

# Wiki's, Beans, and Cats

## The Cascade Theory of Metaphor

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# Background

1980 Conceptual Metaphor Theory (CMT) : General Frame-to-Frame Mapping

## **Love is a Journey**

Source:

Two Travelers in a Vehicle Having Difficulty in Reaching Common Destinations

Target:

Two Lovers in a Relationship Having Difficulty Achieving Common Life Goals

Special Cases: *on the rocks, spinning our wheels, long bumpy road, going in different directions, crossroads, dead-end, off the track, bail out, ...*

Special cases: Image, knowledge about image, special case instance of general case

Source Domain Knowledge Mapped by Metaphor to Target Domain Meaning

# Primary Conceptual Metaphors

They are embodied and arise from commonplace everyday correlated experiences – typically without language, just by living in the world.

They are typically learned in childhood and are widespread around the world.

We list them in red.

## Metaphor Decomposition Into Primary Embodied Metaphors

**LOVE IS A JOURNEY Is Composed of the Primaries:**

- Relationships Are Containers,
- Intimacy Is Closeness,
- Action Is Motion,
- Purposes Are Destinations,
- Means Are Vehicles,
- Difficulties Are Impediments to Motion

# Embodied Cognition as of 1980's

(Talmy & Langacker, 1970's) (Johnson, 1987)

Primitive embodied image schemas: Containment, Source-path-goal, Up-Down, Front-Back, Around, Contact, Near-Far, Balance,...

(Rosch, 1978) Basic-level categories

(Kay & McDaniel, 1977) Color categories

(Lakoff and Johnson, 1980)

Happy Is Up. More Is Up. Affection Is Warmth. Knowing Is Seeing. Seeing Is Touching. .... **Arises From Correlation in Experiences**

(Lakoff 1987): ANGER IS...

Heat, Pressure, An Opponent, Loss Of Control, Impaired Perception

(Lakoff, 1987) Embodied Grammar

Deictic There-constructions

# Narayanan's Neural Theory of Metaphor (1997)

- Primary Metaphors: Embodied Experiences Activate Brain Circuits in Two Distinct Brain Regions. Activations Spreads Till shortest Distance Circuit Is Formed.
- 2012: Spike-Time Dependent Plasticity operates to strengthen connections in the direction from first-spiking node, weakening connections in opposite direction. Explains asymmetry of primary metaphor.

# The Neural Theory of Thought and Language

- All thought is physical, carried out by neural circuitry.
- Neural theory links embodied aspects of meaning to embodied aspects of form via neural circuitry
- Circuits don't move. All 'composition' of schemas, frames and metaphors must be carried out by ***fixed binding circuits*** and ***cascades***
- Special cases activate general cases, binding to them what distinguishes the special from the general

# Cascade Theory

- Central to Neural Theory of Thought and Language
- Cascades are Brain Circuits that link diverse brain regions (Koechlin, Ody and Kouneiher 2003; Dehaene 2009)
- Cascades monitor and control the activation and inhibition of other brain circuits (like executing schemas, called ***X-Schemas***)
- Cascades control the formation of complex schemas, frames, metaphors, and their inferences via the control of neural bindings
- Cascades control branching circuits
- Cascades flow both ***upstream*** (body to pre-frontal) and ***downstream*** (prefrontal to body)

# Wikileaks, Spilling the Beans, and Letting the Cat Out of the Bag

- They share a common semantic complex, mapped from source to target

Source Frame:

- There are entities in a container that are supposed to stay there.
- There is a restraining force keeping them there.
- The restraining force fails and a portal opens in the container and entities are released
- They cannot be put back (or they can, but the damage is already done)
- They make a mess

Metaphors apply to shared complex:

- Secrets are entities in a container that are supposed to stay there
- There is a restraining force keeping the secrets contained
- The restraining force fails and the secrets are released to the public
- They cannot be made private again
- They make a social mess



# Gating

- A **Gate** is a modulating node, that is, a node that emits different neurotransmitters at different firing rates.
- In Cascade Theory we assume:
  - A Gate emits an inhibiting neurotransmitter at normal firing rate, and an activating neurotransmitter when firing above normal base rate
  - A circuit is gated when a Gate emits its neurotransmitters into a synapse in that circuit.

# Binding

- Two nodes are neurally bound when there are active two-way connections between them
- This allows them to fire in synch, so that the brain treats them as if they were a single node.
- Binding circuits are gated.
- When binding is inhibited by the gate, the nodes fire independently. When the gate is active, the nodes fire together and act as one node.
- **“G” signifies a gate.**

# Gates and Binding

**$B \leftarrow G \rightarrow C$**

A binding circuit gated by node G, with two-way activating connections between nodes B and C.

**$A \rightarrow [B \leftarrow G \rightarrow C]$**

An activating connection from A to the Gating node G in the binding circuit with two-way connections between B and C.

**$B \rightarrow G \rightarrow C$**

There is gated activation from B to C. Metaphor mappings use gated activation.

**$A \rightarrow B$**

There is an activating connection or a chain of them from A to B. If there is a chain, it can be gated anywhere along the chain.

# Cascades and Compositionality

- **Cascades** are circuits that control the flow of activation in the brain.
- **Composition** of concepts works by Neural Binding and Cascades.
- **Binding Circuits** form more complex schemas from simpler schemas by binding a role in one schema to a role in another schema.
- **A Mini-Cascade:** Very complex concepts are formed from a collection of two or more bindings, when a single node activates the gating nodes of all the bindings at once.

# Cascades and Embodiment

- Since **meaning is always embodied**, a cascade for a meaningful concept must terminate at circuits for **Embodied Schemas** and **Primary Metaphors**.

(indicated in red)

# Cascade Notation

- Each Mini-cascade is a node that characterizes a complex concept by virtue of the **embodied** concepts that it is ultimately connected to. We will use a **K** to indicate a **Mini-cascade** node.
- The name of that concept — or an abbreviation — will be given as a subscript on that **K**, e.g., **K<sub>SECRET</sub>** for the complex concept of a secret.

# Cascade Notation

Here is a sample notation:

$K_{\text{CONCEPT}} + \longleftrightarrow \text{Schema1}$   
 $\text{RoleA.Schema2} \leftarrow G \rightarrow \text{RoleB.Schema3}$   
 $\neg \text{Schema4}$

This says that  $K_{\text{CONCEPT}}$  has activating connections to the gestalt node of Schema1, to the gating node G, and to '¬' — a node that inhibits Schema4.

The nodes in red —  $\text{RoleA.Schema2}$  and  $\text{RoleB.Schema3}$  — indicate directly embodied nodes.

The ' $\longleftrightarrow$ ' indicates that the cascade node is two-way

'+' indicates that  $K_{\text{CONCEPT}}$  has a firing threshold that is a sum of at least some of the inputs.

Wikis, Beans, and Cats:

# **THE CASCADE**



# The Cascade

- Each specific metaphor is controlled by a cascade circuit that activates general metaphors and general schemas
- Each general metaphor and schema in turn activates, within the same cascade, **shared primary schemas and metaphors**, including x-schemas responsible for actions and processes
- Mini-cascades control intermediate activations and inhibition within a larger network

# Primary Schemas

- **Embodied Schemas:** Container, Physical Entity, Motion, Change, State
- **X-Schemas:** Maintenance\_of\_state (MOS), Action, Change, Cause, Purpose
- **Force Schemas:** Imposing Force, Restraining Force, Releasing Force

# Basic Schemas: Gestalt Nodes

$S_{Name} \longleftrightarrow [A, B, C]$

A gestalt node with two-way activation between itself and its roles, all of which are nodes.

Since gestalt nodes form schemas, we use S to indicate a gestalt node.

S is the whole, and A, B, C are its parts.

$S_{Change} \longleftrightarrow [State_1 < Event < State_2]$  “<” means before

$S_{Cause} \longleftrightarrow [Action < Change < Effect]$

$S_{Purpose} \longleftrightarrow [Desirer, Goal, Means, Difficulty]$

$S_{Ongoing\_action} \longleftrightarrow [Actor, [Precondition < Ongoing]]$

$S_{Knowing} \longleftrightarrow [Knower; Know ; Knowledge]$

$S_{Communication} \longleftrightarrow [Communicator; Communicate; Information; Recipient]$

$S_{Access} \longleftrightarrow [Accessor, Path, Means, Goal]$

# Primary Metaphors

- IDEAS ARE OBJECTS
- COMMUNICATION IS OBJECT TRANSFER
- KNOWING IS SEEING
- MULTIPLEX IS MASS
- DIFFICULTIES ARE OBSTRUCTIONS TO MOTION

# Source Domain Cascades

- Complex schema circuits are formed by neural bindings, multiple bindings controlled by cascade node “ $K_{\text{SUBSCRIPT}}$ ”
- Notation:
  - **Contained\_entity.Container**: the ‘contained entity’ role in the Container Schema (gestalt)

# Source Domain Cascades

$$\underline{K_{\text{State1}}} + \longleftrightarrow [K_{\text{INCONT}} ; K_{\text{MORE}} ; K_{\text{PCONT}} ; K_{\text{NOCHANGE}}]$$

Here is a cascade for a complex concept formed from 4 concepts.

1. Initially, the contents of a container impose a force on the container.
2. The restraining force of the container is greater than the force on the container.
3. The portal to the container is closed.
4. This situation persists with no change.

# Source Domain Cascades

$$K_{\text{State1}} + \longleftrightarrow [\underline{K_{\text{IN.CONT}}}; K_{\text{MORE}}; K_{\text{PCONT}}; K_{\text{NOCHANGE}}]$$

$$K_{\text{IN.CONT}} + \longleftrightarrow \text{Location\_entity.Containing} \leftarrow G \rightarrow \text{Interior.Container}$$
$$\text{Contained\_entity.Containing} \leftarrow G \rightarrow \text{Recipient.Imposing\_force}$$

The location of the contained entity is the container interior.

The contained entity in the container schema is the recipient of the imposing force.

# Source Domain Cascades

$$K_{\text{State1}} + \longleftrightarrow [K_{\text{INCONT}} ; K_{\text{MORE}} ; \underline{K_{\text{PCONT}}} ; K_{\text{NOCHANGE}}]$$

$$K_{\text{PCONT}} + \longleftrightarrow$$

Boundary.Container  $\leftarrow G \rightarrow$  Physical\_object.Object

Restrainer.Restricting\_force  $\leftarrow G \rightarrow$  Physical\_object.Object

State<sub>1</sub>.MOS  $\leftarrow G \rightarrow$  Portal\_state(=closed).Container

The Container Boundary is a Physical Object that exerts restraining force and maintains the state in which the portal of the container is closed.



# Source Domain Cascades

$K_{\text{State1}} + \longleftrightarrow [K_{\text{INCONT}} ; \underline{K_{\text{MORE}}} ; K_{\text{PCONT}} ; K_{\text{NOCHANGE}}]$

$K_{\text{MORE}} + \longleftrightarrow$

Greater.More\_than  $\leftarrow G \rightarrow$  Force\_amount.Restricting\_force

Lesser.More\_than  $\leftarrow G \rightarrow$  Force\_amount.Imposing\_force

The restraining force is greater than the imposing force.

# Source Domain Cascades

$K_{\text{State1}} + \longleftrightarrow [K_{\text{INCONT}} ; K_{\text{MORE}} ; K_{\text{PCONT}} ; \underline{K_{\text{NOCHANGE}}}]$

$K_{\text{NO.CHANGE}} + \longleftrightarrow$

[Precondition.Ongoing\_action  $\leftarrow G \rightarrow$  State<sub>1</sub>.Change]

[Goal.Purpose  $\leftarrow G \rightarrow$  State<sub>1</sub>.Change]

[Actor.Action  $\leftarrow G \rightarrow$  Desirer.Purpose]

[Actor.Action  $\leftarrow G \rightarrow$  Exerter.Restricting\_force]

[Ongoing.Ongoing\_action  $\leftarrow G \rightarrow$  Exertion.Restricting\_force]

The purpose of the restraining containment is to maintain the initial state

# More Complex Circuits In Source Domain Cascade

$K_{\text{SOURCE}} + \longleftrightarrow [K_{\text{STATE1}} < \underline{K_{\text{CHANGE}}} < \underline{K_{\text{FINAL}}}]$

$K_{\text{CHANGE}} + \longleftrightarrow$

Causal\_action.Cause  $\leftarrow G \rightarrow$  Force.Releasing\_force

Changing\_event.Change  $\leftarrow G \rightarrow$  Initiate\_motion.Motion

Portal\_state=open.Container  $\leftarrow G \rightarrow$  Path.Motion

Contained\_entity. $K_{\text{STATE1}}$   $\leftarrow G \rightarrow$  Mover.Motion

$K_{\text{FINAL}} + \longleftrightarrow$

State<sub>2</sub>.Change  $\leftarrow G \rightarrow$  Effect.Cause

Contained\_entity\_location. $K_{\text{STATE1}}$   $\leftarrow G \rightarrow$  Exterior.Container

A releasing force opens the portal, letting out the contained entity with the effect that the previously contained entity is outside of the container.

# Target Domain Cascade

$K_{\text{TARGET}} + \longleftrightarrow [\underline{K_{\text{NO.CHANGE}}}; \underline{K_{\text{STATE1}}}]$

$K_{\text{TARG.EVENT}}$

$K_{\text{TARG.PUB.ACC}}$

$K_{\text{TARG.STATE2}}$

# Target Domain Cascade

$K_{\text{TARGET}} + \longleftrightarrow [\underline{K_{\text{NO.CHANGE}}} ; K_{\text{STATE1}}]$

$K_{\text{NO.CHANGE}} \rightarrow$

$[\text{Precondition.Ongoing\_action} \leftarrow G \rightarrow \text{State}_1.\text{Change}]$

$[\text{Goal.Purpose} \leftarrow G \rightarrow \text{State1.Change}]$

$[\text{Actor.Action} \leftarrow G \rightarrow \text{Desirer.Purpose}]$

$[\text{Actor.Action} \leftarrow G \rightarrow \text{Exerter.Restricting\_force}]$

$[\text{Ongoing.Imperfective\_action} \leftarrow G \rightarrow \text{Exertion.Restricting\_force}]$

# Target Domain Cascade

$K_{\text{TARGET}} + \longleftrightarrow [K_{\text{NO.CHANGE}} ; \underline{K_{\text{STATE1}}}]$

$K_{\text{TARG.STATE1}} + \longleftrightarrow$

[Knower.Knowing  $\leftarrow G \rightarrow$  Exerter.Restricting\_force]  
[Information.Communication  $\leftarrow G \rightarrow$  Knowledge.Knowing]  
[Force.Restricting\_force  $\leftarrow G \rightarrow$  Force.Social\_force]  
[Goal.Access  $\leftarrow G \rightarrow$  Knowledge.Knowing]  
 $\neg$  [Knower.Knowing  $\leftarrow G \rightarrow$  Public.Public]  
 $\neg$  [Recipient.Communication  $\leftarrow G \rightarrow$  Public.Public]  
 $\neg$  [Accessor.Access  $\leftarrow G \rightarrow$  Public.Public]

Initial Target state:

Someone knows some information that the public doesn't know  
is under a social force to exert restraint to prevent the public  
from gaining access to the information.

# Target Domain Cascade

$K_{\text{TARG.EVENT}} + \longleftrightarrow [\text{Goal.Purpose} \leftarrow G \rightarrow \text{Change.Change}]$   
 $[\text{Event.Change} \leftarrow G \rightarrow \text{Act.Action}]$   
 $[\text{Act.Action} \leftarrow G \rightarrow \text{Exert.ReleasingForce}]$   
 $[\text{Act.Action} \leftarrow G \rightarrow \text{Communicate.Communication}]$

Then the person's goal changes and he releases restraint and communicates the information.

# Target Domain Cascade

$$K_{\text{TARG.PUB.ACC}} + \longleftrightarrow [\text{Accessor.Access} \leftarrow G \rightarrow \text{Public.Public}]$$
$$[\text{Goal.Access} \leftarrow G \rightarrow \text{Knowledge.Knowing}]$$

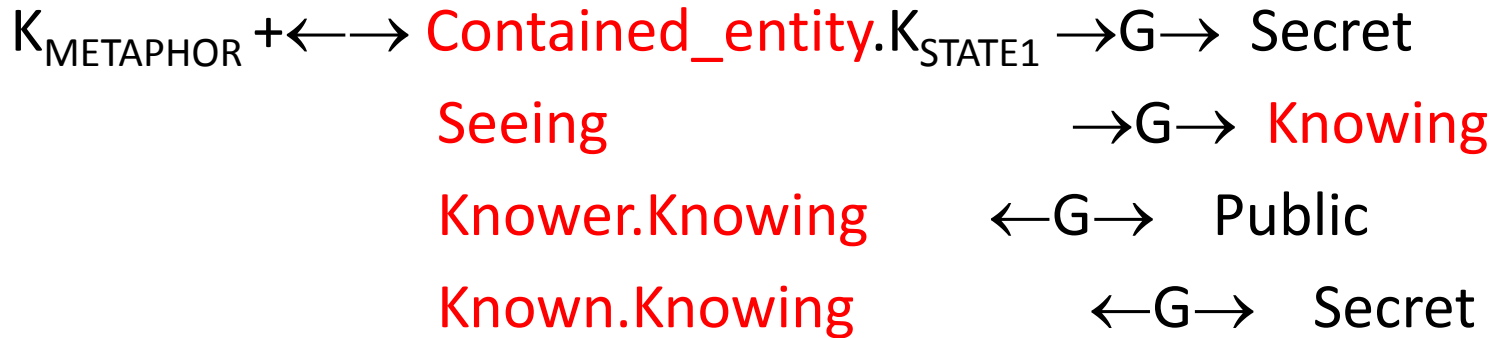
The public has access to the knowledge.

$$K_{\text{TARG.FINAL}} + \longleftrightarrow [\text{State}_2.\text{Change} \leftarrow G \rightarrow K_{\text{TARG.PUB.ACC}}]$$

That is the final state.



# Metaphor Cascade



$K_{\text{METAPHOR}}$  and all its links constitute the cascade shared by leaks, spilt beans, the cat being let out of the bag.

Notice that the embodied concepts are in **red**, while the mini-cascades and bindings are not. The mini-cascades and bindings characterize complex concepts that make use of **embodied primary concepts**.

# Cascades and Embodiment

- Cascades are both fixed and flexible
- Cascades allow us to make effectively infinite conceptual use of finite embodied circuitry.
- Each “fixed” ***mini-cascade*** creates a complex concept while allowing the conceptual parts to be used independently.
- It is “fixed” since the connections with strong synapses are fixed.
- It is flexible because the binding circuits used are gated via modulation.

# Conclusions

- Wiki-leaks, spilling the beans, and letting the cat out of the bag share complex semantic content. That shared content is given by the Metaphor Cascade, which maps the Source Cascade to the Target Cascade.
- The cascades and bindings combine simple embodied schemas to form the shared complex semantic content.
- Other cascades (not shown here) link the special cases of leaks, beans, and the cat to initially restrained content that later is released to public access.
- Differences among the three result from ***inferences and bindings established for the special cases, not*** from differences at the highest shared levels. They result from the neural binding of **Entities** at the general case level to specific frames (cats in bags, canned beans, liquid leaks).

**THANK YOU!**

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