Mental Metalogic and its Initial Empirical Justifications: The Case of Reasoning with Quantifiers and Monadic Predicates

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In psychology of human deductive reasoning, mental logic theory claims that people reason by applying inference schemas (e.g., Braine & O'Brien, 1998; Rips, 1994), and mental models theory claims that people reason by constructing mental models (e.g., Johnson-Laird and Byrne, 1991). There is a great deal of empirical evidence supporting each theory. The authors have proposed a mental metalogic theory (Yang & Bringsjord, 2001) studying the interactions between applying inference schemas and constructing mental models based on the current theories of mental logic and mental models. We report a set of experiments designed to examine possible interactions of this kind. Mental metalogic suggests ways of modeling reasoning strategies.

Our strategy for constructing experimental problems was to integrate one problem type used in mental logic research (Yang, et al. 1998) and another problem type used in mental model research (Yang & Johnson-Laird, 2000). Below is a resulting sample problem used the experiment.

> The premises given below are either all true or all false:
> All the beads are wooden or metal.
> The wooden beads are red.
> The metal beads are green.
> The square beads are not red.
> Is possible that the square beads are green?

This new problem type can be used to manipulate two independent variables. The first independent variable is about the set of premises. For a given problem, it can have the set of original premises, or the denials of these premises. The second independent variable is how a question is presented. It can take the form, "Is it possible that …" or "Does it necessarily follow that …". Thus, by manipulating these two independent variables, four types for a given problem are produced. The first experiment used a 2x2 between-subjects design to manipulate two independent variables in four conditions according to the 4 problem types explained above. 18 original multi-step problems similar to the example above were carefully selected from Yang, et al. Their task was to choose among the given responses (i.e., Yes, No, or Can't tell). The mean accuracy for the original/necessity problems was 45.5%, for the original/possibility problems 91%, for the denials/necessity problems 83%, and for the denials/possibility problems 60%. (N=40 for each problem type). The results are clear-cut. For the problems using original premises, the problem type of possibility was evaluated significantly more accurately than the problem type of necessity (Mann-Whitney $Uz = 5.17$, $p < .001$). For the problems using the denials of the original premises, the problem type of necessity was evaluated significantly more accurately than the problem type of possibility (Mann-Whitney $Uz = 5.14$, $p < .001$). In addition, there was a reliable interaction. The difference between problem types of necessity and possibility for the problems using original premises was greater than for the problems using the denials of the original premises (Mann-Whitney $U = 44$, $p < 0.01$). The similar results were obtained from a second set of experiments using dyadic predicate problems parallel to the monadic predicate problems used in the first experiment A 2x2 within-subjects design was used (N=140, individually tested). This time the latency data were also collected, and the results showed that an answer took significantly longer time when two cases (both "all true" and "all false" situations) needed to be considered than when only one case (i.e., "all the premises are true") needed to be considered. For the problems with original premises and necessity questions, 55% subjects answered yes, which was an illusion because they failed to consider the "all false" case. But they could apply inference schemas in the local situation of "all true". However, another fairly large portion of participants (45%) responded "No" to the problems of this type, and would have needed to consider the "all-false" case, which took longer time. In this local situation, there are no inference schemas currently available to deal with the denials of the original premises, and reasoners may likely construct mental models.

There are long-standing controversies between mental logic and mental model theories, as well as other emerging controversies between the mental logic/model paradigm, mental metalogic, and other approaches in reasoning. Deduction is core to human cognition. These issues deserve open discussions and debates, which have been the ways for different theories to grow in this field.

(Note. References are available upon request.)