DFT and grounded cognition

Gregor Schöner Institute for Neural Computation (INI) Ruhr-University Bochum Conceptual structure, grounding

Grounding language

Roadmap

- Representing conceptual structure
- Grounding relational concepts
- Mental mapping
- Grounding nested phrases

human communication, in its simplest form, is about objects or events that are perceivable or reachable by action in a shared environment



- a phrase is perceptually grounded when the listener directs attention to the same object that the speaker is talking to
- joint attention: speaker and listener attends to the same object



- Grounding often engages forms of communication beyond language
- e.g., pointing (deictic code)
- 🗖 e.g. context



the term "perceptual grounding" is not universally used in this sense, other terms include

"targeting" (Talmy)

"referring"

"grounding" is sometimes used to refer to how words come about in the evolution of a language



- human communication about objects or events in a shared environment
- generalizes to shared experiences, knowledge, intentions, etc



Spatial language

- the simplest form of phrases entail relations or actions
- "the cup to the right of the green book" directs perceptual grounding through spatial language
- "he reaches for the cup" directs perceptual grounding through action language



Spatial language

such phrases entail grammatical roles

in which a target object is related to a reference object





Spatial language

the speaker presupposes that the reference object can perceptually grounded by the listener (Grice)







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Representing conceptual structure

nodes stand for concepts by virtue of their (bidirectional) connectivity to features spaces

property concepts, object concepts etc



[Tekülve, Schöner Cog Sci 2024 (in press)]



object categories represented by nodes may receive input from complex FF networks including DNN



[Grieben, Schöner CogSci 2022]

Representing relations

relational and action concepts are similarly perceptually grounded through reciprocal connectivity to relevant spaces



[Sabinasz, Schöner Cog Neurodyn 2023]

Representing the arguments of relational/action concepts

Representing the arguments of relational/action concepts

- in relations, object
 concepts play
 (grammatical) roles
- here: reference, target
- similar: agent, tool, ...

"green to the right of red" reference target



[Sabinasz, Richter, Schöner: Cog Neurodyn 2023]

Role-filler binding

need different object concepts nodes for the different roles

joint representation of object and role

[Sabinasz, Richter, Schöner: Cog Neurodyn 2023]



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- bring objects into foreground
- make coordinate transformation
- apply comparison operators



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"where is the green object relative to the red object?"



"which object is above the blue object?"



"where is the green object?"



Spatial comparison in DFT

accounts for human data



DFT architecture for grounding and description





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A Neural Dynamic Model of the Perceptual Grounding of Spatial and Movement Relations[©]

Mathis Richter, D Jonas Lins, Gregor Schöner Institut für Neuroinformatik, Ruhr-Universität Bochum







2D field activation

1D field activation

mapping (convolution)

 \diamond steerable neural

O inactive node

• active node

notation

 \longrightarrow excitatory connection

→ inhibitory connection → patterned connection

---- homogeneous inhibitory

⊡► Cartesian/polar conversion

cognitive operations

ground relational

phrase

ground

reference

ground

relation

categorical concepts

toward

away

above

below

right

m

с

& sequences





Concept nodes...

relational concepts







"what is to the right of green?"



"where is the orange relative to the green object"



"red to the left of green?" conceptual structure



Grounding movement relations



perceptual grounding

"the red moving to the right"



[Richter et al]

description



"the red moving toward the green"

[Richter et al]

Autonomous hypothesis testing



"the red cup that is to the left of the green cup"

[Richter, Lins et al, CogSci 2014]









"the red to the left of the green"



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Mental mapping and inference

propositions

"There is a cyan object above a green object."

"There is a red object to the left of the green object."

"There is a blue object to the right of the red object."

" "There is an orange object to the left of the blue object."

inference

"Where is the blue object relative to the red object?"

[Ragni, Knauff, Psych Rev 2013]



[Kounatidou, Richter, Schöner, CogSci 2018]







Sequential organization





[Kounatidou, Richter, Schöner, CogSci 2018]

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Grounding nested phrases

"the tree to the right of the tree that is below the lake and above the house"





[Sabinasz, Schöner, TopiCS 2023; Sabinasz, Richter, Schöner Cog Neurodyn 2023]

Neural representation of conceptual structure

object index

separates two instantiations of "tree"

solving the problem of two



[Sabinasz, Richter, Schöner Cog Neurodyn 2023]

Neural representation of conceptual structure

relation index

enables multiple instances of same relation in a nested phrase



[Sabinasz, Richter, Schöner Cog Neurodyn 2023]



[Sabinasz, Richter, Schöner Cog Neurodyn 2023]

Architecture for processing conceptual structure



[Sabinasz, Richter, Schöner Cog Neurodyn 2023]

index 3

le 2

action ind. 5

2

Architecture for the perceptual grounding of conceptual structure

RIGHT OF





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Why are relations and actions important?

Lakoff and Johnson 1980; 1999: Metaphor

Lifting embodied/grounded concepts to language and thinking more generally... three basic concepts

spatial relations...

path.. actions

container relations

Conclusion

DFT on path to higher cognition

compositionality

systematicity

productivity