Summer School 2026
Institut des sciences cognitives
Université du Québec à Montréal

Reasoning with Conditionals: Abduction, Deduction and Dual Processes

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A switch in the use of logic

- Traditionally: logic is used as a formal normative system that shows us how we should reason in order to be rational
- Our perspective : to rely on results of the experimental psychology of reasoning and to use logic as a relevant methodological toolbox for the modeling of these results and to try, this way, to contribute to cognitive science
- So, this talk will provide a new explanation of famous experiments in the psychology of reasoning, via the logical study of abduction
- 4 sections in this talk:
  - 1. Abductive reasoning in causal cognition (slides 3 to 11)
  - 2. Deductive reasoning in normative contexts (slides 12 to 18)
  - 3. The dynamics of correction of abductions (slides 19 to 26)
  - 4. Conditional reasoning and dual processes (slides 27 to 33)

1. Abductive reasoning in causal cognition

Experimental results in the psychology of reasoning

- Wason cards selection task (since 1966):
  - A strong tendency not to respect the laws of logic, committing AC and DA fallacies
- Cards selection tasks in normative contexts of cost-benefit relations (since 1982, Grigg & Cox)
  - A strong tendency to respect the laws of logic using MPP and MTT logically valid inferences
- Why is it so?
- A new explanatory theory associating the logical analysis of truth tables with the theory of abduction

Three reasoning structures (see C. S. Peirce)

- Reasoning usually involves a rule, a case and a result
- Induction: (A … B) ⊃ (A ⊃ B): if a case and a result, then the rule
- Deduction: ((A ⊃ B) & A) ⊃ B: if a rule and a case, then the result
- Abduction: ((A ⊃ B) & B) ⊃ A: if a rule and a result, then the case
- Logical validity: if the premises are true, then the conclusion is necessarily true: deduction is logically valid when it respects the laws of logic (see above the deductive *modus ponendo ponens* inference)
- Not logically valid: if the premises are true, the conclusion could be at best possibly true: induction and abduction are not logically valid, but they are cognitively relevant, they are ampliative inferences
- Our standpoint will focus on abductive reasoning: important works on abduction since Peirce and R. Hanson: P. Thagard and C. P. Shelley, A. Aliseda, L. Magnani…

Different truth tables in the use of conditionals

Logical conditional

A	⊃	B	(if A, then B)
T	T	T	
T	F	F	
F	T	T	

F	T	F

"Abductive" conditional

A	⊃⊂	B	(if A, then B & if B, then A)
T	T	T	
T	F	F	
F	F	T	

F	T	F

The nature of the abductive conditional

- A ⊃⊂ B is logically equivalent to the logical biconditional, according to their truth tables
- But they are cognitively different:
  - A ⊃⊂ B involves a temporal succession
  - A is anterior (antecedent) to B, B is posterior (consequent) to A
- A ⊃⊂ B is spontaneously at work in cognitive contexts when we look for causality in the perception of successive events: we think of event A as the cause and of event B as its effect
- Such causal conditionals provide explanations of past or present events and provide predictions of future events

Abduction in causal cognitive cards selection

- Our thesis: in causal cognitive contexts, in which we seek causal explanations and causal predictions, we apply spontaneously the abductive conditional
- This explains the usual Wason cards selection behavior
- In a classical occurrence of the experiment, the four cards displaced on the table show respectively an A, a D, a 4 and a 7
- The rule presented to the participants: "If a card shows an A on one face, then its opposite face shows a 4"
- The answer to the question raised is a procedure of prediction:
  - To turn over the A card, to make sure that there will be a 4 on the other side (row 1 of the table should occur and not row 2, an A causes a 4)
- And a procedure of explanation:
  - To turn over the 4 card, to make sure that there is an A on the other side (row 1 of the table should occur and not row 3, presuming by abduction that a 4 is caused by an A; and row 4 is considered as not cognitively relevant, as not triggered by the question)

4 types of abductions

- Abductive explanation of the past
- Affirmative: ((A $\supset\subset$ B) & B) $\supset\subset$ A (affirmation of the consequent: B is the case and so we tend to presume that it has been caused by A)
- Negative: ((A $\supset\subset$ B) & ~B) $\supset\subset$ ~A (accidentally equivalent to the logically valid *modus tollendo tollens*: B is not the case and so we conclude that A has not been the case)

- Abductive prediction of the future
- Affirmative: ((A $\supset\subset$ B) & A) $\supset\subset$ B (accidentally equivalent to the logically valid *modus ponendo ponens*: A is the case and so B will be the case)
- Negative: ((A $\supset\subset$ B) & ~A) $\supset\subset$ ~B (denial of the antecedent: A is not the case and so we predict that B will not be the case)

Why do people use abductive conditionals in causal reasoning?

- We try to confirm our causal beliefs about the state of the world
- See Friston: we do active inference, we try to minimize predictive error, to minimize free energy, to fight against entropy, and abduction is a kind of active inference
- Because we rely on our long-term memory for establishing causality and take decisions: our cognitive beliefs are determined by the experiences stored in our LTM: what we believe causally is determined by the successions of events that we have registered in our LTM; so, we tend to consider the causes we believe in as necessary and sufficient conditions for the effect
- Classical examples of causal abductions:
  - Medical diagnosis and police investigation: from the result (the symptoms) we try to reach the cause

Abduction and the psychology of reasoning

- Our thesis is not opposed to the two dominant psychological theories on reasoning with conditionals: the mental models theory and the probabilistic theory (see last week in our SS, especially H. Markovits)
- Our standpoint is that the procedures described by these two theories (mainly algorithmic) are different strategies used to realize cognitive abductions (a more computational theory)

Counterexamples and complex causal chains

- Our cause-effect beliefs often encounter counter-examples and, given that we happen to have an openness to learn about the world, we tend to develop complex causal chains
- Normative reasoning is, on the contrary, as we will see now, not abductive and much less open to learning

2. Deductive reasoning in normative contexts

Normative cost-benefit cards selection tasks

- Participants are told that they are barmen who do not want to lose their job
- 4 cards disposed on a table, only one side can be seen (see Griggs and Cox, 1982)
- Participants are informed that each card contains an ordered beverage on one side and the age of the person who orders it on the other side
- The four cards displaced on the table show respectively drinking beer, drinking Coca-Cola, being at least 21 years old and being less than 21 years old
- A rule is presented to the participants: "If one wants to order alcohol, then she must be at least 21 years old"
- The question raised: which card or cards must be turned over to verify if the rule has been correctly applied?
- The logically valid answer: to turn over the beer card to make sure that the person is at least 21 years old (the logically valid *modus ponendo ponens*) and to turn over the less than 21 years old card to make sure that the person does not order alcohol (the logically valid *modus tollendo tollens*)
- The conditional is normative and not causal, and the usual answer is to respect perfectly the laws of a logical conditional

The Cosmides and Tooby explanation (1989): the cheater detection device

- Human beings are social animals
- They need cost-benefit rules for their survival and so they create standard contracts based on shared social rules: if one wants a privilege, then she must pay a price
- The barman experiments always establish a conditional relation between a privilege and a price that must be paid
- According to C & T, we have inherited from our hunter-gatherer ancestors a cheater detection device (in frontal lobe) that allows us to recognize cheaters: the creation of the rule of law vs the rule of nature
- Cheaters are the ones who try to get the privilege without paying the price
- The device protects us against the cheaters, allows better cooperation and helps for our collective survival
- The device would makes us use the MPP and the MTT to avoid the cheaters (avoid the false second row of the truth table)

The behavior appraisal device (Robert)

- In the barman experiment, Cosmides and Tooby are right to hold that participants look for the detection of cheaters (they are aware that row 2 of the truth table is false)
- But, the difference in the truth tables of the abductive conditional and of the logically valid deductive conditional is in row 3 (which is true in deduction and false in abduction)
- So, the device is not only a detector of cheaters, but also a detector of the altruists (the ones, in row 3, who pay the price, who do not take the privilege and who could give it to someone else, and they are detectable as respecting the rule, see Stenning & van Lambalgen,2008)
- So, versus Cosmides and Tooby, the device is more than a cheater detector, it is a behavior appraisal device that can detect:
  - Fair players: the ones who pay the price to get the privilege (true row 1) and the ones who do not pay the price and accept not to get the privilege (true row 4)
  - Cheaters: the ones who try to get the privilege and who are not ready to pay the price (false row 2)
  - And also, altruists: the ones who pay the price and give the privilege to someone else (true row 3, detectable as even better than fair play)

The evolutionary importance of altruism

- Given that there are often cheaters in social groups, altruists are necessary for compensating for cheaters
- The rule of law is not sufficient for the survival in human societies
- A certain amount of altruist behaviors is necessary for the survival of a community, notably for the survival of children, handicapped and elders
- A device for the detection of altruists is also necessary for our survival: detecting altruists, we recognize them as being so and we encourage and glorify their behavior

Reasons and causes

- The major premise in a conditional reasoning can express a cognitive causal belief or a normative reason for judging an action: so, both use conditional connectives, but they do so using two different conditionals generating very different procedures
- When the conditional expresses a cause, it refers to an event in the world that makes another event happen, as its effect
- When the conditional expresses a reason, it refers to a human beliefs that is used to justify or condemn decisions and actions

Varieties in the use of conditionals in human reasoning

- Abductive reasoning in cognitive causal inferences, in order to make explanations of past events and prediction of future events: the reasoner is dealing with the state of the world
- Deductive reasoning in normative contexts, in order to make appraising judgments on human behaviors: the reasoner tries to impose is values to the world
- In spontaneous reasoning, these two activities use different inferential procedures, as shown in Wason cards experiments and in the barman experiment

Synthetic figure of two different spontaneous reasoning procedures

Mental activity	Cognitive	Normative
Type of context:	Discovery	Justification
Type of relation:	Cause-effect	Price-privilege
Major premise:	Cause of events	Reason for action
Goal:	Explanation and prediction	Judgment on human action
Type of reasoning:	Abductive conditional	Deductive conditional
Logical value:	Invalid	Valid
Counterexamples:	More accepted	More condemned
Dynamics:	More changing	More stable
Emotions involved:	Anticipation and surprise	Trust, admiration, disgust
Types of signs:	Nudges	Banners

3. The dynamics of correction of abductions

The learning dynamics of spontaneous causal reasoning

- We perceive successions of events and we tend to consider these successions as causal mechanisms (see Hume and Kant)
- So, the non logically valid abductions by which we treat causal cognition are not certain and often meet counterexamples
- Abductions are reasoning procedures that are appropriate for finding causes, given that they are flexible and revisable
- When our abductions meet counterexamples, our causal beliefs can change and we can learn new causal rules
- 2 types of situations based on experiments
  - Meeting alternative antecedents: the effect occurs, but not the cause
  - Meeting conditional disablers: the cause occurs, but not the effect

Alternative antecedent experiments: the effect occurs, but not the cause

- The causal inference:

  if one throws a stone at a window, then the window breaks

  And the window breaks

  Then, someone has thrown a stone at the window
- But, actually, nobody threw a stone at the window, and it broke
- So, the participants can conclude that something else is responsible for the breaking of the window, like an earthquake or a severe storm
- The cause, that was considered abductively as a necessary and sufficient condition for the breaking of the window, is now considered as only a sufficient condition that is not necessary
- The reasoner can learn, this way, alternative causes
- See Barrouillet, P. & Markovits, H. (2002), plus Markovits' lecture last week

Meeting alternative antecedents in causality

- Finding alternative causes:
  - We move from $(A \supset\subset B)$ to $((A \vee C) \supset\subset B)$
- Learning an alternative cause in the affirmative abductive explanation of the past (affirmation of the consequent):
  - $((A \supset\subset B) \& B) \supset\subset A$: but at times, B occurs and A did not occur
  - Then, we move to: $(((A \vee C) \supset\subset B) \& B) \supset\subset (A \vee C)$
- Learning an alternative cause in the negative abductive prediction of the future (negation of the antecedent):
  - $((A \supset\subset B) \& \sim A) \supset\subset \sim B$: but at times, A does not occur, but B nonetheless occurs
  - Then we move to: $(((A \vee C) \supset\subset B) \& \sim A) \supset\subset (C \& B) \vee \sim B)$
- So, learning alternative causes comes from the failure of the affirmation of the consequent in explanations and from the failure of the negation of the antecedent in predictions: so, the correction of these fallacies allows learning
- The logical interpretation of causal conditionals helps to wary of abductions and to find alternative antecedents: in that case, logic is cognitively relevant: it helps to consider as true row 3 of the truth table, which precisely opens the door to alternative causes: in this case, we cognitively make abduction (algorithmically), but treating formally (computationally) the conditional involved as a logical one

Conditional disablers experiments: the cause occurs, but not the effect

- See Ruth Byrne (1989):
- 1) If Mary has a homework to do, then she will study late at the library

  And she has a homework to do

  Participants tend to conclude that she will study late at the library (MPP)
- 2) If the library is open, then Mary will study late at the library

  And the library is open

  Participants tend to conclude that she will study late at the library (MPP)
- 3) If Mary has a homework to do, then she will study late at the library

  And she has a homework to do

  Participants tend to avoid making the *modus ponendo ponens,* not knowing if the library is open
- The ignorance of the schedule of the library is considered as a disabler of the MPP
- Note that our standpoint is that we are dealing here with the affirmation of the antecedent abduction and not with a real MPP

Meeting disablers in causality

- Meeting disablers makes the cause not sufficient: for example, to throw a stone at the window is not sufficient, it must also be thrown hard
- What is sufficient, from now on, is a conjunction of two causes (just like the homework and the library being open)
- In negative abductive explanation of the past (logically equivalent to MTT):
- $((A \supset\!\subset B) \ \& \ \sim B) \supset\!\subset \sim A$: but at times, B does not occur, and A with a disabler has occurred

- In affirmative abductive prediction of the future (logically equivalent to MPP):
- $((A \supset\!\subset B) \ \& \ A) \supset\!\subset B$: but at times, A occurs, it does with a disabler, so B will not occur

- The conditional happens to be disabled, precisely because it is an uncertain abductive conditional, not a logical one
- Meeting a disabler, a causal chain can be lengthened, which is another kind of causal learning: we move from a simpler conditional $(A \supset\!\subset B)$ to a lengthened conditional $((A \ \& \ C) \supset\!\subset B)$
- This is in accordance with Stenning & van Lambalgen:
  - According to them, prediction works as: $(((A \ \&$ nothing abnormal$) \supset B)$ and not as a $(A \supset B)$
  - And when something abnormal occurs (i.e. a disabler), then B is not drawn as a conclusion

Abduction and causal chains

- Through successive encounters of alternative causes and additional causes, we learn progressively causal chains: ((A v B) ⊃⊂ C) ⊃⊂ D…, that make us take appropriate decisions in specific situations
- An important part of what we know is made of these causal chains
- Given that these chains are numerous in our memory and that it might be hard to find which one to activate in a given situation, nudges are often useful to trigger these chains (see Thaler & Sunstein, 2008)
- Disjunctions are useful logical tools for the modeling of alternative causes, just like conjunctions are useful logical tools for the modeling of additional causes
- Induction is necessary to establish a causal conditional, to start a causal chain; then, abductions and the correction of these abductions can explain the building of causal chains

Abduction, deduction and structural properties

- Given that alternative causes are discovered in the failure of abduction (the usual cause is not a necessary condition), the treatment of abductive causal conditionals as behaving as logical conditionals, avoids the affirmation of the consequent and the negation of the antecedent fallacies, helps to discover alternative causes and to open our mind to diversity
- On the other hand, given that additional causes are discovered in avoiding the abductions that are equivalent to the logically valid MPP and MTT (the usual cause is no more a sufficient condition), the treatment of abductive causal conditionals as working like a classical logic conditional is an obstacle to discover additional causes, it keeps our beliefs too rigid
- Learning additional causes requires an openness to creative thinking, beyond the limits of classical propositional logic
- Deductive conditionals are non ampliative and monotonic: they organize information so that they are not subject to revision (see what happens in normative contexts)
- Abductive conditionals are ampliative and non-monotonic: they create information and are uncertain and subject to revision (see causal contexts)
- What happens with counterfactual conditionals (a third type of conditionals, see R. Byrne, Rationality and Imagination)?

Normative deduction and counterexamples

- The cost-benefit normative inferences are deductive: facing a counterexample, we do not tend to revise our beliefs (contrary to what we do in causal inferences), we tend, on the contrary, to condemn the counterexample as cheating, as not respecting a rule that we judge important to respect
- Our norms tend to keep rigid, we change them rarely, they apply deductively the logically valid MPP and the MTT rules

4. Conditional reasoning and dual processes

Recall on systems S1 and S2

- The dual-process theory (Evans, Tversky, Kahneman…):
  - S1: implicit, automatic, low effort, rapid, default
  - S2: explicit, controlled, high effort, slow, inhibitory

Our thesis on S1 and S2 causal processes

- Our thesis on S1 in causal reasoning:
  - 2 subsystems in S1:
  - A flexible S1: the abductive non-logical connective is used to discover causes in the world as necessary and sufficient conditions, closing the world; but the encounter of counterexamples happens to constrain the reasoner to open the world and to accept alternative or additional causes
  - There ore also dogmatic S1 procedures that actively oppose counterexamples and the opening of the world that it involves: reasoning biases are strategies that realize such a closure (like the confirmation bias, the belief bias…); conspiracy theories do the same, reducing numerous events as effects of a single invading cause, i.e. the presumed conspiracy
  - In S2:
  - A tendency to open the world: finding causality in the world is valued as a dynamics of formulation of hypotheses and of corrections of these hypotheses to improve progressively our knowledge

Dual processes, closed and open mind

- Stanovich and Toplak (2023): they characterize S2 reflective processes as actively open-minded thinking
- According to our previous slide:
- Dogmatic S1 is actively closed-minded thinking: it requires an active fight against new evidence to keep the world closed
- Flexible S1 is passively open-minded thinking: it accepts, with a certain resistance, new evidence as requiring a complexification of the causal chain
- S2 is actively open-minded thinking: it looks for new evidence that could make causal chains more complex, it is eager to learn
- In accordance with De Neys 2.0 dual process theory: S1 is smarter than in version 1.0; the distance between S1 and S2 gets narrower: people fight their intuition in S1 or they concede to their intuition
- The importance of the studies of V. Thompson on the feeling of rightness for the testing of 2.0 thesis

Ampliativity, monotonicity and non-monotonicity

- Causal reasoning is abductive: being so, it is ampliative, not logically valid, but nonetheless necessary to produce causal beliefs about the world and to take rather easy decisions
- Classical logic is non-ampliative and so, avoids treating causes as necessary condition; it helps to open the world to alternative causes; but it is monotonic and so, cannot help to learn additional causal rules
- Probabilistic logic is non-ampliative, but non-monotonic; so, it can help to open the world to additional causes
  - The conditional probability can represent the probabilistic truth value of different alternative causes
  - The Bayes law can represent the modification of probability when additional causes appear

A new definition of reasoning procedures

- In our logico-cognitive perspective, reasoning procedures should have a cognitive definition and a formal definition
- Abduction :
  - Formal definition : the first premise is a causal conditional rule and the second premise is the affirmation or the negation of one of its components and then, the conclusion is the affirmation or the negation of the other component (like AA, DA, for prediction; AC, DC, for explanation)
  - Cognitive definition : a procedure of discovery for establishing a cognitive causal explanation or prediction
- Deduction :
  - Formal definition : the premises are rules that are assumed to be true and the conclusion is necessarily true, following a logically valid (truth-preserving) logical rule (like the MPP and the MTT are with conditionals)
  - Cognitive definition : a procedure of justification for drawing a conclusion that would be necessarily true, given premises containing a rule that is presumed to be true
- Our presentation implies that numerous new experiments are required…

Some conclusions: a naturalist explanation of reasoning

- Reasoning with conditionals in causal cognitive contexts and in normative price and privilege contexts are very different
- Reasoning in causal cognitive contexts treats conditionals as abductions
- Abductive causal reasoning is usually open to learning causal chains through the discovery of alternative causes or additional causes
- The learning of alternative causes occurs in the discovery of counterexamples in the use of abductive conditional fallacies (in the use of AC and DA fallacies)
- The learning of additional causes occurs in the discovery of counterexamples in the use of the abductive equivalent of the MPP (the AA) and of the MTT (the DC)
- Reasoning in normative price and privilege contexts is deductive and much less open to revision
- In S2 reflective reasoning, learning is made easier:
  - Treating causal abductions as logical conditionals helps to learn alternative causes
  - Treating causal abductions as conditional probabilities, helps to learn additional causes
- Our moral conclusion: open-mindedness and S2 procedures are important conditions for a peaceful survival of human beings

Basic references

- Wason, P. C. (1968). Reasoning about a rule. *Quarterly Journal of Experimental Psychology, 20*, 273-281.
- Peirce, C. S. (1931-1935). *Collected Papers, 5*. Cambridge MA: Harvard University Press. 172 and 590.
- Hanson, N. R. (1958). *Patterns of Discovery: An Inquiry into the Conceptual Foundations of Science*. Cambridge UK: Cambridge University Press.
- Robert, S. & Brisson, J. (2016). The Klein Group, Squares of Opposition and the Explanation of Fallacies in Reasoning. *Logica Universalis,* Springer Birkhäuser, volume 10, issue 2-3, p. 377-392.
- Griggs, R. A., & Cox, J. R. (1982). The elusive thematic materials effect in Wason's selection task. *British Journal of Psychology*, *73*, 407–420.
- Cosmides, L. (1989). The logic of social exchange: Has natural selection shaped how humans reason? Studies with the Wason Selection Task, *Cognition*, *31*, 187–286.
- Stenning, K & van Lambalgen, M. (2008). *Human Reasoning and Cognitive Science*. Cambridge MA: MIT Press.
- Barrouillet, P. & Markovits, H. (2002). Developmental and Content Effects in Reasoning with Causal Conditionals April 2002 *Journal of Experimental Child Psychology* 81(3), 235-48.
- Byrne, R. M. J. (1989). Suppressing valid inferences with conditionals, *Cognition, 31, 1, 61-83.*
- Parr, T., Pezzulo, G. Friston, K. J. (2022). *Active Inference: The Free Energy Principle in Mind, Brain, and Behavior.* Cambridge MA: MIT Press.
- Tomkins, S. (1987). Script Theory. *The Emergence of Personality*. Eds. Joel Arnoff, A. I. Rabin, and Robert A. Zucker. New York: Springer Publishing Company,147–216.
- Kahneman, D. (2011). *Thinking, Fast and Slow*. Macmillan.
- Stanovich, K. E., & Toplak, M. E. (2023). Actively open-minded thinking and its measurement. *Journal of Intelligence, 11*(2), 1–22.

Contemporary references in this Summer School

- Aliseda Llera, A. (2006) *Abductive Reasoning. Logical Investigations into Discovery and Explanation*. Springer.
- Magnani, L. (2017). *The Abductive Structure of Scientific Creativity: An Essay on the Ecology of Cognition*. New York: Springer.
- Thagard, P. & Shelley, C. P. (1997). Abductive reasoning: Logic, visual thinking and coherence. In Della Chiara, M. L., Doets, K., Mundici, D., van Bentham, J. (Eds) *Logic and Scientific Methods.* Florence It.: Volume 1 of the Tenth International Congress of Logic, Methodology and Philosophy of Science, 413-427.