Report from Dagstuhl Seminar 19032

# Conditional Logics and Conditional Reasoning: New Joint Perspectives

**Edited by**

**Guillaume Aucher[1], Paul Egré[2], Gabriele Kern-Isberner[3], and Francesca Poggiolesi[4]**

1 **University of Rennes 1, CNRS, FR, guillaume.aucher@irisa.fr**
2 **CNRS, ENS, PSL University, FR, paul.egre@ens.fr**
3 **TU Dortmund, DE, gabriele.kern-isberner@cs.tu-dortmund.de**
4 **CNRS, University of Paris 1, ENS, FR, poggiolesi@gmail.com**

**Abstract**

In the last decades, with the emergence of artificial intelligence, a large number of logics called conditional logics have been introduced to model our conditional reasoning captured by so–called conditionals, which are statements of the form 'if A then B'. More recently, conditional reasoning has also come under scrutiny by psychologists, yet with more pragmatic and empirical considerations. The main objective of this seminar was to provide an opportunity for these different communities working on that topic to meet and reinforce their ties. We focused on three specific issues. First, we investigated how people's intuitions about 'counterpossibles' can be understood empirically and classified with respect to the theoretical accounts of conditional logics. Second, we reconsidered the various semantics of system P and we wondered to which extent pragmatics plays a role in the relevance relation between the antecedant and the consequent of a conditional. Third, we strove to apply the recent advances in proof theory and correspondence theory to conditional logics. These working groups were preceded by short talks and tutorials.

**Seminar** January 13–16, 2019 – https://www.dagstuhl.de/19032
**2012 ACM Subject Classification** Artificial intelligence → philosophical/theoretical foundations of artificial intelligence, Artificial intelligence → knowledge representation and scheduling, Mathematical logic and formal languages → proof theory, Mathematical logic and formal languages → modal and temporal logic
**Keywords and phrases** Commonsense reasoning, conditionals, correspondence theory, proof theory, psychology of reasoning
**Digital Object Identifier** 10.4230/DagRep.1.9.47
**Edited in cooperation with** Mario Günther

## 1 Executive Summary

*Guillaume Aucher (University of Rennes 1, CNRS, FR, guillaume.aucher@irisa.fr)*
*Paul Egré (CNRS, ENS, PSL, FR, paul.egre@ens.fr)*
*Gabriele Kern-Isberner (TU Dortmund, DE, gabriele.kern-isberner@cs.tu-dortmund.de)*
*Francesca Poggiolesi (CNRS, University of Paris 1, ENS, FR, poggiolesi@gmail.com)*



Logic in the first half of the 20th century has been mostly concerned with mathematical reasoning and providing a unified framework for the foundations of mathematics. In the second half of the 20th century, with the emergence of artificial intelligence, new formalisms have been introduced to model kinds of inference closer to everyday life.


Conditional Logics and Conditional Reasoning: New Joint Perspectives,
*Dagstuhl Reports*, Vol. 9, Issue 1, pp. 47–66
Editors: Guillaume Aucher, Paul Egré, Gabriele Kern-Isberner and Francesca Poggiolesi
Dagstuhl Reports
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

"Commonsense reasoning", the reasoning that humans perform in everyday life, is significantly different from the reasoning of mathematicians, which has been the object of study of (mathematical) logic for a long time. It is very rich and includes different kinds of reasoning, such as counterfactual reasoning, default reasoning or uncertain and plausible reasoning. Commonsense reasoning is often captured by means of conditionals, which are sentences of the form 'if $A$ then $B$'. These conditionals can also be of various kinds: counterfactual, indicative, or subjunctive. The benefits of conditionals for formalizing commonsense reasoning are basically twofold: first, they can encode reasoning patterns of various types if one chooses suitable semantics or calculi, and second, they provide a common syntactic element that can be used to relate and compare the different kinds of commonsense reasoning as well as the mathematical reasoning.

Conditionals are also studied in the psychology of reasoning, which has recently witnessed a new wave of work. In particular, an effort to confront semantic frameworks with empirical results has been made. In parallel, a number of mathematical advances have been made in modal logic, an area closely related to conditional logics. However, the techniques developed in modal logic with respect to proof theory and correspondence theory have not fully been applied to the conditional logics introduced in artificial intelligence and philosophy. The main objective of this seminar was to provide an opportunity for computer scientists, logicians, psychologists, linguists and philosophers working on that topic to meet and reinforce their ties over several days in the Dagstuhl castle.

We focused on three specific issues which were discussed and worked out in three different working groups. First, we investigated how people's intuitions about 'counterpossibles' can be understood empirically and classified thanks to the theoretical accounts of conditional logics. Second, we reconsidered the various semantics of the basic system P and wondered to which extent pragmatics plays a role in the relevance relation between the antecedant and the consequent of a conditional. Third, we strove to apply the recent advances in proof theory and correspondence theory to conditional logics. These three topics correspond respectively to the working groups "Investigating people's intuitions about counterpossibles" (Section 4.1), "The semantics of conditionals" (Section 4.2) and "Correspondence theory and proof theory for conditional logics" (Section 4.3).

These working group discussions were preceded by 13 short talks and 3 tutorials: "Semantics of Conditionals" (by Graham Priest), "Proof Theory of Conditionals" (by Nicola Olivetti) and "The psychology of Indicative Conditionals" (by Karolina Krzyzanowska). These talks and tutorials are summarized in Section 3.

## 2 Table of Contents

**Working Groups**

# 3 Summary of Talks and Tutorials

## 3.1 Representing and Reasoning with Conditionals: What Cognitive Neuroscience has (not (yet)) Taught Us

*Giosué Baggio (NTNU – Trondheim, NO)*



In this talk I gave a flash review of EEG and fMRI experiments on conditional reasoning, calling attention to the theoretical issues addressed or raised by these studies: the mental models vs mental logic debate, dual-process accounts of reasoning, the separability of logical inference from other forms of inference, and the nature of the deductive process. I pointed out some methodological problems with some of these studies, and I argued that research on how conditionals are represented in the mind/brain (as syntactic and semantic objects) should serve as a prerequisite and foundation for research on conditional reasoning proper. I finally presented work from our group and associated labs engaging with this issue.

## 3.2 Conditionals: the Three-valued Approach

*Didier Dubois (University of Toulouse, FR)*


**Joint work of** Didier Dubois, Henri Prade
**Main reference** Didier Dubois, Henri Prade: "Conditional objects as nonmonotonic consequence relationships" in IEEE Transactions on Systems, Man, and Cybernetics, vol. 24, no. 12, pp. 1724–1740, Dec. 1994.
**URL** https://doi.org/10.1109/21.328930

One question that has bothered philosophers such as Lewis and Stalknaker in the 1970's is the difference between a conditional in Boolean logic (such as the material implication) and the conditional that appears in a conditional probability. In the 1930's, De Finetti [1] had already suggested the answer. A conditional is a three-valued proposition, a more faithful representation of an if-then rule than a material implication. The idea is just to distinguish between possible worls that are examples of a rule, those that are counterexamples, and finally situations where the rule does not apply [2]. Under this view a conditional is a pair of nested Boolean events whose probabilities fully characterize the conditional probability. It can be captured in a three-valued logic of conditional statements, that can be combined by Sobocinski's conjunction (equivalent to Adams' quasi-conjunction) [3]. The syntax and axioms of this logic are precisely the ones of System P of Kraus Lehman and Magidor [12], which is sound and complete with respect to this three-valued semantics. This is the simplest semantics for this non-monotonic logic; see [12, 6, 7, 8, 9] for other semantics. The works of G. Kern-Isberner [11] can be seen as akin to this tradition. Then the probability of such conditionals is indeed the conditional probability. There are two ways of defining such conditionals, one using a Boolean version of Bayes rule, and the other more explicit one, as a pair of Boolean events. The two definitions yield the same definition for conditional probability. But the two definitions differ for other set functions such as belief functions and possibility measures [4, 10]. These two forms of conditioning correspond to distinct tasks: one is for question answering based on evidence, the other is the revision of uncertain beliefs [5].

**References**

1 B. De Finetti. La logique de la probabilité. In Actes du Congrès International de Philosophie Scientifique (1935), Paris, France, 1936. Hermann et Cie Editions.
2 D. Dubois, I.R. Goodman, P.G. Calabrese: Special Issue on Conditional Event Algebra, IEEE Trans. on Systems, Man and Cybernetics, 24(12) 1994.
3 D. Dubois, H. Prade: Conditional objects as nonmonotonic consequence relationships. pp. 1724–1740 of this special issue
4 D. Dubois, H. Prade, P. Smets: Representing partial ignorance. IEEE Trans. on Systems, Man and Cybernetics, 26(3), 1996, 361–377.
5 D. Dubois, H. Prade: Focusing vs. Belief Revision: A Fundamental Distinction When Dealing with Generic Knowledge. Proc. ECSQARU-FAPR, Lecture Notes in Computer Science 1244, Springer 1997: 96–107
6 S. Benferhat, D. Dubois, H. Prade: Nonmonotonic reasoning, conditional objects and possibility theory. Artificial Intelligence Journal, 92, 259–276, 1997.
7 S. Benferhat, D. Dubois, H. Prade, Possibilistic and standard probabilistic semantics of conditional knowledge bases, Journal of Logic and Computation, 9, 873–895, 1999.
8 D. Dubois H. Fargier, H. Prade, Acceptance, Conditionals, and Belief Revision, In: G. Kern-Isberner et col. (Eds.) Conditionals, Information, and Inference, Lecture Notes in Artificial Intelligence, Vol. 3301, Springer, 2005, p. 38–58.
9 D. Dubois, H. Prade: Non-Monotonic Reasoning and Uncertainty Theories. In : Nonmonotonic Reasoning. Essays Celebrating its 30th Anniversary.. Gerhard Brewka, Victor Marek, Miroslaw Truszczynski (Eds.), College Publications, p. 141–176, Vol. 31, Studies in Logic, 2011.
10 D. Dubois, T. Denoeux: Conditioning in Dempster-Shafer Theory: Prediction vs. Revision. Belief Functions 2012: Advances in Intelligent and Soft Computing 164, Springer 2012, 385–392.
11 G. Kern-Isberner: Conditionals in Nonmonotonic Reasoning and Belief Revision – Considering Conditionals as Agents. Lecture Notes in Computer Science 2087, Springer 2001
12 S. Kraus, D. Lehmann, and M. Magidor. Nonmonotonic reasoning, preferential models and cumulative logics. Arti
cial Intelligence, 44:167–207, 1990.

## 3.3 Three-valued Conditionals and Three-valued Consequence

*Paul Egré (CNRS, ENS, PSL University)*



Logical consequence is standardly defined as the preservation of designated values from premises to conclusion in an argument. In recent years, some attention has been given to so-called **mixed** consequence relations, in which designated values are allowed to vary between premises and conclusion in an argument (viz. Cobreros, Egré, Ripley, van Rooij [6], Smith [11], Zardini [12]). In this presentation I report on two lines of ongoing work dealing with the typology of three-valued conditional operators, the first pursued with Emmanuel Chemla, the second with Lorenzo Rossi and Jan Sprenger. The first line of inquiry concerns the extraction of conditional operators that internalize three-valued (and more generally, many-valued) **intersective mixed** consequence relations (see Chemla, Egré, Spector [3], Chemla and Egré [4, 5]). The second concerns the selection of an adequate notion of validity for the family of three-valued de Finettian conditional operators (de Finetti [8], Reichenbach [10]), which

take the value of the consequent when the antecedent is true, and the value indeterminate when the antecedent is false. Specific attention is given to a variant of de Finetti's table introduced independently by Cooper [7] and Cantwell [2], and on whether it is better behaved if it is asked that a conditional operator **internalize** the consequence relation (in the sense of Avron [1]).

### References


1 Avron, A. (1991). Natural 3-valued logics–Characterization and proof theory, *The Journal of Symbolic Logic*, 56(1): 276–294.
2 Cantwell, J. (2008). The logic of conditional negation. *Notre Dame Journal of Formal Logic*, 49(3):245–260.
3 Chemla, E., Egré, P., and Spector, B. (2017). Characterizing Logical Consequence in many-valued logic. *Journal of Logic and Computation*, 27(7):2193–2226.
4 Chemla, E. and Egré, P. (2018). From Many-Valued Consequence to Many-Valued Connectives. *Synthese* (forthcoming).
5 Chemla, E. and Egré, P. (2018). Suszko's Problem: Mixed Consequence and Compositionality. Manuscript available on arXiv.org: https://arxiv.org/abs/1707.08017.
6 Cobreros, P., Egré, P., Ripley, D., and van Rooij, R. (2012). Tolerant, Classical, Strict. *Journal of Philosophical Logic* 41(2):347–385.
7 Cooper, W. S. (1968). The propositional logic of ordinary discourse. *Inquiry*, 11:295–320.
8 De Finetti, B. (1936). La logique de la probabilité. *Actes du congrès international de philosophie scientifique*, 4:1–9.
9 Egré, P., Rossi, L., and Sprenger, J. (2019). De Finettian Logics of Indicative Conditionals. Manuscript available on arXiv (under review).
10 Reichenbach, H. (1944). *Philosophic foundations of quantum mechanics*. University of California Press.
11 Smith, N. (2008). *Vagueness and Degrees of Truth*, Ocford University Press, Oxford.
12 Zardini, E. (2008). A model of tolerance. *Studia Logica*, 90(3):337–368.


## 3.4 Proper Display Calculi for Conditional Logics via Multi-Type Correspondence Theory

*Giuseppe Grecco (University of Utrecht, NL)*



Connections between correspondence phenomena and proof theory have been seminally observed and exploited by Marcus Kracht, in the context of his characterization of modal axioms which can be effectively transformed into 'analytic' structural rules of display calculi. Applying insights from unified correspondence theory, Kracht's results were extended to the setting of DLE-logics (logics the algebraic semantics of which is based on bounded distributive lattices) characterizing the space of 'properly displayable DLE-logics'. In a series of co-authored papers, I contributed to extend the boundaries of this line of research in structural proof theory to a number of logics captured by axioms that are not analytic in the original language. In my presentation, I analyzed the features of well known (non–analytic) axioms for conditional logics challenging a unified logical framework, and I suggested possible directions of research.

## 3.5 A Strengthened Ramsey Test Semantics for Missing-Link Conditionals

*Mario Günther (Universität Regensburg, DE)*


**Joint work of** Mario Günther, Holger Andreas
**Main reference** Holger Andreas, Mario Günther: "On the Ramsey Test Analysis of 'Because' ", in Erkenntnis, June 2018.
**URL** https://doi.org/10.1007/s10670-018-0006-8

To accept a conditional 'If $A$ then $B$', so suggest Douven [2] and Krzyżanowska et al. [3], requires a relation of relevance between its antecedent $A$ and its consequent $B$. Conditionals that miss a relevant link, such as "If Lund is a town in Sweden, Munich is a town in Germany" sound odd because there is no apparent connection between the antecedent and the consequent. Douven [2, p. 1542] observes that "none of the currently popular semantics" elevates a relevance relation to be a necessary condition for a conditional to hold. In this talk, we aim to remedy this situation. Inspired by Rott [4], we strengthen the Ramsey Test by a suspension of judgment: accept 'If $A$ then $B$' iff, after suspending judgment on $A$ and $B$, you can infer $B$ by assuming $A$. The suspension of judgment creates a context of the remaining beliefs. If $A$, together with the remaining beliefs, is sufficient to infer $B$, we accept the conditional; otherwise we do not. Andreas and Günther [1] have shown that this strengthened Ramsey Test gives rise to a new semantics for conditionals that requires $A$ to be inferentially relevant for $B$. We argue that the strengthened Ramsey Test semantics can solve the challenge posed by missing-link conditionals.

### References

1 Andreas, H. and Günther, M. (2018). On the Ramsey Test Analysis of 'Because'. *Erkenntnis*, https://doi.org/10.1007/s10670-018-0006-8.
2 Douven, I. (2017). How to account for the oddness of missing-link conditionals. *Synthese* 194(5): 1541–1554.
3 Krzyżanowska, K., Collins, P. J., and Hahn, U. (2017). Between a conditional's antecedent and its consequent: Discourse coherence vs. probabilistic relevance. *Cognition* 164: 199–205.
4 Rott, H. (1986). Ifs, Though, and Because. *Erkenntnis* 25(3): 345–370.

## 3.6 Connexive Logic and Conditional Logics

*Andreas Kapsner (LMU München, DE)*



Connexive logics are non-classical logics that validate the following intuitively appealing principles:

Aristotle: $\neg(A \to \neg A)$ and $\neg(\neg A \to A)$ are valid.

Boethius: $(A \to B) \to \neg(A \to \neg B)$ and $(A \to \neg B) \to \neg(A \to B)$ are valid.

These are not valid in classical logic, and in fact, they aren't valid in most well-known non-classical logics, either. (A good place to get a first orientation about the topic is the SEP entry "Connexive Logic".)

In this short talk, I will comment on the relationship between connexive logics and conditional logics in the Lewis/Stalnaker family of theories. In particular, I will be interested in the philosophical underpinnings of these two large projects and in how much these underpinnings intersect. Though it has always been clear that there seems to be some connection here, it has, I believe, not yet been established what that connection is, precisely. I will propose a view of connexivity (drawing on earlier work) that not only fits well to the philosophical discussion about conditonal logics, but is also able to shed new light on topics in that discussion, such as the dispute about the Law of Conditional Non-Contradiction.

## 3.7 Worlds are not Enough

*Stephan Kaufmann (University of Connecticut, USA)*



The thesis that the probability of a conditional is the corresponding conditional probability – henceforth The Thesis – has long intrigued philosophers and enjoys wide and growing support in psychology. It seems to hold in a wide range of situations, though not without exception. However, despite its merits, no semantic theory based on the The Thesis has established itself in the mainstream. There are two reasons for this. Firstly, Lewis's triviality results and much subsequent work showed that any such semantic theory would have to be at odds with certain entrenched assumptions about the proper formal framework, and logicians starting with Lewis himself have been queasy about the radical changes that would be required to resolve this tension. Secondly, and relatedly, it is unclear how a theory incorporating The Thesis, if one can be given, would be integrated with semantic approaches to other linguistic forms, or for that matter with the wider context of epistemological and metaphysical theories with which familiar possible-worlds models interface so seamlessly.

But it has been known for some time that a semantic theory building on The Thesis can be developed, and in view of the renewed interest in probabilistic semantics in linguistics, philosophy, psychology and artificial intelligence, this is a good time to work it out and explore the consequences. My work in this area builds on the "Bernoulli Models" pioneered by van Fraassen and further developed by Stalnaker and Jeffrey. Specifically, I am interested in (i) the predictions of this framework about compounds with embedded conditionals (and theoretical knobs to turn where those predictions clash with intuition); (ii) extensions to linguistic forms other than 'if-then' sentences, and to various forms of context dependence; and (iii) models of belief and belief dynamics.

## 3.8 A Common Semantic Base for Reasoning with Conditionals

*Gabriele Kern-Isberner (TU Dortmund, DE)*



There is a large variety of different conditional logics with different semantics, and beyond that, there are general semantic frameworks to evaluate conditional statements, like probabilities, possibilities, or plausibilities. In this short talk, I address the problem of what general principles guide the derivation of "new" conditionals from a conditional knowledge base. I

present the basics of the theory of conditional structures which is built upon De Finetti's 3-valued conditionals, and which becomes effective for inductive reasoning and belief revision via the principle of conditional preservation. This principle can be linked to various semantic frameworks, in particular, probabilities, possibilities, plausibilities, and purely qualitative preorders.

Therefore, conditional structures provide a versatile algebraic framework for reasoning with conditionals for various tasks:

- probabilistic reasoning via the principle of maximum entropy;
- iterated belief revision covering the seminal postulates by [Darwiche & Pearl, 1997];
- nonmonotonic reasoning from conditional knowledge bases as an alternative to Pearl's system Z (with better results in many cases);
- extracting background knowledge from the statistical outcomes of empirical studies that helps explaining people's reasoning behaviour.

## 3.9 The Psychology of Indicative Conditionals (Tutorial)

*Karolina Krzyzanowska (University of Amsterdam, NL)*



Indicative conditionals play a central role in reasoning. Unsurprisingly then, a lot of psychology of reasoning research has been devoted to the question of how people interpret conditional sentences and what kind of inferences they draw from them. Starting with the ancestor of all reasoning tasks, Wason's card selection problem (1966), I present some of the most important findings about people's interpretation of conditionals. Finally, I discuss three recent experiments that highlight the significance of a relevance relation between the conditionals' antecedents and consequents.

### References

1 Barrouillet, P., Grosset, N., & Lecas, J.F. (2000). "Conditional reasoning by mental models: Chronometric and developmental evidence". *Cognition* 75(3): 237–266.
2 Byrne, R. M. J. (1989). "Suppressing valid inferences with conditionals". *Cognition* 31: 61–83.
3 Douven, I. and Verbrugge, S. (2010). "The Adams family". *Cognition*, 117: 302–318.
4 Douven, I., Elqayam, S, Singmann, H., van Wijnbergen-Huitink, J. (2018). "Conditionals and inferential connections: A hypothetical inferential theory". *Cognitive Psychology* 101: 50–81.
5 Evans, J. St. B. T., Handley, S. J., & Over, D. E. (2003). "Conditionals and conditional probability". *Journal of Experimental Psychology: Learning, Memory and Cognition* 29: 321–355.
6 Oaksford, M., & Chater, N. (1994). "A rational analysis of the selection task as optimal data selection". *Psychological Review* 101: 608–631.
7 Oaksford, M., & Chater, N. (2003). "Conditional probability and the cognitive science of conditional reasoning". *Mind and Language* 18(4): 359–379.
8 Skovgaard-Olsen, N., Singmann, H., and Klauer, K. C. (2016). "The relevance effect and conditionals". *Cognition*, 150: 26–36
9 Wason, P.C. (1966). "Reasoning". In B. M. Foss (Ed.), *New horizons in psychology* (pp. 135–151). Harmondsworth, UK: Penguin.

## 3.10 Proof Theory of Conditional Logic (Tutorial)

*Nicola Olivetti (Aix-Marseille University, FR)*



Many systems of conditional logics have been proposed the last 50 years. They can be naturally grouped in three families determined by their semantics, namely Basic Conditional Logics, Preferential Conditional Logics, and Lewis' Logics of Counterfactuals. If semantics and axiomatization of each system are both well understood, their proof theory, in the form of sequent calculi, is not as developed as the one of other families of logics. In this tutorial I first propose the main requirements or properties of proof systems, and then I present analytic sequent calculi for each family of conditional logics at the state of the art.

### References

1 R. Alenda, N. Olivetti, and G. L. Pozzato, Nested Sequents Calculi for Normal Conditional Logics. *Journal of Logic and Computation*, 26 (1): 7–50, 2016.
2 H. C. M. de Swart, A Gentzen- or Beth-type system, a practical decision procedure and a constructive completeness proof for the counterfactual logics VC and VCS. *Journal of Symbolic Logic*, 48, 1–20, 1983.
3 I. P. Gent, A sequent or tableaux-style system for lewis's counterfactual logic $\mathbb{VC}$. *Notre Dame Journal of Formal Logic*, 33(3): 369–382, 1992.
4 M. Girlando, B. Lellmann, N. Olivetti, G. L. Pozzato, Standard Sequent Calculi for Lewis' Logics of Counterfactuals. JELIA 2016, Logics in Artificial Intelligence, LNAI 10021, 2016: pp. 272–287, 2016.
5 M. Girlando, B. Lellmann, N. Olivetti, G. L. Pozzato, Hypersequent Calculi for Lewis' Conditional Logics with Uniformity and Reflexivity. TABLEAUX 2017, Automated Reasoning with Analytic Tableaux and Related Methods, Vol. LNCS 10501, pp. 131–148, 2017.
6 B. Lellmann, D. Pattinson, Sequent Systems for Lewis' Conditional Logics. *JELIA 2012*, 320–332, 2012.
7 S. Negri and N. Olivetti, A sequent calculus for preferential conditional logic based on neighbourhood semantics. *TABLEAUX 2015*,Vol LNCS 9323, pp. 115-134, 2015.
8 S. Negri and G. Sbardolini, Proof analysis for Lewis counterfactuals. *The Review of Symbolic Logic*, vol 9: 44–75, 2016.
9 D. Pattinson and L. Schröder, Generic modal cut elimination applied to conditional logics. *Logical Methods in Computer Science*, 7, 2011.
10 F. Poggiolesi, Natural Deduction Calculi and Sequent Calculi for Counterfactual Logics. Studia Logica 104(5): 1003–1036, 2016.

## 3.11 Conditionals: a Logician's Perspective (Tutorial)

*Graham Priest (CUNY Graduate Center, USA)*



In this talk, I will suggest that a conditional, $A > B$, is true iff $B$ is true in all those worlds where $A$ holds and where certain contextually determined information, imported from the actual world, also holds. I will explain a standard formal semantics and tableau proof system for such a view. I will then discuss how this view bears on three further issues. (1) Inferences that are formally invalid, but are contextually correct. (2) The distinction between indicative and subjunctive conditionals. (3) Conditionals with impossible antecedents.

**References**

1 Berto, F., and Jago, M. (2018), 'Impossible Worlds, in E. Zalta (ed.), Stanford Encyclopedia of Philosophy, https://plato.stanford.edu/entries/impossible-worlds/.
2 Priest, G., (2008), Introduction to Non-Classical Logic, Cambridge: Cambridge University Press, chs. 5 and 19.
3 Priest, G. (2018), 'Some New Thoughts on Conditionals', Topoi 27: 369–77.

## 3.12 Difference-making Conditionals and the Relevant Ramsey Test

*Hans Rott (Universität Regensburg, DE)*



This paper explores conditionals expressing that the antecedent makes a difference for the consequent. It employs a 'relevantised' version of the Ramsey Test for conditionals in the context of the classical theory of belief revision due to Alchourrón, Gärdenfors and Makinson (1985). The idea of this test is that the antecedent is relevant to the consequent in the following sense: a conditional is accepted just in case the consequent is accepted if the belief state is revised by the antecedent *and* fails to be accepted if the belief state is revised by the antecedent's negation. The connective thus defined violates almost all of the traditional principles of conditional logic, but it obeys an interesting logic of its own.

The paper also gives the logic of an alternative version, the 'Dependent Ramsey Test' according to which a conditional is accepted just in case the consequent is accepted if the belief state is revised by the antecedent *and* is rejected (e.g., its negation is accepted) if the belief state is revised by the antecedent's negation.

**References**

1 Igor Douven. *The epistemology of indicative conditionals: Formal and empirical approaches*. Cambridge University Press, Cambridge, 2016.
2 Luis Fariñas del Cerro and Andreas Herzig. Belief change and dependence. In Yoav Shoham (ed.), *Proceedings of the Sixth Conference on Theoretical Aspects of Rationality and Knowledge*. Morgan Kaufmann, San Francisco, CA, 1996, pp. 147–161.
3 Peter Gärdenfors. Conditionals and changes of belief. In I. Niiniluoto & R. Tuomela (eds.), *The Logic and Epistemology of Scientific Change*. Amsterdam: North Holland, 1978, pp. 381–404.
4 Hans Rott. Ifs, though and because. *Erkenntnis* 25 (1986), pp. 345–370.

## 3.13 The Dialogical Entailment Task

*Niels Skovgaard Olsen (Universität Göttingen, DE)*



The goal of this talk is to present a novel experimental paradigm for probing the participants' acceptance of entailments. In the psychology of reasoning, there has been a recent change from the use of deductive task instructions to probabilistic tasks instructions by Singmann & Klauer [1]. One side-effect of this change is that entailment judgments are no longer a primary focus of investigation although they arguably constitute the main source of data for semantic

theories [4]. This even holds for recent studies on p-validity within the new paradigm, which arguably probe probabilistic coherence in probability assignments to the premises and the conclusion rather than entailment judgments per se. Through the introduction of the Dialogical Entailment Task, we seek to remedy this predicament [2]. By adopting this task, the participants' acceptance of inferences with conditionals and negation operators are investigated and evidence is found that the participants do not accept the equivalence of wide and narrow scope negations of indicative conditionals, across relevance levels. As such, these results are in line with recent results on the interaction of conditionals with negation operators in probability judgments under manipulations of relevance [3].

### References


1 Singmann, H., & Klauer, K. C. (2011). Deductive and inductive conditional inferences: Two modes of reasoning. *Thinking & Reasoning*, 17(3), 247–281.
2 Skovgaard-Olsen, N. (in review). The Dialogical Entailment Task.
3 Skovgaard-Olsen, N., Collins, P., Krzyzanowska, K., Hahn, U., and Klauer, C. K. (2019). Cancellation, Negation, and Rejection. *Cognitive Psychology*, 108, 42–71.
4 Winter, Y. (2016). *Elements of Formal Semantics*. Edinburgh: Edinburgh University Press.


## 3.14 There Isn't One Logic of Human Reasoning: What does 'Pragmatic (Logical) Pluralism' Mean for the Cognitive Science of Human Reasoning ?

*Keith Stenning (University of Edinburgh, UK)*



Michiel van Lambalgen and I have been developing a multiple-logics framework for cognition for some years (Stenning & van Lambalgen 2008). The empirical part of this work has mostly focussed on modelling human nonmonotonic narrative reasoning in Logic Programming. This focus is required by the neglect (sometimes even denial) of this topic as reasoning. Recently however, we have turned to revisiting human monotonic reasoning (the classical logical syllogism) to show how much empirically richer this becomes if one takes the logic seriously. If instead of assuming that the conventional 'draw-a-conclusion-from-these-premisses' task invokes a classical logical goal in 'logically naive subjects', one compares it with a more obvious situation of dispute. This talk would attempt to motivate the study of betting against Harry-the-Snake on the validity of syllogisms, as a task more suitable for invoking classical logic in these subjects. And to give a flavour of some preliminary results.

## 3.15 From Defeasible Conditionals to Preferential Modalities and Beyond

*Ivan José Varzinczak (Artois University, FR)*



We investigate an aspect of defeasibility that has somewhat been overlooked by the non-monotonic reasoning community, namely that of defeasible modes of reasoning. These aim to formalise defeasibility of the traditional notion of necessity in modal logic, in particular of its different readings as action, knowledge and others in specific contexts, rather than defeasibility of conditional forms. Building on an extension of the preferential approach to modal logics, we introduce new modal operators with which to formalise the notion of defeasible necessity and distinct possibility, and that can be used to represent expected effects, refutable knowledge, and so on. We show how KLM-style conditionals can smoothly be integrated within our richer language. Moreover, we show that the computational complexity of the resulting framework remains in the same class as that of the underlying classical modal logic we start off with. Finally, we also show how our semantic constructions are fruitful in similarly structured logics such as description logics.

## 3.16 On the Nature of Nonmonotonic Reasoning – Some Formal Clarifications

*Emil Weydert (University of Luxembourg, LU)*



We provide a general perspective on semantic-based approaches to default reasoning, pointing to several important – but hardly known – facts, as well as to desirable principles and standards. This includes the

- Interpretation of defaults as object-level expressions evaluated by suitable semantic structures fixing their acceptance
- Distinction – crucial and reflected by diverging logical properties – between object-level defaults (a $>$ b) in the default base D, and meta-level inferential relationships a $|$ D b based on D
- Identification of 3 central postulates at the level of defeasible reasoning with defaults: (1) Irrelevance, (2) Boolean invariance, (3) Left Logical Equivalence for defaults
- Observation that ranking measures (rkm) are the simplest linear plausibility valuations correctly handling independence
- Fact that rational rkm-values are both necessary and sufficient for advanced default reasoning
- Insight that there is a necessary tradeoff between, on one hand, strong and intuitively adequate default inference relations (e.g. ME or JZ), and on the other hand, well-behaved conditional logics for the defaults themselves. In particular, it turns out that AND and RW (Right Weakening) are not compatible with the former.

# 4 Working Groups

## 4.1 Investigating People's Intuitions about Counterpossibles

*Nicole Cruz de Echeverria Loebell (Birkbeck, University of London, UK), Giosué Baggio (NTNU – Trondheim, NO), Andreas Herzig (CNRS, FR), Andreas Kapsner (LMU München, DE), Karolina Krzyzanowska (University of Amsterdam, NL), Francois Olivier (ENS – Paris, FR), Graham Priest (CUNY Graduate Center, USA), Keith Stenning (University of Edinburgh, UK), Jakub Szymanik (University of Amsterdam, NL)*



Our group started out discussing broader questions around counterpossibles, counterfactuals, contextualisation/framing, and related topics. But towards the end we narrowed our focus to counterpossibles, i.e. conditionals with an impossible antecedent, and to what intuitions people might have about these conditionals. We are planning an online experiment to assess this question. In the experiment, we seek to compare three accounts of the semantics of counterpossibles, which we refer to as vacuism, non-vacuism, and suspension-of-judgment. According to non-vacuism, people will judge some counterpossibles as true and others as false. For example, they will judge 'If $1+2=4$, then $1+3=5$' more often as true than 'If $1+2=4$, then $1+3=147$'. According to vacuism, people will tend to judge any counterpossible as (vacuously) true. According to the suspension-of-judgment account, people will tend to suspend judgment when encountering a counterpossible, and so will tend to judge that the truth of any counterpossible cannot be determined. We will compare people's judgments about counterpossibles with their judgments about corresponding possible conditionals, *e.g.* 'If $1+2=3$, then $1+3=5$'. We will also explore potential differences in people's judgments when the above conditionals are formulated in the subjunctive as opposed to indicative mood. Through this experiment we hope to gain information about how people understand and reason with counterpossibles, and to what extent the three theoretical accounts compared capture people's intuitions about them.

## 4.2 The Semantics of Conditionals

*Paul Egré (coordinator, ENS – Paris, FR), Didier Dubois (CNRS, FR), Mario Günther (Universität Regensburg, DE), Stefan Kaufmann (University of Connecticut – Storrs, US), Gabriele Kern-Isberner (TU Dortmund, DE), Eric Raidl (Universität Konstanz, DE), Hans Rott (Universität Regensburg, DE), Niels Skovgaard Olsen (Universität Göttingen, DE), Emil Weydert (University of Luxembourg, LU)*



Our group considered three main topics for discussion:

(A) What is the relation between probabilistic semantics and possible-worlds semantics for conditionals?
(B) How do truth-functional approaches to conditionals and intensional approaches compare?
(C) Which role does relevance play as regards conditionals?

The discussion on (A) and (B) centered on the System P of non-monotonic logic, as laid out by Kraus et al. [11] (KLM) who claim it to be the "conservative core of a nonmonotonic reasoning system". Under the restriction to non-nested conditionals, there are various ways to semantically describe the rules of System P: the probabilistic semantics of Adams [1]; a certain possible worlds semantics à la Stalnaker [17] and Lewis [12] or Chellas [6], namely Burgess semantics [5]; the three-valued approach of Dubois and Prade [9]; and, of course, the preferential models of KLM. It is no wonder, then, that System P is often taken to be a fundamental system of conditional logic. The discussion left open whether we can find translations between the various semantics without invoking System P. Another unsettled issue that came up was whether Dubois and Prade's system really has the expressiveness of KLM's system, or is in fact less expressive.

As regards (C), the question emerged whether a condition of relevance should constrain the semantics of conditionals, or whether considerations of relevance rather belong to their pragmatics only. It proved hard, to say the least, to find a clear demarcation between the semantics and pragmatics of conditionals. Different operationalizations of the notion of relevance were discussed, with specific attention to the probabilistic constraint that a conditional of the form $A > B$ is relevantly asserted provided $Pr(B \mid A) - Pr(B) > 0$ (as discussed by Douven [8, Chs. 4&5], with a recent variant considered by Crupi and Iacona [7]). Various qualitative alternatives were considered.

A paper presented by Hans Rott [15] during the Dagstuhl meeting, titled "Difference-making conditionals and the Relevant Ramsey Test" was given particular attention. The idea of this test is that the antecedent is relevant to the consequent in the following sense: a conditional is accepted just in case the consequent is accepted if the belief state is revised by the antecedent and fails to be accepted if the belief state is revised by the antecedent's negation. Even though Rott does not conceive of the Relevant Ramsey Test as a compound of two object-language sentences, Eric Raidl suggested to interpret the proposal as follows: a conditional $A \gg B$ is a difference-making conditional provided the conjunction $(A > B) \wedge \neg(\neg A > B)$ is true or accepted. In fact, Raidl [13, 14] has already worked out that the relation of sufficient reason due to Spohn [18] can be spelled out by plugging the conditional based on the ranking-theoretic Ramsey Test into the conjunctive schema.

In the discussion, Mario Günther put forth the conjecture that the second conjunct expresses the pragmatic component of a difference-making conditional. A reason supporting the conjecture is that uttering 'If $A$ then $B$' explicitly states the first conjunct, while it leaves the second implicit. Niels Skovgaard-Olsen provided a reason against the conjecture based on the empirical work [16] investigating relevance effects found for the probability assessment of indicative conditionals. He argued that the empirical evidence is most consistent with making a positive delta-$p$ value ($P(B \mid A) - P(B \mid \neg A) > 0$) a conventional implicature. A conventional implicature is not cancellable, does not arise on the basis of Gricean maxims of communication, and does not normally influence direct truth evaluations of conditionals. It is rather a second layer of meaning that is lexically encoded into conditionals, and as part of the conventional meaning of conditionals, it is a part of the semantic content of indicative conditionals. However, it remained contestable whether indicative conditionals carry a (probabilistic) counterfactual meaning arising from the second conjunct of difference-making conditionals.

In his Dagstuhl talk, Mario Günther delivered yet another strengthening of the Ramsey Test to spell out a relevance relation between the antecedent and the consequent. The idea is to accept 'If $A$ then $B$' iff, after suspending judgment on $A$ and $B$, you can infer $B$ by assuming $A$ (see Andreas and Günther [2]). Andreas and Günther [3] provide an analysis of causation by plugging in this strengthened Ramsey Test conditional in the above conjunctive schema.

Among the tasks entertained as possible continuations of the discussion group, two main projects were put forth:

1. Elaborate a survey paper on bridges between semantic approaches giving system P, while making sure to not duplicate extant surveys, which provide translations between some semantics for P and semantics for PCL in the full language, e.g. Arló-Costa and Shapiro [4] and Friedman and Halpern [10].
2. Prepare a paper on the division of labor between semantics and pragmatics and the relation between inferential and difference-making conditionals.

## References


1 Adams, E. (1966). Probability and the Logic of Conditionals, in *Aspects of Inductive Logic*, J. Hintikka and P. Suppes (eds.), pp. 265–316.

2 Andreas, H. and Günther, M. (2018). On the Ramsey Test Analysis of 'Because'. *Erkenntnis*, https://doi.org/10.1007/s10670-018-0006-8.

3 Andreas, H. and Günther, M. (2019). Causation in Terms of Production. *Philosophical Studies*, https://doi.org/10.1007/s11098-019-01275-3.

4 Arló-Costa, H. and S. Shapiro (1992). Maps Between Conditional Logic and Non-monotonic Logic. In *Principles of Knowledge Representation and Reasoning: Proceedings of the Third International Conference*, B. Nebel, C. Rich, W. Swartout, (eds.), San Mateo, CA.: Morgan Kaufmann, pp. 553–565.

5 Burgess, J. (1981). Quick Completeness Proofs for Some Logics of Conditionals, *Notre Dame Journal of Formal Logic*, 22:76–84.

6 Chellas, B.F. (1975). Basic Conditional Logic, *Journal of Philosophical Logic*, 4:133–153.

7 Crupi, V. and Iacona, A. (2018, December). *Three ways of being non-material*. Manuscript.

8 Douven, I. (2016). *The epistemology of indicative conditionals: Formal and empirical approaches*. Cambridge University Press, Cambridge.

9 D. Dubois, H. Prade (1994). Conditional objects as nonmonotonic consequence relationships. *Special Issue on Conditional Event Algebra, IEEE Trans. on Systems, Man and Cybernetics*, 24(12):1724–1740.

10 Friedman, N. and Halpern, J. (2001). Plausibility measures and default reasoning. *Journal of the ACM*, 48:648-685.

11 Kraus, S., Lehmann, D. and Magidor. M. (1990). Nonmonotonic reasoning, preferential models and cumulative logics. *Artificial Intelligence*, 44:167-207.

12 Lewis, D. K. (1973). *Counterfactuals*. Blackwell Publishers.

13 Raidl, E. (2018a). Ranking semantics for doxastic necessities and conditionals, in *Logica Yearbook 2017*, Arazim, P. and Lávička, T. (eds), London: College Publications, pp. 223–238.

14 Raidl, E. (2018b). Completeness for counter-doxa conditionals – using ranking semantics, *The Review of Symbolic Logic*, https://doi.org/10.1017/S1755020318000199.

15 Rott, H. (2019, January). *Difference-making conditionals and the Relevant Ramsey Test*, Manuscript.

16 Skovgaard-Olsen, N., Collins, P., Krzyżanowska, K., Hahn, U. Klauer, K. C. (2019). Cancellation, negation, and rejection, *Cognitive Psychology*, 108:42-71, https://doi.org/10.1016/j.cogpsych.2018.11.002.

17 Stalnaker, R. (1968). A Theory of Conditionals. In Rescher, N. ( ed.), *Studies in Logical Theory (American Philosophical Quarterly Monograph Series)*, pp. 98–112.

18 Spohn, W. (2015). Conditionals: A unifying ranking-theoretic perspective. *Philosophers' Imprint*, 15(1), 1–30.

## 4.3 Correspondence Theory and Proof Theory for Conditional Logics

*Guillaume Aucher (coordinator, University of Rennes 1, CNRS, FR), Christoph Beierle (Fern Universität in Hagen, DE), Giovanni Casini (University of Luxembourg, LU), Marianna Girlando (Aix-Marseille University, FR), Giuseppe Greco (Utrecht University, NL), Nicola Olivetti (Aix-Marseille University, FR), Ivan José Varzinczak (Artois University, FR)*



Our group dealt with the problem of finding out an appropriate semantics for the family of conditional logics in order to develop a uniform correspondence theory and proof systems for these logics.

Many different semantics have been defined in the literature for conditional logics, such as the selection function semantics, the preferential semantics or the sphere semantics. Selection function models are sound and complete with respect to $\mathbb{CK}$, the basic system of conditional logics, and can be extended to the whole family by specifying properties of the selection function. Thus, strictly speaking, a unified semantics for the family of conditional logic already exists. However, as underlined in [4], this semantics is not enough to define a proof system for the strongest systems, as the properties added are not informative enough to define rules. Moreover, the selection function semantics is not really suitable for developing a correspondence theory between semantics and proof systems. Hence, we looked at some richer models capturing $\mathbb{CK}$ and extensions.

Our first attempt was to consider the Routley-Meyer semantics as a unifying semantics for conditionals, because a correspondence theory based on this semantics can be developed from the correspondence theory for modal logic based on Kripke models [1]. This semantics, defined for relevance logics, adds to standard Kripke models a ternary relation $R$ among worlds: $Rxyz$. The truth condition of the conditional operator in this class of models is the following:

$x \Vdash A > B$ iff for all $z, y \in W$, if $Rxyz$ and $y \Vdash A$, then $z \Vdash B$.

It is possible to construct a class-selection function model from a Routley-Meyer model by defining the class-selection function as follows:

$y \in f(S, x)$ iff there exists $z \in S$ such that $Rxyz$.

Similarly, the ternary relation of the Routley-Meyer semantics can be defined in terms of the class-selection as follows:

$Rxyz$ iff there exists $S \subseteq W$ such that $z \in S$, and $z \in f(S, x)$.

However, the conditional defined on the basis of this ternary semantics will yield in any case a *monotonic* inference relation. Moreover, this semantics validates as well the axiom (OR) of the conditional logic $\mathbb{PCL}$, which should not be valid in the weaker system $\mathbb{CK}$. So, the Routley-Meyer semantics cannot be used to represent the conditional operators in their full generality.

This led us to focus on a different class of models, namely preferential models, first defined for the conditional logic $\mathbb{PCL}$ [2]. These models add to Kripke structures a preferential ordering among worlds, which can also be expressed in terms of a ternary relation. Our conjecture is that by dropping some properties of the relation we might capture logics weaker than $\mathbb{PCL}$ and, in particular, $\mathbb{CK}$.

## References


1 Guillaume Aucher. A new road towards universal logic? Research report, Université de Rennes 1, April 2017.

2 John P. Burgess. Quick completeness proofs for some logics of conditionals. *Notre Dame Journal of Formal Logic*, 22(1):76–84, 1981.

3 Nir Friedman and Joseph Y. Halpern. On the complexity of conditional logics. In J. Doyle, E. Sandewall, and P. Torasso, editors, *Principles of Knowledge Representation and Reasoning: Proceedings of the Fourth International Conference (KR'94)*, pages 202–213. Morgan Kaufmann Pub, 1994.

4 Laura Giordano, Valentina Gliozzi, Nicola Olivetti, and Camilla Schwind. Tableau calculus for preference-based conditional logics: PCL and its extensions. *ACM Transactions on Computational Logic (TOCL)*, 10(3):21, 2009.

5 Marcus Kracht. Power and weakness of the modal display calculus. In *Proof theory of modal logic*, pages 93–121. Springer, 1996.

6 Donald Nute. *Topics in conditional logic*, volume 20. Springer Science & Business Media, Switzerland, 1980.

## Participants

- Guillaume Aucher
University of Rennes 1, CNRS, FR
- Giosué Baggio
NTNU – Trondheim, NO
- Christoph Beierle
Fern Universität in Hagen, DE
- Didier Dubois
CNRS, Toulouse, FR
- Giovanni Casini
University of Luxembourg, LU
- Nicole Cruz de Echeverria Loebell
Birkbeck, University of London, UK
- Paul Egré
ENS – Paris, FR
- Marianna Girlando
Aix-Marseille University, FR
- Giuseppe Greco
Utrecht University, NL
- Mario Günther
Universität Regensburg, DE
- Andreas Herzig
CNRS, Toulouse, FR
- Andreas Kapsner
LMU München, DE
- Stefan Kaufmann
University of Connecticut – Storrs, US
- Gabriele Kern-Isberner
TU Dortmund, DE
- Karolina Krzyzanowska
University of Amsterdam, NL
- Nicola Olivetti
Aix-Marseille University, FR
- Francois Olivier
ENS – Paris, FR
- Graham Priest
CUNY Graduate Center, USA
- Eric Raidl
Universität Konstanz, DE
- Keith Stenning
University of Edinburgh, UK
- Jakub Szymanik
University of Amsterdam, NL
- Hans Rott
Universität Regensburg, DE
- Niels Skovgaard Olsen
Universität Göttingen, DE
- Ivan José Varzinczak
Artois University, FR
- Emil Weydert
University of Luxembourg, LU