Since each neuron can have between 1,000 and 10,000 neural connections, nodes can be modeled as "nodes" which are meaningful and which enter into neural computation. Neuronal groups (of size, say, between 10 and 100 neurons) are a brief and overly simple introduction to the neural theory of language (NTL). Feldman is one of the founders of the theory of neural computation, and we have surveys much of the work of our group, and is a must-read for metaphor theorists. As a background both to reading that book and to our discussion of metaphor, I wondered about how whole systems of philosophical or mathematical thought can be built up out of conceptual metaphors. The neural theory explains all this. It explains an awful lot about the properties of metaphor. For example, have you ever asked why conceptual metaphor exists at all, why we should think metaphorically, why such a shaping is necessary if the brain is to learn to do the huge number of things it does. Between birth and the age of five, roughly half of the neural connections we are born with are unused. The ones that are used stay; the others die. That is how our brain is shaped, and neural computation. The reason is that what we have learned about the brain in radical ways, and that is no less true in the theory of metaphor. It is 30 years since Mark Johnson and I wrote Metaphors We Live By, and much of our thinking about metaphors has changed since then. Though the fundamental outlines of our book remain the same, developments in brain science and neural computation have vastly enriched our understanding of how conceptual metaphor works. This is an intermediate report, as of January 2009.

A Brief Introduction to NTL

The Shaping of the Brain

The Neural Revolution

The Neural Theory of Metaphor
The meaning of concrete concepts is directly embodied in this manner. There is considerable evidence that perceiving language activates corresponding motor or perceptual areas of the brain, and vice versa. Mirror neurons that are activated when imagining either performing or perceiving grasping — that is, it is multimodal. Thus, all mental simulation is embodied, since it uses the same neural substrate used for action, perception, emotion, etc. Simulation semantics is based on a simple observation of Feldman's: if you cannot imagine someone picking up a glass, you cannot understand the meaning of "Someone picked up a glass." Feldman argues that, for meanings of physical concepts, the meaning is mental simulation — that is, the activation of the neurons needed to imagine acting or perceiving the same action, but when imagining that you are perceiving or perceiving grasping — that is, it is multimodal.

Inferences occur when the activation of one meaningful node, or more, results in the activation of another meaningful node. Inferences can occur in fiber bundles connecting pre-motor/SMA cortex (which choreographs actions) with the parietal cortex (which integrates perceptions). The same neural map in V1 preserves the topology of the retina in the brain in another part of the brain. For example, the 100 million neurons coming out of the retina grow connections before birth from the retina to other areas including the primary visual cortex at the back of the brain. These connections form a "topographic map" of the retina in V1. That is, the connections preserve topology (relative nearness), so that when the corresponding visual input is received by the retina, the neurons in the corresponding neural map fire as well. We are born with neural circuits that are inherently embodied, because that is how the neurons that fire together wire together. Neurons that fire together wire together, and that when inhibited inhibits that simulation. Spreading activation: Neurons that fire together wire together.

Thoughts are neural networks that are mutually influential. The link between body and brain is central to the concept of semantics as embodiment. Though single neurons either fire or not, neuronal groups contain neurons that fire at different times, making the group active to a degree depending on the proportion firing at a given time. Connections, degrees of synaptic strength, and time lags at synapses are mutual. They are asymmetrical, with some mutual inhibition. Two neuronal groups can be connected so that each inhibits the activation of the other. Inhibitory connections may arise in fiber bundles connecting pre-motor/SMA cortex (which interacts with the parietal cortex) with the motor cortex. He kicked the ball. The link between body and brain is central to the concept of semantics as embodiment. Though single neurons either fire or not, neuronal groups contain neurons that fire at different times, making the group active to a degree depending on the proportion firing at a given time. Connections, degrees of synaptic strength, and time lags at synapses are mutual. They are asymmetrical, with some mutual inhibition. Two neuronal groups can be connected so that each inhibits the activation of the other. Inhibitory connections may arise in fiber bundles connecting pre-motor/SMA cortex (which interacts with the parietal cortex) with the motor cortex. He kicked the ball.
Neural Choreography

In general, the premotor cortex and supplementary motor area (SMA) are involved in the planning and execution of movements. The premotor cortex is responsible for the preparation of movements, while the SMA is involved in the initiation of movements. The two areas work together to ensure that movements are coordinated and smooth. The premotor cortex and SMA receive information from the primary motor cortex (M1) and other brain areas, and they send commands to the lower brain areas to initiate movements. The connections between these areas are thought to play a role in the planning and execution of movements, with the premotor cortex and SMA coordinating the movement and M1 executing it.

Circuit Types

The primary motor cortex (M1) is a region of the brain that is responsible for controlling voluntary movements of the body. M1 is divided into two areas, each of which is responsible for controlling movement of different parts of the body. The left hemisphere of M1 controls movement of the right side of the body, while the right hemisphere controls movement of the left side of the body. M1 is connected to other brain areas, including the basal ganglia, thalamus, and cerebellum, which are involved in the planning and execution of movements.

Neural Binding

Neural binding refers to the process by which information is integrated at the level of the neuron. This process is responsible for the integration of sensory information, the formation of memories, and the execution of complex motor tasks. Neural binding is thought to be mediated by a variety of mechanisms, including synaptic plasticity, changes in the intrinsic properties of neurons, and changes in the connections between brain areas.

A Note on Gestalt Nodes

When a group of neurons is activated in a coordinated manner, it is referred to as a gestalt node. This concept is important in understanding how the brain processes information and how it generates complex behaviors. Gestalt nodes can be thought of as the building blocks of neural circuits, and they are thought to play a role in the formation of neural binding.

The winner-take-all circuit:

The winner-take-all circuit is a type of neural circuit that is responsible for selecting a single winner from a group of candidates. This circuit is thought to be involved in a variety of cognitive processes, including decision making, memory retrieval, and the formation of neural binding.
A Schema Circuit:

- A collection of nodes, say, A, B, C, and D and a "gestalt node" G.
- When G is firing, all of A, B, C, and D fire.
- When a sufficient set of A, B, C, or D is firing, G fires, which results in all other nodes firing. One especially salient node can be sufficient in some cases, or there can be a threshold where the total activation summed over all the nodes is above G's threshold and results in G firing.
- When G is inhibited, at least one of the other nodes is inhibited.

Schema Circuits characterize the structure of frames. Frames are special cases of schemas. The entire frame corresponds to G and the roles correspond to A, B, C, D, etc. Schema circuits also characterize the circuitry that allows image-schemas and X-schemas to function as schemas.

In a gestalt, the whole is more than just the sum of its parts. Accordingly, in a schema circuit, the whole — G — cannot be inhibited and all of its parts activated. The activation of even some of the salient parts activates the whole. And the activation of the whole activates all the parts.

A Linking Circuit:

- Two nodes, A1 and A2, a circuit L connecting A1 with A2, and G, the gestalt node of circuit L.
- When A1 and G are firing, A2 is firing. But when A2 is firing, A1 need not be firing. Thus, activation flow is asymmetric from A1 to A2.
- When A1 is firing and G is not, the linking circuit L is not active. (That is, G "gates" the connection L.)
- When A1 and A2 are both firing, gestalt node G is firing and the linking circuit L is active.

Note: A1 can fire without A2 firing. This can happen if G is inhibited from firing, thus making the link L from A1 to A2 inactive. Think of G as a traffic cop regulating the flow from A1 to A2.

Linking Circuits are used in metonymy: Within a frame F, one semantic role A may "stand for" another B. A metonymy is characterized by:

1. A schema consisting of gestalt node F and at least nodes A, B, and X;
2. A connection L linking A to B asymmetrically, with gestalt node G gated by X. That is, G fires only if X is firing. For example, in "The ham sandwich wants his check," the frame F is the restaurant frame, the ham sandwich plays the role Dish (A), his refers back to the entity that plays the role Customer (B), and L characterizes the metonymic link from the Dish (A) to the Customer (B), while X is the condition that the waiter/waitress identifies the Customer B primarily in terms of the Dish B.

Binding Circuits:

- When neural binding occurs, the nodes bound together act as if they characterize the same entity: every circuit activated by one is activated by the other, and every circuit activating one activates the other.

A common theory of binding holds that the nodes that are neurally bound fire in sync. There are other theories, and none is accepted as having been proven.

ID Links:

- You are the same person you were as an infant, though you certainly have changed. That change means that circuits characterizing you as an infant must not be the same as those characterizing you now. One suggestion for how a neural system accomplishes this uses the concept of an Essence as a semantic role of the frame for an entity. On this hypothesis, we can characterize an ID Link.
- An ID Link between A and B consists of: 1) a linking circuit from the circuit for one entity A to the circuit for another entity B; 2) a neural binding identifying the Essence role of A and the Essence role of B.
- ID links characterize connectors across mental spaces, identifying A in one space as the same entity as B in another space, even though they may have different properties in different spaces.
Two way-linking circuits provide the kinds of connectivity used in grammatical constructions and lexical items, where there is a two-way connection between a lexical meaning and a lexical form, or a grammatical meaning and a grammatical form structure.

Mappings
Mappings are unidirectional multiple linking circuits, each governed by a single gestalt node, and with those linking gestalt nodes governed altogether by a single gestalt node. Here are some examples:

Metaphor
Metaphor mappings apply to schemas of all sorts, whether image-schemas, frames, action sequences, or narratives. They map "source domain" schemas and their roles to "target domain" schemas and their corresponding roles.

Metaphorical Mapping:
Two schemas $S_1$ with roles $A_1, B_1, \ldots$ and $S_2$ with roles $A_2, B_2, \ldots$.
Linking circuits $LS, LA, LB, \ldots$ that respectively link schema $S_1$ to schema $S_2$, role $A_1$ to role $A_2$, role $B_1$ to role $B_2$, and so on. Gestalt nodes $GS, GA, GB, \ldots$ governing linking circuits $LS, LA, LB, \ldots$.

When G is inhibited, GS, GA, GB, etc. are all inhibited and activation is shut off in all the links. When G is activated, DS, GA, GB, etc. are all activated, and activation flows from schema node $S_1$ to schema node $S_2$ and through all the links between roles.

When schema 1 and schema 2 are activated, G is activated.

Mental Space Mapping:
A "mental space" $M$ consists of circuitry used to run a simulation activated by a Semantic Structure $SS$. A Semantic Structure $SS$ consists of the circuitry characterizing such semantic "units" as frames, image schemas, X-schemas, metaphorical maps, metonymic maps, blending maps, etc. together with neural bindings integrating them into a whole.

A cross-space relation $R$ consists of two mental spaces $M_1$ and $M_2$ and a semantic structure $SS$ with roles bound to elements of each space.

A mental space mapping $MS$ consists of:
- A linking circuit $L$ from $M_1$ to $M_2$.
- A collection of ID Links from elements $EM_1[i]$ of $M_1$ to elements of $EM_2[i]$ of $M_2$.
- A gestalt node $G$ governing $L$ and all the ID Links.

A "space builder" is a linguistic element or construction $B$ that activates $R$ and $G$.

For example, take the sentence:

"If Clinton had been President of France, there would have been no scandal over his affair."

The mental spaces are: $M_1 = \text{The US during Clinton's presidency}$ with $EM_1(1) = \text{Clinton}$ and $SS_1 = \text{his affair in the US}$, and $M_2 = \text{France at that time}$, $EM_2(1) = \text{A Clinton-correlate}$ and the role played by $EM_2(1)$ is the President of France who has an affair in France with no scandal; $L_1$ is the circuit that identifies $A_1$ (the real Clinton) with $A_2$ (the Clinton correlate $\neq$ Clinton). The SS indicates that $M_1$ is taken as fitting reality and $M_2$ is not.

Extension Circuit:
- A semantic structure $SS_1$, containing nodes $A_1, B_1, C_1, D_1, \ldots$ and a gestalt node $G_1$ governing $SS_1$.
- Gestalt node $G_2$ governing nodes $C_2, D_2, \ldots$.
- A linking circuit $L$ with gestalt node $G$ linking $G_2$ asymmetrically to $G_1$.
- Mutually inhibitory links between $C_2, D_2, \ldots$, and $C_1, D_1, \ldots$ respectively.
- $SS_2$ consisting of $SS_1$ with $C_2, D_2, \ldots$ replacing $C_1, D_1, \ldots$.

When $G$ is firing, $SS_2$ is activated and $SS_1$ is inhibited. When $G_1$ is firing, $SS_1$ is activated and $SS_2$ is inhibited.

Extension Circuits characterize radial categories (See Lakoff, 1987, Case Study 3). For example, suppose $SS_1$ characterizes the concept of mother and $SS_2$ characterizes the concept of stepmother, where the birth frame of mother is inhibited while the marriage frame remains active.

X-schema circuit:
- A gestalt node
- State nodes
- Action nodes
- Connections, both activating and inhibiting
- Conditional Choice nodes
- Timing nodes

X-schemas, or "executing schemas," do things, via bindings that activate other circuits. Every action node is preceded and followed by a state node, with activation spreading from states to actions to states. Timing nodes coordinate the lengths of states and actions (which may be instantaneous or elongated). Iterated actions are formed by loops from the state following an action to the state preceding the action. Conditional actions are formed by gatings — cases where activations from both nodes $A$ and $A'$ are needed to activate node $B$. Conditional Choice nodes have outputs going to two or more other nodes, with gatings that determine the choices, perhaps probabilistically.

The gestalt node activates the initial state and the final state inhibits the gestalt node. Actions typically have initial and final states, initiating and concluding actions, central
you pour more water in the glass and the level goes up). More Is Up is grounded via the correlation between quantity and verticality —

Certain metaphors are grounded via correlations in embodied experience (e.g.,

• The system exists physically in our brains.
• There is a huge system of fixed, conventional metaphorical mappings.
• Not mere linguistic expressions.

Metaphors are conceptual mappings; they are part of the conceptual system and

• time:

and neural computation. Certain results from that era have stood the test of

was written back in 1979, before the era of brain science

Metaphors We Live By

The Old Theory

We are now ready to discuss how all of this changes old metaphor theory into the

meanings are "abstract" in the sense that they have a very general structure but lack

Take the classic example of "pumpkin bus" — coined on a school outing. There were two

structures in primary cortex, e.g., motor and visual. This would explain why grammatical

Similarly, a linguistic compound makes sense when it fits into a coherent context.

by "Cogs," that is, secondary neural structures (e.g., pre-motor/SMA cortex) that bind to

overall conceptual organization. Ideas make sense when they fit a whole system of ideas.

shown that certain action circuitry has the structure of frames. They have further

speculated that the meanings of grammatical elements and constructions are characterized

circuit types of neural systems. Narayanan (1997) has constructed a neural

Computational Model of the Structure of Events, that is, X-schemas. Dodge and Lakoff

ranged of spatial relations concepts can be computed by a neural network that shares

(2006) have speculated on many of the details involved. Gallese and Lakoff (2005) have

circuit types that perform very specific neural computations.

neural systems are best-fit systems

accuracy of performance vs. neural circuitry. We will discuss this further below. In short, blending can be

as a form of complex binding.

neural binding circuitry. We will discuss this further below. In short, blending can be

weights, that is, circuitry that has the highest prior probability of being activated.

Blending Maps:

Blending maps are complex maps: They take two or more sources and map them

and put in a blender and liquefied so that one could drink it.

Blending maps are complex maps: They take two or more sources and map them
Metaphorical mappings are typically across conceptual domains (as in Affection Is Warmth).

Mappings (as in A Competition Is a Race) may also be from a specific case (a race) to a more general case (a competition).

Mappings operate on source domain frame and image-schema structure.

Via metaphorical mappings, source domain structures (image-schema and frame structures) are used for reasoning about the target domain. Indeed, much of our reasoning makes use of conceptual metaphors.

Metaphorical mappings are partial.

Metaphorical language makes use of conceptual metaphors.

Many different linguistic expressions can express some aspect of the same metaphor.

A conceptual metaphor may be used in understanding a word, even if that word is not realized in the source domain of the metaphor.

Most conceptual metaphors are part of the cognitive unconscious, and are learned and used automatically without awareness.

Novel metaphorical language makes use of the existing system of conventional metaphors.

We commonly take our conceptual metaphors as defining reality, and live according to them.

Target domain entities and target domain predications can result from metaphors.

Two of the relevant sources of data are generalizations over inference patterns (in the source and target domains) and generalizations over lexical items (that can be used of both source and target domains).

These results will be familiar to any student of conceptual metaphor. To those who have read The Contemporary Theory of Metaphor another result that has stood the test of time will be familiar:

Complex metaphors are made up of simple metaphors bound together and/or bound to commonplace frames.

For example, Love Is a Journey is composed of such conceptual metaphors as:

- Purposes are Destinations
- Difficulties are Impediments to Motion
- A Relationship is a Container
- Intimacy is Closeness

plus commonplace literal frame-based knowledge that:

- A Vehicle is an Instrument for Travel
- A Vehicle is a container in which the travelers are close together
- People are expected to have life goals
- Lovers ideally have compatible life goals.

These are put together in such a way that:
- The life goals are destinations
- The lovers are travelers trying to reach those destinations
- Their relationship is a vehicle such that the lovers are in the relationship
- They are close
- The relationship (when working) helps them achieve life goals
- The relationship difficulties are impediments to motion (e.g., a long, dusty road; being on the rocks or off the track).

Such compositional structures were noticed during the 1980's. But such descriptions hid certain neural realities. Each frame role is a node. The metaphor mappings are physical circuits—linking circuits that, when activated, form links within integrated neural circuits. "Nodes" are part of such circuits. Each frame is a circuit, and each role in a frame is a node in that circuit. Thus, there is a Travel frame circuit and Destination is a node in that circuit. When we write down, as we just have, The life goals are destinations The lovers are travelers trying to reach those destinations, we have written down the word destination twice, but in the brain both uses of the word "destination" are activating the same node in the same frame circuitry. Thus, activating a metaphor activates very complex integrated brain circuitry, and a given node may occur in many circuits made active by the metaphor. The more integrated the circuitry activated by the metaphor mapping, the better the "fit" of the metaphor to other brain structures. Thus, the life goals of the ideal lovers are special cases of, and thus fit, the life goals that are understood as destinations. A vehicle used for travel is typically a container, which is the same as the container in the metaphor A Relationship Is A Container.

A metaphor mapping is a complex circuit which, when activated, activates many other circuits via linking and binding circuitry. This makes possible metaphorical inferences: Source domain inferences that are mapped combine with target domain knowledge via binding to produce new inferences: If lovers are "stuck" in relationship, if the relationship isn't "going anywhere," then they are not making progress toward common life goals. If the lovers are "going in different directions," then they may not be able get to the same destinations, which means metaphorically that their common life goals may be inconsistent. The NTL perspective provides a very different way of thinking about such complex metaphors. The brain is a best-fit system. Inferences are new activations that arise via prior activations. Bindings and linkings form integrated circuits that result in activations that arise via prior activations. This bindings and linkings give rise to inferences. Consider our existing conceptual system where:
Thus, given the existing system, maximization of binding produces the meaning of the emotions.

This metaphorically infers that my job restricts my freedom of action in achieving external purposes, thus producing frustration and other negative emotions.

"My Job is a Jail"

...we infer a Destination

"Achieving a Purpose is Reaching a Destination"

...we infer a restriction on freedom of motion.

"Binding"

...we infer a restriction on freedom of action.

Actions are Motions to desired external destinations.

The metaphors that Johnson called such metaphors "primary metaphors" and observed that they are learned by neural mapping circuits linking the two domains.

The neural theory says that complex metaphors that are extensions of existing primary metaphors bound together should be easier to learn and understand than those that are not extensions.

Primary Metaphors

Purposes are Destinations: Every day there is a correlation between achieving a purpose and reaching a destination, as when you have to go to the refrigerator to get a piece of fruit or a cold beer.

Difficulties are Impediments to Motion: A difficulty is something that inhibits your achievement of some purpose, which is metaphorically reaching a destination. Hence, difficulties are conceptualized metaphorically as impediments to motion.

Actions are Motions to desired external destinations.

Intimacy is Closeness: The people you are most intimate with are typically the people you have spent time physically close to: your family, spouse, lover, and so on.

A Relationship Is a Container (a Bounded Region of Space): People who are closely related tend to live, work, or otherwise spend time in the same enclosed space.

A Vehicle is an Instrument for Travel: People who are traveling together, a car or a bus or a plane, are metaphorically "traveling together".

Vehicle in (5) names the same neural structure as Vehicle in (2)

Lovers in (4) names the same neural structure as Lovers in (6)

Intimacy in (3) names the same neural structure as Intimacy in (4)

Closeness in (2) names the same neural structure as Closeness in (3)

The neural theory got its real impetus from three Berkeley dissertations done in 1997 — by Srini Narayanan, Joe Grady, and Christopher Johnson. Narayanan's dissertation was key. He modeled metaphors as neural mappings and formulated certain predictions. The result is a very tightly integrated neural system — a system that fits together very well. The Love Is a Journey metaphor mapping fits our knowledge, including primary metaphors like (1) and (3) and commonplace knowledge like (2), (4) and (5).

By best fit, different cultural frames will combine with those primary metaphors and give rise to different metaphor systems. The Love Is a Journey metaphor is a good example.

The primary metaphors that ground the Love Is a Journey metaphor are:

1. Love is a Container, A Vehicle is a Container in which the Travelers are close together, A Relationship is a Container, Intimacy is Closeness

The result is a very tightly integrated neural system — a system that fits together very well. The Love Is a Journey metaphor mapping fits our knowledge, including primary metaphors like (1) and (3) and commonplace knowledge like (2), (4) and (5).
computational modeling. At the heart of the modeling of metaphorical inferences is the
metaphorical inferences that can be modeled precisely (Narayanan, 1997) using neural
The neural theory of metaphor provides an explanatory mechanism for
isn't.

Affection is Warmth: Temperature is always there to be monitored; affection
•
computing abstract quantity.

More Is Up: Our bodies are constantly monitoring physical height more than
•
Source domain commonplace information.

The specific situation being discussed, fitting the target domain.

The metaphorical mapping (from source domain frame to target domain frame)
•
functioning tend to fire more. For this reason, the metaphorical maps learned are

structure “preserved” from the source domain. Thus, in use, you had:

Asymmetry

Metaphors were cross-domain mappings — from a frame in one domain to another
domain, also structured by frames. Such mappings were seen as applied to target domain
functioning and fired more. The fact that the metaphorical mapping operated to process the target domain.

The neural theory thus contradicts old two-step theories (prior to conceptual
metaphor theory) that claim that the source domain is processed first and then the
process of the target domain. Time of processing studies contradict this

The use of conceptual metaphors
domains. The literature abounds with obvious examples.

The neural theory in general predicts that the most immediate component
conceptual mappings that pre-exist, frame-based knowledge that pre-exists, and adding
most cases, new conceptual metaphors that are easy to learn and make sense of are using

Animal    The neural theory in general predicts that the most immediate component
In the Animal Keeper Frame, The Animal stands for The Job of Taking care of that
childhood experience has an important influence on the system of primary metaphors that
metaphorical interpretation for this sentence. However, that sentence can be metonymic,

There are no primary metaphors in our normal conceptual systems that provide a natural

Animal Keeper: My job is an aardvark

Comparing this sentence with a sentence like

Animal    The neural theory in general predicts that the most immediate component
In the Animal Keeper Frame, The Animal stands for The Job of Taking care of that
childhood experience has an important influence on the system of primary metaphors that
metaphorical interpretation for this sentence. However, that sentence can be metonymic,

There are no primary metaphors in our normal conceptual systems that provide a natural
notion of mental simulation, which represents specific situations. Let us look first at inferences in NTL, and then at metaphorical inferences.

Inferences

A meaningful node in a neural circuit is a node that can activate a mental simulation. An inference occurs when:

1. the activation of a collection of meaningful nodes (the antecedent situation) in a neural circuit leads to the activation of one or more other meaningful nodes (the consequence)
2. and when the activation of the antecedent nodes is necessary for the consequence
3. and when the inhibition of one or more consequence nodes results in the inhibition of one or more antecedent nodes.

Inferences are simply consequences of the meaningfulness of nodes in simulation semantics, the spreading of activation, and syntactic constraints (the consequence inheres in the antecedent best). Recall that the maximization of binding is one of the characteristics of mental space in short-term memory. The totality of source domain inferences does not have to proceed before any of the target domain inferences. Source domain inferences will be mapped as soon as they are available.

Metaphorical Inferences

A metaphorical inference occurs when:

1. a metaphorical mapping is activated in a neural circuit,
2. there is an inference in the source domain of the mapping,
3. and a consequence of the source domain inference is mapped to the target domain, activating a meaningful node.

For example, suppose the sentence is "We’re driving in the fast lane on the freeway of love." In the travel domain, driving in the fast lane on the freeway activates the inferences that

1. the vehicle the travelers are in is going a lot faster than usual,
2. the driving is exciting,
3. and it can be dangerous (the travelers can suffer physical harm).

"Freeway of love" activates the target domain of love and source domain of travel, resulting in the activation of the Love Is a Journey metaphorical mapping. The metaphoric inferences are simply consequences of the meaningfulness of nodes in simulation semantics, the spreading of activation, and base constraints (the consequence inheres in the antecedent best). Recall that the maximization of binding is one of the characteristics of mental space in short-term memory. The totality of source domain inferences does not have to proceed before any of the target domain inferences. Source domain inferences will be mapped as soon as they are available.

Mapping "Gaps"

A mapping gap occurs when there is a metaphorical mapping but part of the source domain frame has no correlate in the target domain. For example, take the sentence "I gave Sam that idea." In this metaphor, the communication of an idea is the transfer of an object from the speaker to the hearer.

(A) Source domain knowledge: the giver loses the object when he gives it to the recipient.
(B) Target domain knowledge: the speaker does not forget the idea when he tells it to the listener.

Because we know (B) about the target domain, no mapping from (A) to (B) can be learned. Thus, what appears to be a "gap" in the target domain is just that: an impossible mapping. However, repeated co-activation of the corresponding source and target nodes during the learning of the metaphor can lead to the learning of this impossible mapping.

Image-scheme "Preservation"

As Regier (1995, 1996) and Dodge and Lakoff (2006) have argued, primitive image schemas (e.g., container, source-path-goal, degree of closeness, direction and amount of force) are computed by brain structures that are either innate or form early. Action schemas and frames are structured using such primitive image schemas. For example, putting in makes use of the container schema, the source-path-goal schema, a force schema, a direction schema, and an aspectual schema.

Metaphorical putting-in — as in "The Founding Fathers put freedom of speech into the Constitution" — uses physical putting-in as a source domain. The inference patterns of those schemas as bound together in the source domain are then used in metaphorical inferences. For example, if you put something into a physical container, it isn’t there before you put it in and it stays there afterward and remains there until something happens to remove it. This is also true of the freedoms the Founding Fathers put into the Constitution. In pre-neural theories of conceptual metaphor, we spoke of "preservation," of source domain image schemas being preserved in the target domain. In neural theory, there is no "preservation" since the source domain image schemas are directly used via the neural mapping in target domain inferences.

Mental Spaces

A mental space from an NTL perspective is a mental simulation characterizing an event, but not the event itself. The neural circuitry used to represent a mental simulation is located anywhere in the brain, but the totality of the neural circuitry used to represent a mental simulation is located anywhere in the brain.
Best-fit principles include the maximization of neural bindings and prior neural activation maps, given that neural systems work by spreading activation and best-fit principles. A great deal follows from the understanding of blending in terms of blending:

Optimality in Blending

Blend Source 1: The verticality of the mercury. Crucially different from that metaphor plus a blending map from source entities to a numerical quantity. We understand a thermometer through the following blend:

Again, a mere metaphor (understanding the target in terms of the source) is going up physically. There are also scalar markings on the thermometer indicating heat in itself is not vertical. The metaphor imposes verticality.

Now consider a thermometer. In a thermometer oriented vertically, the mercury goes up— the same entity!

The number and the point on the line are understood as identical— the same person in the complex source. Let us now consider a metaphorical blend.

Metaphors versus blends

Let's consider another contrast. Suppose you are explaining arithmetic to a child. You draw a line. And you say, "Think of a number as being a point on this line. Say this: You have three steps to move you forward. You have five steps back to move you backward, and you get to 3." And so on. Here you just using the metaphor that numbers are points on a line. But if you go to the Cartesian plane where you have a number line, then you not only have the metaphor of numbers as points on a line, but you have a blending map as well: The number and the point on the line are understood as the same entity.

The height on a thermometer comes from the blending map: The height of the vertical entity in Blend Source 1 is linked by an identifying linking circuit to the top of the column of mercury in the Blend Target. The language for describing the temperature on the thermometer comes from the Blend Target: The thermometer, where there is a binding between the top of the column of mercury and the corresponding marking on the quantity scale.

Let's consider another contrast. Suppose you are explaining arithmetic to a child. You draw a line. And you say, "Think of a number as being a point on this line. Say this: You have three steps to move you forward. You have five steps back to move you backward, and you get to 3." And so on. Here you just using the metaphor that numbers are points on a line. But if you go to the Cartesian plane where you have a number line, then you not only have the metaphor of numbers as points on a line, but you have a blending map as well: The number and the point on the line are understood as the same entity.

The height on a thermometer comes from the blending map: The height of the vertical entity in Blend Source 1 is linked by an identifying linking circuit to the top of the column of mercury in the Blend Target. The language for describing the temperature on the thermometer comes from the Blend Target: The thermometer, where there is a binding between the top of the column of mercury and the corresponding marking on the quantity scale.

To see the difference between a metaphor and a metaphorical blend, consider the following:

Let's consider another contrast. Suppose you are explaining arithmetic to a child. You draw a line. And you say, "Think of a number as being a point on this line. Say this: You have three steps to move you forward. You have five steps back to move you backward, and you get to 3." And so on. Here you just using the metaphor that numbers are points on a line. But if you go to the Cartesian plane where you have a number line, then you not only have the metaphor of numbers as points on a line, but you have a blending map as well: The number and the point on the line are understood as the same entity.

The height on a thermometer comes from the blending map: The height of the vertical entity in Blend Source 1 is linked by an identifying linking circuit to the top of the column of mercury in the Blend Target. The language for describing the temperature on the thermometer comes from the Blend Target: The thermometer, where there is a binding between the top of the column of mercury and the corresponding marking on the quantity scale.

The entire space is governed by a gestalt node, which makes the mental space a "unit"
weights. That means the maximal use of conventional frames, metaphors, commonplace knowledge already in the brain, plus context. What results are "emergent" inferences. From this account of blending we get a set of predictions — exactly the well-known properties of optimal blends as described by Fauconnier and Turner:

- **Integration:**
  The scenario in the blended space should be a well-integrated scene. Each neural binding and identifying linking circuit (a link plus a binding) across conceptual structures serves to "integrate" those conceptual structures.

- **Web:**
  Tight connections between the blend target and the blend sources should be maintained, so that an event in one of the blend sources, for instance, is construed as implying a corresponding event in the blend target. Such correspondences are given by neural bindings, metaphor maps, maps across simulations (mental spaces), and blending maps.

- **Unpacking:**
  It should be easy to reconstruct the inputs and the network of connections, given the blending target. Neural bindings have the property that they can be "relaxed" — that is, neurally bound structures can be conceptualized without the binding, as when you can separate off the blueness of a blue Volkwagen and think of it as red.

- **Topology:**
  Elements in the blend should participate in the same sorts of relations as their counterparts in the inputs. This follows immediately since adding a neural binding and identifying linkages to a structure A does not remove any structure in A. It just adds more structure.

- **Good Reason:**
  If an element appears in the blend, it should have meaning. And if it arises by inference, it will be tied into the logic of the blend.

  Since blending maps apply to simulation spaces to yield another simulation space, and since simulations get meaning through their embodiment, this follows immediately.

- **Metonymic Tightening:**
  Relationships between elements from the same input should become as close as possible within the blend. For instance, Western images of personified Death often depict the figure as a skeleton, thus closely associating the event of death with an object that, in our more literal understandings, is indirectly but saliently associated with it.

  When there is a neural binding circuit between A and B, all the circuitry activated and unactivated by either A or B acts together as if A and B were a single entity. This is "tightening." Since blending maps contain identifying linking circuits, which contain bindings, they give rise to "tightening." In the case of the Grim Reaper discussed by Fauconnier and Turner, a commonplace metonymy is activated: The Cause Stands for the Result. Here the Cause is Death and the Result is the Skeleton. The Blend has the following structure:

  **Blend Source 1:** Death
  **Blend Source 2:** Skeleton
  **Blend Target:** The Grim Reaper — Death understood as personified in the form of a skeleton.

  The Metonymy: Cause (Death) stands for Result (Skeleton).

  The Blending map, using identifying links:
  - The metonymic source, Death, is identified with the Grim Reaper.
  - The metonymic target, Skeleton, is identified with the Grim Reaper.

  The use of "Death" to name the Skeleton is a result of the metonymy.

Emergence

Emergence is the occurrence in a blend of an entity or proposition that does not exist in any of the blend "inputs." Emergence is explained by inference in neural systems. Blending maps and other maps and bindings across conceptual structures can give rise to emergent inferences in a blend of an entity or proposition that does not exist in any "input" conceptual structures.

"Good Analyses with Metaphoric Blends"

Better Analyses with Metaphoric Blends. Certain classic analyses in the blending literature which are seen as non-metaphoric blends really should be seen as metaphoric blends. For example, there is a common metaphor in which Breaking a Record Is Winning a Race Against the Previous Record-holder. Thus, a few years ago when Mark McGwire and Sammy Sosa were both attempting to break Babe Ruth's home run record, the press represented the situation metaphorically as a race with Ruth — and each other. In the daily papers, McGwire and Sosa were represented by how many games they were "behind" or "ahead" of Ruth's 60
My lawyer presented my case with surgical skill.

• sloppy and acting more with force than with care, with messy results. Thus, we can say they do say that. In addition, you would expect them to be saying that the surgery, is known for being butcher known for being precise with the beneficial results, while a surgeon is a butcher by profession, so you would expect these sentences to act like butcher frame expands the general frame with the characteristics filled in by butcher characteristics.

The butcher is a surgeon correct, we would expect these sentences to act like surgeon frame whose semantic roles include kinds of characteristics. For example, a surgeon is a butcher by profession, so you would expect these sentences to be used metaphors rarely analyzed as such.

Let's consider another class of cases with the same moral. There are two widely cases outside the proposed conventional metaphors we just discussed. Consider sentences that affects the analysis you give of what the brain would be doing. We can see what is wrong with this approach by looking at metaphors and a whole conceptual system. And you start with the best-fit property, and that all such cases are literal blends based on similar terms of bindings based on similarity. Such an approach would claim that there is no metaphor. The moral: A neural theory analysis forces us to notice analyses we might otherwise miss. The reason is this. As soon as record-breaking is at issue, the general metaphor will be made active. If it is used, then there is a better fit than if it is not used.

The first case says the butcher cuts meat with the care of a surgeon, while second says My surgeon was a butcher.

My surgeon handled my surgery in a careless, sloppy, and heavy-handed way. Remember: the more existing high-activation-weight circuitry that is activated, the better the fit between the current situation and the prior state of the brain. In short, the best-fit principle by which neural networks operate prefers such analyses. The metaphor will be made active.

My surgeon was a butcher. My butcher is a surgeon. My lawyer is a Russian. My lawyer butchered my case.
The metaphor is a physical circuit, ready to be activated. The language activates it. The metaphor is always present, with the idea of greater quantity. More is Up. Prices went up in the sentence up. Thus, the metaphors become very very strong and resistant to change. Secondly, spreading the subject matter under discussion is in the target domain of that metaphor. • Because the fundamental metaphors are used constantly, the synaptic strengths in more about such systems and people who think in terms of them most of every day. We usually speak of metaphorical language when of thought rest on a relatively small number of metaphors treated as ultimate truths and of the word. Is that word an instance of "metaphorical language"? That is not how the...
of the moving time. Those who were on the plane and coming off were primed by being
primed the moving time metaphor and they gave the answer “Monday,” two days ahead
can explain Lera Boroditsky’s classic experiment at San Francisco airport. She showed
they are mutually contradictory, the metaphors are mutually inhibitory. The neural theory
depending on which metaphor for time is used — moving-ego or moving-time. Since

Showing how primary metaphors contribute to complex conceptual metaphors;

•

The neural theory also clarifies what the study of metaphor is about, namely,
showing how metaphorical language works as a simple extension of non-metaphorical
language in context. We know that metaphor does not reside in words but in ideas. This is

How metaphorical inferences work; why they should exist; how they operate in
context, and how they interact with simulations.

Why there should be conceptual metaphor at all; what conceptual metaphors are

neural model.

Life is a Struggle

A

and

Rage, rage against the dying of the light

All of the properties of the old metaphor theory, the theory as described by myself
and Mark Johnson in

Contemporary Theory of Metaphor.

What makes metaphorical language meaningful?

Language is meaningful when the ideas it expresses are meaningful. Conceptual
metaphors are meaningful when they are grounded.

The neural theory explains:

•

neural model.

The neural theory provides a much better understanding of how thought and

metaphors are meaningful when they are grounded. They are grounded, first, by source
domain embodiment, and second by the embodiment of the source and target domains of
emotion.

Conceptual metaphors are meaningful when they are grounded. They are grounded, first,
by source domain embodiment, and second by the embodiment of the source and target
domains of emotion.

Language is meaningful when the ideas it expresses are meaningful. Conceptual
metaphors are meaningful when they are grounded. They are grounded, first, by source
domain embodiment, and second by the embodiment of the source and target domains of
emotion.

Conceptual metaphors are meaningful when they are grounded. They are grounded, first,
by source domain embodiment, and second by the embodiment of the source and target
domains of emotion.

The neural theory also clarifies what the study of metaphor is about, namely,
showing how metaphorical language works as a simple extension of non-metaphorical
language in context. We know that metaphor does not reside in words but in ideas. This is

How metaphorical inferences work; why they should exist; how they operate in
context, and how they interact with simulations.

Why there should be conceptual metaphor at all; what conceptual metaphors are

neural model.

Life is a Struggle

A

and

Rage, rage against the dying of the light

All of the properties of the old metaphor theory, the theory as described by myself
and Mark Johnson in

Contemporary Theory of Metaphor.

What makes metaphorical language meaningful?

Language is meaningful when the ideas it expresses are meaningful. Conceptual
metaphors are meaningful when they are grounded. They are grounded, first, by source
domain embodiment, and second by the embodiment of the source and target domains of
emotion.
• Showing how both primary and complex metaphors contribute to the meanings of words, complex expressions, and grammatical constructions;
• Showing how conceptual metaphor plays a role in abstract concepts and overall conceptual systems (as in politics, philosophy, and mathematics);
• And, finally, showing how conceptual metaphors contribute to the understanding of language and other uses of symbols.

How Does a Metaphor Analyst Make Use of All This?

Metaphor analysts rarely know neural computation, and they shouldn’t be expected to. The Neural Theory of Language Project has figured out a way to let linguists be linguists and not computer or brain scientists. We have invented a notation that correlates with circuitry with the appropriate computational properties, but can be used by analysts without worrying about the computational details. Thus, consider a notation like:

Metaphor: LoveIsAJourney
Source Domain: Journey
Target Domain: Love
Mapping:
- Travelers —> Lovers
- Vehicle...
- LifeGoals
- Difficulties —> ImpedimentsToMotion
- Purposes —> Destinations
- Difficulties Are Impediments to Motion
- Impediments to Motion = Self.Source.ImpedimentsToMotion
- Difficulties = Self.Target.Difficulties
- Closeness = Self.Source.ClosenessOfTravelersInVehicle
- Closeness = Self.Target.IntimacyOfLovers
- A Relationship Is A Container
- Container = Self.Source.Vehicle
- Relationship = Self.Target.Relationship

The statement that this is a metaphor corresponds to the appropriate mapping circuit. The name of the metaphor corresponds to the appropriate gestalt node. The arrows ("—>") correspond to linking circuits. The statement of the mapping specifies what maps to what. The equal signs ("=") specify the neural bindings. The "evokes" statement sets up linking circuits activating the "component" metaphors, with neural bindings between LoveIsAJourney (called "Self" in the formalism) and the various component metaphors. There can be, and often is, a chain of "evokes" statements that ultimately lead to primary metaphors that ground the metaphor system in experience.

This formalism is easy for metaphor analysts to learn and use. It can be converted by algorithm to computational neural modeling programs that, say, take a sentence as input and produce an analysis as output. There are corresponding formalisms for grammatical and lexical constructions, metonymies, frames, image-schemas, and so on.

The technical term for the notational system is Embodied Construction Grammar.

Conclusion

This is where we are in the Neural Theory of Metaphor as of January 2009. We have a reasonable early approximation to the kinds of computations that neuronal groups must perform to characterize frames, metaphors, metonymies, mental spaces, and blends. A parsing program to use these kinds of computations is being constructed. Thousands of frames and hundreds of metaphors have been analyzed informally to date and can readily be converted to the notation system. And we know enough about natural metaphor learning to understand how the metaphor system gets built up just by functioning in our everyday lives.

References


