Cross-domain knowledge sharing in PDP models:
How learned, distributed representations support metaphor and analogy

Paul Thibodeau
May 4, 2012
how does the brain make meaning?

1. predictive error driven learning
2. sensitivity to coherent covariation
3. distributed representation

How do we think about things that we cannot experience at all?
- abstract concepts like TIME, JUSTICE, IDEAS
- complex social issues like CRIME or the ECONOMY
how does the brain make meaning?

How do we go beyond the information given to attribute unseen properties to things? For example, when you see a bird on a branch, how do you know it might fly away?
how does the brain make meaning?

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- TIME, VIRTUE, IDEAS
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- TIME, VIRTUE, IDEAS
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IDEAS are FOOD

I hope this lecture is food for thought
And that you can really sink your teeth into it
And that it’s not too hard to digest
Especially if the claims are hard to swallow
Which might be the case if it were filled with half-baked ideas and warmed-over theories
Those leave a bad taste in everyone’s mouth
TIME is SPACE

Next Wednesday’s meeting has been moved forward two days.

I started hearing the noise at noon but then it continued through the afternoon: from noon to five.

I will see you before 4 o’clock.

The reception after the talk will be fun.

The deadline is approaching.

The war is behind us.

His whole future is before him.
“Metaphor is not just a matter of language, that is, of mere words... On the contrary, human thought processes are largely metaphorical... The human conceptual system is metaphorically structured and defined.”

Lakoff and Johnson
Metaphors We Live By (1980)
1. is our knowledge of abstract domains grounded in more concrete, experiential domains?
2. does metaphoric grounding or inference require a specialized mapping mechanism?
3. how does this process of knowledge sharing emerge?

cross-domain knowledge sharing
cross-domain knowledge sharing

1. is our knowledge of abstract domains grounded in more concrete, experiential domains?
cross-domain knowledge sharing

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2. What kinds of representations and processes could support the metaphoric grounding of abstract concepts?
cross-domain knowledge sharing

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3. A simulation of conceptual metaphor: TIME as SPACE
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Monday

Friday

Boroditsky (2000)
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Boroditsky (2000)
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what kinds of representations and processes could support the metaphoric grounding of abstract concepts?

A. metaphor as analogy
   i. metaphors are processed as on-line mappings between domains
   ii. representations: disjoint propositions
   iii. mechanism: analogy/metaphor-specific mapping
metaphor as analogy

The Stripe Family

The Solid Family
metaphor as analogy

The Stripe Family

FatherStripes husband_of MotherStripes
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The Solid Family

Hinton (1986)

Thibodeau, Flusberg, Glick, & Sternberg (in prep)
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Emergent Analogy

Figure 7. Each of the plots above illustrates the similarity structure of the learned Subject representations in simulation 3. Hierarchical clusters are on the left and correlation matrices are on the right.

Early in training (the upper panels), the network does not group individuals by family or relation. Later in training, at 1,300 epochs (the lower panels), the network has aligned the families according to their relational similarity.

Several proponents of the Structural approach to analogy have suggested that a defining feature of analogical reasoning is the ability to perform structured pattern completion (Gentner & Markman 1993; 1995), which refers to a process whereby “a partial representation of the person1 relation person2 is completed.”

Even though daughter solid and daughter stripe were never presented to the model simultaneously, the network learned to associate them—the predictive error-driven learning mechanism leveraged the shared relational structure of the two domains to learn more efficiently.

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relation

person2

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TIME as SPACE

Network as agent experiencing its world, making predictions about it, learning about how actual events differ from predictions.
TIME as SPACE

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The world consists of items and relations (spatial and temporal sequences).
the spatial environment

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<td>blue, green, yellow</td>
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Flusberg, Thibodeau, Sternberg, & Glick (2010)
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Network as agent experiencing its world, making predictions about it, learning about how actual events differ from predictions.

The world consists of items and relations (spatial and temporal sequences).

The network will learn about two spatial perspectives.
movement in SPACE

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TIME as SPACE

Network as agent experiencing its world, making predictions about it, learning about how actual events differ from predictions.

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The network will learn about two spatial perspectives.

It will also learn that using the word “forward” in the temporal domain is ambiguous.
movement in TIME

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Mean Activation

Monday

Friday

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TIME as SPACE

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The world consists of items and relations (spatial and temporal sequences).

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It will also learn that using spatial language in the temporal domain is ambiguous.

Can the network adopt a particular spatial perspective to disambiguate the temporal domain?
Flusberg, Thibodeau, Sternberg, & Glick (2010)
Wednesday Meeting
other

item
output
relation

moves forward

Flusberg, Thibodeau, Sternberg, & Glick (2010)
can the network use structure from the spatial domain to resolve an ambiguity in the temporal domain?

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Online Spatial Context

Mean Activation

- Monday
- Friday

item

output

Mean Activation

- ambiguous
- self-moving
- other-moving
cross-domain knowledge sharing

1. Is our knowledge of abstract domains grounded in more concrete, experiential domains?

2. What kinds of representations and processes could support the metaphoric grounding of abstract concepts?

3. A simulation of conceptual metaphor: TIME as SPACE
implications of this view

1. at least some analogies and metaphors can be thought of as generalization over relational structure (and not the product of an on-line mapping mechanism)

2. direct co-occurrence is not necessary for such learning to take place (high-order co-occurrence of relational structure can facilitate cross-domain learning)

3. metaphor (indeed, all kinds of cross-domain knowledge sharing) is a natural byproduct of a conceptual system that utilizes an error-driven learning mechanism to build overlapping, distributed representations

a. this may be why metaphors are so common

b. why they don't take any longer to process
implications of this view

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2. at least some analogies and metaphors can be thought of as generalization over relational structure (and not the product of an on-line mapping mechanism)

3. direct co-occurrence is not necessary for such learning to take place (high-order co-occurrence of relational structure can facilitate cross-domain learning)
Thanks!

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