Word Specificity: A Measure to Investigate Semantic Abstraction and Linguistic Creativity

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Abstraction, a hallmark of human cognition, is the ability to *pull off* meaning *from* the experience





WHAT IS ABSTRACTION?

Lower levels of abstraction (i.e., higher levels of concreteness) capture thoughts that are **more specific, detailed, vivid, and imageable** [...]. Higher levels of abstraction (i.e., lower levels of concreteness), on the other hand, include fewer readily observable characteristics and therefore capture thoughts that are less imageable_[1] [Starting from the concrete notion of bridge], humans can easily understand extended and metaphorical notions such as "water bridges," "ant bridges," "the bridge of a song," "bridging the gender gap," "a bridge loan," "burning one's bridges," "water under the bridge," and so on. [...] One makes an abstraction of a concept when one extends that concept to more general instances, ones that are more removed from specific entities, as in the examples of "bridge"_[2]

[1] Burgoon, Henderson, Markman(2013). There are many ways to see the forest for the trees: A tour guide for abstraction. Perspectives on Psych Science, 8, 501–520.

[2] Mitchell, M. (2021). Abstraction and Analogy-Making in Artificial Intelligence.

DISENTANGLING TWO VARIABLES

(Abstractness) Concreteness

- the degree of perceptibility of a word referent
- a quality of concept (word) that has often exemplified by multiple interactive elements with low percetual similairy.

Specificity

- the degree of precision of a word meaning in terms of category inclusiveness
- taxonomic hierarchical organization







ABSTRACTION



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VARIABLES OF ABSTRACTION



LOW SPECIFICITY

[3] Bolognesi, Burgers, & Caselli(2020). On abstraction: decoupling conceptual concreteness and categorical specificity. Cognitive Processing, 21(3), 365-381.



ABSTRACTION IN LANGUAGE

Language is a lens through which we investigate conceptual representation.

Investigate how humans deal with abstraction from a data-driven perspective

- Corpus analyses and Distributional Semantic Models
- Linguistic capabilities of Large Language Models (LLMs)





3 QUESTIONS ON WORD SPECIFICITY

- 1. How does Specificity affect conceptual representation (through the lens of linguistic distributions)?
- 2. How does Specificity affect language comprehension in LLMs?
- 3. What role does word Specificity play in mechanisms of linguistic productivity and creativity?



THE ROLE OF CONTEXT IN ABSTRACTION

Context Availability Hypothesis_[4]

there are differences in the availability and strength of contextual associations between concrete and abstract words.



Abstract words appear in various contexts, while concrete words are found in fewer contexts.

What about words varying in Specificity?

[4] Schwanenflugel et al. (1988). Context availability and lexical decisions for abstract and concrete words. Journal of Memory and Language, 27(5), 499-520.



THE ROLE OF CONTEXT IN ABSTRACTION

What are the data-driven patterns highlighting differences between words with different degrees of abstraction?

Is this difference explainable only for abstract vs concrete words, or it is related to the different degree of Specificity?

Contextual Variability Depends on Categorical Specificity rather than Conceptual Concreteness: A Distributional Investigation on Italian data

Giulia Rambelli

Marianna M. Bolognesi

The Contextual Variability of English Nouns: The Impact of Categorical Specificity beyond Conceptual Concreteness

Giulia Rambelli, Marianna M. Bolognesi







EXPERIMENTS OVERVIEW

Material

- 676 English and 662 Italian nouns from ANEW
- Contexts extracted from ukWaC and ItWaC, used to create DSM

Contextual Variability Measures

- TNk / TCk: cosine similarity between a word and its k neighbors/contexts
- NNk / CCk: cosine similarity of the k neighbors/contexts
- Entropy

Regression Analyses

- investigate how CV measures are explained in terms of
 - 1. Concreteness 2. Specificity

3. Their interaction



R1: CONCRETENESS EFFECTS

	EN	IT
TN5	4.74%	2.10%
NN5	9.88%	2.40%
TC5	15.80%	4.70%
CC5	3%	4%
ENTROPY	0.13%	2.10%

- Higher R^2 : TC and NN
- High correlation between Concreteness and TC10 (.44) and NN5 (.42)



R2: SPECIFICITY EFFECTS

	EN	IT
TN5	4.74%	2.10%
NN5	9.88%	2.40%
TC5	15.80%	4.70%
CC5	3%	4%
ENTROPY	0.13%	2.10%

	EN	IT	
TN5	2.83%	13%	
NN5	6.90%	11.80%	
TC5	11.18%	26.50%	
CC5	2.53%	0%	
ENTROPY	14.96%	34.30%	

- Higher R^2 : TC and NN
- High correlation between Concreteness and TC10 (.44) and NN5 (.42)

- Higher R^2 : Entropy and TC
- Negative correlation between Entropy and Specificity



R2: SPECIFICITY EFFECTS

	PASTA	FOOD
Concreteness	4.86	4.8
Specificity	4.23	1.52
TC10	.65	.49
Top contexts	dish (.66), sauce(.81), bread (.59), rice (.59) , food (.49), salad (.78)	eat (.64), find (.29), drink (.61), chain (.35), animal (.51), fast (.22)

- Generic words occur in various contexts not closely tied to the target word
- Specific words exhibit a stronger association with similar contexts
 - The same for abstract words (thus less evident in English)



R3: INTERACTION EFFECTS

	EN	IT
TN5	4.54%	13.10%
NN5	10.09%	11.80%
TC5	16.81%	27.70%
CC5	3.76%	6.70%
DCR	1.49%	4.60%
ENTROPY	26.80%	36.60%

TC10: avg. sim btw a target and its10 most associated contexts





- 1. IT: Abstract specific words are more related to their contexts
- 2. EN: Concrete specific words are more related

ENTROPY



Same trend for EN and IT

- 1. generic words have high entropy (top)
- 2. specific words have low entropy (bottom)



TAKEHOME MESSAGE

- Specific words have well-defined, similar contexts.
- Generic words, whether abstract or concrete, have broader and more diverse contexts.
- Concreteness is more significant in explaining noun contextual variability in English than in Italian.
- The **interaction** between Concreteness and Specificity accounts for a significant portion of the variation in the regression analyses.
- Entropy is cross-linguistically reliable, while measures computed using similar neighbors or syntagmatic contexts are correlated but more language-dependent.



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SPECIFICITY AS CONCEPTUAL COMBINATION

Two lexical concepts are often used together as phrases to represent a combined concept of **greater specificity**_[5].





[5] Dunbar & Myers (1988). Concept combination and the characterization of lexical concepts. In Hüllen, Werner; Schulze, Rainer (eds.). Understanding the lexicon: meaning, sense and world knowledge in lexical semantics, 292–302.



CASE STUDY: COMPOUND INTERPRETATION

"Noun-noun compounds have three semantic components:

a **head** that determines the category,

a **modifier** that determines how the subcategory is different from other subcategories,

and a relation between modifier and head." [5]

[6] Krott, A. (2009). The Role of Analogy for Compound Words. In Blevins, J. P., Blevins, J. (Eds.), Analogy in Grammar: Form and Acquisition, 118-136.



THE MYSTERY OF COMPOUNDS

- chocolate cake = 'a cake made with chocolate in it'
- *birthday cake* = 'a cake to be eaten as part of celebrating a birthday'
- *coffee cake* = 'a cake to be eaten along with coffee and the like'
- *marble cake* = 'a cake that resembles marble'
- *layer cake* = 'a cake formed in multiple layers'
- cupcake = 'a little cake made in a cup'
- ?urinal cake = 'a (nonedible) cake to be placed in a urinal'

[7] Jackendoff R. (2016). English noun-noun compounds in Conceptual Semantics. In: ten Hacken P, ed. The Semantics of Compounding, 15-37.



UNDERSTAND CONCEPTUAL COMBINATIONS

Do LLMs Grasp Semantic Relations in Lexicalized Noun Compounds?

Can Large Language Models Interpret Noun-Noun Compounds? A Linguistically-Motivated Study on Lexicalized and Novel Compounds

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EXPERIMENTS OVERVIEW

	compound	coarse-grained (Tratz, 2011)	fine-grained (Tratz, 2011)	Hatcher-Bourque (Pepper, 2022)	paraphrase (Pepper, 2021)
Data 668 compositional and lexicaliz compounds	plastic bag	containment	SUBSTANCE -MATERIAL- INGREDIENT	COMP(OSITION)-R	a bag that is composed of plastic
• 9 semantic relations	trash bag supermarket shelf	containment loc_part_whole	CONTAIN LOCATION	CONT(AINMENT)-R LOCATION	a bag that contains trash a shelf that is located in a supermarket
 concreteness ratings₁₇₁ 	car door	loc_part_whole	PART_OR MEMBER_OF	PARTONOMY	a door that is part of a car
 paraphrases to avoid parroting strategies 	food company	purpose	CREATE- PROVIDE- GENERATE- SELL	PRODUCTION	a company that produces food
	bank loan	causal	CREATOR- PROVIDER- CAUSE OF	PROD(UCTION)-R	a loan that a bank produces
	research group	purpose	PERFORM& ENGAGE_IN	PURPOSE	a group intended for research
	art class wind turbine	topical topical	TOPIC MEAN	TOPIC-R US(A)G(E)-R	a class that is about art a turbine that uses wind

[7] Tratz, S. (2011). Semantically-enriched Parsing for Natural Language Understanding. Ph.D. thesis

[8] Muraki, et al. (2023). Concreteness Ratings for 62,000 English Multiword Expressions. Behavior Research Methods, 55(5),2522–2531.

[9] Pepper, S (2022). Hatcher-Bourque: Towards a Reusable Classification of Semantic Relations. In Binominal Lexemes in Cross-Linguistic Perspective, 303–354.



EXPERIMENTS OVERVIEW





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Surprisal of sentences

🚫 LLaMA 🖟

S_{good} = "olive oil is an oil made of olives" S_{bad} = "olive oil is an oil intended for olives"

 $S(S_{good}) < S(S_{bad})$

Metalinguistic prompting

Which is the most likely description of "olive oil"?

- an oil that uses olives;
- 2. an oil that is part of olives;

9. an oil that is composed of olives



SURPRISAL

OVERALL RESULTS

model	ACCURACY		
BERT-large	0.262		
GPT2-xl	0.338		
Llama-2	0.401		
Falcon	0.433		
Mistral	0.403		
Llama-2-7B-chat-hf	0.448		
Falcon-7B-Instruct	0.38		
Mistral-7B-Instruct	0.428		

model	1-shot	3-shot	
Llama-2-7B-chat-hf	.41	.18	
Mistral-7B-Instruct	.59	.56	
Falcon-7B-Instruct	.15	.14	

PROMPTING



SURPRISAL RESULTS





TAKEHOME MESSAGE

- Some relations (e.g., PRODUCTION) are overall easier to recognize
- Compounds highly concrete are more accurately interpreted



What linguistic properties make compounds more or less difficult for humans and LLMs to interpret?



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(LINGUISTIC) CREATIVITY

"Let me describe activities which characteristically produce examples drawn from a fixed and known (even if infinitely large) range as '**F-creative**', and activities which characteristically produce examples that enlarge our understanding of the range of possible products of the activity as '**Ecreative**'."_[10]

- F-Creativity= Productivity is "the original use of established possibilities of the language" [10]
 - apple cake -> avocado cake
- E-Creativity is the ability to invent, manipulate, and combine linguistic elements in new and unexpected ways

[10] Sampson, G. (2016). Two ideas of creativity. In Evidence, Experiment and Argument in Linguistics and Philosophy of Language, 15-26
 [11] Leech, G.N. (2014). A linguistic guide to English poetry. Routledge.



INTERPRETATION OF NOVEL CONCEPTS

AVOCADO CHAIR

A chair *shaped like* an avocado

A chair for avocados





ABSTRACTION CASE STUDY: NOVEL COMPOUND INTERPRETATION

- Interpreting a novel compound (*birthday dessert*) involves both the conceptual and lexical systems; one must:
 - access the concepts denoted by the words
 - select a relation (e.g., a dessert intended for a birthday) to form a unified conceptual representation_[12]
- Analogy with existing instances can help interpretation of novel categories [13]

[12] Gagné & Spalding (2006). Using Conceptual Combination Research to Better Understand Novel Compound Words. In
 SKASE Journal of Theoretical Linguistics, 3(2),9-16.
 [13] Rambelli et al. (2022). Compositionality as an Analogical Process: Introducing ANNE. In Proceedings of CogALex 2022.

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CONCEPTUAL COMBINATIONS IN LLMs

Are LLMs able to generalize semantic relations over novel compounds?

Can Large Language Models Interpret Noun-Noun Compounds? A Linguistically-Motivated Study on Lexicalized and Novel Compounds

> Giulia Rambelli University of Bologna Claudia Collacciani University of Bologna

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EXPERIMENTS OVERVIEW

Same task as for lexicalized compound

- Surprisal + Prompting
- 64 novel compounds
 - Head/modifier substituted with a hypernym from WordNet_[14]



EQUIPMENT BOX

GLOVE BOX

GLOVE COMPARTMENT



NNC RESULTS



- Less errors when the novel word is the modifier
- More errors when the novel word is the head

glove container

Ζ
F
P
\leq
R N

J

SURPRISAL

	same	Head	sameMod	
model	1	3	1	3
	shot	shot	shot	shot
Llama-2-7B-chat-hf	.156	.172	.141	.219
Mistral-7B-Instruct	.578	.531	.469	.30
Falcon-7B-Instruct	.047	.063	.079	.047

"a container intended for gloves"

× "a container that contains gloves"





TAKEHOME MESSAGE

- Suboptimal solutions is to choose the PURPOSE relation, which has a more general paraphrase (*indended for*)
- Changing the modifier is less problematic than changing the head
- Instead of taking novel compounds, we manipulated lexicalized ones by varying the specificity of components.

EXPLORE CREATIVE LANGUAGE

BSTRACTION

- Still, even the most creative metaphor has to use established means (analogy) and comply with most of the rules governing language use and linguistic interaction. Thus, metaphors are actually also examples of F-creativity in the widest sense; they do not expand the rules of language as such.^[12]
- While everyday language creativity is now an established area of ongoing linguistic research, there is a continuing lack of clear agreement about the precise definition and scope of creativity itself. [13]

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 to identify processes and mechanisms within our repertoire of computational algorithms and representations_[14]

[15] Bergs & Kompa (2020). Creativity within and outside the linguistic system. Cognitive Semiotics, 13(1).
[16] Maybin, J (2015). Everyday language creativity. The Routledge handbook of language and creativity, 25-39.
[17] Veale, T. (2006). Understanding Creativity: A Computational Perspective. New Generation Computing, 24, 203-207.



CONCLUSIONS

- Specificity is an important linguistic variable that could affect language processing.
- Stimuli for psycholinguistic and computational tasks should be balanced considering this variable
 - But there are no ratings for Specificity!



Word Ladders is a free, educational mobile application for Android and iOS.







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