Deduction

weekly_readings #week-10-11-12 #my-notes-755

> Taken from:
>
> 1. Class PPTs
> 2. The Reading: Deductive Reasoning.pdf
> 3. The Reading: deduction_theories.pdf

What is Deduction?

A deduction is a conclusion that follows from things we believe or assume.

For example, you meet Sue, who tells you that Mary is her mother. You immediately infer that Sue is Mary's daughter, although that is not the fact that was presented to you. This means that you must carry around rules such as If x is the mother of y and y is female, then y is the daughter of x

It is not that you are conscious of this rule or of applying it to make this deduction but it must be there in some form in your brain, together with some mechanism for applying it to facts and observations.

Deduction has obvious benefits for human beings.

- **Our memories are limited** and our brains can only store so many beliefs about the world. However, if we also hold a number of general rules, then these can be applied to draw out implications as and when they are required.
- Deduction is also involved in **hypothetical thinking** when we ask "What IF?" questions.

Example: Scientific theories take the form of rules, often formalised with mathematics.

Logic in Deduction

- For deduction to be useful, it needs to be accurate.
- This has been recognised in the discipline of philosophy for centuries. Philosophers devised systems of logic, whose purpose is to ensure accurate deduction.
- A logically valid argument is one whose conclusion necessarily follows from its premises

Criteria for a Good Argument

- TERMS must be clear and unambiguous
- PROPOSITIONS / PREMISES must be true
- ARGUMENT must be logically valid (i.e., conclusion must follow from premises)

Paradigms in Reasoning

- There is a tradition in philosophy that logic is the basis for rational thought (Henle, 1962; Wason & Johnson-Laird, 1972). This view held a powerful influence on psychology during the second half of the twentieth century and was responsible for a major method of studying human reasoning, which I will call the **deduction paradigm** (Evans, 2002).
  - Huge numbers of experiments were run with this paradigm and I will try to summarise their main findings in this chapter.
  - While many important things were learnt about the nature of human thinking and reasoning, a lot of **psychologists eventually lost faith in the importance of logic for rational thinking**.
- In recent years, this has a led many to revise their methods and adopt what is called the **new paradigm** psychology of reasoning.

Deductive Paradigm

- The deduction paradigm tests whether **people untrained in logic** can **make valid inferences**.
- The idea behind this is that:
  - If logic is the basis for rationality in everyday thinking
  - then, **everyone** should comply with it, not just those who have taken logic classes.
- Therefore, there are some conditions to follow in this method.
  1. Exclude participants with formal training.
  2. Present them with some *premises (assumptions)*, from which a *logical deduction* can be made.
     - Often a *conclusion* is also given and people are asked whether it follows or not.
     - Two other instructions are usually given:
       - (1) assume that the premises given are true and
       - (2) only make or endorse a conclusion which necessarily follows from them.
     - Given these instructions, only the form of the argument should matter, not the content.
     - **For example**, *people should always agree that Modus Ponens and disjunction elimination are valid arguments, no matter what we substitute for x and y in the rules given above*. By this means, the paradigm assesses whether or not people are logical in their deductive reasoning.

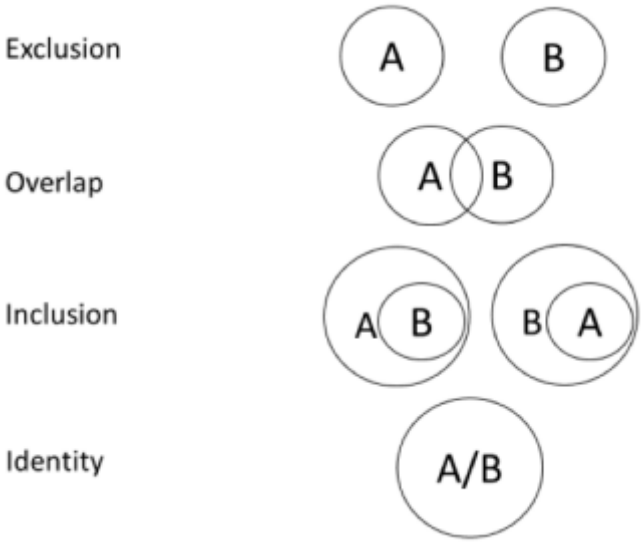
Main Methods and Findings of Deduction Paradigm

- Intensive study occured from the 1960s onwards.

- People were observed to make **frequent logical errors**, to show **systematic biases**, and to be **influenced by their beliefs about the content of the premises and conclusions**
- All of these findings have been replicated many times since using three major methods, or sub-paradigms:
    1. Syllogistic Reasoning
    2. Conditional Inference
    3. Wason Selection Task

(1) Syllogistic Reasoning

- One of the most ancient systems of logic, devised by *Aristotle*.
- A syllogism involves 2 promises and 3 terms (A, B, C)
- There can be different **models** for the relation between any two categories (say A and B)



- The statements (premises & conclusion) in a classical premise can be in one of the **four different moods**. Most moods are ambiguous (except one) and hence can be represented by more than one models.
    - (A) All A are B
        - ambiguous, can be represented by two models:
        - **model of identity** ("All men have Y chromosomes")
        - **model of inclusion (A inside B)** ("All boys are male")
    - (E) No A are B
        - It is unambiguous, only 1 model can represent it.
        - **model of exclusion**
    - (I) Some A are B
        - It is highly ambiguous, can be represented by 3 models:
        - **model of overlap**
        - **model of inclusion (B inside A)**
        - **model of identity**
    - (O) Some A are not B

    - It is highly ambiguous, can be represented by 3 models:
    - **model of overlap**
    - **model of inclusion (B inside A)**
    - **model of exclusion**
- Based on the order in which terms are arranged in a syllogistic argument, we have different **figures of syllogism**

1	2	3	4
A – B	A – B	B – A	B – A
B – C	C – B	B – C	C – B
———	———	———	———
A – C	A – C	A – C	A – C

Valid Argument

For the argument to be valid, its conclusion has to be true in all models of this three-way relationship that the premises allow.

Fallacy

- A fallacy is an argument whose conclusion need not be true, given the premises.
- A basic finding with syllogistic reasoning is that participants endorse many fallacies.
- But these mistakes are not random – there are systematic biases in syllogistic reasoning.
- Two common types of effects are: **Atmospheric Effects** and **Belief Bias**

Atmospheric Effect

disposition to accept conclusions whose mood matches that of the premise.

- **Example (1):** false
    - All A are B
    - All B are C
    - Therefore, All C are A
- **Example (2):** false
    - All Alsatians are Dogs
    - All Dogs are mammals
    - Therefore, All Mammals are Dogs
- **Example (3):** true
    - All A are B
    - All B arw C

    - Therefore, Some C are A

- **OBSERVATIONS:**

    - argument (1) is a fallcy, still 77% participants said it is valid.
      (atmospheric effect - since conclusion and premise had the same mood)
    - This effect was not observed in argument (2)
      (it is observed only in case of abstract arguments)
    - The same participants who said argument-(1) to be valid, said that argument-(3) was false.
        - This is strange because:
            - Firstly, If "All C are A" is claimed True then Logically "Some C are A" should also be claimed true
            - Secondly, "Some C are A" is actually True
        - Explanation for such a bias, is that the mood of conclusion and premise is different in this case

Belief Bias

disposition to accept an argument as valid because the conclusion seems believable.

- **Example (4):** true

    - All Doctors have Medical Degrees
    - All College Professors are Doctors
    - Therefore, All College Proffessors have Medical Degrees.

- **Example (5):** false

    - All addictive things are inexpensive
    - Some cigarettes are inexpensive
    - Therefore, some addictive things are not cigarettes.

- **Example (6):** false

    - No millionaires are hard workers
    - Some rich people are hard workers.
    - Therefore, some millionaires are not rich people

- **OBSERVATIONS:**

    - arg-4 is logically true but many people reject it since its not realistically believable
    - arg-5 is logically false but 71% agreed the syllogism to be True
    - arg-6 is logically false but 10% agreed the syllogism to be True

- **INTERPRETATIONS:**

- Though arg-5 and arg-6 have the same logical form and are both logically false, yet participants tend to claim arg-5 to be true more often than they do for arg-6. This is because arg-5 is realistically believable, while arg-6 is clearly not.
- Its observed that, belief bias also occurs in case of valid arguments (arg-4), but their effect is not so strong. For valid arguments, they claimed the argment to be True for:
  - 89% if the valid argument was at the same time believable too
  - 56% if non-believable

(3) Conditional Inference

- Basis of Hypothetical Reasoning
- Uses in real life:
  - Causal: "If you heat water, it will boil"
  - Prediction: "If you vote Republican, you will get your taxes cut"
  - Promise: "If you wash my car, I will give you ten dollars"
  - Tip: "If you wash Dad's car, he will give you ten dollars"
- The 3 statements are:
  - Conditional - Major Premise - assumed to be true
  - Assertion - Minor Premise - (which states that either the 1st or 2nd part of the conditional is T or F)
  - Conclusion

Four main Conditional Inferences:

Label	Rule	Example
Modus Ponens (MP)	If p then q; p: therefore q.	If the letter is B then the number is 3; the letter is B: therefore the number is 3.
Denial of the Antecedent (DA)	If p then q; not-p; therefore not-q.	If the letter is G then the number is 7; the letter is not G: therefore, the number is not 7.
Affirmation of the Consequent (AC)	If p then q; q: therefore p.	If the letter is T then the number is 5; the number is 5: therefore the letter is T.
Modus Tollens (MT)	If p then q; not-q; therefore not-p.	If the letter is M then the number is 1; the number is not 1: therefore, the letter is not M.

- MP and MT are logically Valid
- DA and AC are logically Invalid

Take an Example Conditional, "If the Letter is B, then the number is 3"

Psychological studies show that,

- MP inference is made 100% of the time

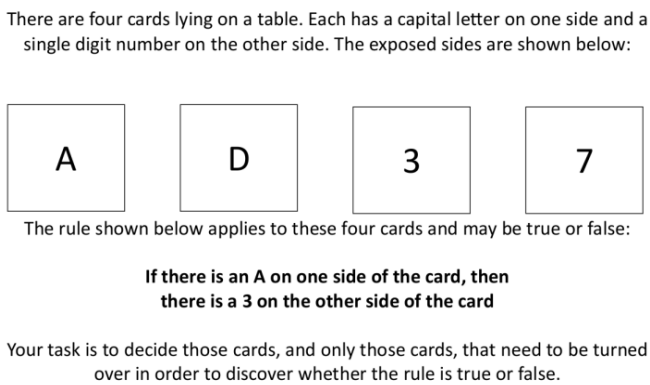
- MT is endorsed only 60% of the time
- DA and AC though logically false, are still each endorsed 40% of the time
  - A likely reason: People are making pragmatic inferences rather than logical inferences
  - For example,
    - Arg-1: (promise)
      - "If you wash my car, I will give you ten dollars"
      - "You don't wash my car" (DA)
      - Most people will say: You will not get 10 dollars (claim DA to be valid)
      - Although logically invalid, this makes sense
    - Arg-2: (tip)
      - "If you wash Dad's car, he will give you ten dollars"
      - A tip is weaker than a promise pragmatically because the speaker suggests an action will produce a desired outcome but has no actual control over it.

(3) Wason Selection Task

- Developed by ***Peter Wason*** (Father of modern psychology of reasoning)
- Known for developing several task that allowed testing of deduction theories in laboratory setting
  - The most influential of these were: "**the four-cards selection task**"
- **Tasks do not meet strict criteria of the deduction paradigm** as it involves hypothesis-testing and reasoning

CONFIRMATION BIAS

- **EXAMPLE-(1)** Standard Abstract Wason Selection Task



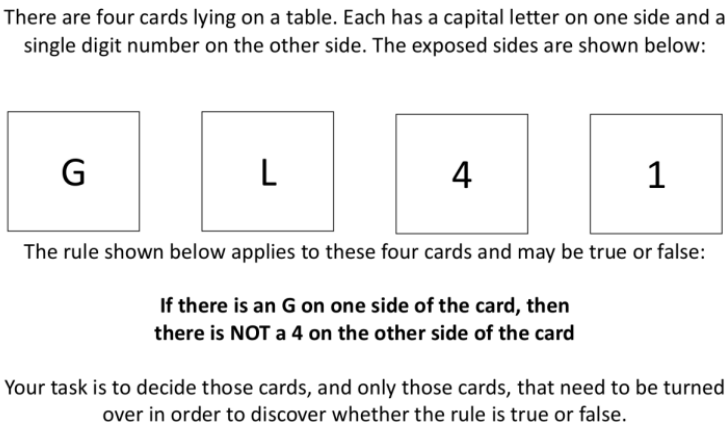
  - **Correct Answer:**
    - Choose the A and 7 cards
    - Wason pointed out that the conditional statement can only be falsified if there is a card which has an A on one side and does not have a 3 on the other. Clearly, the A card must be turned over because it must have a 3 on the back, and if it does not, disproves the claim. Similarly, the 7 card – which is not a 3 –

could have an A on the back, which would also disprove the statement. Turning the 3 is unnecessary, as it cannot disprove the rule. It need not have an A on other side.

- **Observations:**
  - Most people choose either {A} or {A, 3}
- **Interpretation:**
  - Wason originally suggested that they had a verification or **"confirmation bias"**. They were trying to prove the rule true rather than false, and hence **looking to find a confirming combination of A and 3**.
  - In support of this account, if you ask people to give written justifications for their choices, they typically say that **they were looking for 3 when turning the A and vice versa because this would make the rule true**
- **Counter-argument by Evan:**
  - However, in an early research paper of my own, I showed that this account cannot be right.
  - The trick is to include a negative in the second part of the conditional.

MATCHING BIAS

- **EXAMPLE-(2)** Abstract Wason Selection Task with an added negation

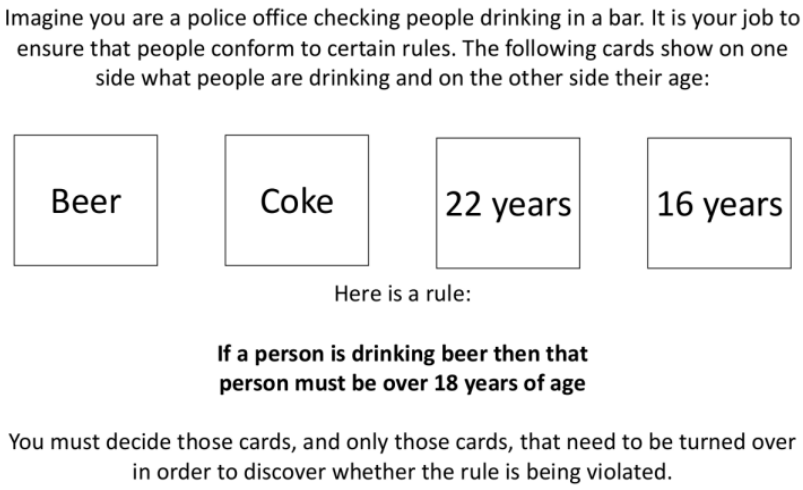


- **Correct Answer:**
  - Choose cards {G, 4} as they have the potential to correctly falsify the rule.
- **Observations:**
  - This time most people did select {G, 4}
  - Once again, participants say that they are turning the G to find a 4 and vice versa (Wason & Evans, 1975) but now in order to make it false.
- **Interpretation:**
  - If confirmation bias (which states that, people tend to find evidences to prove a rule rather than falsify it) were true, then participants should not have chosen (4) since it has potential to disprove the rule. Yet they choosed it.
  - So this time, the bias is something different. In fact its called **"matching bias"**. People tend to choose the cards which match those named in the conditional, whether or not negations are present.
  - Matching Bias (like the atmospheric effect) operates with abstract materials

THEMATIC FACILITATION EFFECT

> - It was thought initially that simply using realistic materials made the problem a lot easier with higher rates of correct selections (Wason & Johnson-Laird, 1972).
> - This was known as the **thematic facilitation effect**.
> - However, it was later shown that the versions that make the task really easy include a subtle change to the logic.

- **Example-(3)** Deontic Selection Task: Drinking Age Rule



  - **Realistic Context:**
    - People are first of all given a short context. They are asked to imagine that they are police officers enforcing rules.
    - Then the rule is given which requires "beer drinkers to be over 18 years of age".
    - Then they are given the above 4-cards selection task (one side *drink*, other side *age*)
  - **Correct Answer:**
    - Check for {"Beer", 16 years (something that is NOT "over 18")}
  - **Observations:**
    - Most people checked the "beer drinkers" and those "under 18 of years of age".
    - Experiments which give the drinking age rule find much higher rates of correct answers than with the standard abstract version.
  - **Interpretations:**
    - Making the task more realistic, made the problem a lot easier - *"thematic facilitation effect"*
  - **Some Critics (not actually):**
    - problems like the drinking age rule **change the task** from one of ***indicative logic*** (concerned with truth and falsity) to one of ***deontic logic*** (concerned with obeying rules and regulations)
    - Different theoretical accounts to explain why the deontic version is so much easier:
      1. we acquire and apply **"pragmatic reasoning schemas"** (*Cheng & Holyoak, 1985*):

    - Rules which apply in certain contexts and can be instantiated with the content of a particular problem.
    - *So people might solve the drinking age rule because:
        - They have a permission schema such as:
            - "If an action A is to be taken, then condition C must be filled",
        - which could be instantiated as:
            - A = drinking beer, and
            - C = 18 years or age or older.
        - The schema tells them violations of this rule occur when the action is taken without the precondition being filled*
2. The use of innate evolved rules for social exchange (*Cosmides, 1989*)
3. Interpreting the problems as a decision-making task in order to maximise perceived benefits (*Manktelow & Over, 1991*)
4. The role of pragmatic relevance for different forms of conditional statement (*Sperber, Cara, & Girotto, 1995*).

Theoretical Issues in the Psychology of Deduction

> There are 3 important theoretical explanations of Deduction:
> 0. Logic (**INCORRECT**)
>
> 1. Mental Logic (Mental Rule Theory)
> 2. Mental Models Theory
> 3. Dual-process Theory

(0,1,2) - Logic, Mental Logic (Mental Rule Theory), Mental Models

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Despite the frequency of errors and biases, people do show some level of deductive competency on reasoning tasks, especially those of higher cognitive ability (Stanovich, 2011).
For example, people endorse far more valid inferences than invalid ones on both syllogistic and conditional inference tasks.

Some psychologist have focussed on the competence rather than the errors and asked questions about the mechanisms by which people draw deductions. Few such approaches are:

1. Mental Logic
2. Mental Models

MENTAL LOGIC (more accurately be described as Mental Rule Theory)

- **Philosophers** and **logicians** considered "rules of logic" as the basis of thinking.
- **Psychologists** however doscovered that people had their own built-in set of rules that differed from the logic rules.
- *Example:*
  - According to Logic, there should be no difference between MP and MT.
  - But, People are better at MP

Mental Logicians have tried to address this problem (MP > MT)

- Only MP is a simple rule where one can apply direct inference.
- MT can be drawn but by an indirect reasoning procedure called "*reductio reasoning*" (use contradictions)
- *Example:*
  - Major Premise: "If the letter is B, the number is 3"
  - Case-1: Minor Premise: "The letter is B" (MP)
    - If people are told there **is a B**, then they can immediately apply their built-in rule for MP and conclude that there is a 3.
  - Case-2: Minor Premise: "The number is 3" (MT)
    - If told there **is not a 3**, they do not have a rule for MT that can be applied in the same way.
    - Instead, they have to reason as follows:
      - "If I imagine there is a B on the card, then there must be a 3. But I have been told there is not a 3 which is a contradiction. So I must have been wrong to suppose that there was a B on the card. Hence, I can conclude that there is not a B."
    - This indirect reasoning is harder to execute and more prone to errors, explaining the lower acceptance rate of MT

MENTAL MODEL THEORY

- proposed by *Kenneth Craik*, developed by *Philip Johnson-Laird* (student of *Peter Wason*).
- **MENTAL MODEL:** Internal Representations of some possible states of the world, having the same structure as that state.
- *Example:*
  - "Kay" is taller than "Ray"; "Ray" is taller than "Jay"; What do you say about "Kay" and "Jay"?
  - People imagine 3 lines (one for each boy), and assign relative heights based on the statements. Use the same relativity to answer the question of who is taller.

This theory also proposes that people are:

- deductively competent in principle,
- but fallible in practice,

- but does not rely on the application of mental rules.

The core of the theory is the idea that,

- People reason about possibilities, which are states of the world that might be true or false.
- These possibilities are represented by mental models.
- When the premises of an argument are presented, people are supposed to construct mental models to represent all possibilities and then reason as follows:
  1. If the conclusion is true in all models of the premises, it is necessary
  2. If the conclusion is true in some models of the premises, it is possible
  3. If the conclusion is true in no models of the premises, it is impossible

Mental Model to explain Disjunctive Elimination

- Major Premise: "Either the Letter is B, OR the Number is 3"
  - people construct the following models as possibilities:
    - (1) There is a B
    - (2) There is a 3
    - (3) There is both B and 3
- Minor Premise: "The Number is not 3"
  - on hearing this, people eliminate the last 2 models, and are left with only 1st model
  - Hence, "There is a B" is the answer that they give.

Hence, people will conclude B as a correct deduction but without having any rule of disjunction elimination for the inference.

Mental Model to explain MP and MT

- Major Premise: "If there is a B, then there is a 3"
- **INCORRECT WAY TO REPRESENT THE MODELS**
  - The full set of possibilities for this statement, according to the published theory, is the following:
    - (1) B , 3
    - (2) not-B , 3
    - (3) not-B , not-3
  - Given these possibilities, the minor premise B eliminates all but the first model, so the conclusion 3 follows (MP). The minor premise not-3, eliminates all the last model, so that not-B follows (MT)
- However, to account for the relative difficulty of MT, mental-logic theorists (Johnson-Laird and Byrne) proposed the following:
- **CORRECT WAY TO REPRESENT THE MODELS**
  - People initially represent conditionals as:
    - [B] , 3
    - . . .

    - The first model means that in all cases of B (meaning of [ ]), there is a 3. The ellipsis '. . . ' means there are other possibilities
    - So if B is presented, people can immediately do Modus Ponens and conclude 3. However, if not-3 is presented, then they have to 'flesh out' the models to the fully explicit set given above in order to make Modus Tollens.
- **Fleshing out is error prone, so people sometimes fail to make this valid inference**

> I think it fair to say that both mental rule and mental model theory are firmly rooted in the traditional deduction paradigm, as they both put an account of logical competence foremost and deal with effects of beliefs and pragmatics as add-ons.
>
> *~ Evans*

(2) Mental Models

- Johnson-Laird argues that, **"reasoning involves constructing mental-models"**
- a **mental model** is "**an iconic representation of a possibility that depicts only those clauses in a compound assertion that are true**".

Example:

- Premises:
    - The lamp is on the right of the pad.
    - The book is on the left of the pad.
    - The clock is in front of the book.
    - The vase is in front of the lamp.
- Conclusion
    - The clock is to the left of the vase.
- According to Johnson-Laird (1983), people use the information contained in the premises to construct a mental model like this:

book	pad	lamp
clock		vase

ASSUMTIONS OF MENTAL MODEL THEORY

1. A mental model describing the given situation is constructed and the conclusions that follow are generated.
2. An attempt is made to construct alternative models to falsify the conclusion by finding counterexamples to the conclusion. If a counterexample model is not found, the conclusion is deemed valid.
3. The construction of mental models involves the limited resources of working memory
4. Reasoning problems requiring the construction of several mental models are harder than those requiring only one mental model because the former impose greater demands on working memory.

5. The **principle of truth: "Mental models represent what is true, but not what is false"** (*Khemlani & Johnson-Laird, 2017*). This minimises demands on working memory

FINDINGS OF MENTAL MODEL THEORY

Working Memory

- Several studies support the notion that working memory plays a central role in the formation of mental models.

Brunyé et al. (2008)

- Found the central executive and visuo-spatial sketchpad components of the working memory system were heavily involved in constructing mental models.

Copeland and Radvansky (2004)

- Found working memory capacity correlated (+42) with syllogistic reasoning performance

Khemlani and Johnson-Laird (2017) - Testing the Principle of Truth

- Reviewed 20 studies testing the principle of truth. These studies used various reasoning tasks, in all of which individuals failing to represent what is false in their mental models would produce illusory inferences.
- Numerous illusory inferences were drawn. In contrast, performance was very good with similar problems where adherence to the principle of truth was sufficient to produce correct answer.
- *Example:*

  Only one of the following premises is true about a particular hand of cards:
  There is a king in the hand or there is an ace, or both.
  There is a queen in the hand or there is an ace, or both.
  There is a jack in the hand or there is a 10, or both.
  Is it possible there is an ace in the hand?

  - **Correct Answer:**
    - "No"
    - If there were an ace in the hand, both the first two premises would be true. However, the problem states that only one of the premises is true.
  - **Observations:**
    - Nearly everyone says "Yes" (which is wrong)

Khemlani and Johnson-Laird (2012)

- carried out a meta-analysis of syllogistic reasoning studies to compare seven theories.
- The mental model theory was:
  - best at predicting participants' responses with a 95% success rate.

- However, relatively weak at rejecting responses people do not produce

Newstead et al. (1999) - "people search for counterexamples after initail model"

- obtained no support for this conclusion

Khemlani et al. (2012)

- Found that people generate relatively few counterexamples.
- *Example:*
  - Particpnats were told: *They're "**not living adult males**". So, who could they be?*
  - There are seven possibilities (e.g., dead adult males; living girls; ...)
  - **Observations:** But participants listed only four possibilities on average.
  - **Conclusion:** people generate few counterexamples

Ragni & Knauff, (2013) - Struggles with ambiguous Reasoning

- *Consider the example:*

  The Porsche is to the right of the Ferrari.
  The Beetle is to the left of the Porsche.
  The Dodge is in front of the Beetle.
  The Volvo is in front of the Porsche.

- Question asked: "Which relation holds between the Beetle and the Ferrari?"
- There is no definit answer to this question
- **Drawback of Mental Model:** Does not predict which answer will be given by most participants.

EVALUATION OF MENTAL MODEL THEORY

Successes:

1. The theory **compares well against other theories** of reasoning (Khemlani & Johnson-Laird, 2012; Johnson-Laird et al., 2018) and also performs well when predicting performance on Wason's selection task (Ragni et al., 2018).
2. As predicted, **working memory is involved** in the construction of mental models.
3. There is **substantial support for the principle of truth**.
4. The theory has recently been developed to **account for reasoning about probabilities** (Johnson-Laird et al., 2015).

Limtations:

1. Most people find deductive reasoning very hard and so resort to easier forms of processing (discussed shortly).
2. Most people **do not typically search for counterexamples** as predicted theoretically.

3. **The processes involved in forming mental models are underspecified**. It is assumed people use background knowledge when forming mental models, but the theory does not spell how we decide which information to include in a mental model.
4. Often **fails to predict people's answers with ambiguous reasoning problems** (e.g., Ragni & Knauff, 2013)

(3) Dual-Process Theories

Several theorists (Stanovich, Evans, Sloman, Kahneman, De Neys) have proposed dual-process (sometimes called dual-system) theoretical accounts of **human reasoning** and **other aspects of higher-level cognition**.

Evans and Stanovich (2013) provided an integrative account of dual-process theories based on a distinction between **Type 1** (intuitive processing) and **Type 2** (reflective processing)

> **Autonomy:** it is mandatory or necessary when the appropriate triggering stimuli are encountered
> **Cognitive Decoupling:** hypothetical reasoning not constrained by the immediate environment.

Defining Features:

1. **Type-1:** Autonomy, No Working Memory
2. **Type-2:** Cognitive Decoupling, Working memory needed

Characteristics Featuers:

1. **Type-1:** Fast, High-capacity, automatic, independent of cognitive ability
2. **Type-2:** Slow, Limited-cap, controlled, dependent on cognitive ability

Default-intervenionist model

- Assumed that individuals trying to solve reasoning problems,
  - initially use intuitive Type 1 processing to generate a rapid heuristic answer
  - which may be corrected by a subsequent more deliberate answer produced via slow Type 2 processing.
- A key assumption is that reasoning performance will generally (but not invariably) be superior when it involves Type 2 processing in addition to Type 1 processing.

Why is it wrong to equate {Type1: biased (often incorrect), Type1: correct reasoning}

- We often get things done right via habbit or reliable intuition involving Type-1 processing.
- Our effortful Type-2 processing (while solving Maths solving) can also produce incorrect response

When is Type-2 used? (**Predictions** made by **Early Dual-Process Theories**)

1. Reasoners are intelligent
2. Availability of time to process information
3. Reasoners do not need to perform a secondary demanding task simultaneously

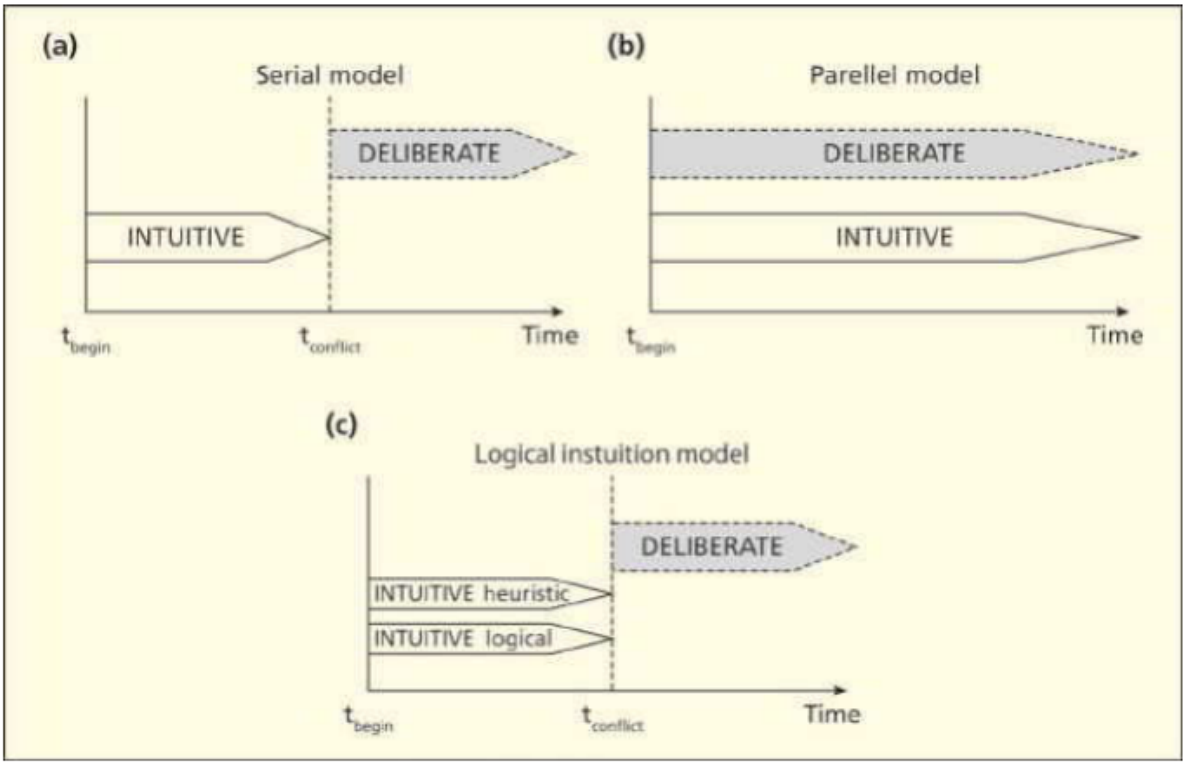
FINDINGS OF EARLY DUAL-PROCESS THEORIES

> Much research to test the above predictions has focused on **"belief bias"**
> According to dual-process theories, there will be less belief bias (and superior performance) when Type-2 processes are used.

1. More intelligent reasoners might show less belief bias because of their high cognitive ability or because they choose to adopt an analytic cognitive style.
2. There is also support for the second prediction that there should be less belief bias with ample thinking time because restricting thinking time reduces reasoners' ability to use Type 2 processes. In similar fashion, errors in conditional reasoning occur more often when reasoners must respond rapidly.
3. *De Neys (2006)* found that reasoners exhibited much more belief bias when performing a demanding secondary task.

THEORETICAL DIFFERENCES AND DEVELOPMENTS

The early Theories were oversimplified

- The assumption that correct reasoning performance reflects Type 2 processing whereas incorrect reasoning performance reflects Type 1 processing is only partially correct
- The relationship between Type 1 and 2 processing during reasoning tasks. Several early theorists (Evans & Stanovich) proposed serial models for reasoning.
  - De Neys (2012) identified three models of how Type 1 and 2 processing combine:
  - 

- (1) **Serial Model:** as per the traditional theories
- (2) **Paraller Model:** Type-1 and Type-2 occur at the same time. This model is a waste of cognitive resources.
- (3) **Logical Intuition Model:**
  - Two types of intuitive responses (**intuitive heuristic** and **intuitive logical**) are activated in parallel.
  - If these two responses conflict, deliberate (Type 2) processes resolve matters.
  - De Neys argued that traditional logical principles can be activated fairly automatically (intuitive logical).

FINDINGS FOR LATER DUAL-PROCESS MODELS

Supports for Logical-Intuition Model

De Neys et al. (2010)

- **Task:** Participants were given syllogistic reasoning tasks with conflict (between the logical validity and believability of conclusion).
- **Observations-1:** 89% accuracy on NON-conflict-trials, 52% accuracy on conflict-trials.
- **Interpretation-1:** The very poor performance on conflict problems (marginally greater than chance) suggests reasoners failed to detect their logical structure.
- **Observation-2:** Greater physiological arousal on conflict trials
- **Interpretation:** conflict was registered within the processing system below the conscious level.
- **Conclusion:** Some logical processing can be intuitive rather than analytic.

Trippas et al. (2016)

- **Task:** Participants were asked to decide how much they liked various sentences.
- **Observation:** Sentences following logically from preceding sentences were rated more likeable than those that did not.
- **Interpretation:** Since the task made no reference to logical validity, this finding suggests participants had an **"implicit" sensitivity to "logical structure" based primarily involving Type 1 processes**.

Bago and De Neys (2017)

- **Task:**
  - presented participants with various syllogistic reasoning problems involving conflict between the believability and validity of the conclusion.
  - The participants provided two responses to each problem:
  - (1) a fast, intuitive response; and (2) a much slower and more deliberate response.
- **According to the default-interventionist model** (e.g., *Evans & Stanovich, 2013*)
  - we would predict: **low levels of accurate fast responses** and **substantially more correct deliberate responses** than intuitive ones.
- **Observations:** Neither prediction was supported.

- **Modification:** They performed the same task, with an additional secondary demanding task at the same time, (to reduce their engagement in Type-2 analytical processing)
- **Observations:** Nevertheless, 49% of fast responses on conflict problems were correct.
- ***Overall, these findings support the logical intuition model in that fast (and presumably Type 1) processes often produce logically correct responses.*

> Contrary to the predictions of early dual-process theories, fast responses were often correct based on logical validity and slow responses were often incorrect and exhibited belief bias. These findings suggest a blurring of the distinction between Type 1 and Type 2 processes.

Trippas et al. (2017)

- **Tasks:** Asked participants conditional-reasoning problems involving conflict between logical validity and believability of the conclusion.
- **According to the EARLY dual-process theories,**
  1. Responding on the **basis of belief** (involve Type 1 processing) and so should be faster than responding on the **basis of logic** (involving Type 2 processing).
  2. The **believability of the conclusion** (accessed rapidly) should interfere with **logic-based responses** (accessed slowly) but the reverse should not be the case
- **Observations:** Neither predictions were true
  1. Response times were comparable on belief-based and logic-based trials, and
  2. The logical validity of the conclusion interfered with belief-based responding
- **However, these findings were consistent with parallel-processing theories**

Thompson et al. (2018)

- **Task:** Participants **differing in cognitive ability** received incongruent reasoning problems:involving a conflict between belief and logic and had to respond on the basis of belief or logic.
- **Observations:**

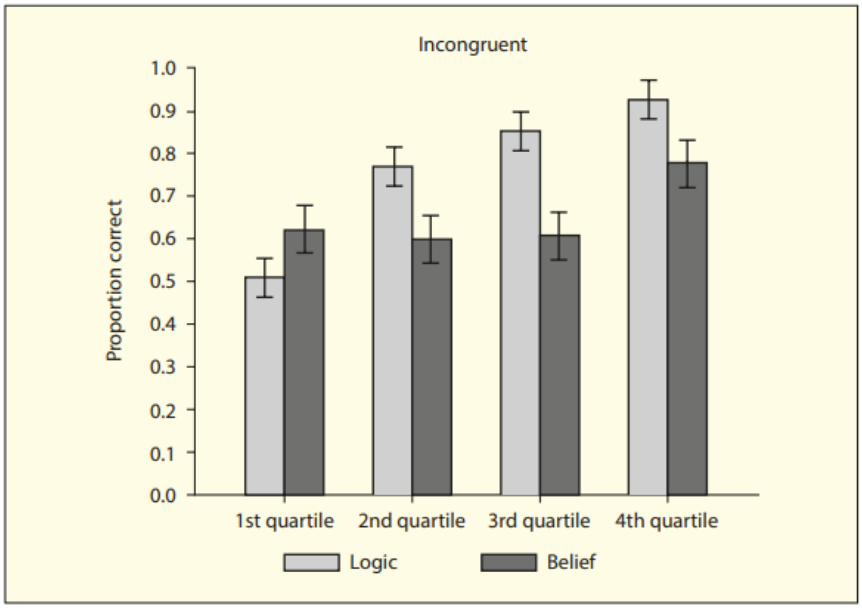


Figure 14.5
Proportion correct on incongruent syllogisms as a function of instructions (respond on the basis of logic or belief) and cognitive ability (1st quartile = lowest; 4th quartile = highest).
From Thompson et al. (2018).

    - More intelligent people produce logic-based responses faster than belief-based responses. (opp. for less-intelligent people)
- **Conclusion:**
    - **Individual differences** seem to play a key role in the **type of response chosen**
    - Since, both Logic and Belief based responses can be generated both automatically (and quickly) as well as deliberately (and slowly). Responses merely differ on a single dimension, namely, "complexity"

WHAT CAUSES TYPE-2 PROCESSING?

> What determines whether reasoners' responses are based on analytic (Type 2) processing or whether they reflect only intuitive (Type 1) processes?

Traditional serial models

- assume that Type 2 processes monitor the output of Type 1 processes and it is this monitoring process that determines whether reasoning performance is based on Type 2 processes.
  Many parallel models
- assume Type 2 reasoning is triggered when "conflict monitoring" (involving Type 2 processing) leads to "conflict detection".

What is puzzling about all these theories is that, "They assume that Type 2 processing is effectively caused by itself"

Meta Reasoning - Ackerman and Thompson (2017)

- **Meta Reasoning:** "The processes that monitor the progress of our reasoning and problem-solving activities and regulate the time and effort devoted to them"
- Monitoring processes assess the **probability of success "before"**, **"during"** and **"after"** performing a reasoning task.
- The most important monitoring feature is the **feeling of rightness**: "the degree to which the first solution that comes to mind feels right"
- Only **when this feeling is weak do reasoners engage in substantial Type 2** (or analytic) processing.

Role of Feelin-of-Rightness Ratings on use of Type-2 processes - Thompson et. al. (2011)

- **Task:**
    - Participants given syllogistic and conditional-reasoning tasks.
    - To provide an initial answer, immediately after reading each problem (intuitive - Type1).
    - The asked to assess the answer's correctness (feeling-of-rightness)
    - Then, given unlimited time to reconsider initial answer and provide a final answer.
- **Observations:**
    - participants

- **spent longer reconsidering their intuitive answer** and **were more likely to change it**
- **when they had low feelings of rightness.**

What determines this Feeling-of-Rightness? - Thompson et. al. (2013)

- **Task:**
  - Participants given syllogistic and conditional-reasoning tasks.
  - To provide a first response that came to mind.
  - Provide a feeling-of-rightness rating
  - Then, produce a slower (more deliberate) response
- **Observations:**
  - Feeling of rightness was higher, when the first response was produced rapidly

EVALUATION OF DUAL-PROCESS THEORIES

Strength:

1. dual-process theories have become increasingly popular and wide-ranging. For example, they provide explanations for syllogistic reasoning and conditional reasoning.
2. Dual-process theory provides a valuable high-level framework within which more specific and testable models can be developed

Limitations:

1. dual-process theories are over-simplified:
   - (1) they often imply that Type 1 processes are “bad” and error prone, whereas Type 2 processes are “good”; and
   - (2) they assume many cognitive processes can be assigned to just two types
2. The absence of a clear and general definition of a Type 1 or Type 2 response does create difficulty for researchers wishing to test dual-process theories

The New Paradigm Psychology of Reasoning

Classical Paradigm:

- During reasoning, people are drawing **logical inferences**
- Reasoning involves determining truth and falsity of arguments.

New Paradigm:

- People naturally reason from their beliefs and this should not be considered an error r cognitive bias
- During reasoning people are making decisions
- Reasoning involves determining:
  - What is believed and to what extent? (Degree of Belief)

- What is its value? (Utility)

Earlier View: Logic was the basis of reasoning

As evidence of logical errors, cognitive biases, and belief-based reasoning accumulated, this presented a clear problem both for psychologists and for philosophers

The problem with the view was that, by the original assumptions, **people were turning out to be irrational**.

Peter Wason, for example, was quite clearly of the view that people were illogical and therefore irrational

Jonathan Cohen

- Argued that people were in fact inherently rational and that psychological experiments could never prove otherwise (Cohen, 1981).
- He suggested that the **experiments were unrepresentative or being misinterpreted**.
- He also pointed out that **standard logic, for example, is not the only kind that logicians have offered**. There could be alternative normative accounts of how to be rational. (A normative theory is one of how people ought to reason)

Mike Oaksford and Nick Chater

- Their first important contribution was an alternative normative account of the Wason selection task, arguing that the **typical answer can be seen as rational** from a **decision-making perspective**
- they took the view that human behaviour must be rationally adapted to the environment and if a standard normative account does not explain it, then we should look for another

> The essence of the **new paradigm** is that people naturally reason from their beliefs about the world and that this should not be treated as an error or cognitive bias
>
> A key feature of the new paradigm is the proposal of the **suppositional conditional**, also known as the probability conditional (*Evans & Over, 2004; Oaksford & Chater, 2001*)

Material Condition vs Suppositional Condition

Consider the example: "If the letter is B, then the number is 3"

Truth table as per Standard Logic:

Letter	Number	Condition
B	3	True
B	not 3	False
not B	3	True
not B	not 3	True

Therefore, in Standard Logic, the above conditional can also be written in a Disjunctive Form:
"Either the letter is not B, or the number is 3"

This is referred to as **Material Conditional**

However, many philosophers have rejected the material conditional as an account of the ordinary conditional of everyday language. Since it can lead to unacceptable inferences.
Example

- Since, the material condition "If p, then q" is valid whenever, "p is false" or "q is true"
- The following inferences are also valid:
  - If President Trump is French, then Paris is the capital of the USA (**due to "p is false"**)
  - If 2+2 = 5, then 3 is a prime number (**due to "q is true"**)
- But, no normal person will endorse these inferences.

Ramsey Test

A conditional is not material, but suppositional, therefore, the probability of the consequent s evaluated assuming the antecedenthas already happened.

> - The philosopher Ramsey famously argued that belief in the ordinary conditional if p then q, is in effect the probability that q will be true if p is
> - He also suggested that we do this by adding p to our current stock of beliefs and arguing about q on that basis.
> - This is known as the Ramsey test and we suggested that conditional statements are suppositional – they depend on the supposition of p

Example
"If teachers' pay is raised, then recruitment will increase"

- Many people will agree with this statement or assign a high probability to it.
- They do this by:
  - **supposing first that teacher's pay is in fact raised** and
  - then using **other beliefs to calculate the likelihood that they will prove easier to recruit**. (They may be aware that recruitment has been difficult in recent years and that one factor is almost certainly that salary levels have fallen behind those of workers in other professions. So, they believe that financial incentive will help address the issue).

- In doing this, **they ignore any beliefs they have about what will happen if pay is not increased**, which they regard as irrelevant.

Consider, however this statement (conditional)
"If the global economy grows then there will be less poverty and starvation in the world"

- The Ramsey test will not produce a high level of confidence in this conditional for many people.
- (They may believe, for example, that the growth in the global economy increases wealth for rich individuals and rich countries but is not likely to be distributed to the third world. where most of the poverty and starvation is concentrated).
- If their belief in the conditional is low, they will also be reluctant to draw inferences from it, even the apparently obvious Modus Ponens.

> - There is now much evidence that, with real-life conditionals like these, people do indeed assign very similar belief levels to "if p then q" as they do to the probability of "q given p" (e.g. *Over, Hadjichristidis, Evans, Handley, & Sloman, 2007*).
> - People act as though the conditional only applies on the supposition that p is true, in people's minds, and is otherwise irrelevant.
> - This is not consistent at all with the material conditional of standard logic.

Bayesian decision theory

- A system which takes account of subjective beliefs
- and also evaluate the degree of uncertainty