Strategy and Cognitive Capacity

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Contributor: Henry Markovits

There is little consensus about the underlying parameters of human reasoning. Two major theories have been proposed that suppose very different mechanisms. The mental model theory proposes that people use working memory intensive processes in order to construct limited models of problem parameters. Specifically, a recently developed diagnostic questionnaire has identified two major categories of reasoners: Counterexample reasoners use a mental model form of processing, while Statistical reasoners use a probabilistic form of processing. Strategy use correlates with performance on very different kinds of thinking, such as contingency judgments, processing of negative emotions, or susceptibility to social biases.

Keywords: reasoning ; dual strategy ; individual differences

1. Are There Two Kinds of Reasoners?

Deductive reasoning in its most simple form involves generating a conclusion based on a given set of premises. Such reasoning is both a core element of the development of advanced mathematical and scientific models and is a ubiquitous component of ordinary social interactions. Understanding the nature of human reasoning is thus one of the core dimensions of any model of human intelligence. There is, however, no real consensus about the underlying processes that define how people generate conclusions. In the following, I present evidence that there is a qualitative distinction between two different modes of reasoning that form a strong individual difference, one that is instantiated in the dual-strategy model of reasoning.

Underlying this model is a debate between two major theories of reasoning, mental model, and probabilistic theories. The mental model theory (Hinterecker et al. 2016; Johnson-Laird 2001; Johnson-Laird 2012) postulates that reasoning involves the active construction of simple, iconic models of problem premises. Although the full theory is much more complex than will be presented here, three critical components are of particular concern here. The first is that models are simplified representations that focus on key aspects of a given deductive problem. The second is that such models are actively generated in working memory and require significant cognitive resources. The final aspect is that when attempting to generate a putative conclusion from a given model set, people will examine this for any potential counterexamples: a conclusion is considered to be valid if and only if the model set does not contain any cases that contradict this conclusion. The mental model theory is based on the underlying idea that the semantics of logical connectors (if-then, etc.) generally correspond to the truth-table interpretation of these connectors in standard logics. Deviations from standard logic are explained by cognitive capacity, since manipulating models requires significant short term memory usage, and by other factors such as pragmatic considerations (Johnson-Laird 2001) which may modulate the nature of the models that are generated.

The mental model theory, despite the existence of factors that could in principle explain the very great amount of variability observed when people reason is empirically examined, remains tied to the structures of propositional logic. Probabilistic theories, on the other hand, attempt to incorporate variability directly into the underlying structure of reasoning. Although there are different varieties, the basic model is that when faced with some premises, people will derive an intuitive probability of some putative conclusion (Evans et al. 2003; Oaksford and Chater 2009; Oaksford et al. 2000). This will be performed not only with respect to the premises, but also by considering what people know about the premises. These theories attempt to model the nature of informal reasoning, which very often is expressed as when “something is more or less probable” to some degree. Underlying these theories is an essentially Bayesian model of probabilistic updating. These suggest that when evaluating a potential conclusion, people make intuitive evaluations that incorporate their understanding of how the world works. Deduction is then an inherently probabilistic enterprise. Dichotomous judgments of validity are, in this perspective, not a natural outcome of this kind of reasoning. When making a deduction, the intuitive probability that is assigned to a putative conclusion must be translated into a judgment of validity, but one that maintains the basic information generated by the initial probabilistic evaluation.

These theories have been proposed as unitary models of human reasoning, each of which has claimed to be able to understand, with some adjustments, how people reason. However, Verschueren and colleagues suggested that these divergent theories could be seen as different ways of reasoning (Verschueren et al. 2005a, 2005b). They incorporated this hypothesis within the context of dual-process theories which postulate the existence of two different reasoning systems (Evans and Stanovich 2013; Evans 2007; Sloman 1996; Stanovich and West 2000). Briefly, Type 1 reasoning is essentially rapid, intuitive, and associative in nature, while Type 2 reasoning is more conscious and working memory intensive. Within this context, they proposed that probabilistic reasoning could be seen as a form of Type 1 processing, while mental model-like reasoning was a form of Type 2 processing. In other words, they proposed that people can make both a probabilistic judgment that considers the statistical distribution of potential alternative antecedents in order to generate an estimate of the likelihood of a potential conclusion being true, and categorical judgments of validity for which a single potential counterexample is sufficient to reject a potential conclusion. They examined verbal protocols and found evidence for use of both counterexamples and likelihood estimates. In addition, there was evidence that use of a probabilistic strategy was relatively greater among reasoners with lower working memory spans, i.e., that less competent reasoners will tend to produce a likelihood estimate more often. Finally, they found that access to counterexample information was a slower process than generating likelihood estimates. Their results provide a useful basis for the proposed distinction. However, the use of verbal protocols might have an influence on the way that people reason and does not allow for a clear way of distinguishing the two ways of reasoning.

Markovits et al. (2012) proposed a more direct way of distinguishing these two ways of reasoning. This involves presenting participants with simple conditional reasoning problems using an affirmation of the consequent inference (P implies Q, Q is true), for which there is no valid logical response. Reasoners were asked if the putative conclusion “P is true” was valid or not. In order to reduce the extent to which existing knowledge might impact inferences, premises referred to unknown elements situated on a different planet. The key addition was the results of 1000 observations made on the planet that concerned the if-then relation used in the major premise, based on a previous study by (Geiger and Oberauer 2007). This gave the number of times that P and Q were observed together, and the number of times that Q was observed but not P. Critically, this gives two kinds of information. The ratio of (P and Q) to the total gives the statistical probability of the putative conclusion being true. The existence of a non-zero number of (not-P and Q) cases indicates the presence of counterexamples to this conclusion. Now, since there is no clear algorithm for translating a probabilistic evaluation into a dichotomous validity judgment, presenting a single inference of this kind would not be diagnostic. The key was presenting two sets of five such inferences, one of which presented about a 90% rate of (P and Q) cases, with the other presenting about a 50% rate of these cases. A reasoner who used the statistical information would end up accepting the 90% inferences more often than the 50% inferences, at a rate that would generally reflect the difference in probabilities. A reasoner who focused on potential counterexamples would reject all of these inferences.

This diagnostic instrument is the basis for the dual-strategy model of reasoning, which supposes that people have a preferred mode of reasoning corresponding to either a Statistical or a Counterexample strategy. Initial studies concentrated on validation of this basic idea. The results of (Markovits et al. 2012) provided clear initial support for the usefulness of the diagnostic instrument, showing that reasoners identified as using a Counterexample strategy showed better abstract reasoning abilities than those identified as using a Statistical strategy. More direct were the results of (Markovits et al. 2013), which examined performance on the diagnostic instrument under both unlimited and time constrained conditions. In addition, participants were asked for their level of confidence in their overall choices. The key results showed that under time constraint, people preferentially responded to the diagnostic instrument with responses that indicated used of a Statistical strategy, even when they responded with a Counterexample pattern when given unlimited time. In addition, transitions under different time conditions were predicted by people’s confidence in their initial strategy choice. These results provided strong evidence for the idea that people have access to different ways of reasoning, and that these were under some degree of metacognitive control.

2. Strategy and Cognitive Capacity

A second, more complex but related question is the relation between cognitive capacity and reasoning strategy. The initial studies by (Verschueren et al. 2005b) suggested that people whose explicit justifications indicated use of a mental model-like form of reasoning had higher levels of working memory capacity. Later studies have indeed shown a strong correlation between several measures of cognitive capacity and strategy use. In (Thompson and Markovits 2021), the authors observed that Counterexample reasoners had higher scores on measures of IQ and the Cognitive Reflection Test (CRT). The CRT is a measure of the tendency of people to avoid giving an immediate (but clearly wrong) answer (Frederick 2005). More recently, Markovits (2024) found that this extended to the scale of Actively Open-Minded Thinking

(AOT), which is a measure of the tendency of people to consider alternative options when reasoning and has been found to correlate with deductive performance (Stanovich and West 1997).

There are two interesting aspects to these results. The first is the fact that the strategy diagnostic can successfully distinguish clear differences in a variety of different measures of cognitive ability. For example, using normalized scores on IQ, CRT, and AOT measures, Markovits (2024) found that Counterexample reasoners had a combined score ($M = 0.438$) that was much higher than Statistical reasoners ($M = -0.099$), with this difference being similar across all three measures. Second, this raises the question of whether the observed relationship between strategy use and various forms of reasoning and judgments tasks might simply be due to the fact that Counterexample reasoners are smarter, less prone to immediate wrong answers and more flexible in their judgments. There is, however, evidence that differences in performance related to strategy use are not solely a product of underlying differences in cognitive capacity. In the first direct examination of the potential role of differences in cognitive capacity on the effect of reasoning, (de Chantal et al. 2019) examined performance on syllogisms for which logical validity and conclusion belief are in conflict, leading to the belief-bias effect, which is one of the most extensively studies forms of heuristic bias (Evans et al. 1983). In their study, de Chantal et al. (2019) measured both performance on belief-biased inferences and working memory capacity. They found that Counterexample reasoners were significantly less prone to belief-bias effects, even when differences in working memory are factored out. In a recent more extensive study, Thompson and Markovits (2021) examined the respective contributions of strategy use, IQ, CRT, and numeracy on four different heuristic effects, belief-bias, base rate neglect, the conjunction fallacy and denominator neglect. They found that strategy use accounted for a significant proportion of the variance in belief-bias, base rate neglect and denominator neglect over and above the contribution of the other cognitive measures. Importantly, the latter two do not involve deductive reasoning, but involve judgment under uncertainty which gives additional evidence of the generality of the strategy use distinction.

Even stronger evidence for the unique contribution of strategy use is given by results examining the respective contributions of strategy use and cognitive capacity on performance under severe time constraint. These studies specifically examined the ability of participants to produce “valid” responses when given standard belief-biased syllogisms. There are two models that suggest that this ability should be strongly correlated with cognitive capacity. The first is the standard dual-process model that suggests that making valid deductions to such syllogisms (and not giving the heuristic belief-driven response) is generally acknowledged to require Type 2 conscious, working memory-dependent processes (De Neys 2006). Thus, reducing the time allotted for making inferences should decrease the rate at which the valid response is chosen (Evans and Curtis-Holmes 2005), and should make differences in working memory correspondingly more important. Another approach to fast reasoning considers that people might have access to a form of “logical” intuition which would allow generating the valid response without using processes that require cognitive capacity (De Neys 2012; De Neys and Pennycook 2019). Thus, use of such intuitive reasoning would allow fast logical reasoning that does not depend on working memory-dependent processes. However, there is evidence that the ability to make intuitive responses that are logical is concentrated among better reasoners (Raoelison et al. 2020), and thus, fast logical reasoning should be strongly associated with increased cognitive capacity.

In two studies, the ability to make fast, logical inferences was examined along with measures of strategy use and measures of cognitive capacity. The results obtained by Markovits et al. (2021) and Markovits (2023) clearly show that strategy use is a strong predictor of the ability to reason logically under severe time constraints, even when cognitive capacity is factored out. These results are particularly striking since they also show that, in contrast with studies examining reasoning under normal conditions, once strategy use is considered, other measures of cognitive capacity have little effect.

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