The Analogical Mind
Perspectives from Cognitive Science
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Dedre Gentner
Keith J. Holyoak
Boicho N. Kokinov

1. Introduction: The Place of Analogy in Cognition. (Holyoak Gentner Kokinov)

Thinking about Relational Patterns. Analogy underpins language, art, music, invention and science. It seems that analogical capabilities were well developed in humans at least 50,000 years ago. Humans have the ability to pick out patterns and to identify recurrences of these patterns despite variation in the elements that compose them, to form concepts that abstract and reify these patterns, and to express these concepts in language. Chimpanzees also have some capacity for relational patterns (but other monkeys do not) and human infants demonstrate the capability early in development. Simulating this capability is easy using symbols but difficult in a neural substrate where 'binding' the role to the filler is particularly difficult. Even more difficult (for both systems) is the flexible dynamic re-organization apparent in human representations.

From Gilgamesh to the Microbiology Lab. Direct expression of analogy in historical record became possible with the development of written language. Emotional experiences are notoriously difficult or impossible to convey by literal language; but by connecting the relational pattern of a novel experience with that of a familiar emotionally-laden one, analogy creates a way of recreating a complex pattern of feelings. The progression of highly specific, single-case analogies to more abstract concepts or schemas is one of the most powerful roles that analogy plays in cognition. Analogy forms a critical part of the core of cognition.

Analogy in Cognitive Science. Research into analogy only began in the late 1960's and expanded in the 80's. Gentner was struck by the idea that in analogy, the key similarities lie in the relations that hold within the domains, and often relations between relations. Gentner set forth the view that analogy entailed finding a structural alignment, or mapping between domains. Gick an Holyoak provided evidence that analogy can provide the seed for forming new relational categories, by abstracting the relational correspondences between examples into schema for a class of problems.

“In a typical reasoning scenario, one or more relevant analogues stored in long-term memory must be *accessed*. A familiar analogue must be *mapped* to the target analogue to identify systematic correspondences between the two, thereby aligning the corresponding parts of each analog. The resulting mapping allows analogical inferences to be made about the target analog, thus creating new knowledge to fill gaps in understanding. These inferences need to be evaluated and possibly *adapted* to fit the unique requirements of the target. Finally, in the aftermath of analogical reasoning, learning can result in the generation of new categories and schemas, the addition of new instances to memory, and new understanding of old instances and schemas that allow them to be accessed better in the future.

Overview of the Book.

2. Exploring Analogy in the Large. (K.D.Forbus)

Introduction. Simulating the roles comparison plays in larger-scale cognitive processes is important.

SME and MAC/FAC: A Brief Review. SME simulates Gentner's Structural Mapping Theory of psychologically consistent comparison processes. SME accepts a base and target which are symbolic representations of a predicate/argument structure. Each representation can include attributes, relations between entities and higher-order relations between relations. SME computes a handful of mappings between the target and base, each of which align corresponding items in the target and base. SME operates in polynomial time and can be incrementally extended as more information becomes available about the target or base. MAC/FAC models similarity-based retrieval by rapidly selecting a few promising candidates (non-structurally) and then using SME to analyze them further for a structural match. These approaches have both initiated further psychological research and enjoyed some confirmations. The additional limitations of working memory and of sequential processing in time are under investigation with LISA and SIAM.

Arguments for Large Scale Analogical Simulations. Isolating processes in cognitive science is both highly valuable and notoriously difficult to achieve. However, when a process is isolated then the assumptions about the surrounding system are critical.

The Integration Constraint. Is that a cognitive simulation must be able to serve as a component of a larger simulation.

Other Components are coming together. There is now a better understanding of how to build AI systems, tremendous increases in computing power and memory, and increased interest in larger scale systems. In larger scale systems, the number of under-constrained assumptions becomes unmanageable, but assumptions in smaller systems are often made without justification. Reaction times are unlikely to be a useful performance measure at the larger scale and more emphasis will have to be placed on content orientated measures

Large Scale Analogical Processing as a Source of Constraints. Brian Falkenhainer (1987, 1990) created Phineas which learned physical domain theories by analogy with previously understood examples. Phineas used SME and two other self-contained modules: QPE employs Qualitative Process theory which produces an envisionment (predictions for a specific situation given the qualitative laws of the domain); and DATMI which takes the envisionment and explains the specific behavior in terms of the envisionment.
An example was given of an analog drawn between hat flow into a cold brick from the surrounding liquid and the flow of water between two vessels.

Example: Mental Models. Mental models are the models people use in reasoning about the physical word. They are runnable in that there is a sense of deriving answers via mental simulation rather than logical reasoning. Qualitative physics research has developed a variety of techniques for reasoning from first principles about physical situations, even with very little information. The results involve high level conceptual descriptions of physical values and their changes, typically involving sign (+-) information and ordinal relationship between parameters. People often use these when describing interactions between continuous parameters. However the reduced resolution of this approach results in an exponential growth of possible solutions and a large number of spurious (impossible) outcomes. The solution may lie in the use of in-domain analogies as observed behaviors do not include logically or physically impossible behaviors. Memory based reasoning is more generative than might be expected because 1) qualitative representation groups many similar situations, 2) Analogy can generate a prediction in a novel situation and 3) multiple analogies can cover complex situations.

The Hybrid Similarity Model of Commonsense Reasoning. Commonsense reasoning may arise from the interaction of analogical and first-principles reasoning. While qualitative physics assumes that domain knowledge is completely generic, this model recognizes that knowledge varies continuously from generic through to intermediate (context dependent) situated rules through to the highly specific. Simulation is within reach with existing modules and techniques.

Example: case based coaching. A web/email based system which provides coaching to Engineering thermodynamics students. An analogy is drawn between the students design and an existing base design. Each base design has a specific associated problem and transformation providing a solution to the problem. The associated improvement which is suggested to the student via email. The system has the advantage of speed and of avoiding the need for manual indexing and linking between related training examples.

Scaling Up: How structure-mapping fares. The real world examples provided and two others (reasoning from historical precedents about

international crisis and critiquing battlefield courses of action) are promising. Some of these cases involved thousands of propositions.

The Integration Constraint Revisited. Processes need to operate in a range of domains. Systems must be able to scale up. Candidate inferences must be structurally sound. Processes must have realistic resource requirements. Tailorability in processing should be avoided. Constraints can emerge from the interaction of processes.

Discussion.

Thoughts.
This fellow is pinning his hopes on “more power” and at the same time casting aside the importance and elegance of efficiency.

3. Integrating Memory and Reasoning in Analogy-Making: The AMBR Model.
(Boicho N. Kokinov and Alexander A. Petrov)

Reuniting Memory and Reasoning Research; An Appeal for a Second Marriage after their Divorce. It is important in the study of Cognition, to separate the problem into manageable pieces for study, but it is also important to study the assembly of the pieces. Various authors in this volume attempt to integrate various aspects of cognition such as analogy, memory, learning, conceptual blending etc.

Successful modeling requires as many constraints as possible to eliminate degrees of freedom. Modeling of cognitive processes can exploit behavioral, biological, evolutionary, developmental, and architectural constraints.

Reconstructing the Dinosaur: The Dynamic and Constructive Nature of Human Memory. There is no consensus on a single and unified theory of memory or even on a single general metaphor for memory. The classical “storehouse” metaphor involving static structures and active processes has been very influential but under continuous challenge. An alternate view considers memory as a re-“constructive” process. Investigations based on the storehouse metaphor have used simple artificial material such as lists of numbers or words and measures success/failure ratio. Investigations based on the constructive metaphor focus on human recollections and errors of memory in real world situations. We argue that the constructionist metaphor is highly relevant and reveals important behavioral constraints for modeling.

Human Memory: Sharp, Complete and Fixed or Blurry, Partial and Flexible? Even so called “flashbulb” memories for important events are partial and distorted and everyday memories more-so. Recollection is very context dependent with every difference in context responsible for a reduction in the priming effect.

“To summarize, people make many omissions and describe objects and events only partially, but they do so in a context sensitive manner: different omissions on different occasions. There is an apparent hyper-specificity of human memory, which leads us to think that all aspects of an episode are encoded and all of them facilitate our memory for that episode, but on any occasion only a very small part of them can be reproduced. The conclusion that we draw is that memory representations are very flexible and context dependent.” pg 67

Concepts are also probably constructed on the fly rather than invariant categories.

A**re there False Memories and Memory Illusions?** "False memories arise by two major means: either by blending two or more episodes, or by intrusions from some generic knowledge or schema." pg 68

Failure to distinguish between various sources of information results in inclusion of misinformation and in confabulation to varying degrees.

"Partial information about a target item is used to construct a partial description of the item and this description is then used to recover new fragments." pg 71

"we may conclude that there are no clear cut boundaries between episodes or between episodes and generic knowledge." pg 72

Dynamics of Recall and Order Effects. Memory order effects are the effect that the recollection order has on the analogy-making process.

Interplay between Memory, Reasoning and Perception in Analogy-Making: Interaction Effects. Most research (storehouse and constructional) has concentrated on deliberate and voluntary remembering with only sparse research on selection of an appropriate episode from long term memory.

"It has been established that the existence of similar story lines or similar objects is a crucial factor in analogical reminding ... [and] ... that structural correspondence does not have much effect on reminding" pg 74

Omissions, Blendings, and intrusions in Spontaneous Remindings in Analogy-Making: Effects of Reasoning on Memory. An "experiment has shown that remindings about the base story are not all-or-nothing events and that subjects make omissions, insertions, and blendings with other episodes influenced by the correspondences established with the target problem." pg 76

Priming: Effects of Memory on Reasoning. A problem solving experiment showed that the priming effect decreased exponentially and disappeared after 25 minutes and that the subject remained unaware of the priming effect.

Context Effects: Effects of Perception on Reasoning. The perception of incidental elements of the environment during a problem solving process can alter it. The subjects can be unaware of this effect and furthermore a positive influence from the environment can be disturbed by drawing attention to it. The perceptual order can also have an influence.

General and Specific Behavioral and Architectural Constraints on Models that Integrate Analogy and Memory.

Findings specific for analogy-making
•*Similarity effect*: semantic similarity between story lines, objects, properties, and possibly relations in both domains is crucial for analogical reminding
•*Structural effect*: structural correspondence (similar objects playing similar roles) plays a very restricted role in analogical reminding and operates only when there is general similarity between the domains
•*Encoding effect:* similarity between encoding and test conditions (type of task and focus on similar aspects) plays a role in reminding
•*Schema effect*: the presence of generalizations of several analogous experiences from the past assists analogical reminding
•*Familiarity effect:* familiar analogs have advantage during reminding Memory order effect: the order of recalling the elements of the old episode influences the mapping
•*Perceptual order effect:* the order of perceiving the elements of the target influences the mapping
•*Mapping effect on memory:* the mapping process influences the recall of details of the old episode(s) and their order
•*Mapping effect on perception:* the mapping process influences the encoding of details of the target and their order (no experimental support for this potential effect)

Findings about human memory in general
•*Omissions:* details of the episodes are recalled selectively depending on the context
•*Blending:* episodes are blended; intrusions from other episodes take place, especially when important elements are not available in the dominant episode
•*Schematization:* intrusions from generic knowledge take place
•*Context-sensitive representation of episodes and objects* (effects on reminding, recognition, priming)
•*Context-sensitive representation of concepts*
•*Gradual recall and order of recall:* episode elements may be recalled in different order
•*Priming effects on episodes*
•*Priming effects on generic knowledge, including facts and concepts*
•*Environmental context effects:* perception of accidental elements from the environment may play a role in reminding and mapping

The storehouse metaphor, with centralized and frozen representations of episodes underlies most

analogy making models, including AMBR1.

Analogy-Making in a DUAListic Society: The AMBR View of Analogy. Associative Memory Based Reasoning was proposed by Kokinov in 1988. The AMBR research group is established a the New Bulgarian University.

Basic Principles of the AMBR Research Program.
Methodological principles
•Integrating analogy-making with memory, perception, learning, reasoning, i.e., reintegrating human cognition
•Integrating various subprocesses of analogy-making such as representation building, analogical reminding, mapping, transfer, evaluation, learning, i.e., reintegrating analogy
•Grounding the model of analogy-making in general cognitive architecture
Design Principles.
•Dynamic context-sensitive emergent computation
•Dynamic context-sensitive emergent representations
•Integrating symbolic and connectionist processing by microlevel hybridization

The DUAListic Society: A General Cognitive Architecture. The DUAL cognitive architecture represents knowledge as the dynamic communication between a coalition of micro agents. An agent might represent a single proposition or concept, and carry out information processing within th architecture. The participation of an agent is graded by its relevance to the current task which determines both the processing speed and the degree of influence on neighboring agents. Agents are a hybrid between symbolic and connectionist approaches as they process symbols internally and pass symbols along the connections between agents. There are both permanent and temporary agents and links.

DUAL is an adaption of Minski's Society of Mind but, compared to other adaptations, DUAL is deterministic and has a less centralized storage.

The AMBR1 Model.

AMBR1 integrated memory, mapping, and transfer and simulated analogy-making in a common sense domain – boiling water and preparing tea and coffee in the kitchen and in the forest. The model has realistic working memory requirements, mapping and memory interact, hypothesis are constructed dynamically, the context determines the participants in the constraint satisfaction network, semantic similarity is computed dynamically, and structure mapping can proceed despite a different number of arguments. However, AMBR1 has a rigid and frozen representation of episodes which was the driver for developing AMBR2.

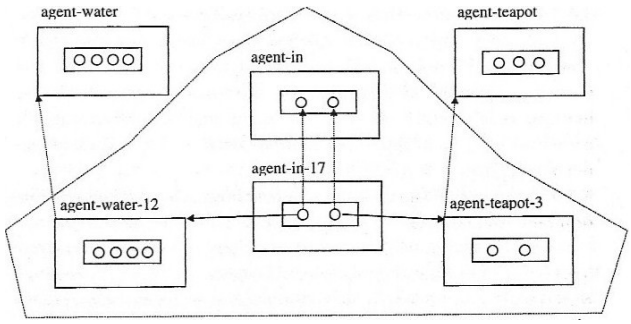
The AMBR2 Model.

The improvement over AMBR1 is that episode representations are also emergent and context sensitive. Concepts and objects are stored as for AMBR1, by a coalition of agents, but with a named leader with a partial list of members. Episodes are the same but without a leader or a name. Mapping and transfer are difficult to achieve in the absence of full lists of propositions. AMBR2 implements mapping but not transfer.

Integration of Memory and Reasoning in AMBR2.

Collective Memory in AMBR 2.

Memory is a collective phenomenon. A proposition such as “A is in B” has 3 slots holding one or more pointers to other agents which fill the slots.



It is a combination of symbolic and connectionist approaches. A stone might be represented by the named leader of a coalition and each member represents a property or relationship of the stone. The leader only has a partial list of members. Concepts are linked only the most salient instances while all instances are linked to the concept. Episodes are large coalitions, with out a leader but with a unique place/time member which other members are linked to.

Spreading Activation is the basic memory mechanism as the activation level of an agent determines its participation in both the representation and computation process. The slow decay of activation gives rise to priming effects. There are only excitatory links in long-term memory and dynamically built inhibitory links.

Collective Reasoning in AMBR2. Mapping is performed by gradually building and relaxing a constraint satisfaction network CSN. The CSN consists of temporary hypothesis agents and

temporary inhibitory links between them and it is tightly interconnected with the permanent agents. There is a two way flow of activation between the hypothesis agents and permanent agents (containing the concepts and episodes). There are two mechanisms for constructing new hypothesis agents.

Computing Semantic Similarity Dynamically by a Marker Passing Mechanism. When the lead agent of a coalition enters working Memory it emits a marker which propagates up the superclass hierarchy. A new hypothesis is built based on the intersection of a marker from the target and a marker from permanent memory. This mechanism identifies semantic similarities.

Ensuring Structural Consistency by a Local Structure Correspondence Mechanism. Top-down construction is initiated when a hypothesis is established that two propositions correspond to each other. Bottom up .... between the instances of two concepts.

Consolidating the CSN: Secretaries and Life Cycle of Hypothesis Agents. Because hypothesis are established locally it is necessary to have a mechanism to avoid duplicate competing hypothesis agents.

Dynamic Promotion and Selection of Winning Hypothesis. The secretary of each object, relation or concept maintains a current winner hypothesis and only gradually promotes alternate hypothesis. The evaluation and transfer mechanisms operate in parallel and use the current winner hypothesis as a starting point.

Interaction between Memory and Reasoning in AMBR2. This section is based on both case studies and aggregate statistics over many cases.

Perceptual Order Effects have been demonstrated clearly in AMBR2. **Influence of Mapping on Episode Recall** has been demonstrated in AMBR2 to be a result of both recall and mapping running in parallel and each bolstering the distributed representation of the other. **Blending of Episodes** occasionally occurs as spreading activation brings an assortment of agents (from different episodes) into working memory early in the run and occasionally a blend results. Incorporating **Generic knowledge into Episode Representations.** Spreading activation typically brings agents representing both episodes and generic knowledge into working memory. Sometimes a particular episode will provide a good match with the target and win. At other times, the episode will be insufficient for a complete match and generic agents my fill the “valencies”. The instantiation mechanism involves a complicated sequence of messages between agents that result in the generations of a specific proposition to replace the general proposition that is currently mapped to the specific proposition in the target. The instantiation process is an example of the interplay between deduction, memory and analogy.

4 The STAR-2 model for Mapping Hierarchically Structured Analogs.

The importance of analogy has been recognized but under-researched partly because of the difficulty of demonstrating it's effect in the laboratory where they tend to be superficial compared to the deeper, and ephemeral real-world use of analogy.

Analogy as a Mechanism in Children's Reasoning. Much of the research focuses on the age of attainment rather than the role that analogy plays in children's reasoning. The use if analogy by children can often provide viable explanations of research findings such as explaining the difficulties that children have when completing particular tasks. Analogy can provide explanations for the effectiveness of aids in mathematics education. There is also scope for analogy to have a greater explanatory role in logical inference. [link to brains can do logic but do not run on logic]. Abstract logic tasks are more difficult to complete than the same task in a practical setting.

The STAR model of analogy was developed to support the arguments that analogy underpins higher cognitive processes, the implicit-explicit distinction, and processing capacity limitations.

The STAR Model of Analogy.
(Structured Tensor Analogical Reasoning)

STAR-1 is a neural net model that represents analogy as tensor products (the other main alternative is as a synchronous oscillation Holyoak). The *n*-ary relation R on $A_1xA_2xA_3x...xA_n$ is represented as a tensor product space $V_R \otimes V_1 \otimes V_2 \otimes ... \otimes V_n$ where each vector V is orthonormal. A single vector can be retrieved from a relation with a dot-product operation and propositions can be superimposed by addition of the tensor products.

Capacity and Complexity. The STAR model assumes that capacity limitations are defined by the complexity of the relationships that can be processed in parallel. Relations with more arguments (dimensions) impose higher processing loads and adult humans can process a maximum of 4 dimensions in parallel. Tensor processing load increases exponentially with the number of arguments. This load can be managed by *conceptual chunking* into fewer dimensions (with some dimensions temporarily inaccessible) and/or *segmentation* into smaller serially processed steps. The most efficient way of performing segmentation is by using a hierarchical representation for which STAR-1 was limited and STAR-2 was developed.

The STAR-2 Model. Structures are represented hierarchically such that each argument is either an element or a proposition. A constraint satisfaction network sequentially selects pairs of propositions with up to 4 arguments to be mapped in parallel by another constraint satisfaction network. There are three main structures: the focus selection network, the argument mapping network and the information storage structures. The steps involved are:
1.Information storage structures are established to represent the domains (manual input).
2.The focus network is established and selects a single pair of propositions using heuristics.
3.The argument selection network is established and maps between current symbols and arguments. The mappings are stored.
4.Steps 2 & 3 are repeated with different selected pairs of propositions.

Argument Mapping Network. Consists of a constraint satisfaction network mapping up to five relation/symbols to up to five argument positions. Mapping Heuristics are implemented with a biasing excitation/inhibition on each of the nodes including:
•Corresponding argument positions in base and target
•Similarity of the entities
•Type of the entities
•Salience
•Consistency with previous mappings

Focus Selection Network. Consists of a two-layer constraint satisfaction network mapping propositions from the target to those of the base. Layer 1 has similar biases as the argument mapping network and in addition bias to select from a similar hight in the hierarchy, similar number of arguments and corresponding relation-symbols and arguments. The design of Layer 2, and its unidirectional connectivity from Layer 1, selects a single set of winning terms from Layer 1.

Information Storage Structures hold information about the entities in both the base and the target including similarity between pairs or entities, salience of entities, entity type associations and associations between chunked and unchunked propositions. Mapping Scores are also held which reflect the uniqueness of the mapped entities and are used to determine biases in the argument-mapping network and the focus-selection network.

Termination Criteria. When 90% of the propositions in the smaller domain have formed a focus.

Analogies Solved.
1.A heat flow / water flow analogy

2.The Rutherford analogy between the structure of the solar system and the structure of th hydrogen atom (more propositions and more complex than #1)
3.The jealous animals problem is an analogy between isomorphic children's stories where animals play the roles in the story.
4.Addition/Union demonstrates the ability to find isomorphisms without semantic or pragmatic information.
5.The boy-dog analogy where the base and target have an isomorphic structure but there are no higher order propositions and no common relation symbols or arguments. (difficult for humans and STAR-2 fails).

Toward an Understanding of Analogy within a Biological Symbol System

Knowledge Representation in Models of Analogy.

There is a lot of research and ongoing controversy but analogy does involve retrieval of a source analogue from long term memory, mapping of source to target in working memory, generation and evaluation of inferences, and induction of relational schemas. All of these processes depend in part on representations with predicate-argument structure, especially relations (multiple arguments) and higher order relations.

"Analogy provides an important example of what appears to be a highly general cognitive mechanism that takes specific inputs from essentially any domain that can be represented in explicit propositional form, and operates on them to produce inferences specific to the target domain. At its best, analogy supports transfer across domains between analogs that have little surface resemblance but nonetheless share relational structure, and generates both specific inferences and more general abstractions from as few as two examples. ... They also provide a major challenge for computational models, particularly types of neural-network models that depend on huge numbers of training examples and that exhibit severely restricted transfer to novel inputs." pg 162

All major computational models of analogy are symbol systems based on knowledge representations that express the internal structure of propositions, binding values to the arguments of predicates. There has been considerable success but they often ignore capacity limitations on human working memory, and none have achieved full integration of access mapping, inference, and learning.

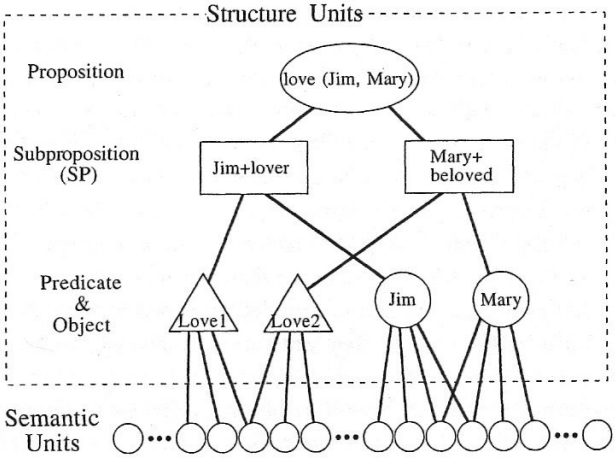
Holyoak and Hummel have been working on an new architecture for analogical thinking and other relational reasoning with greater psychological and biological fidelity.

Symbolic Connectionism: The LISA Model.
(Learning and Inference with Schemas and Analogies)

Dynamic Binding in a Symbolic-Connectionist Model. A basic requirement for relational reasoning is the ability to represent relations independently of their arguments. This allows commonalities in expressions to be recognized and flexibly generalized. LISA attempts to do this in a neurally plausible architecture where the interleaved synchrony of firing binds representations of roles to

representations of fillers.

Analog Representation, Retrieval and Mapping. The core of LISA's architecture is a system for dynamically binding roles to their fillers in working memory (WM) and encoding these bindings in long term memory (LTM). Case roles and objects are represented in WM as distributed patterns of activation on a collection of semantic units; case roles and objects fire in synchrony when they are bound together. Propositions are encoded in LTM by a hierarchy of structure units.



Object units are connected to semantic units that describe things while predicate units are connected to roles. Subproposition units bind roles to fillers. Structure units do not encode any semantic content. Finally, the Proposition units are all interconnected (between analogs), as are the subproposition units, are the predicates and objects. Mapping and retrieval involve selecting one driver and one or more recipients.

During pattern matching the activation in the driver Proposition spreads down to form a characteristic pattern in the semantic units – one pattern for each role-binding. These patterns tend to activate other analogs with similar characteristic, in the upwards direction.

This algorithm reflects many findings in human analog and retrieval including the role of working memory and the effects of analog similarity and size on analog retrieval. Of particular interest is that binding by synchronization is inherently capacity limited by the number of concurrent, different, phase sets that can be maintained. Humans are limited to 4-6 current bindings and LISA to 2-3. As a result, retrievals and mappings are largely serial in LISA and this in turn introduces important effects of the order that mappings occur.

Inference an Schema Induction. When the activation of a driver analogy results I the activation of a recipient analogy but a proposition is missing then this is taken as a cue to LISA to infer a new proposition in the recipient. Similarly, the direct connections between Propositions results in the heightened activation of semantic units common to both propositions. This is a cue to LISA to strengthen the connections to the common structure units - the development of a schema.

The Perception-Cognition Interface. There are some similarities between LISA and the JIM model of visual object recognition. Importantly, both models can solve analogies with different numbers of arguments – which is an important limitation of most models which represent case roles as elements in an ordered list.

The LISA model has been extended to solve transitive inference problems which involve the integration of at least two binary relations (e.g. A>B & C>A). There is some evidence that humans solve these problems by manipulation of mental arrays but it is difficult to explain just how. LISA's success with these problems indicates an alternate explanation.

“Like the representation the JIM uses to compute spacial relations, the symbolic representation of magnitude in MAM specifies all and only that which is relevant to the relation of interest ...” pg 178

Working Memory and Relational Reasoning.

The inherent WM capacity limitations of LISA due to the need to maintain bindings as mutually out of sync groups can be used to make some testable predictions about the characteristics of human reasoning.

Scaling Up: How LISA Can Map Large Analogies Despite Limited Capacity. “One of the apparent paradoxes of human analogical thinking is that people have great difficulty in mapping some small spartan analogs, yet easily map other analogs that are much larger and might seem more complex” pg 179

A large scale analogy between the Gulf War and WWII were used to investigate analogical mapping in humans and in LISA. This incorporated the important aspect of human's reading the analogy in a particular serial manner and LISA being presented with the information in comparable temporal fashion. LISA was able to identify sensible mappings for a large, ambiguous, and semantically rich analogy of the sort that humans are able to map. There was an interesting exception that humans appeared to try and commit to analogies as soon as possible (and play down subsequent information) while LISA placed more weight on the information presented

last.

Grouping Effects and Mapping Asymmetries. Analogical inferences are asymmetrical, but most models support an inherently symmetrical mapping process. However, LISA maps in a directional, capacity limited, and sequential process. "...recent studies point to a general conclusion: analogical mapping is highly sensitive to the specific information that is processed together in working memory. Relational mappings can be encouraged by manipulations that lead reasoners to consider multiple structurally informative propositions together, and is hindered by manipulations that reduce the effective capacity of working memory." pg 186

Neuropsychological and Neuroimaging Studies of Relational Reasoning. Patients with degeneration (frontotemporal dementia) of prefrontal cortex show dramatic impairment in the ability to make inferences requiring the integration of multiple relational representations. Neuroimaging studies strongly suggest that the prefrontal cortex must be centrally involved in the kind of working memory that is responsible for relational integration.

"...it is tempting to speculate that the mapping connections of LISA may be realized neurally as neurons in prefrontal cortex with dynamically reassignable response properties ..." pg 189

Conclusion. Summary.

There is a book on amazon about brain rhythms which might line up with this synchronous information

Note: the model is not neurally plausible because it has bidirectional excitation, every proposition is connected to every other proposition, and because nodes represent a specific thing and there is no reason to suspect that neurons do (to the contrary)

Metaphor is Like Analogy.
Gentner, Bowdle, Wolff Boronat

This chapter presents an approach that unifies metaphor with processes of analogy and similarity. Novel metaphors can be modeled as extended structural mappings between domains but conventional metaphors cannot. The *career of metaphor* theory describes how metaphors evolve from novel to conventional.

There are many types of metaphors but the structure of relations between base and target is central to metaphor interpretation.

According to structure mapping theory, analogical mapping is a process of establishing a structural alignment between two represented situations and then projecting inferences (Gentner 1983). Situations involve relations between objects and their properties, and the higher order relations between relations. Alignment is made according to structural consistency constraints and guided by the systemacity principle. Structural consistency involves 1:1 mapping between base and target and corresponding arguments to predicates. The systemacity principle favors higher order and connected relations over independent matches. Structure mapping makes a number of predictions that should follow if metaphors are processed like analogies.

Conceptual Metaphors as Extended Analogical Mappings. The possibilities for processing metaphors range from each being processed on-line as local analogical mapping and then discarded, thru to metaphors simply being polysemous (multiple) word groups with an established meaning. **Localist theories.** There is little empirical evidence on the online processing of extended metaphors. Most theories emphasize local interactions between pairs of terms and ignore large scale domain interactions. **Domain-Mapping Theories.** There is evidence to support the claim that metaphors involve mappings between large domains (eg birds and politicians) where the subject occupy similar relative positions within their domains. Various theories involve moving knowledge between domains, developing schemas, and large scale conceptual metaphors that create similarities and provide guidance.

Structure mapping provides a mechanism to explain how extended domain mappings are processed - systemacity and incremental mapping (by adding further assertions from the base).

The apparent transparency of the meaning of metaphors is misleading because they can take on vastly different meanings in different contexts. It is

difficult for researchers to separate the effects of analogy from a standard metaphorical meaning.

The conceptual role of domain mappings may possibly involve:

1. Metaphors create meaning by projective mapping onto the target domain (strongest)
2. Structural parallelisms where two domains share the same conceptual space
3. cognitive archeology where historical mappings have evolved into abstracts systems applicable to both domains.
4. Local lexical relations (weakest)

Testing the Domain-Mapping Hypothesis. We found evidence that novel metaphors are mapped and that highly conventional metaphors are processed in a localist manner (consistent with other evidence)

What Analogy Can Tell Us about the Processing of Individual Metaphors. The Structure Mapping Engine (SME) uses a local-to-global alignment process to arrive at a structural alignment of the two representations. Firstly, there is a blind and local matching of identical predicates; secondly, the local clusters are coalesced into structurally consistent connected clusters (kernels); and thirdly, the kernels are merged into one or a few structurally consistent global interpretations. SME then produces a structural evaluation of the interpretations in which the evidence cascades down from predicates to arguments (which favors deep systems).

"[Experimental] results support a process model in which an early symmetrical alignment process is followed by later directional processing. Early processing of metaphors, as tapped by the interference effect, is symmetrical. However, when full processing is allowed, a pronounced asymmetry appears between forward and reversed metaphors. Overall, the pattern fits the structural mapping claim of an initially symmetric processing followed by later directional projection of interfaces." pg 227.

Implications for Models of Analogy. Challenges many current models including NLAG, IAM, and LISA.

The Career of Metaphor.

"... the career of metaphor proposal traces metaphors from early alignment and mapping between literal meanings (the novel metaphor stage) to a later stage of dual representation in which the metaphor may be understood either by a novel alignment or by accessing an abstract representation (the conventional metaphor stage), to a stage in which the metaphoric representation has become a standard word sense for the base (the polysemy stage). At this point, the sense of metaphoricity disappears, and only polysemy remains. Sometimes, a still further stage occurs, in which the literal meaning disappears entirely, leaving only the (formerly) metaphoric sense as the meaning of the base term." pg 235

General Discussion

Addressing the Classic problems of Metaphor.

1. Metaphor recognition - as opposed to literal
2. Metaphoric meaning – creating meaning or reflecting parallels
3. Metaphoric induction – how and how much?
4. Directionality – why are they directional.

Structure-mapping can serve as an account of each of these problems. We suggest that systematicity imbalance can explain the directional asymmetry of metaphor as structure-mapping has the asymmetry arising after the initial alignment stage. This is supported empirically by the strong preference of subjects to have the more informative term as the base.

Implications for Metaphor research.
Conventional : idiom → metaphor → analogy : Novel
Most research has focused on conventional metaphors and some of that should be reexamined in light of the differences between conventional and novel metaphors.

Implications for Models of Analogy.
At the local level the results support alignment based models of analogy and metaphor. At a global level the importance of systematicity is emphasized with higher order relations (between relations) to constrain interpretation and inference. Also, the highlighting and storing of common schema is the chief mechanism by which novel metaphors become conventionalized.

How Metaphors are Different from Analogies. Metaphors can be more structurally variable that analogies; they can be attributable matches, relational matches, or both; they can even violate structural consistency. Also, metaphor are often used for novel and vivid non-literal comparisons. Analogy is used in explanatory-predictive contexts, while metaphor can be used more broadly, in either explanatory-predictive or expressive-affective contexts.

From Comparison to Conceptual Systems: Metaphoric Systems in Reasoning. "The process of conventionalization can result in stock metaphors, and finally in dead local metaphoric senses. However, some metaphors ... end as conventionalized systems of reasoning." pg 241.

Some do both, such as the water-electricity metaphor and the space-time metaphor. It may be that some metaphors become conventionalized as systems as opposed to categories when they continue to support new reasoning that requires concatenating relations. Space is a common base which is highly systematic.

Conceptual Blending and Analogy.
Gilles Fauconnier.

Conceptual blending aligns two partial structures, like analogical mapping, but in addition it projects selectively to form a third structure, the blend. The blend is not a simple composition but an emergent entity based on pattern completion and dynamic elaboration.

A famous example is a race between two boats along the same course but 140 years apart. The blend consists of partially projecting from two input spaces into a blended space. The boats left on the same day (in a different year) and the idea that it is a race is emergent from pattern completion. The idea of a ghost ship is an elaboration from running the blend in the cultural context (or generic space). This is a simple “mirror network” involving a common organizing frame (sailing from A to B). It requires a cross-space mapping, like analogy, but it is not analogical in purpose or function. The analogy is taken for granted.

Another example is a ski instructor telling the novice to imagine that he was a waiter carrying champagne and croissants. The generic space has only human posture and position. There is stills a (crucial) cross space mapping, but no generic space, and its function is not analogical reasoning. The point, is the direct integration of motion, in the teaching context.

In a metaphor such as “digging one's own grave” there is a mismatch of the relevant temporal, causal and referential structures. This is a double-scope blend where the organizing frame of death and graves comes from one input while the causal and temporal structure comes from the other. The two domains are not structurally analogical in the relevant respect and there is no transfer from one domain to the other.

Counterfactuals in language are the product of conceptual integration networks, often used to construct an analogy or dis-analogy. Examples are “In France, Watergate would not have hurt Nixon” and “If I were you I would ...” where the literal impossibility is striking, but unnoticed, because it is the entire network being manipulated – not just the blended space.

Integrated Action..

That conceptual blends are so efficient in developing new areas of integrated action (skiing example or GUI example below) bears in crucial ways with the issues of embodiment and creativity.

Conceptual blending is not exotic but very common – and invisible.

Consider the computer GUI and mouse which is deeply representative of the fluid neural and psychological embodiment that characterizes successful conceptual integrations.

- **Object blend.** The computer desktop blends 3D objects (with invariance, coherence, stability and nonubiquity) with 2D colored rectangles and an arrow on the screen. Both input spaces and the blended space are maintained concurrently.
- **Arrow and mouse blend.** One input is tactile 3D in one plane and the other is visual 2D in another plane. The motor action is 'felt' to move the arrow and the imperfect correspondence quickly becomes unconscious. The two operate quite differently when the mouse is lifted.
- **Grasping and motion blend.** Another blend from the 3D finger grasping(?) to a 2D arrow sticking. But there are glaring mismatches such as the color of the 2D object changing when grasped and only a phantom being in motion and then the rectangle object jumping instantaneously when released. The user remembers moving the rectangle but rarely remembers the phantom.
- **Containment blend.** The first input space is the grasping and motion blend and the second is 3d containers. However the containers operate very differently regarding size, visibility, capacity and boundaries, colors ..... Yet it is easy to construct and use.

Conclusion. Conceptual blending operates in many varied situations both linguistic and non-linguistic. The integration is not the simple product of ordinary analogy because (1) there are many discrepancies and mismatches in the mappings that associate the inputs and (2) that blended space has a dynamic coherent life of its own that is integrated and autonomous in ways that a mere alignment between structures is not.

Setting Limits on Analogy: Why Conceptual Combination Is Not Structural Alignment.
Mark Keane & Fintan Costello.

Structural alignment can account for results in a number of different domains such as analogy, metaphor, similarity and conceptual combination, but there are results in conceptual combination (e.g. soccer mom, jail job, republican party reptile) that cannot be explained by structural mapping. Compound phrases tend to be one off, compact, category identifiers while analogies are more permanent and diverse descriptions.

Structural Alignment as a Unifying principle. Structural alignment involves one-to-one correspondence, parallel connectivity and systemacity. There is good empirical evidence and many algorithmic implementations. This theory base has been extended to novel metaphors, similarity and conceptual combination. However, structure mapping is inappropriate for conceptual combination.

Interpreting Conceptual Combinations. A given novel combination like 'bed pencil' can have a variety of interpretations.

- **Relational interpretations** establish some relationship between the modifier concept (1st word) and the head concept (2nd word). 30-50% (a bed pencil as pencil used to make beds)
- **Property interpretations** involve the property of one concept being asserted on the other. 30-50% (a bed pencil as a thin bed)
- **Conjunctive or Hybrid interpretations** conjoin both concepts in some way. (a bed pencil as a big flat pencil used as a bed for a doll)
- **Known-concept interpretations.** (a pencil bed as a pencil case)

The focal concept contributes most of the semantic information to an interpretation. The focal concept s usually the first word but focus reversals do occur. Focus reversals are rare but stand as challenges for theories of conceptual combination.

Dual-Process Theory (structural alignment and scenario construction) is a well developed account that makes several novel and interesting predictions about the interpretation of conceptual combinations, many of which have been confirmed empirically. However, the authors believe that structural alignment is not used in conceptual combination and propose Constraint theory as an alternate.

The Constraint Theory describes conceptual combination as a process that constructs representations that satisfy three constraints:

- **Diagnostic Constraint.** Requires that the construction contains diagnostic properties from each of the base concepts – properties that are common in a concept and rare in other concepts.
- **Plausibility Constraint** requires that the construction contains semantic elements that are already know to co-occur.
- **Informativeness Constraint** requires that the constructions contains requisite amount of new information.

Constraint theory assumes that, from the beginning of the combination process, there is direct access to many different sources of knowledge. Dual Process theory works with an initially limited summary prototype information with other types of knowledge only being used for later elaboration.

There is an operational computational implementation of the C3 model which is significant because it deals with the inherent intractability of combining two tasks.

The Constraint Theory predicts that focus reversals should involve the diagnostic properties of the head being applied to the modifier (ie property interpretations). The is supported empirically.

It is difficult to find examples which decide between Dual Process and Constraint Theory in the same corpus of evidence. An example supporting Constraint theory involved subjective judgments of novel combinations such as “bumblebee moth”.

Counterarguments from the Structure-Mapping School include:

- Constraint Theory is empirically deficient Too.
- Similarity and property interpretations
- The predominance of alignable Differences.
- The plausibility Constraint is structural alignment in disguise.

The Analogical Paradox: Why Analogy Is so Easy in Naturalistic Settings, Yet so Difficult in the Psychological Laboratory.

Subjects in many psychology experiments tend to focus on superficial features when using analogy, whereas people in non experimental contexts, such as politicians and scientists, frequently use deeper more structural features.

The Paradox Unfolds: "In Vivo" Investigations of Analogy in Science and politics. Based on analysis of weekly meetings between scientists:

- scientists use analogies to very similar experiments or organisms ('local' analogies) to fix experimental problems.
- scientists use analogies from other related domains when attempting to formulate new models or concepts.

Even analogies to similar domains tended to be dependent on higher-order relational or structural similarities rather than being based on superficial features.

Analogy in Science.

Analogy is one of the first cognitive tools that scientist employ when presented with unexpected findings – initially with in domain analogies. A series of unexpected findings typically prompts a major shift to more distant analogical targets to develop more general hypothesis and theoretical explanations. Analogy use changes with the current goal and it does not occur in isolation, but in conjunction with other psychological processes in often complicated sequences of analogy, generalization and deduction.

"Overall, the results of our analyses of scientists reasoning live or in vivo reveal a number of important features of the analogical reasoning process. First, analogy is common. Second, while the scientists do make analogies based on superficial features, they frequently and spontaneously generate analogies based deep structural features and higher-order relations. Third, the goals that the scientists have influence the range over which an analogy is applied. Fourth, the scientists appear to be using the analogies as scaffolding. Once the analogies serve their purpose of building new explanations and models they are discarded and this is why they forget them." pg 319

Analogy in Politics.

Author used material relating to the referendum on independence in Quebec in 1996 as research material. Over 200 analogies included 75% that were based on higher-order relations and structure rather than superficial features. The analogy sources were often highly emotional subjects.

"In Vitro" Investigations of Analogical Reasoning.

One typical difference between the natural and laboratory setting is that subjects construct their own analogies in the natural and typically choose between analogies in the laboratory. However, it was found that when subjects generate their own analogy in the laboratory the analogies share few superficial features. Generating analogies leads people to focus on structural features.

When an analogy is provided between two problems, subjects are more likely to solve the second target problem if they personally solve the first source problem, rather than having the first answer provided. Thus, the way that the source problem is encoded will influence whether the source is retrieved when working to a structurally similar problem. Subjects often remained unaware of the influence of the source problem.

However, encoding is not the whole answer. The type of retrieval clue provided to Subjects influences their retrieval of analogies based on superficial or relational features.

"When encoding strongly highlights relational features of a source, then regardless of the retrieval cue given, subjects will be able to retrieve analogically similar matches. When encoding is superficial, even when a relational retrieval cue is given, this will not help subjects retrieve the relational analogs. When there is a moderate level of relational information highlighted at encoding, then the type of retrieval cue does matter. A superficial retrieval cue will not help, whereas a relational retrieval cue will help. " pg 328

Conclusion.

"Both encoding and retrieval conditions underlie the paradox: Naturalistic environments make it possible for people to use structural features and higher order relations because information is encoded in a richer way. Furthermore, naturalistic settings influence the retrieval conditions, often stressing the search for higher-order analogs rather than analogs that share superficial features. .... both experts and novices are capable of generating true structural analogies if the circumstances permit." pg 329

Emotional Analogies and Analogical Inference.
Paul Thagard & Cameron Shelly

Introduction. Understanding emotional analogies (that transfer or generate emotion) requires a more complex theory of analogical inference than has been available.

Analogy Inference: Current Models. The logician's schema of logical inference ignores important aspects of human analogies including varying strengths of analogies, the importance of relations over mere properties and their holistic complexity. SME and ACME are richer but still inadequate for emotional analogy as the do recognize the use of multiple concurrent analogies and they operate on symbols in predicate calculus or the like.

"the prevalent models of analogy encode information symbolically and assume that what is inferred is verbal information that can be represented in propositional form by predicate calculus, or some similar representational system".

See nonverbal analogy in VAMP system for visual analogical mapping Thagard, Gochfeld & Hardy 1992.

Analogical Inference in HOTCO. Thangard (2000) proposed a theory of emotional coherence that has applications to numerous important psychological phenomenon such as trust. The theory assumes that:

- all inference is coherence based,
- that coherence is a matter of constraint satisfaction,
- coherence has 6+ types (analogical, conceptual, explanatory, deductive, perceptual deliberative), and
- that coherence involves acceptance / rejection and a positive / negative emotional assessment.

From this perspective all inference is defeasible and holistic (very different from logic systems)

The HOTCO implements these theoretical assumptions and amalgamates ECHO, IMP, ACME & DECO. "What is novel about HOTCO is that representational elements possess not only activations that represent their acceptance and rejection, but also valencies that represent a judgment of their positive or negative emotional appeal." pg 338 HOTCO does not actually infer a new proposition (as in a predicate logic system), but rather it simply establishes an excitatory link between the unit representing the source proposition and the target proposition. This link represents a positive constraint between the two propositions such that the will both tend to be either accepted or rejected. "Thus multiple analogies can contribute to the defeasible and holistic character of analogical inference." pg 341

Analogies about Emotions.
Emotions are difficult to express and writers often resort to multiple analogies to bring out different aspects of an emotion. The purpose of these analogies is often explanatory and sometimes advisory. Sometimes the point of the analogy is to transfer an emotional attitude (beyond simple verbal transfer).

Analogies that Transfer Emotions.
There are at least three kinds of emotional transfer:

- persuasion: to adopt an emotional attitude
- empathy: transferring ones emotional reaction to another,
- reverse empathy: inviting another to use an emotional situation familiar to them to understand ones reaction to a novel situation.

Descriptive words such as 'wonderful' and 'awful' are simply not as effective as an analogy.

More that half of the analogies used in the Canadian Quebec referendum had an identifiable emotional dimension.

Holyoak and Thagard (1995) theorized that semantic and visual similarity would influence how two analogs are mapped to each other. These authors add emotional similarity.

Identifying yourself with someone else is a personal form or persuasive emotional analogy.

The purpose of Empathy is to understand rather than to persuade. Descriptive words do not work nearly as effectively a an analogy with a comparable personal experience.

HOTCO only transfers positive and negative valencies but could easily be expended to include an emotional vector with many dimensions to allow the transfer of a pattern of various aspects of emotion.

"Starbucks coffee shops are spreading through Toronto faster than head lice through a Kindergarten class."

Analogies that Generate Emotions.

There are at least four classes of emotional states that generate emotion: humor, irony, discovery and motivation. A surprising combination of congruity and incongruity make an analogy funny. Ironies are sometimes amusing but can also produce negative emotions such as despair.

An Internet Survey.

Articles were gathered automatically from the Internet and, when the purpose of he analogy was clear, classified as:

- Analogies (87)
  - Clarification (7) thru similarity
  - Inference (9) of additional information from source
    - Hot (55) with an emotional tag
      - Empathy (3)
      - Reverse Empathy (28)
      - Persuasion (24)
    - Cold (16) non emotional
- Description

There was a surprising lack of empathy analogies, possibly because empathy is personal (but stereotypical situations were used) or because empathy is often a first step in persuasion where knowledge of the persons current position is first required.

Examples of reverse empathy were approximately 50/50 positive/negative emotionally. Examples of persuasion were overwhelmingly negative emotionally. Empathy and persuasion can be difficult to tell apart in newspaper articles.

Note :
pg 337 Symbolic systems are criticized but then on pg 339 we see that HOTCO is a symbolic system!?
pg 338 HOTCO sounds like bolt together 4 theories and then overlay another network of emotion connections (ugly)

Analogy and Analogical Comparison in Choice.

Arthur B. Markman and C. Page Moreau.

" .. in order for people to evaluate an alignable difference, they only need to know the relative goodness of the attribute, because they have values for all of the options. In contrast, to evaluate a nonalignable difference, they need to know the absolute level of goodness of the attribute." pg 381

"This analysis suggests that one reason nonalignable differences are ignored is that attending to them requires substantial cognitive resources, because the comparison process does not make nonalignable differences available." pg 390

Using Analogy in Choice.

"In this chapter, we have discussed two central ways that analogy influences the choice process. First, analogies to other domains can be used to provide a representation for a choice situation. In general, making a decision requires some familiarity with the choice setting. In cases where the domain of the choice is new, analogies can be used to relate the choice to previous experience. These analogies can be used to provide a general framework for thinking about a choice (as in the use of the domino analogy during the Cold War) or they can be used to generate options for making a choice (as in the Korea analogy to Vietnam). Because the role of the analogy in this case is to structure the representation of the choice situation, it exerts a strong influence on the outcome of the decision. In particular, it constrains the range of options considered and the evaluation of those options. Further, this influence may go unnoticed by the decision maker. Thus, when reasoning in new situations, it is critical to think about the analogies that may affect the choice.

The structural alignment processes involved in analogy also plays a role in choice through the comparison of options. New options can be learned through comparison to existing options. These comparisons will highlight both the commonalities and the alignable differences of the options at the expense of the non-alignable differences. Thus, alignable differences will typically be learned before nonalignable differences. Options whose attributes are already known may also be compared during choice. In these situations, alignable differences are used more frequently than nonalignable differences. Nonalignable differences of new options can be

learned, however, when the decision maker is motivated to process information and when the decision maker is already generally familiar with the domain.

An examination of the role of analogy in decision-making highlights the parallels between categorization and choice. The study of categorization is focused on understanding how people's mental representations are learned, and how those representations are structured. Future work in this area will not only shed light on how people make choices, but also on how mental representations are formed in the process of determining preferences. " pg397

[link to prior chapter – open vs closed lab questions]
[link to minskis narrowing of options]

Semantic Alignments in Mathematical Word Problems.
Miriam Bassok.

Analogical thinking is available from infancy onwards.

The Relational Similarity Constraint. Analogical reasoning involves both surface similarity and relational similarity. We are attempting to isolate and investigate only analogical reasoning using relational similarity in children.

The Item Analogy Task. Early research concluded that analogical reasoning ability develops at about 11-12 years of age but the research involved reasoning about the similarities between the relations between objects (2nd order analogy)

The Role of Relational Familiarity in Analogical Development. More recent research employed pictorial versions of basic causal relations that are know to be acquired at an early age. Children of age 4, 5 & 9 all performed significantly above chance.

The Relationship between Relational knowledge and Analogical Responding. The relational familiarity hypothesis is that children's analogical performance depends on their relational knowledge. Hence relational knowledge of children needs to be assessed as a prerequisite to assessing analogical capabilities. Results show that both relational knowledge and analogical capabilities increase with age from at least 3 yeas of age.

Analogical Reasoning in Infants and Toddlers. Research involves the infant transferring the solution to one problem across to a analogous problem. Infants of 10 months could solve the target problem when shown the solution to the base problem. Surface similarity also provided assistance to the problem solving. Analogical capabilities may extend below 10 months.

The Origins of Relational Reasoning. The first few months of infancy involves a very rapid expansion of knowledge about objects, events and the causal explanation underlying their relations. Infants preferentially remember causally related events and seek causal explanations. A common mechanism may underlie both analogy and categorization.

Relational Processing in Infants: The Physical World. "Infants may first be sensitive to the similarity between the inherent structure of physical events, and then com to represent them as relationally similar." pg449. "....infants preferentially attend to changes in the visual scene. Change is informative because change signals the occurrence of events.

Events in the visual world are usually described by relations between objects." pg 450

"... Baillargeon has repeatedly found that infants reason on the basis of relational information before they reason on the basis of absolute information when making judgments about the physical properties of objects." pg 451

Relational Processing in infants: The Psychological World. "... sensitivity to causal relationships may partly underlie the development of a notion of agency." pg 451 "Causal analysis of he everyday world of objects and events supply information about the physical world of inanimate objects and also about the mental world of animate objects." pg453

Relational Processing in infants: Imitation. "... imitation involves an early form of analogizing." pg 454 because it requires the infant to move it's own tongue, which it can feel but not see, in a similar manner to the adults tongue which the infant can see but not feel.

Piaget noted that his children "imitated the opening and closing of a matchbox by opening and closing their hands and mouths. .... the infants were trying to understand the mechanism of the matchbox through a motor analogy." pg 454

".... it is perhaps not a coincidence that imitation, analogy, and the understanding of mental states ('theory of mind') are absent in the animal kingdom (with the possible exception of highly 'language-trained' chimpanzees." pg 454

Analogies in Foundational Domains. Developmental psychologists argue that the developing knowledge base should be divided into three foundational domains: naive biology, naive physics and naive psychology.

Analogy as a Mechanism for Understanding Biological Principles. ".. preschoolers' understanding of biological phenomena arises from analogies based on their understanding of people. " pg456 Personification analogy.

Analogy as a Mechanism for Understanding Physical Principles. Research involving a mechanical balance (single force) and a force table (dual forces) showed that children's responses varied systematically with the solution provided by an analogical model.

There has been no research regarding naive psychology.

Analogies in Piagetian Tasks. Paigetain tasks are used to measure the different levels of logical reasoning postulated by Piaget's stage theory of logical development. But there are alternative proposals.

Halford's Structure Mapping Theory of Logical Development. Halford's structure-mapping theory of cognitive development proposes that most logical reasoning is analogical and that limitations in primary (working) memory constrains the kinds of analogy that children can use at different stags of development. This critical capacity limitation is governed by the number of relations that can be held in primary memory at any one time. Conceptual chunking and serial process must be used withing these limits to reason about more complex problems.

Analogies Based on Pairs of Relations. "... the ability to solve analogies based on pairs of relations was governed by relational familiarity." pg 461

Analogies in a Transitive Mapping Task. Relational familiarity and real-world knowledge about family size relations seem to have helped the three year olds with a task involving the relative size of Father, Mother and Baby Bear in Goldilocks as a basis.

Analogies in a Class Inclusion Task. Halford suggested that families provide potentially useful analogues for class inclusion tasks. The logical concept of class inclusion involves understanding that a set of items can be simultaneously part of a combined set and part of an embedded set. Results indicate that Halford's structure-mapping theory is both powerful and plausible.

Conclusion.

"It is not unusual in developmental psychology for researchers to demonstrate that apparent changes in children's cognition are in reality changes in the knowledge that children have available as a basis for exercising a particular skill. Analogical reasoning appears to be no exception. If measures of analogy are based on unfamiliar relations, then these measures seriously underestimate children's analogical skills. Hence early research concluded that analogical reasoning was absent until early adolescence because it depended on experimental tasks that used analogical relations that were unfamiliar to younger children. Later research has demonstrated that analogical reasoning is used by children as young as one, two, and three years of age. It has also been shown that forms of relational reasoning which probably involve relational comparisons are present in young infants.

Nevertheless, it is important to note that the nature of a cognitive skill measured at time 1 may differ completely from the nature of a cognitive skill measured at time 2. For example, Strauss (1998) has argued that the kind of analogies made by infants may be completely different from the kind of analogies made by older children. He suggests that the kind of analogies made by young infants are perceptual in nature, whereas those made by young children use conceptual knowledge. Such questions about the continuity of cognitive skills are important ones for answering the question of "what develops" in analogical reasoning.

In this chapter, I have argued that the early age at which analogies appear suggest that they provide a powerful logical tool for explaining and learning about the world. Analogies also contribute to both the acquisition and the restructuring of knowledge, and play an important role in conceptual change. As children's knowledge about the world becomes richer, the structure of their knowledge becomes deeper, and more complex relationships are represented, enabling deeper or more complex analogies. This means that, as children learn more about the world, the type of analogies that they make will change. Another important developmental question is whether these changes are driven solely by changes in the knowledge base, or whether information processing factors, such as the number of relations that can be represented in primary memory at anyone time, determine these changes." pg 464

Can an Ape Reason Analogically?
Comprehension and Production of Analogical Problems by Syrah, a Chimpanzees
David L. Oden, Roger K. R. Thompson, and David Premack

"Collectively, the results from the four conditions reported here not only confirm that an adult chimpanzee can solve analogies (Gillan, Premac . and Woodruff 1981), but also demonstrate that she does so spontaneously, even in situations where a simpler associative strategy would suffice.

In condition 1 we replicated Gillan, Premack, and Woodruff (1981) earlier findings, which demonstrated that when faced with a partially constructed analogy problem, Sarah, the same adult chimpanzee subject, successfully selected from two available choices that item which would complete the analogy. In condition 2 of the completion task, Sarah demonstrated conclusively that her performance was mediated by analogical relationships and not a simple associative similarity matching strategy. When presented with only the two base elements of a classical analogy problem she successfully chose from three alternatives the two elements necessary to complete the target pair of the problem. More importantly however, was the finding that Sarah's spatial arrangement of these choices was guided by the relation initially established by the experimenters and not on the basis of mere similarity along any single physical dimension.

In conditions 3 and 4 we further demonstrated that the same chimpanzee, Sarah, could not only complete but also construct analogies. When presented with a randomized grouping of elements from which an analogy could be constructed she proceeded to do so spontaneously. When presented with the minimum of four elements, Sarah proceeded to arrange all of them in analogical fashion. When presented with five elements she arranged four of the five items analogically. However, Sarah did so in a manner analogous to, but not identical with that of her human experimenters. On one hand, we had attended to both specific physical factors and their number in each within-pair transformation. Sarah, on the other hand, had attended primarily to only the latter numerical dimension. Nevertheless, the resulting patterns produced by Sarah's arrangements were analogical. Our anthropocentric emphasis led to our initially underestimating Sarah's capacity for analogical reasoning. " pg 488

"Analogical reasoning may indeed be a hallmark of human reasoning. Nevertheless, the results on

completion and construction of analogical problem-solving by Sarah, a representative of the common chimpanzee species Pan troglodytes, demonstrate that this uncommon individual is predisposed, as are humans, to reason about relations between relations. .....

The data summarized here provide a cautionary tale for psychologists as to the potential traps and snares of the psychologist's fallacy discussed above. When constructing both the base and target relations of an analogy from four of five elements in condition 4, Sarah did so in a manner analogous to, but not identical with that of her human experimenters. As we have emphasized throughout this discussion, an anthropocentric bias can blind one to an animal's or, for that matter, a child's alternative, but no less successful strategies. Our cautionary tale is perhaps the analogical "other side of the coin" to Haith's (1998) warning to developmental psychologists that uncritical projections of an adult's understanding of a phenomenon onto that of human infants or children may lead to overly rich interpretations of their cognitive capacities. In the present case, however, the potential problem of projection was one which would have led us to underestimate the conceptual capacities of Sarah, a chimpanzee.

The analyses of Sarah's selection and arrangement of items on her analogy board in both types of analogy task provide no evidence that she attempted to use a less efficient associative strategy, as can occur with young children (Alexander et al. 1989). We can only be confident in this conclusion because of our exhaustive re-analyses of Sarah's response patterns. We concur with the recent recognition by some developmental psychologists of the theoretical and empirical utility of such detailed "microgenetic" analysis (Siegler and Crowley 1991).