Title
Relational Learning: Common Signatures Across Four Different Contexts

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Relational Learning: Common Signatures Across Four Different Contexts

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Signatures of Relational Learning

What makes humans smart? We think it has to do with our analogical ability—our ability to perceive common relational patterns between different objects, events, or ideas. It is a cornerstone of our higher-order reasoning ability and may have its origins in a relational processing mechanism that allows us to abstract relations using comparison. In this symposium, we present research on the nature of our relational learning ability. We show that findings from infants, preschoolers, elementary school students, and adults reveal common signatures across a wide variety of contexts. These studies provide evidence about how to improve learning of abstract relational concepts and provide insight about how to build better AI models.

The first talk presents infant studies that demonstrate that (1) comparison across sets that share relational structure can foster relational alignment and abstraction; and (2) the presence of salient objects can hinder relational learning. Next, these same signatures are discussed in the context of rule learning, which so far has largely been considered separate from analogical processes. Rule learning studies with toddlers and adults show that as in analogical learning, object matches can both hinder and help rule abstraction. The third talk discusses the role of comparison and alignment in education. Relational alignment helps children grasp the connection between planetary motion and the day/night cycle in formal and informal learning contexts. The fourth talk will use these signatures to build better artificial intelligence models. More broadly, this research influences our understanding of human cognition and how it differs from that of other species. This, in turn, will help us make better models of human cognition in artificial intelligence.

This symposium brings together experts in relational learning with backgrounds in cognitive and developmental psychology, education, and machine learning towards the common goal of characterizing how the mind abstracts and generalizes relations between objects, events, or ideas. In a concluding panel, the speakers will discuss how highlighting these common attributes has implications for education and computer science.

Relational Learning in Infants

Susan Hespos and Dedre Gentner

How does relational cognition in human infants begin? To gain an understanding of the source of our species' extraordinary relational ability, we must investigate young infants, who lack extensive exposure to culture and language. We traced the early development of relational cognition. There is evidence that infants as young as 7-9 months, and even 3 months of age, can carry out analogical generalization over a series of examples and thereby form abstract relations such as *same* [X, X] and *different* [Y, Z]. As in older children, the infant studies show that facilitating comparison across exemplars promotes abstracting the common relation and rendering individual objects salient disrupts relational learning. Together these findings suggest that there might be continuity across development in our relational learning ability.

Rule Learning Is Like Analogical Learning

Stella Christie and Qiuchen Ma

Analogical reasoning can be manifested in multiple ways, including the canonical form A:B::C:D, linguistic forms such as metaphors, or symbolically as in Raven's Progressive Matrix Task (Gentner & Maravilla, 2018). Under this view, the ability to abstract a rule—**Rule Learning**—is also a form of analogical reasoning. When 7-month-old infants are able to abstract a rule from a mere 2 minutes' familiarization (ABB syllable

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strings like "li-na-na" or "ga-ti-ti"), differentiating between never-heard-before "wo-fe-fe" and "wo-fe-wo" at test (Marcus et al., 1999), infants are noticing that "li-na-na" at familiarization follows the same relation as "wo-fe-fe" at test. So far, however, the extensive rule learning literature has been largely separate from the analogical reasoning literature. Here we bridge these two literatures by showing that rule learning is subject to an important signature of analogical learning: that object matches (e.g., matching red to red) both hinder and help relational learning (Christie, 2021). Using the original Marcus et al. 1999 stimuli, we found that unlike previous rule learning findings with infants, 4-year-olds were not adept at rule abstraction. However, they could abstract rules that contained object matches. Surprisingly, while adults could abstract ABB or ABA rule, their abstraction was disrupted by object matches. Overall, this set of experiments suggests that rule learning shares common mechanisms with analogical reasoning, where object matches can both constrain and foster rule abstraction.

Aligning Observations and Models to Promote Causal Learning in Space Science

Benjamin Jee and Florencia Anggoro

To understand fundamental scientific models, students must learn the relationship between observable events and invisible entities and processes. Our research explores an instructional approach in which children explicitly compared and aligned their observations of the day/night cycle with a model of Earth's motion. One study, conducted in a formal learning context, found that guided comparisons helped 3rd-grade students understand the day/night cycle, especially those who began with little prior knowledge (Jee & Anggoro, 2019). A second study, conducted in an informal learning context, found that a comparison-based museum exhibit increased children's causal understanding of the day/night cycle, with younger children (3-5 years old) benefitting the most. We will discuss the implications of these findings for science learning in different contexts, at different ages, and in other domains.

Modeling Rapid Learning Via Working-Memory Analogical Generalizations

Kenneth Forbus

A hallmark of human learning is that we can learn with very few examples. Analogical generalization provides a possible mechanism for this since it creates probabilistic relational generalizations incrementally. We hypothesize that such generalization processes occur both over long-term knowledge (e.g., when learning word meanings, linguistic constructions, and event schemas) but also in working memory. We suggest that working-memory analogical generalizations are responsible for the rapid learning often observed in developmental studies (e.g., Chen et al., 2020). This contribution to the Symposium will describe SageWM (Kandaswamy et al., 2014), our model of working-memory analogical generalization. I will summarize how it has been used to model several phenomena in cognitive development. Of special note is the simulation of infant pattern learning where, unlike rule-based accounts, this model predicts that concrete properties can still be found in generalizations (Kuehne et al., 2000). This parallels Jamrozik & Gentner's (2015) finding that abstract prepositions retain aspects of their original spatial meaning. These findings illustrate the potential utility of analogical generalization in explaining the trajectory from embodied concepts to abstractions in human cognition.

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