High-level inference through mental simulation

Chairperson
Robert Mackiewicz
Department of Psychology, University of Social Science and Humanities,
PL - 03815 Warsaw, Poland.
rmackiew@swps.edu.pl

Discussant
Sangeet Khemlani
Navy Center for Applied Research in Artificial Intelligence, Naval Research Laboratory
Washington, DC 20375 USA
skhemlani@gmail.com

Speakers

Philipp Koralus
Faculty of Philosophy, University of Oxford
Oxford, OX2 6GG, UK
philipp.koralus@philosophy.ox.ac.uk

Robert Mackiewicz
Department of Psychology, University of Social Science and Humanities
PL - 03815 Warsaw, Poland
rmackiew@swps.edu.pl

Walter Schaeken
Laboratory for Experimental Psychology, KU Leuven
B - 3000 Leuven, Belgium
Walter.Schaeken@ppw.kuleuven.be

Marco Ragni
Center for Cognitive Science, University of Freiburg
D-79098 Freiburg, Germany
ragni@informatik.uni-freiburg.de

Reasoners without any background in logic can make valid deductions. They can reason about sentences and relations (Mackiewicz & Johnson-Laird, 2012), ascribe culpability and causality (Bucciarelli et al., 2008), creatively generate algorithms to solve tasks (Khemlani et al., 2013), make inferences about mechanisms and physical scenes (Hegarty, 2004; Battaglia et al., 2013), and construct explanations to cope with inconsistencies (Johnson-Laird et al., 2004). Recent evidence implicates mental simulation as the conceptual foundation of all these behaviors (Johnson-Laird & Khemlani, 2014). People appear to build small-scale discrete mental simulations that mimic the relations of what they represent, and Craik (1943) was the first to explore their importance in thinking. The idea can be used to predict reasoning difficulty: the more simulations reasoners have to build for a given problem, the harder that problem will be.

Despite considerable theoretical development in the last 30 years, open questions remain: how does simulation synthesize deductive, inductive, and abductive reasoning? How does it develop? How do reasoners incorporate uncertainty into their simulations? Do simulations arise in non-linguistic contexts? Researchers have begun to investigate each of these outstanding issues. This symposium highlights recent insights from the last five years into the pivotal role that mental simulation plays across a broad swathe of high-level reasoning behavior. Discussants will highlight developmental trends, computational models, and new data that provide converging progress toward a unified theory of human reasoning based on mental simulation.

Illusory inferences and the erotetic theory of reasoning

Philipp Koralus

Human reasoners are subject to fallacious inferences from very simple premises that have been described as tantamount to cognitive illusions (Walsh & Johnson-Laird, 2004; Khemlani & Johnson-Laird, 2009). We present new experiments that show that these phenomena are much more general and systematic than has previously been thought, including inferences from disjunctive premises and premises involving quantifiers. The novel illusory inferences we present are predicted by the erotetic theory of reasoning (Koralus and Mascarenhas, 2013). The key idea is that, by default, we reason by interpreting successive premises as questions and maximally strong answers to those questions, which generates the observed fallacies.

Kinematic mental simulations in childrens' abduction of algorithms

Robert Mackiewicz

The theory of mental models postulates that the creation of algorithms depends on kinematic mental simulations. We present three experiments with children whose task was to devise informal algorithms to rearrange the order of cars in trains (using a siding). Children were able to solve rearrangements of trains containing six cars and the minimal theoretical number of moves predicted the difficulty of rearrangement (Experiment 1). When children were asked to create and verbally describe algorithms for rearrangements, the difficulty of the task depended not on the number of moves but on the theoretical complexity of the algorithm (Experiment 2). Children used many gestures mimicking actual moves in formulating their algorithms. Gestures obviate verbal identifications of cars and descriptions of their moves. A final study supported this hypothesis: children formulated accurate algorithms on 13% more trials when they were able to gesture than when they were unable to gesture (Experiment 3).

Tracing Cognitive Complexity in Relational Reasoning

Marco Ragni

The core interest from a cognitive modeling perspective is to find theory inherent predictions for human reasoning difficulty typically measured by error rates or response times. The theory of mental logic, for instance, claims that reasoning difficulty depends on the number and kind of rules that need to be applied to derive a conclusion. In contrast the mental model theory explains reasoning difficulty by the initial mental model and the possible number of models. In this talk I will first introduce prominent theories for relational reasoning. In a second step I will analyze their predictions for cognitive complexity and discuss if measures from artificial intelligence can provide additional insights.

Training of Spatial Reasoning

Walter Schaeken

The mental models theory of relational reasoning postulates that individuals reason by constructing the possible models of the situation described by the premises. The present article reports two experiments about spatial relational reasoning and focuses on the possibility of training In Experiment 1, we compared two different training methods, one in line with the mental models theory and one in line with the rule-based account Both accuracy and training data supported the mental models theory. In Experiment 2, we compared different training methods for children. Again, results were in line with the mental models theory. Hence, training both children and adults in small-scale discrete mental simulations that mimic the relations expressed by the premises enhances the reasoning performance.

References

Battaglia, P. W., Hamrick, J. B., & Tenenbaum, J. B. (2013). Simulation as an engine of physical scene understanding. *Proceedings of the National Academy of Sciences, 110*, 18327-18332.

Bucciarelli, M., Khemlani, S., & Johnson-Laird, P.N. (2008). *The Psychology of Moral Reasoning. Judgment and Decision Making, 3*, 121-139.

Craik, K. (1943). *The Nature of Explanation*. Cambridge: Cambridge University Press.

Hegarty, M. (2004). Mechanical reasoning by mental simulation. *Trends in Cognitive Sciences, 8*, 280-285.

Johnson-Laird, P.N. & Khemlani, S.S. (2014). Toward a unified theory of reasoning. *Psychology of Learning and Motivation, 59*, 1-42.

Johnson-Laird, P.N., Girotto, V., Legrenzi, P. (2004). Reasoning from inconsistency to consistency. *Psychological Review, 111*, 640-661.

Khemlani, S.S. & Johnson-Laird, P.N. (2009). Disjunctive illusory inferences and how to eliminate them. *Memory & Cognition, 37,* 615 – 623.

Khemlani, S.S., Mackiewicz, R., Bucciarelli, M., & Johnson-Laird, P.N. (2013). Kinematic mental simulations in abduction and deduction. *Proceedings of the National Academy of Sciences of the United States of America, 110*, 16766-16771.

Koralus, P. & Mascarenhas, S. (2013). The erotetic theory of reasoning: Bridges between formal semantics and the psychology of deductive inference. *Philosophical Perspectives, 27*, 312-365.

Mackiewicz, R. & Johnson-Laird, P.N. (2012). Reasoning from connectives and relations between entities. *Memory & Cognition*, *40*, 266-279.

Walsh, C.R. & Johnson-Laird, P.N. (2004). Co-reference and reasoning. *Memory & Cognition, 32*, 96-106.