Abduction and Evidence
in
Medical Diagnosis

EVIDENCE AND CAUSALITY

IN THE SCIENCES

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Previous and Ongoing Research

Abductive Reasoning: Logical Investigations into Discovery and Explanation. Springer, 2006.

Medicine and Reasoning: The Diagnostic Process in Neurology (w/ A.C. Rodríguez de Romo and A. Arauz). Ludus Vitalis, 2008.

An Adaptive Logic for Hypothesis Testing: A Neurological Case (with Laura Leonides). Work. In progress.

The Role of Hypotheses in Medical Diagnosis. In Progress. Model Based Reasoning in Science and Technology. MBR'12.
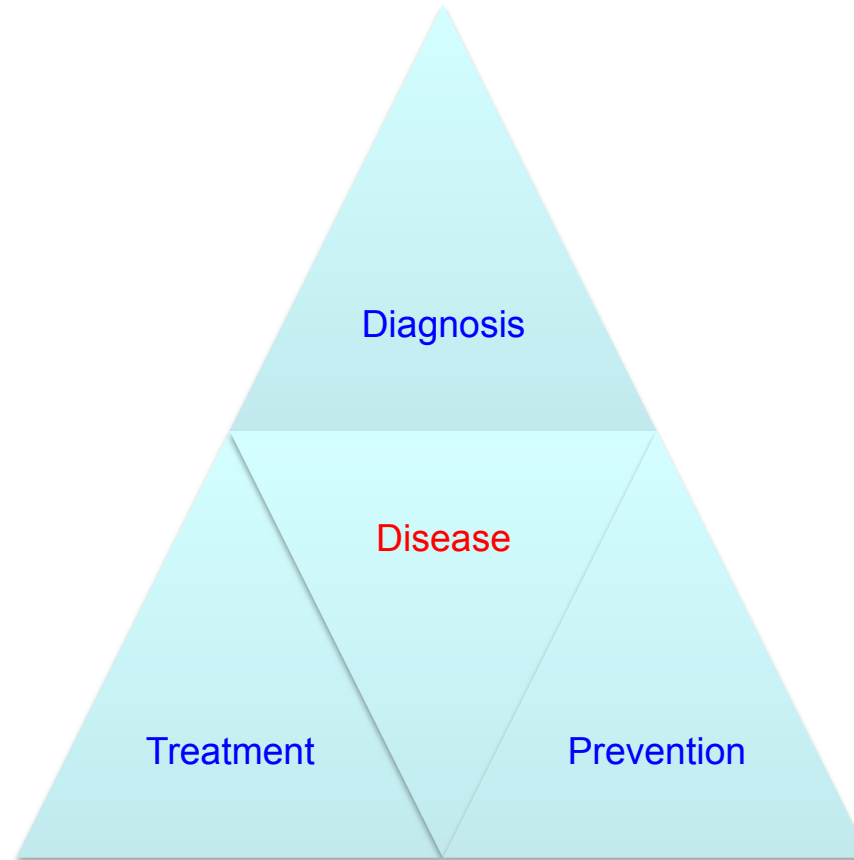
Introduction

- Medicine: What is it? A Science? An Art?

Introduction

- Medicine: It is the applied science or practice of the diagnosis, treatment, and prevention of disease.

Medicine

Introduction

- Medicine: It is a Design Science.

Herbert Simon. The Sciences of the Artificial.

Introduction

- Medicine: It is a Design Science.

Goal-oriented ("to cure")

Problem solving for "human problems".

Possibility for manipulation of <certain> causal factors.

Aims at success rather than at "truth".

Introduction

- Medicine as a Design Science

- Medical Practice (vs. Medical Research)

Paul Thagard. How Scientists Explain Disease

Introduction

- Medicine as a Design Science

- Medical Practice (vs. Medical Research)

- Medical Diagnostics (vs. Automatized MDiag)

Peng and Reggia. Abductive Inference Models for Diagnostic Poblem-Solving.

Outline

- The Practice of Medical Diagnosis
- Abduction and Inference to the best explanation (IBE)
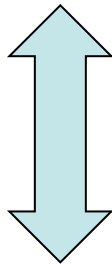
- Evidence and Hypothesis
- Conclusions

Outline

- The Practice of Medical Diagnosis
- Abduction and Inference to the best explanation (IBE)

- **Evidence and Hypothesis ($H_{<e>}$)**
- **Thesis** An argument is **infused** with evidence to confirm/refute a hypothesis.

Medical Diagnosis: Motivation

- How do physicians think when they construct a diagnosis?

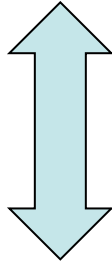Symptoms and signs +

physical examination + tests results

⬍

Diagnostic Hypothesis

Medical Diagnosis: Motivation

- How do physicians think when they construct a diagnosis?

E?

Symptoms and signs +

physical examination + tests results

Diagnostic Hypothesis

Medical Diagnosis: Some Challenges

- Diagnoses are UNCERTAIN

- Diagnoses are constructed with INCOMPLETE and DYNAMIC Information

- There is NO SINGLE PROCEDURE or MODEL for the construction of Diagnoses.

Why are Diagnoses Uncertain? There are no general laws

- Usually, when a brain tumour is present, among the signs we could find, there is progressive growth and compression of neighbouring structures, which altogether may lead to an increase in the intracranial pressure or cephalea (headache).

Why are Diagnoses Uncertain?
There are no general laws

- Most patients with a brain tumour present an increase in the intracranial pressure and a headache.

- Some patients with a brain tumour present neither intracranial pressure nor a headache.

- Few patients with no brain tumour present an increase in the intracranial pressure and a headache.

Why are Diagnoses Uncertain?
Inferential Statistics is at Work

- Individuals may not belong to the specific domain of the test generated by the statistics. (Hempel's reference class).

- Symptoms express themselves different in different people (e.g. pain), or even not the same at all times in the same person.

Medical Diagnosis: Some Challenges

- Diagnoses are UNCERTAIN

Medical diagnoses are just probable or even just plausible.

Why are diagnoses constructed with Incomplete Information?

- MD´s do not have (or know) from the start all relevant information for the case in view.

- Information is generated on the way by questions, tests, and even treatments.

Why are diagnoses constructed with Incomplete Information?

Example:

- A patient, with antecedents of hyperthyroidism, went to the hospital for a problem that began eight months earlier with difficulties in walking, in articulating language and in swallowing solids and liquids.

Why are diagnoses constructed with Incomplete Information?

- Suppose we hypothesize a certain patient has a brain tumour. We need to check whether she presents an increase in intracranial pressure and a headache.

- Suppose she presents neither an increase in intracranial pressure nor a headache.

- Shall we rule out the hypothesis based on the negative evidence?

Why are diagnoses constructed with Incomplete Information?

- We conclude --after an MRI of the brain –
  she does not have a brain tumour…

- But …

Why are diagnoses constructed with Incomplete Information?

- Due to her symptoms and medical knowledge, we may still suspect she may have a tumour elsewhere in the body…

- Medical Knowledge: Paraneoplastic syndrome is caused by the remote effects of a –usually malignant– tumorous lesion.

Why are diagnoses constructed with Incomplete Information?

- But: Where to look at?
  Given her antecedents (hyperthyroidism):
  here is our <existential> abductive hypothesis:

- There is a tumorous lesion in the thyroid gland.

- A test corroborated above hypothesis.

Why are diagnoses constructed with Dynamic Information?

- Ilnesses evolve, and what may seem an accurate diagnosis at some point, may be faulty at a later moment.

- Information changes, due to results of examination, treatments, or just by the passing of time…

Why there is no single procedure/ model to reach a Diagnosis?

- The construction of a diagnosis is a complex phenomenon. There is no single procedure, much less a privileged one, for the construction of a medical diagnosis.

- Many reasoning types –as well as other cognitive tasks– are involved in reaching a diagnosis.

Why there is no single procedure/ model to reach a Diagnosis?

- Medical practice involves observation, reasoning, intuition and testing, all interacting with each other!

Why there is no single procedure/model to reach a Diagnosis?

- Medical practice involves observation, reasoning, intuition and testing, all interacting with each other!

- Analogy, Induction, Abduction, Deduction coexist.

ABDUCTION AND IBE:
A VARIETY OF PATTERNS

- Charles Peirce's Formulation and its interpretations

- Inference to the Best Explanation

- Etc…

Peirce: Abduction

(Peirce, 1839--1914)

The surprising fact, C, is observed

But if A were true, C would be a matter of course

Hence, there is reason to suspect that A is true

Peirce: Abduction

(Peirce, 1839--1914)

The **surprising** fact, **C,** is observed

But if A were true, C would be a matter of course

Hence, there is reason to suspect that A is true

C may be Novel or Anomalous!

Peirce: Abduction

(Peirce, 1839--1914)

The surprising fact, C, is observed

But **if A were true**, C would be a matter of course

Hence, there is reason to **suspect that A is true**

Additional Criteria:

A should be "testable"

A should be "economic"

Abduction

(Peirce, 1839--1914)

The surprising **fact**, C, is **observed**

But if A were true, C would be a matter of course

Hence, there is reason to suspect that A is true

C may be

a problem

situation!

Abduction

(Peirce, 1839--1914)

The surprising **fact**, **C**, is **observed**

But if A were true, C would be a matter of course

Hence, there is reason to suspect that A is true

C !

A ⇒ C

A?

Abduction

(Peirce, 1839--1914)

The surprising **fact**, **C,** is **observed**

But if A were true, C would be a matter of course

Hence, there is reason to suspect that A is true

C !   **E?**

A ⇒ C

A?

Abduction

(Peirce, 1839--1914)

The surprising fact, C, is observed

But if A were true, C would be a matter of course

Hence, there is reason to suspect that A is true

C !   Cause?

A ⇒ C   Mechanism?

A?

Inference to the Best Explanation

(IBE)

Given evidence E

and potential explanations A1, …, An of E, infer to the (probable/approximate) truth of the Ai that explains E best.

Harman, Lipton…

E

A1 $\Rightarrow$ E

…

An $\Rightarrow$ E

(Best) Ai

Eliminative Abduction

(EA: Holmesian Inference)

The fact E has an explanation

H1… Hn are the only hypotheses that could explain E

H1 … Hn-1 have been falsified by the evidence

Therefore, Hn explains E

(Bird)

E

$H1 \Rightarrow E \dots Hn \Rightarrow E$

~~$H1$~~, …, ~~$Hn\text{-}1$~~

Hn

Inference to the Best Theory

(IBT)

If a theory has so far proven to be the best one among the available theories, then (choose it i.e. apply RS, and) conclude, for the time being, that it is the closest to the nomic truth T of the available theories.

Kuipers.

If Y has so far proven to be more successful than X, then eliminate X, in favor of Y, for the time being.

Eliminative Abduction

Mill's Method of Difference

Differential Diagnosis: Methods that help to rule out conditions (hypotheses)

But…

Is E an evidence (IBE)?

Is E a fact to be explained?

E

$H1 \Rightarrow E \ldots Hn \Rightarrow E$

~~$H1$~~, …, ~~$Hn\text{-}1$~~

Hn

Eliminative Abduction

Mill's Method of Difference

Differential Diagnosis: Methods that help to rule out conditions (hypotheses)

But…

Do MD's generate their hypotheses in advance and then select the best one?

$$E$$

$$H1 \Rightarrow E \ldots Hn \Rightarrow E$$

$$\cancel{H1}, \ldots, \cancel{Hn\text{-}1}$$

$$Hn$$

EVIDENCE AND HYPOTHESES

- Inductive Probabilities: $p(h|e) > p(h)$

EVIDENCE AND HYPOTHESES

- Inductive Probabilities
- Order? : E ➜H vs. H ➜E

EVIDENCE AND HYPOTHESES
H<e>

- Inductive Probabilities
- E ➜H vs. H ➜E
- H<e> e for H (confirmation)
- H<e> e vs. H (falsification)

EVIDENCE AND HYPOTHESES
H<e>

- Inductive Probabilities
- E ➜H vs. H ➜E
- H<e> e for H (confirmation) Bayesianism
- H<e> e vs. H (falsification) Falsificationism

Abduction
Obs (Evidence) ➔ Hypothesis

Patient P has a headache and shows an increase in intracranial pressure

Most patients with a brain tumour present an increase in the intracranial pressure and a headache.

Patient P <may have> a brain tumour.

C !

$A \Rightarrow C$

A?   **A<c, $A \Rightarrow C$>**

Test⁺(A)   (MRI)

A<c, $A \Rightarrow C$, Test⁺(A)>

Abduction
Hypothesis ➜ Evidence

Patient P has a brain tumour?

A?

Most patients with a brain tumour present an increase in the intracranial pressure and a headache.

A ⟹ C

Patient P has a headache and an increase in intracranial pressure?

C?

C	**¬C**
- - - - - - - -	**- - - - - - - - -**
A	**¬A**

Abduction
Hypothesis ➡Evidence

Patient P has a brain tumour?

Most patients with a brain tumour present an increase in the intracranial pressure and a headache.

Patient P has neither a headache nor an increase in intracranial pressure

Patient P does not have a brain tumour.

A?

A $\Rightarrow$ C

¬C

¬A?

¬A<¬c, A $\Rightarrow$ C>

Postulating the existence of an object by abduction

C: dysarthria, dysphagia, dysmetria, ataxia of the torso.

H1 $\Rightarrow$ C … Hn-1 $\Rightarrow$ C

~~**H1**~~**, …,** ~~**Hn-1**~~

~~H1~~: Pancerebellar Syndrome

~~H2~~: Brain tumour

~~H3~~: Vascular events

~~H4~~: Degenerative disease of the cerebellum

Postulating the existence of an object by abduction

C: dysarthria, dysphagia, dysmetria, ataxia of the torso.

- **Hn:** Paraneoplastic Syndrome (caused by the remote effects of a tumorous lesion).
- **Hn1: There is a tumour in a certain organ or gland of the body.**
- **Where?**

Postulating the existence of an object by abduction

- C' hyperthyroidism, dysarthria, dysphagia, dysmetria, ataxia of the torso.

- **Hn:** Paraneoplastic Syndrome (caused by the remote effects of a tumorous lesion).

- **Hn1: There is a tumour in a certain organ or gland of the body.**

- **Hn2: Tumorous lesion is in the thyroid gland.**

Postulating the existence of an object by abduction

- C' hyperthyroidism, dysarthria, dysphagia, dysmetria, ataxia of the torso.

- **C, H1 $\Rightarrow$ C ... Hn-1 $\Rightarrow$ C**

  ~~**H1 ... Hn-1**~~

  Hn, Hn $\Rightarrow$ Hn1, Hn1 $\Rightarrow$ Hn2

  Hn2

Hn2 Tumorous lesion is in the thyroid gland.

Postulating the existence of an object by abduction

- C' hyperthyroidism, dysarthria, dysphagia, dysmetria, ataxia of the torso.

- **C, H1 ⇒ C … Hn-1 ⇒ C**

  ~~H1~~ … ~~Hn-1~~

  Hn, Hn ⇒ Hn1, Hn1 ⇒ Hn2

  Hn2

Hn2< C, H1 ⇒ C ... Hn-1 ⇒ C, ~~H1~~ ... ~~Hn-1~~, Hn, Hn ⇒ Hn1, Hn1 ⇒ Hn2, Test$^+$<Hn2> **>**

Postulating the existence of an object by abduction

Postulating the existence of a tumour in some place of the body. The antecedent of hyperthyroidism is the key to the search strategy.

Similar to Neptune's discovery?

What is Evidence?

- Data vs. Information vs. Evidence

Majone, G. Evidence, Argument and Persuasion in the Policy Process.

What is Evidence?

- Data vs. Information vs. Evidence

Raw materials found rather than "manufactured" (e.g. symptons?)

What is Evidence?

- Data vs. Information vs. Evidence

Result of operations over data.

Statistical information (RCT, …), lab tests, X rays, MRI's…

What is Evidence?

- Data vs. Information vs. Evidence

Information selected form the available stock of information and introduced / used at a specific point in an argument.

What is Evidence?

- Data vs. Information vs. Evidence

Information selected form the available stock of information and introduced / used at a specific point in an argument.

- An argument for (against) a hypothesis is **infused** with confirming (falsifying) evidence.

What is Evidence?

- A<c, A $\Rightarrow$ C, Test$^+$(A)>   Abduction

- $\neg A$<$\neg c$, A $\Rightarrow$ C>   Deduction (MT)

- Hn2<C, H1 $\Rightarrow$ C … Hn-1 $\Rightarrow$ C, ~~H1~~ … ~~Hn-1~~,
  Hn, Hn $\Rightarrow$ Hn1, Hn1 $\Rightarrow$ Hn2, Test$^+$<Hn2>>
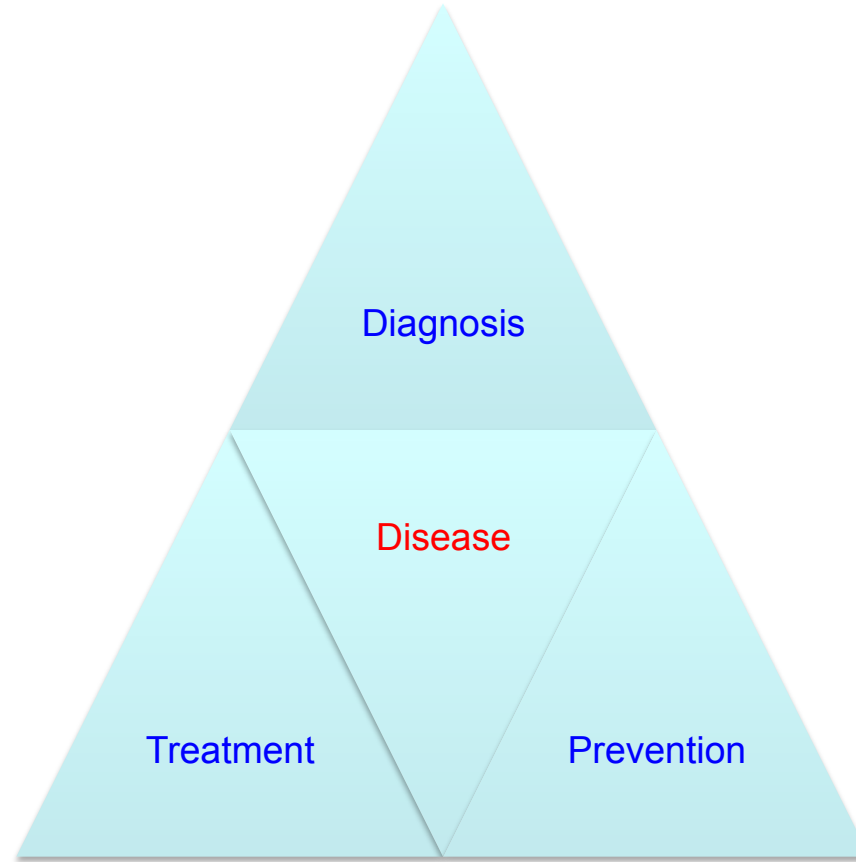
  Eliminative Abduction

Conclusions

- Diagnosis are uncertain, constructed with incomplete and dynamic information.

- A variety of argument patterns for diagnosis construction.

- Several operations (confirmation, refutation)

Conclusions

- H<e>

- An argument for (against) a hypothesis is **infused** with confirming (falsifying) evidence.

Medicine

EBM?

Diagnosis

Disease

Treatment

Prevention

Medicine

Dx Test

EBM?

Diagnosis

Disease

Treatment

Prevention