

only shows that adjustable parameters are needed to fit MMT to data. However, this is true for almost any cognitive theory. It does not make them probabilistic theories.

Another main plank in their argument is that MMT provides a better account of syllogistic reasoning than the probability heuristics model (PHM) [5]. However, the meta-analysis [6] they report comparing PHM with MMT used accuracy as a measure but did not allow PHM to predict no valid conclusion responses. This move contradicts PHM in which no valid conclusion responses are predicted by one of its main heuristics (the *max*-heuristic). When appropriate model comparison methods are used, there is evidence that PHM provides better fits to the data than MMT [7].

According to Johnson-Laird *et al.*, MMT provides a better account of non-monotonicity because they generate explanations of an inconsistency. Such explanations can just as well be represented in causal Bayes nets [8,9]. However, neither theory produces explanations; they only represent them once generated from long term memory for world knowledge.

A further supposed advantage of MMT is that it allows kinematic models that unfold in time. As the representations and processes used in their example of a kinematic MMT bear absolutely no relationship to the representation/process pair that Johnson-Laird and colleagues argue underpins deductive/probabilistic reasoning, this supposed advantage is completely spurious.

In summary, the aim of Johnson-Laird *et al.* was to clarify the relationship between logic and probability. They do not do this. Their denial that or-introduction (from p to $p \vee q$) is valid in MMT is critical here as many fundamental theorems of probability depend on this inference. By contrast, the relation between logic and probability in the New Paradigm, with its probability conditional, could not be closer or more precise (Box 1).

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Letter

Response to Baratgin *et al.*: Mental Models Integrate Probability and Deduction

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Our review, Logic, Probability, and Human Reasoning [1], evaluated attempts to combine probability and deduction, and

concluded that the mental model theory yields a better integration of them than variants of probabilistic logic (p-logic) [2]. Baratgin *et al.* [3] disagree. We thank them for the opportunity to clarify the model theory, and for their argument against p-logic: unlike the model theory, p-logic is ‘monotonic’, and so it does not allow belief in conclusions to falter when facts are to the contrary (cf. [4]). We now consider their three main points.

First, Figure 3 in our paper shows that the model theory makes better predictions about syllogistic reasoning than seven other theories [5]. Baratgin *et al.* correctly note that our handling of the Probabilistic Heuristics Model [6] did not allow it to predict the response, ‘no valid conclusion’. The paper describing the PHM [6] did not list the syllogisms for which it predicts this response. As soon as we can obtain such a list, we will redo the analysis.

Second, the model theory explains probabilistic reasoning [7,8], and allows that reasoning is not deterministic even when an inference does not refer to probabilities. Contrary to p-logic, probabilities are not part of the contents of the inference in this case [9], but the underlying mechanism is probabilistic (Figure 4 in [1]). It yields different conclusions from the same premises on different occasions. It is a mystery why Baratgin *et al.* think that the Monte Carlo mechanism of the procedure is not probabilistic.

Third, Baratgin *et al.* consider this sort of inference, where A and B are any propositions:

A.

Therefore, A or B, or both.

In standard logic, this inclusive disjunction is true provided that one or both of its clauses are true. Hence, if A is true the disjunction is true, and so the inference is valid. Likewise, its conclusion is at least as probable as its premise, and so it is p-valid [2]. Yet, people balk at the inference [10].

Why? Baratgin *et al.* do not say. According to the model theory, the disjunction refers to a conjunction of three possibilities:

A and not-B

not-A and B

A and B

and one impossibility: not-A and not-B. (Disjunctions of the form A or not-A refer to two possibilities: A, and not-A, because the conjunction, A and not-A, yields the null model, akin to the empty set.) Because A does not imply the second possibility in the conjunction, i.e., not-A and B, the conjunction is false. The inference above is accordingly invalid in the model theory. Baratgin *et al.* object that these semantics make almost every disjunction true. However, from any true proposition, A, both logic and p-logic spawn an infinity of inclusive disjunctive conclusions, each containing a new proposition:

A or B.

A or B or C.

A or B or C or D.

... and so on *ad infinitum*.

These inferences are invalid in the model theory, which therefore renders fewer disjunctions true than does either logic or p-logic.

The model theory explains the vagaries in human inference, it predicts correctly more phenomena than any other theory (Table 3 in [1]), and, so far, it remains a feasible integration of deductive and probabilistic reasoning [10,11].

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Scientific Life

Cognitive Enhancement and Beyond: Recommendations from the Bioethics Commission

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Media outlets are reporting that cognitive enhancement is reaching epidemic levels, but evidence is lacking and ethical questions remain. The US Presidential Commission for the Study of Bioethical Issues (Bioethics Commission) has examined the issue, and we lay out the commission's findings and their relevance for the scientific community.

Cognitive Enhancement and Beyond: Defining the Scope

This year, the US Bioethics Commission, of which the authors are a Member and staff member, respectively, released the second volume of its report on neuroscience and ethics – *Gray Matters: Topics at the Intersection of Neuroscience, Ethics, and Society* [1]. In it, the Bioethics Commission explored public and scholarly debates relating to improved understanding of the brain and nervous system. Among them was the debate over the use of so-called ‘cognitive enhancement.’

The term ‘cognitive enhancement’ generally refers to a measure for expanding or augmenting the human capacity to think, feel, react, and remember, potentially ‘beyond the species-typical level or statistically-normal range of functioning’ [2]. Because novel applications of science to expand human capacities are nearly always controversial, it is not surprising that the novel use of neuroscience to enhance cognition is hotly contested.

An April 2015 *New York Times* article examined debates surrounding the growing use of the stimulant drug Adderall by young adults without the condition for which it is indicated. Adderall and other stimulants are used off-label by individuals who desire to increase their competitive advantage by working longer hours with greater attentiveness while sleeping less [3]. At every turn, we see headlines announcing ‘epidemic’ amphetamine use by high-achieving students seeking top grades and standardized test scores. Advertisements for high-tech brain-stimulation devices claim to make us more focused or improve our learning and memory, while essentially the same brain-boosting effects are claimed for low-tech approaches – such as dietary supplements including omega-3 fatty acids derived from fish oil and a good night’s sleep. Researchers say that particular drugs can dampen memories to ease the emotional pain of victims of trauma.