Reasoning
Deduction.
Dual-Process Theories of Deductive Reasoning

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Memento (Horn and Blankson [2012])

All scientific theory is wrong. It is the job of science to improve theory. That requires identifying what is wrong within it and finding out how to change it to make it it more nearly correct.

In laying out the theory, we speak of what we think we know. We say that something is known if there is evidence to support the claim that it is known. Since such evidence is never fully adequate or complete, we do not imply that what we say "is known" is really (*really*) known to be true. [...] we provide provisos and cautions, and put research in a context such that major limitations can be seen.

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Psychological theories of reasoning: three approaches (Oaksford [2006])

Mental logic theories

assume people use formal rules of inference but errors may arise because they do not possess all of the possible rules.

Mental models theory

assumes people represent the true possibilities licensed by connectives. Failing to represent all of these possibilities may then lead to errors.

The probabilistic approach

assumes people are not drawing logical, deductive inferences but endorse inferences based on their assessment and evaluation of appropriate conditional probabilities.

Old vs new paradigm in psychology of reasoning (Evans [2012b])

Old

It was founded primarily on the study of deduction, with especial attention to syllogistic, conditional, and relational inferences, all of which take a deductive form. (...) participants are invited to evaluate or generate conclusions that are logically necessitated by the premises given to them, and which they must assume to be true. [The field] strayed far from its original purpose, which was to assess the logicality of naive human reasoning. It is important to note also that this notion of logicality was a very restricted one, based on traditional extensional or binary logic, in which all propositions are assumed to be either true or false. (...) While [the] authors complained about "logicism" in the psychology of reasoning, it is (...) standard bivalent logic that they had in mind. So it is more accurate to say that authors were objecting to binary logic, (...) rather than logic per se.

Old vs new paradigm in psychology of reasoning (Evans [2012b])

New

The new paradigm is variously described as a shift from viewing reasoning in terms of deduction to that of a probabilistic process; as a common view of reasoning, judgement, and decision making as involving similar processes; as a switch from a normative system based on logic to that based on Bayesianism, or as a recognition of the essential pragmatic and inductive nature of all human reasoning, and so on. The former restriction that premises must be assumed to be true also no longer applies, so that we can now consider how people reason with degrees of uncertainty in all of their beliefs.

Old vs new paradigm in psychology of reasoning (Evans [2012b])

Deduction

Deductive reasoning is now seen as a *strategic-level* concept. That is, it is a form of reasoning that high-ability participants might engage in when suitably instructed and motivated to make deductive effort.

There is no question that at least some people can reason deductively and even enjoy doing so, given the popularity of Sudoku puzzles. And there are certainly real-world applications where the ability to construe and reason in binary logic terms is needed, particularly where legal rules are concerned – for example, deciding whether you are able to claim tax relief.

However, the notion of deductive reasoning as a *strategy* is far removed from the original logicism that drove the development of the paradigm in the 1960s and 70s. Rather than being a built-in function of the human mind, deductive reasoning can be seen as just one of many kinds of problem solving and formal thinking in which people of sufficient IQ can engage.

Three questions concerning anything (Andrzej Klawiter)

1. Susbtantial question: what is it?
2. Functional question: how does it work?
3. Instrumental question: what it is used for?

AK: with respect to the brain 1 & 2 make perfect sense, 3 not so much; with respect to the mind 1 & 2 are just subsidiary to 3.

Mutatis mutandis: reasoning

- different types thereof;
- nature vs workings vs functions.

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The received viev in dual-process theories (Evans [2012a])

Type 1 Processes	Type 2 Processes
Unconscious, preconscious	Conscious
Rapid	Slow
Automatic	Controlled
Low effort	High effort
High capacity	Low capacity
Associative	Rule based
Intuitive	Deliberative
Contextualized	Abstract
Cognitive biases	Normative reasoning
Independent of cognitive capacity (IQ, WCM)	Correlated with individual differences in cognitive capacity

... and some of the fallacies associated with it (Evans [2012a])

1. All dual-process theories are essentially the same.
2. There are just two systems underlying type 1 and type 2 processing.
3. Type 1 processes are responsible for cognitive biases; type 2 processes for normatively correct responding.
4. Type 1 processing is contextualized, whereas type 2 processing is abstract.
5. Fast processing indicates the use of a type 1 rather than type 2 process.

1. All dual-process theories are essentially the same

Dual modes vs types vs system theories:

- Is there more than one kind cognitive mechanism involved?
- What about neural mechanisms involved?
- Are these modes/processes/systems limited to some domains (like learning) or not?

2. There are just two systems underlying type 1 and type 2 processing

If we go for "systems": are they singular, well-defined mechanisms? Or are they more like two minds, both having access to multiple systems?

3. Type 1 processes are responsible for cognitive biases; type 2 processes for normatively correct responding

No real evidence for that; type 2 processing can be as quick and as sloppy as type 1.

In the traditional paradigms, researchers presented participants with hard, novel problems for which they lacked experience (students of logic being traditionally excluded) and also with cues that prompted type 1 processes to compete or conflict with these correct answers.

4. Type 1 processing is contextualized, whereas type 2 processing is abstract

Type 2 processing can be semantically rich; when a novel task requires attention to logical structure and hence decontextualization, type 2 processing will be involved.

5. Fast processing indicates the use of a type 1 rather than type 2 process

Type 2 processin is slow, when a person reflects on a problem and engages in explicit reasoning or mental simulation to try to solve it. But there are also fast type 2 judgements, based on simple rules and heuristics, with minimal reflection:

1. an art expert "knows" that a statue is fake but cannot prove it by any explicit reasoning or knowledge (type 1, information-rich);
2. a hospital employs a short checklist to decide whether to treat patients with chest pain as suspected heart attack cases, with much better success than more complex procedures (type 2, quick and dirty).

Breaking of type 2 processing: The Competence $\leftrightarrow$ Procedural processing model of deductive reasoning. (Ricco and Overton [2011], following Stanovich [2008])

- **Competence** System 2, domain-general: universal, enduring organized operations of mind. Operates on de-contextualized, de-coupled secondary and meta-representations
    - Algorythmic subsystem: Operations, processes, rules underlying norm-based reasoning
    - Reflective-intentional subsystem: Practical & epistemic self-regulation (1. Goal formation & planning, 2. Epistemic norms, thinking dispositions, and intellectual values, 3. Metalogical norms)
- **Procedural** System 1, domain-specific: heuristic, implicit, automatized process. Operates on contextualized representations, heavily dependent on problem content

Breaking of type 2 processing (Ricco and Overton [2011], following Stanovich [2008])

Type 2 processing levels:

1. Algorithmic level: operations, processes, rules and other cognitive structures underlying norm-based processing of reasoning and decision-making problems (kind of mental logic);
2. Reflective (intentional) level: practical and epistemic forms of self-regulation (metalogical knowledge).

Increasing organizational complexity at the algorithmic level is paralleled by progressively more explicit conceptual knowledge about logical categories (metalogical knowledge) at the reflective level.

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Problems (Urbański et al. [2013, 2015])

- What, if any, is a correlation between fluid intelligence (*Gf*) and fluencies in both 'easy' and 'difficult' deductions?
- What, if any, is the impact of learning on the level of *Gf* and fluencies in both kinds of deductions?
- Is it possible to identify different types of difficult deductions?

Tools

- Raven's Advanced Progressive Matrices (APM);
- Deductive Reasoning Test (DR)
- Polisyllogisms Test (PS)
- Erotetic Reasoning Test (ER)

Deductive Reasoning Test (DR)

Instructions: Imagine playing the game in whose realm there exist various peculiar objects: CHIGS, GIDGITS, OZACKS and many others. Though you do not know what these objects actually are, you realize that the realm of the game is controlled by certain rules and conditions, just like in the real world. Answer the questions in each task below, using the information given in the two statements above the line. Mark the right answer in the right box.

1. Every TWAIL is an ANKH.
   Every ANKH is a GIMBEAT.
   ___
   Is every TWAIL a GIMBEAT?

   ☐ Definitely yes ☐ Definitely no ☐ It cannot be stated

Polisyllogisms Test (PS)

Instructions: Imagine playing the game in whose realm there exist various peculiar objects: CHIGS, GIDGITS, OZACKS and many others. Though you do not know what these objects actually are, you realize that the realm of the game is controlled by certain rules and conditions, just like in the real world. In each task below, using the information given in the three statements above the line, determine if the statement below the line is true, is false or it cannot be stated. Mark the right answer in the right box. You can make notes and draw on the test sheet.

1. All DOWS are HOOSES.
   All TWAILS are DOWS.
   All ANKHS are TWAILS.
   ____
   All ANKHS are HOOSES.

☐ True ☐ False ☐ It cannot be stated

Erotetic Reasoning Test (ER)

Each of the three item consists of a detective-like story in which the initial problem and evidence gained are indicated. The task is to pick a question (one out of four), each answer to which will lead to some solution to the initial problem. The subjects are asked to justify their choices.

Study 1

106 subjects (age: $M = 21{,}69$, $SD = 1{,}44$, 89 women), students of the curricula of cognitive science, psychology, educational studies (2nd, 4th or 5th year).

Three groups:

- A extensive logic, selective admission (cognitive science, $N = 27$);
- B basic logic, selective admission (psychology, $N = 40$);
- C basic logic, non-selective admission (educational studies, $N = 39$).

Tools:

1. APM, $\alpha = 0,85$, non-normal distribution;
2. DR, $\alpha = 0,64$, non-normal distribution;
3. ER, $\alpha = 0,76$, non-normal distribution.

Group differences – APM

Kruskal-Wallis: $\chi^2(2, 106) = 44,547,\ p < 0,001$

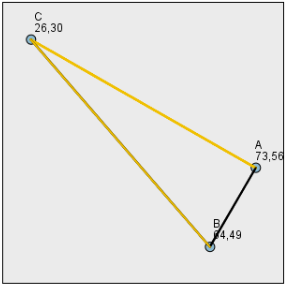

Table: *Post-hoc* tests (Dunn)

Pair	Corr. stat.	p	effect size (r)
A x B	1,625	0,312	–
A x C	6,173	$< 0,001$	-0,74
B x C	-5,069	$< 0,001$	-0,58

Group differences – DR

Kruskal-Wallis: $\chi^2(2, 105) = 53,898,\ p < 0,001$

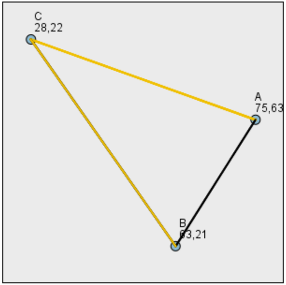

Table: *Post-hoc* tests (Dunn)

Pair	Corr. stat.	p	effect size (r)
A x B	1,278	0,604	–
A x C	6,588	$< 0,001$	-0,75
B x C	-5,915	$< 0,001$	-0,67

Kruskal-Wallis: $\chi^2(2, 106) = 44,905, \ p < 0,001$

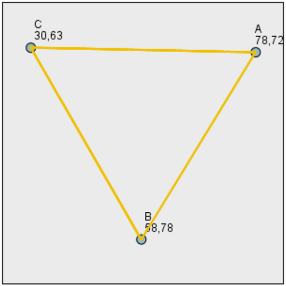

Table: *Post-hoc* tests (Dunn)

Pair	Corr. stat.	p	effect size (r)
A x B	2,728	0,019	-0,42
A x C	6,545	$< 0,001$	-0,74
B x C	-4,261	$< 0,001$	-0,52

Study 1: Correlations, r_s

Tests	A&B&C	A	B	C	A&B
APM x DR	0,61**	0,22	0,24	0,23	0,257*
APM x ER	0,69**	0,08	0,42**	0,59**	0,381**
DR x ER	0,74**	0,43*	0,55**	0,41*	0,525**

$*p < 0,05$, $**p < 0,01$

Study 1, conclusions

- Most participants from group C exhibited not enough competences in both norm-based reasoning (algorithmic subsystem) and epistemic self-regulation (reflective-intentional subsystem).
- As a result, they had to rely on heuristic processes, thus they solved the DR and ER tasks substantially worse than the remaining participants.
- In particular, they found it difficult to provide justification for the ER tasks solutions, which, if present, may be seen as a result of successful interplay between the two subsystems in question.

Study 1, conclusions, ctnd.

- Participants from group B exhibited substantial competences at an algorithmic level, being able to reason in compliance with logical entailment in easy deductions.
- However, their metalogical functioning, although of higher level than in case of group C, were not developed enough to deal with ER tasks effortlessly.
- Participants form group A, who differed from the others with respect to the extent of training in formal logic, were competent enough not only to solve deductive tasks, but also to address underlying epistemic norms of difficult deductions.

Study 2

59 subjects (age: $M = 22.06$, $SD = 1.02$, 42 women), two groups A': cognitive science curriculum (30) and B': psychology (29), 3rd and 4th year.

Tools:

1. APM, $\alpha = 0,77$, normal distribution;
2. DR, $\alpha = 0,49$, non-normal distribution;
3. PS, $\omega_t = 0,79$, non-normal distribution.

Study 2: results, U test

Mann-Whitney U test

Test	U	z	p	effect size (r)
APM	448,50	0,205	0,84	–
DR	321,50	-1,898	0,06	–
PS	301,00	-2,056	0,04	-0,27

Study 2: results, r_s

Tests	A'&B'	A'	B'
APM x DR	0,34**	0,10	0,54**
APM x PS	0,33*	0,21	0,44*
DR x PS	0,44**	0,31	0,65**

$*p < 0,05$, $**p < 0,01$

Studies 1 and 2: results comparison, r_S

Tests	Study 2 A'&B'	Tests	Study 1 A&B&C	Study 1 A&B
APM x TRD	0,34**	APM x TRD	0,61**	0,26*
APM x PS	0,33*	APM x TRE	0,67**	0,38**
TRD x PS	0,44**	TRD x TRE	0,74**	0,53**

$^*p < .05$, $^{**}p < .01$

Study 3 – let's build some bridges

Subjects

31 subjects (age: M=22,1, SD=1,938, 22 women), students of a plethora of curricula at AMU.

Tools

- ER ($\alpha = 0,65$, non-normal distribution);
- PS ($\omega_t = 0,81$, non-normal distribution).

Study 3 – correlations, r_s

Tests	r_s
ER x PS	0,669*
ER_correctness x PS	0,526**

$*p < 0,05$, $**p < 0,01$

Reliability

	S1	**S2**	**S3**	**overall**
APM (α)	0,85	0,77	—	0,84
DR (α)	0,64	0,49	—	0,61
ER (α)	0,76	—	0,65	0,74
PS (ω_t)	—	0,73	0,81	0,75

Summary

- Studies 1 and 2: Correlations between level of fluid intelligence (measured by APM) and fluencies in two kinds of deductions: simple (measured by DR) and difficult ones (operationalized by means of erotetic reasoning and polisyllogisms, and measured by ER and PS).
- Study 1: Groups A and B performed better than group C in all three tests, but group A obtained significantly higher results than group B in tasks involving difficult deductions (measured by ER), while their performance in APM and DR were comparable
- Study 2: The same pattern as in the study 1 occurred for groups A' and B', in which we measured fluency in difficult deductions by PS
- Study 3: Moderate correlation between ER and PS results. It suggests that ER and PS measure fluencies in different types of difficult deductions.

Conclusions

- Different deductive tasks are of different difficulty, and the sky is usually blue.
- Complex conditional inferences and polisyllogisms operationalize different types of difficult deductions.
- Deductions of different complexities call for different abilities to be manifested.
- Fluency in difficult deductions, while related to fluid intelligence, depends also on subjects' experience and that this does not hold in case of simple deductions.

Bibliography I

- Evans, J. St. B. T. [2012]. Dual-Process Theories of Deductive Reasoning: Facts and Fallacies. In: K. J. Holyoak and R. G. Morrison (eds.), *The Oxford Handbook of Thinking and Reasoning*, Oxford: Oxford University Press, pp. 115–133.
- Evans, J. St. B. T. Questions and challenges for the new psychology of reasoning. *Thinking & Reasoning*, 18(1):5–31 (2012).
- Horn, J. L., Blankson, A., N. [2012]. Foundations for Better Understanding of Cognitive Abilities. In: D. P. Flanagan and P. L. Harrison (eds.), *Contemporary Intellectual Assessment* (3rd ed.), London: The Guilford Press, pp. 73–98.
- Oaksford, M. [2006]. Reasoning. In: N. Braisby and A. Gellatly (eds.) *Cognitive Psychology*, Oxford: Oxford University Press (pp. 418–455).

Bibliography II

- Ricco, R. B., Overton, W. F. [2011]. Dual systems Competence $\leftarrow - \rightarrow$ Procedural processing: A relational developmental systems approach to reasoning. *Developmental Review* 31, 119–150.
- Stanovich, K. E. [2008]. Individual differences in reasoning and the algorithmic/intentional level distinction in cognitive science. In: J. E. Adler & L. J. Rips (Eds.), *Reasoning: Studies of human inference and its foundations*, Cambridge: Cambridge University Press (pp. 414–436).
- Urbański, M., Paluszkiewicz, K., Urbańska, J. [2013]. Deductive Reasoning and Learning: a Cross-Curricular Study. Research report.
- Urbański, M., Paluszkiewicz, K., Urbańska, J. (2015). Different types of deductive abilities: the case of easy and difficult deduction tasks (submitted).