

## **Meta-Reasoning: What Can We Learn from the Metacognitive Approach?**

*Rakefet Ackerman and Valerie Thompson*

The past few decades have witnessed a surge of research in the area of metacognition. The foundational principles were articulated in the monitoring and control framework developed by Nelson and Narens (1990). Despite substantial advancements since then, the basic principles of the framework remain widely accepted. This framework was applied mainly to studying memorization tasks, although the underlying principles are clearly relevant for regulating mental efforts in many other cognitive tasks. In this talk, we will present a Meta-Reasoning framework that was developed using Nelson and Naren's framework as a starting point, and will support it with findings from reasoning and problem solving studies. In some respects, there are clear analogies between meta-reasoning and meta-memory, while in others, alternative theoretical approaches are needed. Thus, it is hoped that our framework will provide the basis for future theoretical and empirical work.

### **Discounting and causal conditional inference in children as young as 5: Better than adults.**

*Ali, N., Oaksford, M., Chater, N. & Schlottmann, A.*

Children between the ages of 4-6 were tested with causal and diagnostic conditionals for their patterns of discounting and augmentation inferences. This study replicated Ali et al (2010) but using a younger sample of children. The aim of the study was to push down the age range to establish (a) how early on children understand the qualitative differences between these inferences for these conditionals, and (b) to explore further whether children's performance is more in line with causal model theory than adults, as found in Ali et al (2010). Results showed that pre-school children (4 years) found the task difficult and answered at random. However, for 5 and 6 year olds all four predictions of causal model theory were strongly confirmed. Children at this age performed more in line with causal model theory than adults. Two hypotheses are explored to explain this effect. First, adult's rich experiential knowledge may lead to violations of the constraints on causal models, e.g., the parental Markov condition. Second, children's developing language abilities do not allow them to form a linguistic summary of interrogating their causal models which can be a source of error in adults (Ali, et al, in submission).

### **The engine of thought is a hybrid: Roles of associative and structured knowledge in reasoning**

*Aimee Bright*

Across a range of domains in psychology different theories assume different mental representations of knowledge. For example, in the literature on category-based inductive reasoning, certain theories assume that the knowledge upon which inductive inferences are based is associative whereas others assume that knowledge is structured. In this paper we investigate whether associative and structured knowledge underlie inductive reasoning to different degrees

under different processing conditions. We develop a measure of knowledge about the degree of association between categories and show that it dissociates from measures of structured knowledge. In Experiment 1 participants rated the strength of inductive arguments whose categories were either taxonomically or causally related. A measure of associative strength predicted reasoning when people had to respond fast, whereas causal and taxonomic knowledge explained inference strength when people responded slowly. In Experiment 2, we also manipulated whether the causal link between the categories was predictive or diagnostic. Participants preferred predictive to diagnostic arguments except when they responded under cognitive load. In Experiment 3, using an open-ended induction paradigm, people generated and evaluated their own conclusion categories. Inductive strength was predicted by associative strength under heavy cognitive load, whereas an index of structured knowledge was more predictive of inductive strength under minimal cognitive load. Together these results suggest that associative and structured models of reasoning apply best under different processing conditions, and that the application of structured knowledge in reasoning is often effortful.

### **Counterfactuals and embodied representations**

*Ruth Byrne*, Trinity College Dublin, University of Dublin, Ireland  
& *Orlando Espino*, University of La Laguna, Tenerife, Spain

When people understand counterfactuals such as, ‘if it had been a good year there would have been roses’, they consider two possibilities, one corresponding to the conjecture, ‘it was a good year and there were roses’ and one to the presupposed facts ‘it was not a good year and there were no roses’. An embodied cognition view suggests that people construct representations that are solely iconic and so they think about an alternative to represent the presupposed facts, e.g., ‘it was a bad year and there were lilies’. In contrast, the model theory suggests that iconic representations can contain symbols for negation. The two theories make different predictions about the sorts of representations people construct in binary contexts e.g., ‘in the botanical gardens there are roses or lilies’ versus multiple contexts ‘in the botanical gardens there are roses or lilies or carnations’. We test these predictions in two experiments that examine the length of time participants take to read explicit negations such as ‘there were no roses’ and implicit negations such as ‘there were lilies’ when they are primed by a counterfactual in a binary or multiple context. The results suggest that people represent the presupposed facts for counterfactuals using iconic representations that contain symbols for negation.

### **Ifs and ors**

*Nicole Cruz*, Jean Baratgin, Aidan Feeney, Mike Oaksford, David Over.

The probabilistic paradigm in reasoning research offers a generalisation of binary logic to cover the correctness of deductive inferences under uncertainty. In this new framework, the former concept of binary validity is generalised to that of probabilistic validity ( $p$ -validity), and the former concept

of binary consistency is generalised to that of coherence. People's sensitivity to the p-validity and coherence of an inference was investigated in an experiment using inferences to *p or q* from *p*, and inferences between *p or q* and *if not-p then q*. It was predicted that (1) people's judgements conform to p-validity and coherence more often than expected by chance, and conform less often to p-validity for p-invalid inferences than for p-valid ones; (2) People's judgments conform more often to p-validity and to coherence when evaluating explicit inferences than when evaluating the statements out of which the inferences are composed in isolation. The experiment was conducted through the internet. 871 Participants gave confidence judgements about a list of inferences (inference group) or of statements (statements group) based on information about a character from a short context story. The results were in accordance with both hypotheses. This provides support for the psychological relevance of the normative criteria of p-validity and coherence proposed by the probabilistic paradigm. And it suggests that the binding force of these criteria increases when given the explicit task to draw inferences as opposed to evaluating statements in isolation.

### **Feedback and bias: Advancing the conflict debate**

*Wim De Neys*

Human thinking is often biased by intuitive heuristics. Scattered evidence suggests that this bias might be reduced by presenting elementary response feedback (i.e., telling people whether their answer is “right” or “wrong”). I will show how this simple but somewhat neglected manipulation can help us to gain new insight into the nature of heuristic bias. Results of two large scale empirical studies indicate that feedback not only makes reasoners less biased but also faster. I will point to intriguing implications for our view of the way reasoners deal with conflict between cued heuristics and logical or probabilistic considerations.

### **The role of explanatory factors in updating**

*Igor Douven* and *Jonah Schupback*

There is an ongoing controversy in philosophy about the connection between explanation and inference. According to explanationists, our judgments of the explanatory goodness of hypotheses are directly relevant to the question of how much confidence we should invest in those hypotheses. Bayesians, on the other hand, hold that explanatory considerations should be given no weight in determining which inferences to make. The controversy has focussed on normative issues. This paper investigates experimentally the descriptive question of whether judgments of the explanatory goodness of hypotheses do play a role when people revise their degrees of belief in those hypotheses upon the receipt of new evidence.

### **Models of inference from *is* to *ought***

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We report a structural equation modelling study of inference from ‘is’ to ‘ought’. Participants evaluated utility conditionals with either positive or negative outcomes and high or low probability on a number of indicators including two causality indicators (necessity and sufficiency), two utility indicators (costs and benefits), and two behavioural effectiveness indicators (behavioural intent and behavioural probability). They also evaluated six deontic conclusions. We explore alternative causal models linking normative inference to behavioural effectiveness: (1) normative inference → behavioural effectiveness; (2) behavioural effectiveness → normative inference; and compare them to (3) which postulate only co-variation between these latent variables.

### **Rapid and free time responses to disjunctive inferences: the role of cognitive reflection.**

Juan A. García-Madruga (UNED, Madrid) and  
Sergio Moreno-Ríos (U. de Granada)

In this paper we present the main results of an experiment in which two groups of university participants were asked to solve the four inferences from disjunctive assertions such as: “A or B, or both”, in two versions: with and without time restriction. One group carried out first the free time version, the other the time restricted version. Participants also rated the difficulty of the inferential problems and received the Cognitive Reflection Test (Frederick, 2005). Results confirmed an increase of normative responses in free time condition and showed the relationship of cognitive reflection ability with participants’ inferential performance. Results are analyzed and discussed in the context of mental models and dual processing theories.

### **Young children’s reasoning about probabilities and proportions**

*Vittorio Girotto*

### **Neuropsychology of Reasoning**

*Vinod Goel*

Over the past several years we have tested 150+ neurological patients with focal lesions on logical reasoning tasks (syllogisms, transitive inference, and conditional reasoning). We are in the process of analyzing and writing up the results. I will present some subset of these data.

### **Causal deviance revisited.**

*Geoff Goodwin*

A causally deviant action is one in which an actor intends to cause a particular outcome, and causes that outcome, but not in the intended way. The analysis of deviant causal chains elucidates what it means to say that an action is carried out intentionally, and sheds light on the appropriate conditions

of blame and responsibility. Past research has indicated that actors are blamed less for producing causally deviant actions in comparison with standard, non-deviant actions (Pizarro, Uhlmann, Bloom, 2003). However, this conclusion is premature, owing to confounds in the experimental materials. In the present research, I show that when these confounds are removed, causally deviant actions are judged less blameworthy only in within-subjects designs, but not in between-subjects designs. Thus, while individuals appear to treat causal deviance as normatively relevant to judgments of blame, it exerts little or no effect in the isolated (i.e., non-comparative) contexts typical of real world legal decision-making.

### **Inconsistency of subjective probability**

*Ikuko HATTORI* (Ritsumeikan University),  
Masanori NAKAGAWA (Tokyo Institute of Technology) and  
Yasuhiro MIURA (Tokyo Institute of Technology)

Influence of the subjective probability on deductive reasoning, where the premises are assumed to be true has been reported by many researchers. However, it is still open question how people treat the conflict between their knowledge and the conditional sentence in reasoning task. The subjective probabilities of a conditional and its contraposition can collide each other in human mind, though the truth values of them is consistent with each other in logic. In this talk, two experimental researches will present evidence about inconsistency of subjective probability in human mind and the influence on reasoning.

### **Probabilistic representations in syllogistic reasoning and the effects of contents and figures**

Masaki Hattori (Ritsumeikan University, Kyoto, Japan)

Our reasoning is affected by contents. Belief bias, for example, is characterized as our tendency to overlook counterexamples when a logical conclusion accords with our own knowledge. An appropriate task representation, however, make it easier to detect counterexamples. In this sense, the content effect is caused by the difference in task representations. In this paper, first I will introduce a new model of syllogistic reasoning based on probabilistic mental representations. Second, I will show you a prediction of the model regarding the content effects. Comparing people's response patterns among different syllogistic figures, although the difference in performance will be minimal in default cases, it will grow larger in some cases depending on task representations with the help of content. Third, the results of an experiment to examine this prediction will be shown. Finally, I will conclude that the content effect is explained in terms of probabilistic representation and that errors in syllogistic reasoning are caused by the same mechanism as those in other areas including probability judgment.

### **The truth of conditionals**

*Phil Johnson-Laird*, Emeritus professor, Princeton University; Visiting Scholar: New York University.

*If the legal drinking age in the USA is lowered, there are more traffic accidents.* Such conditionals can be perplexing, and a major theoretical divergence hinges on their status given, say, that the drinking age is *not* lowered but there are more traffic accidents. Is the conditional true in this case, or is it without a truth value? The theory of mental models postulates that if people think about all the possibilities to which such a conditional, *If A then C*, refers they will consider these possibilities: A and C, not-A and not-C, not-A and C. The third possibility shows that the conditional is true in the case above. Many other conditionals differ in meaning, e.g., a biconditional interpretation blocks the third possibility. In contrast, several theories allied to probability logic postulate that a conditional is neither true nor false when its if-clause is false. This paper presents experiments corroborating the model theory's prediction. In a typical study, participants judged whether a set of assertions could all be true together, e.g.:

*If the legal drinking age in the USA is lowered, there are more traffic accidents.*

*The legal drinking age in the USA is not lowered.*

*There are more traffic accidents.*

*Call all these assertions be true?*

Most participants responded, 'yes'. Hence, for logically naïve individuals, a conditional can be true even when its if-clause is false.

### **The conditional probabilities of unique events**

*Sunny Khemlani*

We describe a dual-process theory of how individuals estimate the probabilities of unique events, such as Hillary Clinton becoming US President. It postulates that uncertainty is a guide to improbability. In its computer implementation, an intuitive system 1 simulates evidence in mental models, and forms analog non-numerical representations of the magnitude of degrees of belief. This system has minimal computational power, and combines evidence using a small repertoire of primitive operations. It resolves the uncertainty of divergent evidence for single events and for conjunctions and disjunctions of events by taking a primitive average of non-numerical probabilities. It computes conditional probabilities in a tractable way, treating the given event as evidence that may be relevant to the probability of the dependent event. We report an experiment on conditional probabilities that corroborated the theory's predictions. Participants concurred in estimates of real possibilities. They violated the complete joint probability distribution in the predicted ways. They were faster to estimate the probabilities of compound propositions when they had already estimated the probabilities of each of their components. We discuss the implications of these results for theories of probabilistic reasoning.

### **Modeling imprecise degrees of belief by distributions**

*Gernot D. Kleiter*

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University of Salzburg, Austria

The probabilistic paradigm in the psychology of thinking and reasoning has shifted the analysis of human competence from propositional logic to probability logic. The contribution argues that this is only a first step in the right direction because elementary probability is not rich enough to handle essential properties of human reasoning such as (a) imprecise degrees of beliefs, (b) correlated beliefs, and the (c) updating of beliefs by soft evidence. One way to model these properties is to replace point probabilities by uncertain quantities and to attach continuous probability distributions to them, that assign different weights to the possible values in the  $[0, 1]$  interval.

Many studies on the human understanding of conditionals investigate indicative conditionals where the antecedent and the consequent are required to be unrelated. In the distributional approach the antecedent and the consequent may be correlated. The importance of learning from soft evidence is known from Jeffrey's rule. In the distributional approach a distribution can easily be updated given the value of a probability.

Recently new methods were developed to describe complex multivariate probabilistic relationships between variables, so called copulae and vines. Vines are related to Bayesian networks, they allow, however, to represent imprecise dependence. The contribution explains what vines are and why they are a promising tool for modeling imprecise knowledge.

### **The erotetic theory of reasoning**

*Philipp Koralus*  
*University of Oxford*

We propose that naïve reasoning proceeds by treating information we reason from as questions and maximally strong answers. With recent advances in semantics, the erotetic (or “question-based”) theory of reasoning is developed with formal rigor. It allows us to build on the successes of mental model theory, predicting a new conditional illusory inference that we confirmed. It also allows us to overcome familiar criticisms of mental model theory. Moreover, it points to a new explanation of how our fallible natural endowment makes it possible to learn how to reason validly. Finally, it provides an avenue to unify theories of reasoning with theories of decision-making.

### **External Signs of Kinematic Mental Simulations**

*Robert Mackiewicz, Phillip Johnson-Laird, Sunny Khemlani, and Monica Bucciarelli*

We present studies that explored how naïve individuals solve different rearrangement problems, e.g. numbers 1-2-3-4 have to be rearranged to 4-3-2-1, and how they deduce from algorithms describing make such changes. The mental model theory predicts that the difficulty of rearrangements should depend on number of moves while the difficulty of algorithms should depend on their complexity. We tested the theory using an environment of a single railway track and a siding and confirmed the predictions of the model theory in a series of studies with children and adults. The theory also predicts that an opportunity to unload the burden of working memory to external props should speed up the reasoning processes and make the task easier. Indeed, children formulated accurate algorithms on more trials when they were able to gesture than when

they were unable to gesture and the eye movements of adult participants mirrored their verbal descriptions of the moves of cars.

### **When facts became false during inferential processing**

*Sergio Moreno-Ríos & Ruth Byrne*

We report the results of two experiments that examine inferences from arguments that contain negated conjunctions or disjunctions. Each argument had three premises. The first premise was a conjunction or a disjunction, asserted by an expert witness about the presence of two objects at a crime scene, e.g., ‘at the crime scene there was a knife or a stone or both’ (A or B or both). The next premise was a biconditional with an affirmative or negated antecedent, asserted as the rule governing the charging of the defendant, e.g., ‘if and only if there was a knife at the crime scene, the person was charged’ (if and only if A then C). The third premise affirmed or denied the conjunction or disjunction, asserted as the truth or falsity of the expert’s assertion, e.g., ‘The expert’s testimony was false’ (It is false that A or B or both). Participants were told about the truth or falsity of the expert's testimony early in the sequence of information (before the rule) or late (after the rule). Participants made inferences about whether or not the defendant was charged (i.e., a modus ponens or denial of the antecedent inference about C) and whether or not there was a particular object at the scene (i.e., about B). The results show that participants made systematic errors in the negation of conjunctions and disjunctions which affected their subsequent inferences. The results also show that they made more inferences when they were told the expert's testimony was false, and more inferences when they were told about the expert's testimony earlier rather than later.

### **Interpretation and Discounting in Causal Conditional Inference: Towards an Integrative Model**

Nilufa Ali, Nick Chater, & *Mike Oaksford* (presenting speaker)

To adequately compare psychological theories of reasoning requires that the materials are equally interpretable in terms of each theory. In this paper, experiments are reported which provided independent evidence for the interpretations of pairs of conditionals—sentences rendered in English as “if...then”—used in discounting inferences to test the mental models and causal models theories. In Experiment 1, using appropriate statistical tests in which the null can be supported, there was decisive evidence in favour of causal model theory, replicating previous research (Ali, Chater, & Oaksford, 2011). Experiment 2 addressed a potential confound and allowed a test of more varied interpretations of the conditional. This experiment provided strong evidence against this confound and for the causal model theory. Explaining the evidence for this confound in Experiment 1 suggested an integrative model in which mental models type representations are used to construct a cumulative record in working memory of the results of interrogating a dynamic causal model.

### **Framing Effects in Moral Judgments about Risk**



*Mary Parkinson & Ruth Byrne*  
*School of Psychology and Institute of Neuroscience,*  
*Trinity College Dublin, University of Dublin, Ireland*

We report the results of two experiments that test the effects of framing outcomes as gains or losses on moral judgements of risky and non-risk choices. The framing effect refers to the tendency for people to choose a sure option (e.g., 400 out of 600 people will be saved) rather than a risky option (e.g., a two-thirds probability that everyone will be saved and a one-third probability that no-one will be saved) when the outcomes are framed as gains, but for the preference to reverse when the outcomes are framed as losses (e.g., 200 out of 600 people will die). We examined participants' judgments about the moral acceptability of another person's choices of the risky or sure options, as well as their judgments of moral responsibility and blame. Experiment 1 showed that participants judge another person to be morally responsible for the outcome whether they make the typical choice or not. Experiment 2 showed that participants judge another person to be morally responsible for good outcomes more than bad outcomes, particularly when they are framed as gains. The implications of the results for alternative views of the cognitive processes underlying moral responsibility judgments are discussed.

### **A physical implementation of De Finetti's "logic of the probable".**

*Guy Politzer*

I describe a device (a water tank with movable partitions) which materializes de Finetti's coherence approach to probability. The physical constraints imposed by the capacity of the tank and its subdivisions on the volumes of liquid allow the representation of joint probability distributions and embody the axioms and rules of probability. I will show how to fully determine the limits in probability of the conclusion of deductive inferences under uncertainty without calculation by the sheer displacement of liquids. The analogy also suggests a physical counterpart of Dutch book arguments to assess individuals' rationality in probability judgments in the sense that having a degree of belief in a conclusion that is out of the bounds can be shown to be equivalent to a commitment to execute physically impossible tasks (such as removing more liquid than there exists, or pouring more than the capacity allows).

### **Reasoning about spatial relations and conditionals: A model approach**

*Marco Ragni and Tobias Sonntag*

Psychologists have studied reasoning from conditionals and from spatial relations, but not their combination. We investigated the applicability of the theory of mental models to an inferential task combining the two. When individuals evaluated whether sets of assertions could all be true at the same time, they had difficulty with problems in which the mental models of the conditionals needed to be fleshed out into fully explicit models in order to respond correctly. This difficulty applied both when a conditional about spatial relations occurred with two categorical assertions (Experiment 1), and when a conditional occurred with a categorical

assertion and a diagram (Experiment 2). The effect of a transitive spatial relation was detectable, but of less importance. When the mental models of different assertions conflicted, individuals tend to judge that the assertions were inconsistent, and only a minority were able to flesh out fully explicit models and to respond correctly (Experiment 3). When three assertions contained two conditionals, the evaluation of consistency became progressively harder depending on whether the third assertion held in the mental models of the two conditionals, in those of one conditional, or in those of neither conditional (Experiment 4). Implications of the results for theories of consistency are discussed.

### **Children's counterfactual and false-belief inferences about reasons for actions**

*Célia Rasga*<sup>a</sup>, Ana Cristina Quelhas<sup>a</sup> and Ruth M.J. Byrne<sup>ba</sup>*ISPA-IU, Lisbon, Portugal;* <sup>b</sup>*Trinity College Dublin, University of Dublin, Ireland*

We report two experiments that examined children's reasoning about intentions. Children aged 6 years and 8 years (in Experiment 1) and aged 7 years and 9 years (in Experiment 2) read scenarios in which an observer witnessed an actor carrying out an action, the actor had an initial reason for the action that was subsequently replaced by a different reason for the same action. For example, a boy saw his sister picking up clothes from her bedroom floor; the girl initially did so because she wanted to find her toy, but subsequently because her mother told her to tidy her room. The experiments tested children's counterfactual and false-belief inferences. Younger children aged 6 and 7 years made more counterfactual and false-belief errors about intention changes than older children aged 8 and 9 years. Younger children also made more false-belief errors than counterfactual errors. We discuss the implications of the results for alternative theories of counterfactual and false-belief reasoning.

### **Belief bias in conditional reasoning - an fMRI study.**

*Matt Roser* and Jonathan Evans

We used individual differences in intelligence and thinking disposition to investigate conditional reasoning with functional magnetic resonance imaging (fMRI). Participants engaged in conditional reasoning with statements which were either believable or unbelievable. A tendency to endorse believable statements as logically valid was observed and this was modulated by intelligence and disposition towards engaging in effortful thinking. Brain functional data were modelled separately for the presentation of the major premise and for the presentation of the entire argument. Lateral inferior-frontal and anterior cingulate areas were differentially active according to the believability of the major premise, consistent with the involvement of inhibitory mechanisms at an early stage of the trial. Individual differences in the degree of belief bias correlated strongly with functional activation in dorsolateral prefrontal and parietal cortices at the later stage of the trial. Together these results suggest that inhibitory processes are invoked by the presentation of belief-laden material when participants are instructed to reason deductively, assuming the premises are true, but that individual differences in the degree of belief bias are

affected by later processes of premise-rule integration which draw heavily on working memory. These results are consistent with dual-process accounts of reasoning.

### **A study of the sufficient conditional and the necessary conditional in Chinese**

*Jing Shao* and Jean Baratgin

We present a study of the sufficient conditional and the necessary conditional with Chinese subjects using a conditional reasoning task. We adopt the new paradigm of reasoning under uncertainty, and we use de Finetti's coherence approach to probability to assess participants' answers. We examine the variation of coherent answers as a function of the probability of the conditional sentence and that of the second premise, comparing the sufficient and the necessary conditionals.

### **Fast Logic and Slow Beliefs: Implications for Dual Process Theories of Reasoning**

*Valerie Thompson*, Maia Gibb, Ian Newman (University of Saskatchewan), Gord Pennycook (University of Waterloo), and Dries Trippas (University of Plymouth).

According to Dual Process Theories, many reasoning biases occur because autonomous processes (Type 1) deliver answers based on belief that may not be overturned by slower analyses based on logic and probability (Type 2). Data from two tasks (base rate neglect,  $N = 52$ ) and conditional inference ( $N = 72$ ), challenge this assumption. Participants made initial judgments of probability and logic under time restrictions and a second judgment under free time. As expected, initial judgments were sensitive to beliefs; unexpectedly, they also varied as a function of validity and probability. Both effects increased at time 2. These data provide clear evidence that both logic and probability judgments can be made intuitively and that deliberate thinking may produce "belief bias". In a third experiment aimed at reconciling these findings with the assumptions of Dual Process Theories, 111 participants completed a base rate task; for half of the trials, participants were instructed to respond based on beliefs, and for the other half, to respond based on statistics. Participants also completed measures of thinking dispositions and a standardized measure of IQ. High IQ participants were better than low IQ participants at making judgments on incongruent problems (but not congruent ones) and when asked to make judgments on the basis of statistics (but not beliefs). Thus, whilst it may be possible for autonomous and analytic processes to deliver responses based on both beliefs probability, capacity and thinking dispositions are necessary to resolve conflicting responses in favour of probability. A revised model will be presented to account for these findings.

### **Knowledge Selection and Response Dynamics in Category-Based Induction**

*Eoin Travers*, Queen's University Belfast;  
*Aidan Feeney*, Queen's University-Belfast;  
*Jonathan Rolison*, Queen's University Belfast;

Aimee Kay Bright, Queen Mary University of London.

To investigate the influence of associative and structured knowledge during inductive reasoning, participants completed a triad task, choosing to generalize a biological property from a base category to a foil category whose association with the base varied, or to a taxonomically-related category. Mouse cursor trajectories were recorded during the task. Participants were less likely to generalize normatively to the taxonomically-related species as the strength of the association between the base and the foil increased. Mouse trajectories revealed an attraction towards strongly associated foils, even when the correct response was chosen. Furthermore, this effect manifested as an increase in initial movements straight towards the foil response followed by a direction change, rather than a graded increase in the mean deviation, as observed in previous mouse-tracking studies. This result suggests that associative and more structured knowledge compete for control of inductive reasoning and that structured knowledge is available to reasoning processes later on.

### **The New Tweety-Nixon Puzzle: Implications for Bayesian Models of Human Reasoning**

*Matthias Unterhuber*

We present the new Tweety-Nixon puzzle, which is a challenge to Bayesian models of reasoning. We also describe empirical evidence that supports our criticism. The new Tweety-Nixon puzzle questions Bayesians' ability to account for reasoning with exceptions, much like the original Tweety-Nixon puzzle did for classical logic. The Tweety-Nixon puzzle includes determinate (Tweety case) and indeterminate (Nixon case) exception structures. Although birds fly whereas penguins do not, it seems plausible that Tweety, the penguin (who is also a bird), should be expected not to fly. In contrast, given Quakers are pacifists and Republicans are not, for Nixon, the Republican and Quaker, it is equally plausible that he is a pacifist as that he is not.

Based on a formal argument, we argue that Bayesians have to employ two probability functions to account for either exception structure. This rules out certain brands of Bayesianism which assume that Human epistemic states can be represented by a single subjective probability function. Rather a second probability function is needed that encodes generic world knowledge and which, arguably, should accord with observed frequencies. We finally present empirical evidence that seems to support our dualistic Bayesian account of reasoning.

### **The probability of iterated conditionals revisited**

*Janneke van Wijnbergen-Huitink*

The Import-Export principle states that the probability of an iterated conditional 'If A, then if B, then C' equals the probability of the corresponding imported form 'If A and B, then C'. In combination with the Equation, Import-Export yields what might be the Generalized Equation,  $\Pr(\text{If B, then C} | A) = \Pr(\text{C} | A \ \& \ B)$ , which is one of the key assumptions in Lewis's famous triviality proofs. This talk presents the first experimental evidence comparing Import-Export and the

Generalized Equation, for realistic conditionals. The results indicate that while people's probability judgments do not conform to the Generalized Equation (replicating previous findings), they do conform to Import-Export.

### **Theory of Mind Meets Deontic Introduction: Can We Understand an 'Ought' from an Intention?**

*Meredith. R Wilkinson*<sup>1</sup>, Shira Elqayam<sup>1</sup>, David E. Over<sup>2</sup>, Valerie A. Thompson<sup>3</sup> and Jonathan St. B. T. Evans<sup>4</sup>

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This talk will present recent work we have conducted examining the role of intentions in how we make judgements about an agent's subsequent behaviour. One hallmark of a 'theory of mind' (e.g., Baron-Cohen et al., 1985) is that we are able to understand the mental states of others around us in order to then make a judgement about their behaviour or mental state. An ability to understand the intentions of another agent is extremely important, especially when we are engaged in social interactions, and is also postulated to play a role in inference from norms from descriptions. We present an experiment with two conditions: a control condition in which participants are presented with utility conditionals and asked to rate normative conclusions; and a suppression condition with additional premises in which the agents are presented as lacking intentions. Participants were required to make judgements about deontic conclusions. We will discuss our results both from a theory of mind perspective and as a contribution to the understanding of normative reasoning.