

From objective Bayesian epistemology to inductive logic

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The main aim of this project is to revive inductive logic (the logic of inference under uncertainty) by building on recent developments in epistemology (the theory of knowledge and belief).

Inductive logic has potential application to any area in which one needs to reason about structure, but where evidence is limited and uncertainty is rife. For example, bioinformatics requires formal methods for reasoning about biological structure in the presence of only partial knowledge of genetic function and biochemical processes; natural language processing requires formal methods for reasoning about sentence structure and meaning in the presence of statistical evidence of previously processed sentences.

However, after intensive research in the 1950s-70s, the inductive logic programme faced important philosophical critiques from which it never fully recovered. Thus, while there are a few small pockets of researchers still working on logics for reasoning under uncertainty, the inductive logic programme is widely held to have failed.



In the 1980s-90s, new methods for handling uncertainty were developed – probabilistic network methods – which are computational rather than logical techniques. These new methods filled the need for computationally feasible tools for manipulating and reasoning with probabilities, and research on inductive logic remained on the sidelines. However, while probabilistic networks can handle uncertainty in an elegant way, they were not developed for reasoning about structure at the same time. There are attempts to extend the probabilistic network formalism to cope with richer structure, but these methods are complex and disparate and no clear contender has emerged.

Now is the right time to revive the inductive logic programme. This is for three reasons. First, the need for inductive logic remains: there is still a need throughout the sciences to reason about structure under uncertainty and inductive logic is the natural formalism for fulfilling that need. Second, recent work in epistemology has offered the possibility of developing a new approach to inductive logic that may survive the traditional critiques of inductive logic. In particular, ideas emerging from probabilistic epistemology may offer a coherent approach to inductive logic (see, e.g., "In defence of objective Bayesianism", Oxford University Press 2010). Third, recent work in forging connections between probabilistic logics and probabilistic networks has led to the possibility of developing computationally tractable methods for performing calculations in inductive logic (see, e.g., "Probabilistic logics and probabilistic networks", Springer 2011).

Visitors:

We are keen to welcome visitors who want to work on inductive logic at the University of Kent.

- 10 February 2014 – 30 April 2014: **Christian Wallmann**
- 29 March 2013 – 31 March 2013: **Kevin Korb**
- 15 November 2012 – 28 February 2013: **Soroush Rad**
- 15 September 2012 – 16 November 2012: **Martin Adamcik**
- 12-14 September 2012: **Jeff Paris, Alena Vencovska, George Wilmers.**

Publications

Jon Williamson: **Lectures on inductive logic**, Oxford University Press, 2017.

Teddy Groves: **Let's Reappraise Carnapian Inductive Logic!** PhD thesis, University of Kent, 2015. 

Journal special issue: **Combining probability and logic**, *Journal of Applied Logic* 14. March 2016. Editorial: 

Journal special issue: **Maximum Entropy Applied to Inductive Logic and Reasoning**, *Entropy* journal.

Jim Hawthorne, Juergen Landes, Christian Wallmann & Jon Williamson: **The Principal Principle implies the Principle of Indifference**, *British Journal for the Philosophy of Science*. 68:123–131, 2017.   doi: [10.1093/bjps/axv030](https://doi.org/10.1093/bjps/axv030).

Juergen Landes & Jon Williamson: **Objective Bayesian**

Events and Talks

Teddy Groves – **Revisiting Lakatos's criticism of Carnapian inductive logic**, *CLMPS*, University of Helsinki, 3-8 August 2015.

Jürgen Landes: **Objective Bayesian nets from consistent data sets**. *35th International Workshop on Bayesian Inference and Maximum Entropy Methods in Science and Engineering*, Clarkson University, 19 -24 July 2015.

Jürgen Landes: **Objective Bayesian Nets – from consistent data sets**. British Society for the Philosophy of Science. Manchester, UK, 2 – 3 July 2015.

Jürgen Landes: **Objective Bayesian Nets – from consistent data sets**. Computability in Europe. Bucharest, Romania, 29 June – 3 July 2015.

Jon Williamson – **Epistemic consequentialism and the principle of indifference**, *Epistemic Consequentialism*:

nets from consistent datasets, in Adom Giffin & Kevin H. Knuth (eds), *Proceedings of the 35th International Workshop on Bayesian Inference and Maximum Entropy Methods in Science and Engineering*, Potsdam NY. American Institute of Physics Conference Proceedings 1757, 2016.  doi: [10.1063/1.4959048](https://doi.org/10.1063/1.4959048)

Teddy Groves: **Lakatos' criticism of Carnap's inductive logic was mistaken**, *Journal of Applied Logic* 14:3-21, 2016.  doi: [10.1016/j.jal.2015.09.014](https://doi.org/10.1016/j.jal.2015.09.014)

Teddy Groves: **An application of Carnapian inductive logic to an argument in the philosophy of statistics**, *Journal of Applied Logic* 12(3): 302-318, 2014.   doi: [10.1016/j.jal.2014.05.002](https://doi.org/10.1016/j.jal.2014.05.002)

Juergen Landes & Jon Williamson: **Justifying Objective Bayesianism on Predicate Languages**, *Entropy* 17: 2459-2543, 2015;   doi: [10.3390/e17042459](https://doi.org/10.3390/e17042459).

Objective Bayesianism says that the strengths of one's beliefs ought to be probabilities, calibrated to physical probabilities insofar as one has evidence of them, and otherwise sufficiently equivocal. These norms of belief are often explicated using the maximum entropy principle. In this paper we investigate the extent to which one can provide a unified justification of the objective Bayesian norms in the case in which the background language is a first-order predicate language, with a view to applying the resulting formalism to inductive logic. We show that the maximum entropy principle can be motivated largely in terms of minimising worst-case expected loss.

Jürgen Landes & Jon Williamson: **Objective Bayesianism and the Maximum Entropy Principle**, *Entropy* 15(9): 3528-3591, 2013.    doi: [10.3390/e15093528](https://doi.org/10.3390/e15093528)

Objective Bayesian epistemology invokes three norms: the strengths of our beliefs should be probabilities, they should be calibrated to our evidence of physical probabilities, and they should otherwise equivocate sufficiently between the basic propositions that we can express. The three norms are sometimes explicated by appealing to the maximum

problems and prospects, Kent, 25-26 June 2015.

Teddy Groves – **Response to Jon Williamson**, **Epistemic Consequentialism: problems and prospects**, Kent, 25-26 June 2015.

Teddy Groves – **Accuracy arguments for probabilism**, **Formal Epistemology**, Bristol, 15 June 2015.

Jon Williamson – **Objective vs Subjective Bayesianism**, **The Odds for Bayesianism**, Vienna, 28-30 May 2015.

Teddy Groves – **Problems with Accuracy Arguments for Probabilism**, **The Odds for Bayesianism**, Vienna, 28-30 May 2015.

Jürgen Landes: **A course on Bayesian Epistemology**. Lund, 18-22 May 2015.

Conference: **progic 2015: The Seventh Workshop on Combining Probability and Logic**. Special focus: formal epistemology and inductive logic. Following the **Spring School on Combining Probability and Logic**. University of Kent, Canterbury, UK, 20-24 April 2015.

Teddy Groves: **A problem for objective Bayesian inductive logic**. Progic 2015. University of Kent, Canterbury, UK, 22-24 April 2015.

Jürgen Landes: **Maximum entropy and inductive logic**. Spring School on Combining Probability and Logic. University of Kent, Canterbury, UK, 20-21 April 2015.

Jon Williamson: **Classical, Carnapian and objective Bayesian inductive logics**. Spring School on Combining Probability and Logic. University of Kent, Canterbury, UK, 20-21 April 2015.

Teddy Groves – **Objective Bayesian epistemology and inductive logic**, Reasoning Club, Manchester, 30-31 March 2015.

Jon Williamson: **Classical inductive logic, Carnap's programme and the objective Bayesian approach**.

entropy principle, which says that a belief function should be a probability function, from all those that are calibrated to evidence, that has maximum entropy. However, the three norms of objective Bayesianism are usually justified in different ways. In this paper we show that the three norms can all be subsumed under a single justification in terms of minimising worst-case expected loss. This, in turn, is equivalent to maximising a generalised notion of entropy. We suggest that requiring language invariance, in addition to minimising worst-case expected loss, motivates maximisation of standard entropy as opposed to maximisation of other instances of generalised entropy.

Our argument also provides a qualified justification for updating degrees of belief by Bayesian conditionalisation. However, conditional probabilities play a less central part in the objective Bayesian account than they do under the subjective view of Bayesianism, leading to a reduced role for Bayes' Theorem.

Jon Williamson: **From Bayesian epistemology to inductive logic**, *Journal of Applied Logic* 11: 468-486, 2013.  doi: 10.1016/j.jal.2013.03.006

Inductive logic admits a variety of semantics (Haenni et al., 2011, Part 1). This paper develops semantics based on the norms of Bayesian epistemology (Williamson, 2010, Chapter 7). §1 introduces the semantics and then, in §2, the paper explores methods for drawing inferences in the resulting logic and compares the methods of this paper with the methods of Barnett and Paris (2008). §3 then evaluates this Bayesian inductive logic in the light of four traditional critiques of inductive logic, arguing (i) that it is language independent in a key sense, (ii) that it admits connections with the Principle of Indifference but these connections do not lead to paradox, (iii) that it can capture the phenomenon of learning from experience, and (iv) that while the logic advocates scepticism with regard to some universal hypotheses, such scepticism is not problematic from

Perspectives on Inductive Logic, Irvine, 19-20 March 2015.

Jürgen Landes: **Evidence aggregation, decision making, hierarchy, CHiP**. Theoretical Reasoning seminar, Kent, 28 January 2015.

Jon Williamson: **The Principal Principle implies the Principle of Indifference**. *Objective Probability and Conditional Reasoning seminar*, Institute of Philosophy, London, 18 November 2014.

Jürgen Landes: **How an Objective Bayesian Integrates Data**. *Inductive Logic and Confirmation in Science II*, Utah, 24-25 October 2014.

Jon Williamson: **The Principal Principle implies the Principle of Indifference**. Knowledge in a Digital World, Canterbury, 16-17 October 2014.

Jürgen Landes: **How an Objective Bayesian Integrates Data**. Knowledge in a Digital World, Canterbury, 16-17 October 2014.

Teddy Groves: **Was Carnapian inductive logic degenerate?** Theoretical Reasoning seminar, Kent, 8 October 2014.

Jon Williamson: **The Principal Principle implies the Principle of Indifference**. *Munich Centre for Mathematical Philosophy*, 8 October 2014.

Jürgen Landes: **Philosophy: rational belief formation**. Erasmus lectures at the *Munich Centre for Mathematical Philosophy*, 14-18 July 2014.

Jürgen Landes: **Strictly Proper Scoring Rules and the Probability Norm**, *British Society for Philosophy of Science*, 10-11 July 2014.

Teddy Groves: **Accuracy arguments in the context of Carnapian inductive logic**, *British Society for Philosophy of Science*, 10-11 July 2014.

Jürgen Landes: **Scoring rules, entropies and indifference**

the point of view of scientific theorising.

Jon Williamson: **Inductive logic**, *The Reasoner* 6(11):176-7, 2012. 

Michael Wilde & Jon Williamson: **Bayesianism and information**, in L. Floridi (ed.), *The Routledge Handbook of Philosophy of Information*. In press. 

Bayesianism is a theory of inductive inference that makes use of the mathematical theory of probability. Bayesians usually hold that the relevant probabilities should be interpreted in terms of rational degrees of belief. This still leaves much scope for disagreement, since there is no consensus about what norms govern rational degrees of belief. In this chapter, we first provide an introduction to three Bayesian theories that adopt a degree of belief interpretation of probability: (i) strictly subjective Bayesianism, (ii) empirically based subjective Bayesianism, and (iii) objective Bayesianism. Then we discuss how one might appeal to information theory in order to justify the norms of objective Bayesianism.

Jürgen Landes: **Probabilism, Entropies and Strictly Proper Scoring Rules**, *International Journal of Approximate Reasoning* 63:1-21, 2015.  doi:10.1016/j.ijar.2015.05.007

Accuracy arguments are the en vogue route in epistemic justifications of probabilism and further norms governing rational belief. These arguments often depend on the fact that the employed inaccuracy measure is strictly proper. I argue controversially that it is ill-advised to assume that the employed inaccuracy measures are strictly proper and that strictly proper statistical scoring rules are a more natural class of measures of inaccuracy. Building on work in belief elicitation I show how strictly proper statistical scoring rules can be used to give an epistemic justification of probabilism. An agent's evidence does not play any role in these

ence, Reasoning Club conference, 23-24 June 2014.

Teddy Groves: **Accuracy arguments for probabilism in the context of Carnapian inductive logic**, *4th LSE Graduate Conference in Philosophy of Probability*, 6-7 June 2014.

Jon Williamson: **Induction**. Erasmus lectures at Boğaziçi University Philosophy Department, 26-30 May 2014. CANCELLED.

Jon Williamson: **Inductive logic for automated decision making**. *Italian Association for Logic*, Pisa, 14-17 April 2014.

Jeff Paris & Jon Williamson: **Workshop on Pure Inductive Logic**. *5th Indian School on Logic and its Applications*, Tezpur University, 6-17 January 2014.

Jon Williamson: **Inductive Logic for Automated Decision Making**. Cognitive Science Institute, Osnabrück, 4 December 2013.

Jon Williamson: **Aggregating degrees of belief**. Theoretical Reasoning Seminar, Kent, 7 November 2013.

Jürgen Landes: **Comparing Epistemic and Statistical Scoring Rules**. Theoretical Reasoning Seminar, Kent, 24 October 2013.

Workshop: **Inductive logic and confirmation in science**. University of Kent, Paris Campus, France, 17-18 October 2013.

Teddy Groves: **An application of Carnapian inductive logic to philosophy of statistics**. *progic 2013, The Sixth Workshop on Combining Probability and Logic: Combining probability and logic to solve philosophical problems*, Munich, 17-18 September 2013.

Juergen Landes & Jon Williamson: **Objective Bayesian Epistemology for Inductive Logic on Predicate Languages**. *progic 2013, The Sixth Workshop on Combining Probability and Logic: Combining probability and logic to solve philosophical problems*, Munich, 17-18

justifications of probabilism. Principles demanding the maximisation of a generalised entropy depend on the agent's evidence. In the second part of the paper I show how to simultaneously justify probabilism and such a principle. I also investigate scoring rules which have traditionally been linked with entropies.

Jürgen Landes: **Min-Max Decision Rules for Choice under Complete Uncertainty: Axiomatic Characterizations for Preferences over Utility Intervals**, *International Journal of Approximate Reasoning* 55: 1301-1317, 2014.  doi 10.1016/j.ijar.2013.10.008

We introduce two novel frameworks for choice under complete uncertainty. These frameworks employ intervals to represent uncertain utility attaching to outcomes. In the first framework, utility intervals arising from one act with multiple possible outcomes are aggregated via a set-based approach. In the second framework the aggregation of utility intervals employs multisets. On the aggregated utility intervals, we then introduce min-max decision rules and lexicographic refinements thereof. The main technical results are axiomatic characterizations of these min-max decision rules and these refinements. We also briefly touch on the independence of introduced axioms. Furthermore, we show that such characterizations give rise to novel axiomatic characterizations of the well-known min-max decision rule \geq_{mnx} in the classical framework of choice under complete uncertainty.

Jon Williamson: **Deliberation, Judgement and the Nature of Evidence**, *Economics and Philosophy* 31(1): 27-65, 2015.  doi: 10.1017/S026626711400039X

One kind of deliberation involves an individual re-assessing the strengths of her beliefs in the light of new evidence. Bayesian epistemology measures the strength to which one ought to believe a proposition by its probability relative to all available evidence, and thus provides a normative account of individual

September 2013.

Jon Williamson: **Inductive Logic for Automated Decision Making**. *British Logic Colloquium*, 5-7 September 2013.

Teddy Groves: **An application of Carnapian inductive logic to philosophy of statistics**. *Second Reasoning Club Conference*, Scuola Normale Superiore, Pisa, 17-19 June 2013.

Jürgen Landes: **Objective Bayesianism and the maximum entropy principle**. *Second Reasoning Club Conference*, Scuola Normale Superiore, Pisa, 17-19 June 2013. 

Teddy Groves: **An application of Carnapian inductive logic to philosophy of statistics**. Theoretical Reasoning Seminar, Kent, 13 June 2013.

Workshop: **Bristol-Kent workshop on scoring rules**. London, 10 June 2013.

10:00-11:00 **Juergen Landes - Objective Bayesianism and the maximum entropy principle** 

11:00-12:00 **Jason Konek - An Anti-Luck Solution to the Problem of the Priors**

13:00-14:00 **Richard Pettigrew - Accuracy, risk, and the principle of indifference**

14:00-15:00 General discussion

Teddy Groves: **In what sense is Carnapian inductive logic objective?** *PhDs in Logic V*, Munich, 8-10 April 2013.

Teddy Groves: **In what sense is Carnapian inductive logic objective?** Theoretical Reasoning Seminar, Kent, 4 April 2013.

Jon Williamson: **Inductive Logic for Automated Decision Making**. *Artificial Intelligence and Simulation of Behaviour*, 3-5 April 2013. 

deliberation. This can be extended to an account of individual judgement by treating the act of judgement as a decision problem, amenable to the tools of decision theory. A normative account of public deliberation and judgement can be provided by merging the evidence of the individuals in question and calculating appropriate Bayesian probabilities and judgement thresholds relative to this merged evidence.

But this formal epistemology for deliberation and judgement lacks substance without an account of how evidence can be merged. And in order to provide such an account, we need in turn an account of what the evidence is that grounds Bayesian probabilities. This paper attempts to tackle these two concerns. After finding fault with several views on the nature of evidence (the views that evidence is knowledge; that evidence is whatever is fully believed; that evidence is observationally set credence; that evidence is information), it is argued that evidence is whatever is rationally taken for granted. This view has consequences for an account of merging, and it is shown that standard axioms for merging need to be altered somewhat.

Jon Williamson: **How uncertain do we need to be?** *Erkenntnis* 79(6):1249-1271, 2014. Published version:  Local version:  Video:   doi 10.1007/s10670-013-9516-6.

Expert probability forecasts can be useful for decision making (§1). But levels of uncertainty escalate: however the forecaster expresses the uncertainty that attaches to a forecast, there are good reasons for her to express a further level of uncertainty, in the shape of either imprecision or higher order uncertainty (§2). Bayesian epistemology provides the means to halt this escalator, by tying expressions of uncertainty to the propositions expressible in an agent's language (§3). But Bayesian epistemology comes in three main varieties. Strictly subjective Bayesianism and empirically-based subjective Bayesianism have difficulty in justifying the use of a

Teddy Groves: **In what sense is Carnapian inductive logic objective?** Advanced Topics in Reasoning, Kent, 26 March 2013.

Jürgen Landes: **The OBEIL project and YOU.** Advanced Topics in Reasoning, Kent, 26 March 2013.

Jürgen Landes: **Coordination Problems and You.** Theoretical Reasoning Seminar, Kent, 21 March 2013.

Jürgen Landes: **An objective Bayesian's bedtime story.** Mathematics Department, Manchester, 13 March 2013.

Jürgen Landes: **Proper scoring rules.** Philosophy Department Seminar, Kent, 22 January 2013.

Jürgen Landes: **Mechanism design and you.** Philosophy Department MA seminar, Kent, 5 December 2012.

Soroush Rad: **Updating.** Theoretical Reasoning Seminar, Kent, 15 November 2012.

Martin Adamcik: **Aggregating evidence bases.** Theoretical Reasoning Seminar, Kent, 4 October 2012.

Jon Williamson: **Classical inductive logic.** [Reasoning Club conference](#), VUB, Belgium, 17-19 September 2012. 

Teddy Groves: **What does Shackel show about Bertrand's paradox?** [Reasoning Club conference](#), VUB, Belgium, 17-19 September 2012.

Workshop: **Inductive logic.** University of Kent, Canterbury, UK, 12-13 September 2012.

12th September – [Keynes Seminar room 6](#)
 12.30pm lunch at the Gulbenkian cafe
 1.30-2.00 **Jon Williamson – Welcome and introduction**
 2.00-3.00 **Jeff Paris – Guessing the World**
 3.00-3.30 coffee
 3.30-4.30 **Juergen Landes – How Objective Bayesianism met Dung-Style Argumentation**

forecaster's probabilities for decision making (§4). On the other hand, objective Bayesianism can justify the use of these probabilities, at least when the probabilities are consistent with the agent's evidence (§5). Hence objective Bayesianism offers the most promise overall for explaining how testimony of uncertainty can be useful for decision making. Interestingly, the objective Bayesian analysis provided in §5 can also be used to justify a version of the Principle of Reflection (§6).

Jürgen Landes: **Review of Michael Strevens' *Tychomancy: Inferring Probability from Causal Structure*, *International Studies in the Philosophy of Science* 28(4): 446-448, 2014.**  
doi: 10.1080/02698595.2014.979675

Jon Williamson: **Review of *Reliable Reasoning* by Gilbert Harman and Sanjeev Kulkarni,** *Mind* 121:1073-1076, doi 10.1093/mind/fzt006, 2013.  

Jürgen Landes: **Review of *Evolution and Rationality: Decisions, Co-operation and Strategic Behaviour* by Samir Okasha and Ken Binmore,** *Philosophical Quarterly*, 2014; doi: 10.1093/pq/pqt040.  

Jürgen Landes: **Inductive logic, 12-13 September, The Reasoner** 6(11): 172, 2012.  

George Darby & Jürgen Landes: **There Is More to a Paradox Than Credence,** *Thought* 3(2): 99-109, 2014. 
doi:10.1002/tht3.117

Besides the usual business of solving paradoxes, there has been recent philosophical work on their essential nature. Lycan characterises a paradox as "an inconsistent set of propositions, each of which is very plausible." Building on this definition, Paseau offers a numerical measure of paradoxicality of a set of principles: a function of the degrees to which a subject believes the principles considered individually (all typically high) and of the degree to which the subject believes the principles considered together

4.30-5.30 George Wilmers – The Social Entropy Process: Can it be Justified Axiomatically as a Natural Generalisation of the Maximum Entropy Inference Process?

13th September – [Cornwallis Seminar room 12](#)
9.30-10.30 Jon Williamson – How uncertain do we need to be?

10.30-11.30 Teddy Groves – What does Shackle show about Bertrand's paradox?

11.30-12.00 coffee

12.00-1pm Alena Vencovska – Probability Functions respecting the structure of information in Inductive Logic (as they arise when considering non-unary predicates)

Jürgen Landes: *Inductive logic, 12-13 September, The Reasoner* 6(11):172, 2012. 

(typically low). We argue (a) that Paseau's measure fails to score certain paradoxes properly and (b) that this failure is not due to the particular measure but rather that any such function just of credences fails to adequately capture paradoxicality. Our analysis leads us to conclude that Lycan's definition also fails to capture the notion of paradox.

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