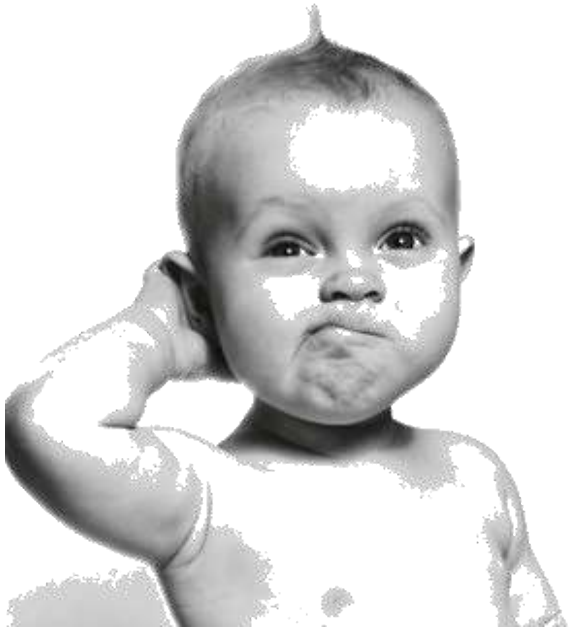
ACADEMIA ENGELBERG
Dialogue on Science

The **Bounds** of **"Bounded Rationality"**

Evangelos Ioannidis and **Morteza Nikravan**



15th Dialogue on Science: ***At the Limits!***

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Contributors

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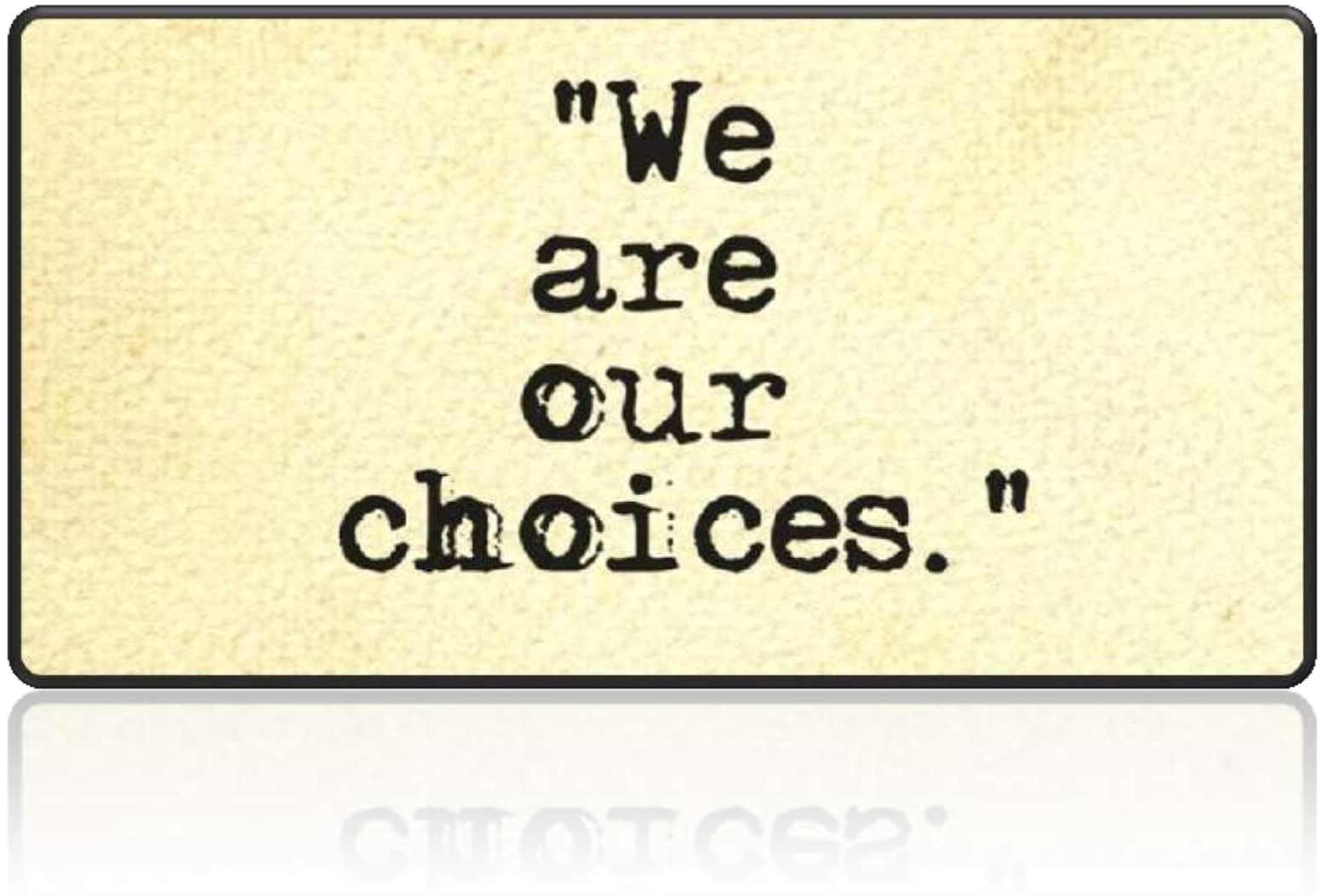
Agenda

- ❑ Decision Making and Rationality
- ❑ Bounded Rationality (Herbert A. Simon)
- ❑ Heuristics approach to Decision Making
- ❑ Ecological Rationality (Gerd Gigerenzer)
- ❑ Rationality and Interconnectedness
- ❑ Internet of Things, Industry 4.0 and Semantic Web
- ❑ Concluding Remarks


"We
are
our
choices."

What is a Choice ?

Passing from **several Potentialities**
to the **single Actualization**

An Example of "Rational Decision"

Customer **A** offers you: **CHF10**

Customer **B** offers you: **CHF20**

In Economics, this is called as "the Rational Agent Assumption"

Decision-Making and Rationality

❑ What is **Decision-Making** ?

Decision-Making is a **Cognitive Process** resulting in a **Choice**, **according to certain Criteria in the frame of a Model.**

❑ What is a **Rational Agent** ?

A **Decision-Maker** who:

- is always **Aware** of the available **Potentialities** (**Sample Space**) and **Probabilities** (**Probability Distribution** over the Sample Space)
- has well-defined **Preferences** (**Utility Function** over the Sample Space)
- **always** selects the **Optimal Decision** (Maximization of the **Expected Utility**)

Agents of Bounded Rationality

In practice, agents make their decisions under **Bounded Rationality** due to **limited available resources**

Limitations of available:

- ❑ Cognitive Capabilities / Computational Intelligence
- ❑ Data, Information, Knowledge
- ❑ Time/Budget

form the **Bounds** of:

- ❑ Computability
- ❑ Accuracy
- ❑ Predictability

Bounds of "Decidability"

Decisions of Bounded Optimality

As agents are **not able** to implement the **Optimal Decision**, they act as **Satisficers** (Satisficing: **Satisfy** and **Suffice**)

Epsilon-Optimization:

$$\mathbf{U(s) \geq \max_{\omega \in \Omega}\{U(\omega)\} - \varepsilon}$$

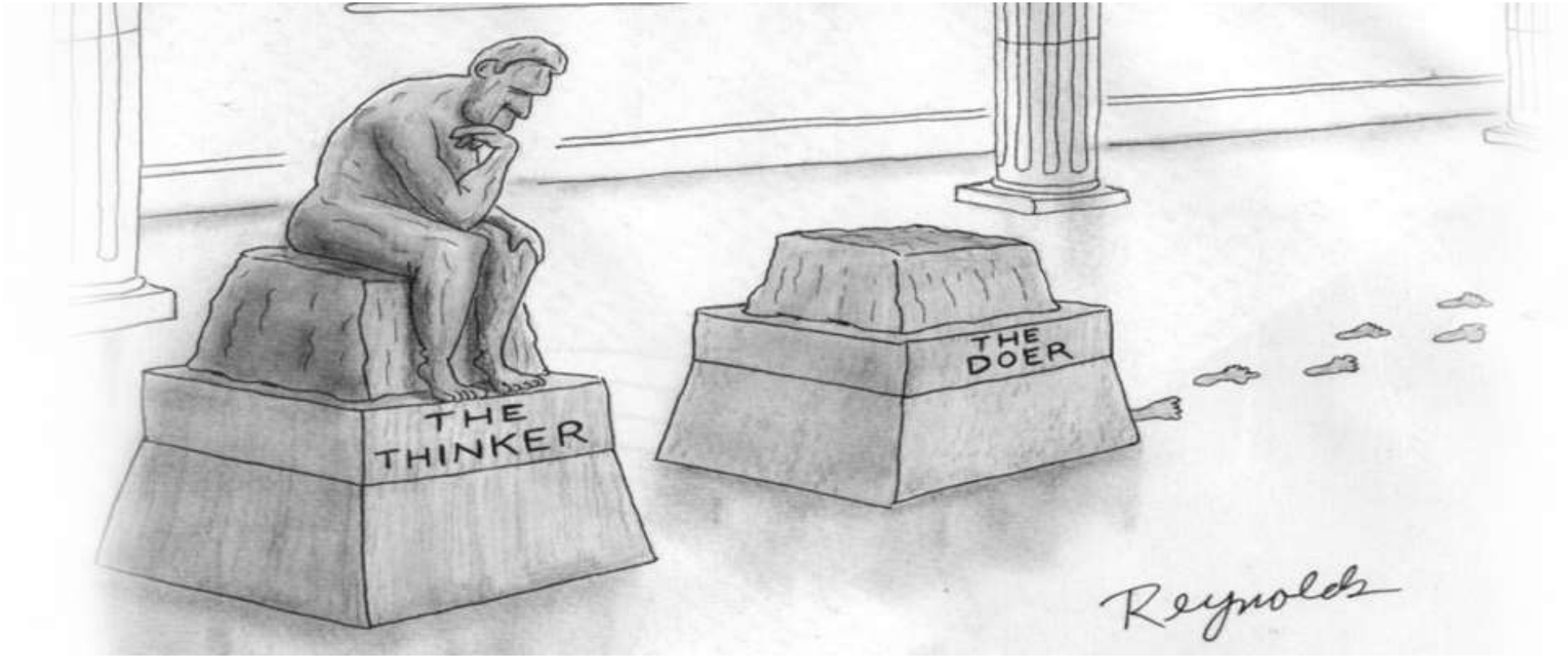
- Ω is the set of all **Possible Outcomes**
- $U(\omega)$ is the **Expected Utility** of Outcome $\omega \in \Omega$
- $\varepsilon \geq 0$ is the epsilon **bound**
- $s \in S(\varepsilon)$ is an **«epsilon–optimizing» Outcome**
- $S(\varepsilon) \subset \Omega$ is the set of all «epsilon-optimizing» Outcomes

Herbert A. Simon
Nobel Prize in Economics (1978)

WHAT is the Problem ?

How to minimize the epsilon bound **ε** **effectively** **?**

the Thinker VS the Doer



If everything seems under control, you're just not going fast enough

Mario Gabriele Andretti

Heuristics

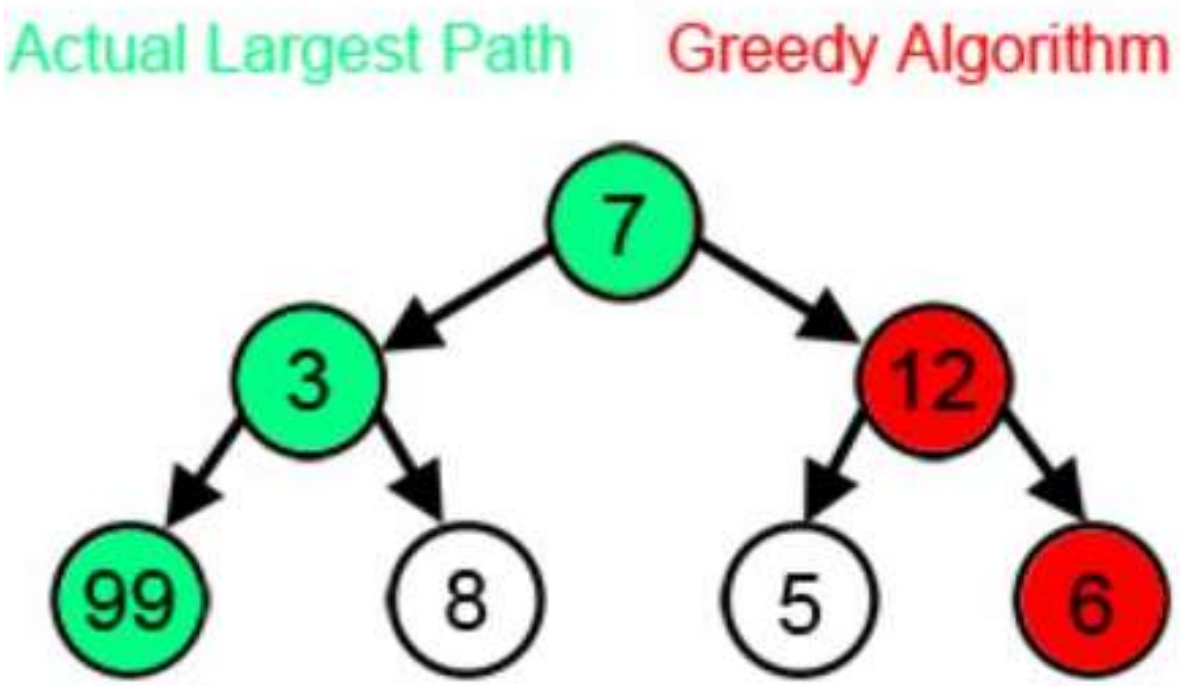
Heuristic Technique: A **fast and «frugal»** Decision-Making method which is based on a **Simple Rule** sufficient for Fast Decision Making under Limited Resources or Uncertainty

Heuristic is a **Mental Shortcut** or **«Bypass»** using ad-hoc selected simplifying assumptions.

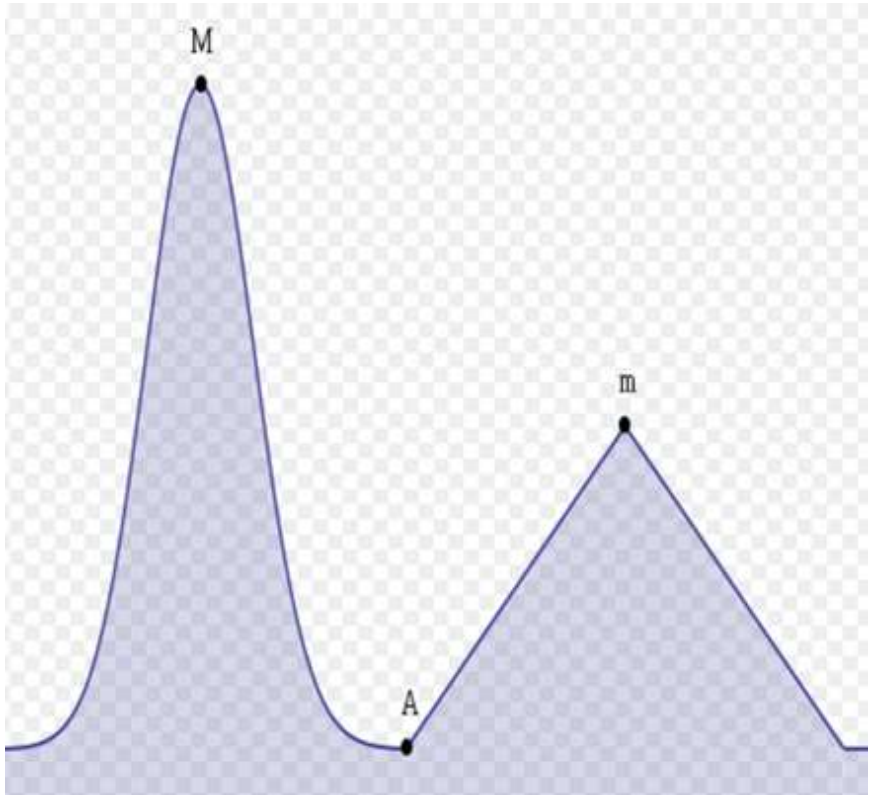
Examples:

- ❑ **Greedy Algorithm** (consider only immediate benefit and wait for the next step)
- ❑ **Trial & Error**

An Example of Heuristics: Greedy Algorithm

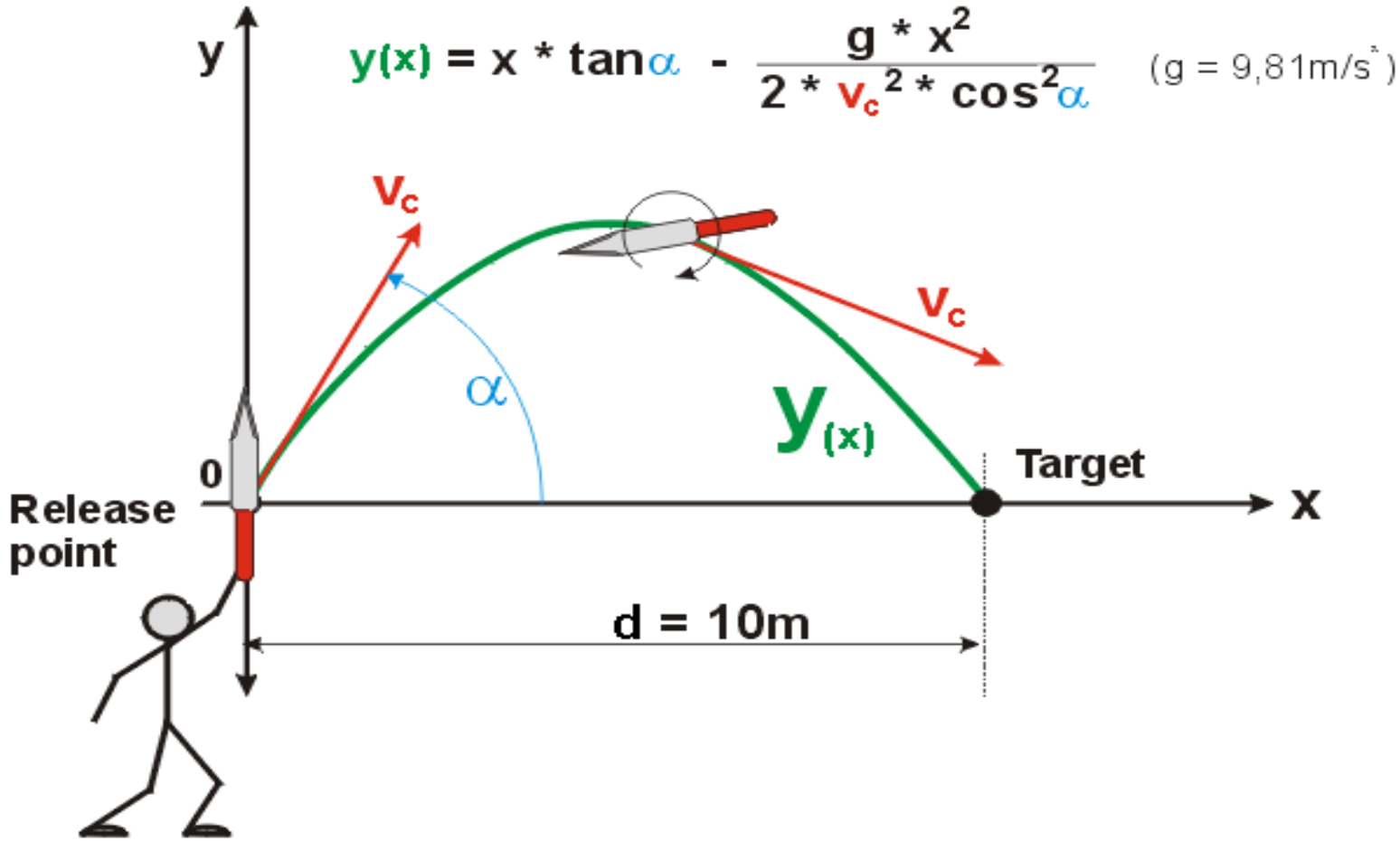


Goal: Reach the **Largest-Sum**



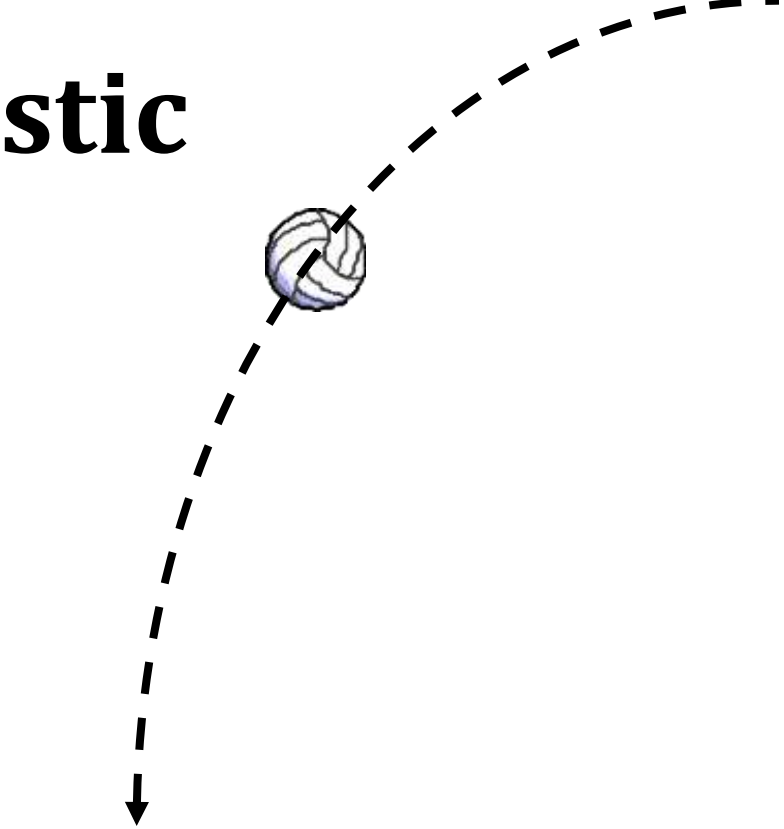
Starting at **A**, a Greedy Algorithm will find the **Local Maximum** at **"m"**, oblivious of the **Global Maximum** at **"M"**

Who does this calculation to catch a ball ?!!



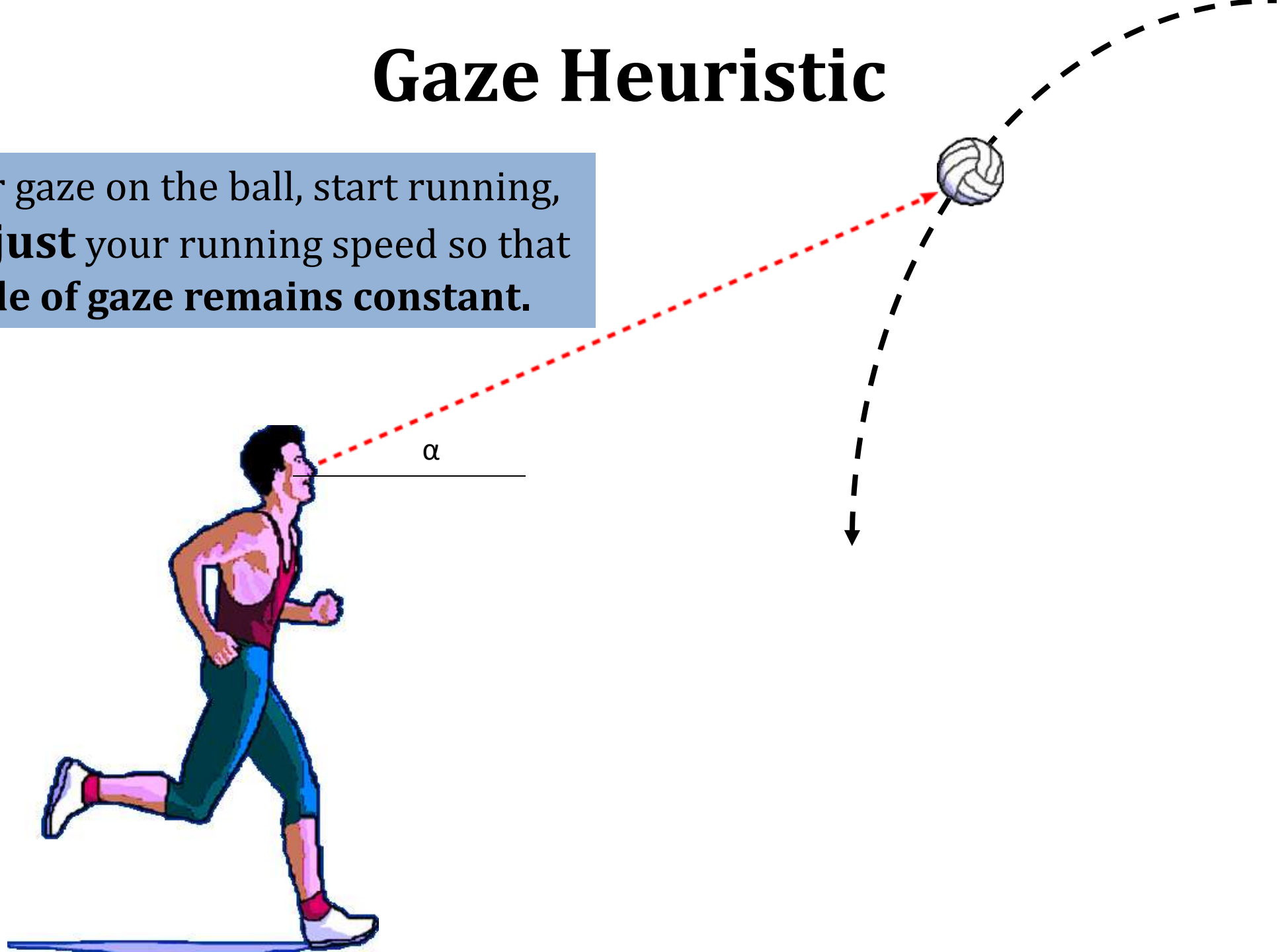
Gaze Heuristic

Adjust your motion to achieve a goal, **using one variable only.**



Gaze Heuristic

Fix your gaze on the ball, start running, and **adjust** your running speed so that the **angle of gaze remains constant.**



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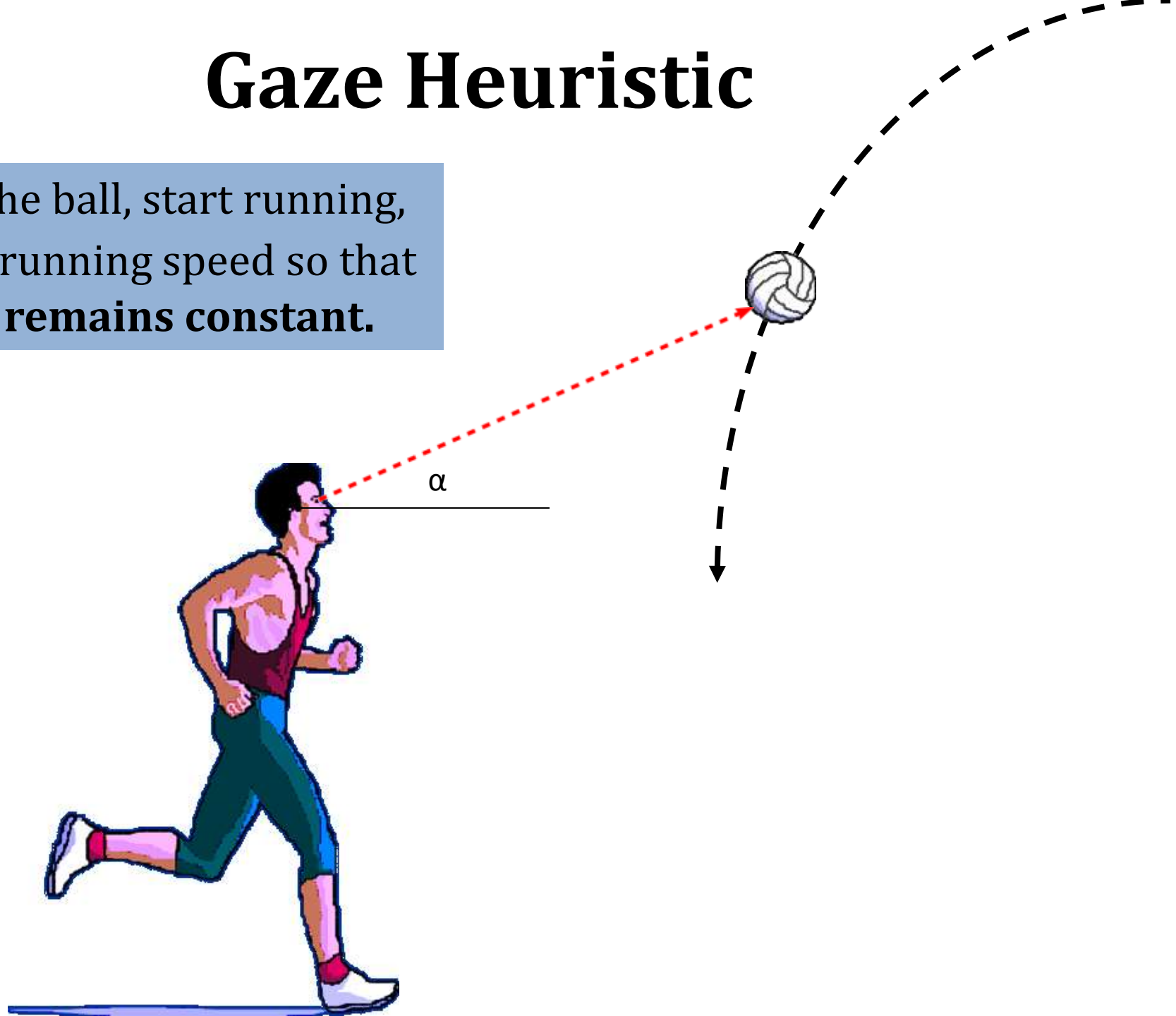

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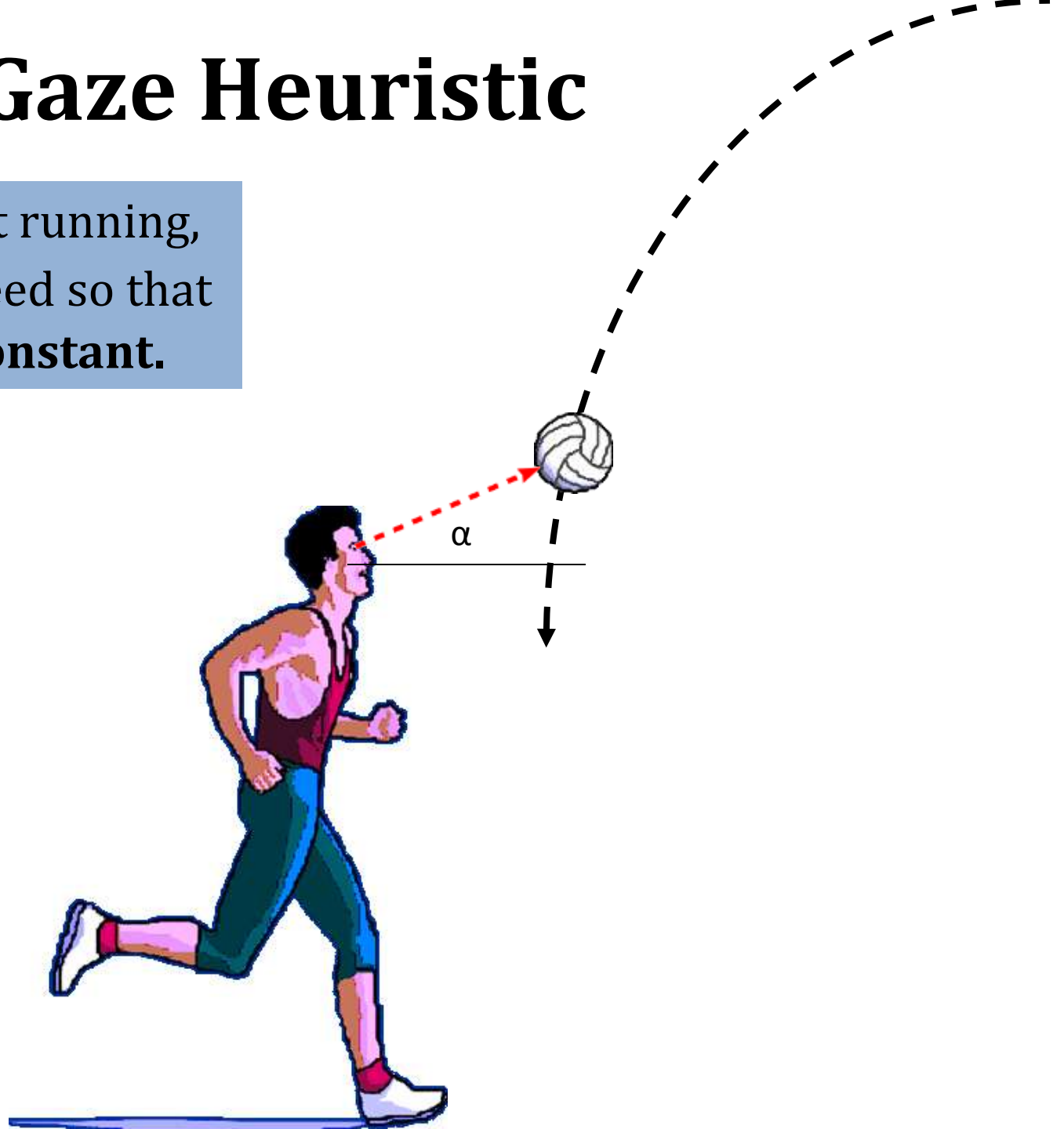


Gaze Heuristic

Fix your gaze on the ball, start running, and **adjust** your running speed so that the **angle of gaze remains constant.**

Adaptive Toolbox and **Ecological Rationality**

❑ **Adaptive** Toolbox

Heuristics are **evolving.**

They are **continuously** shaped by

Evolution and **Learning** (**Feedback Loop**),

resulting into their **Adaptation**

within a **specific** Context/Environment.

Gerd Gigerenzer

❑ **Ecological** Rationality

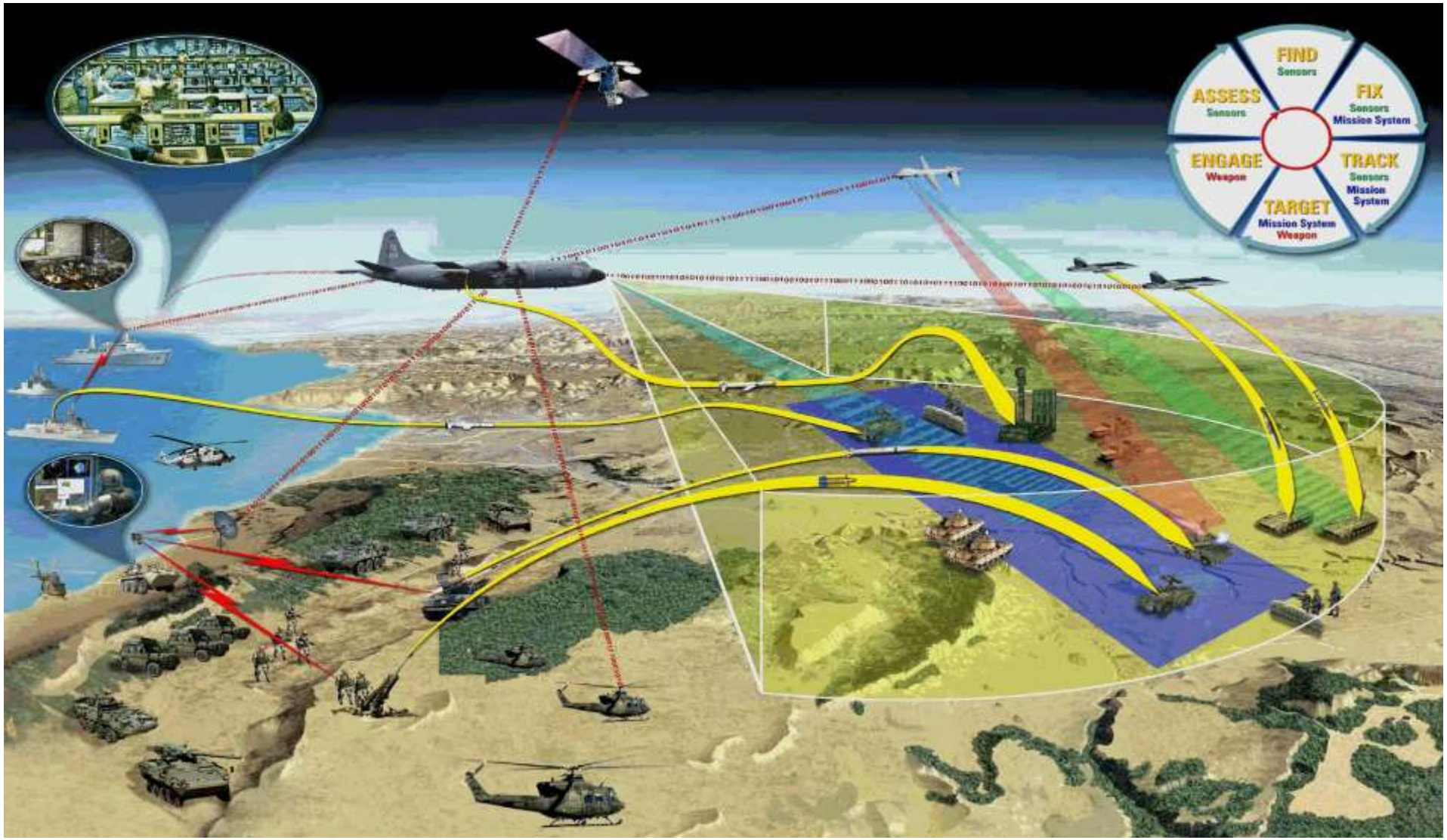
A Heuristic is **Ecologically Rational**

«to the degree that it is adapted to an Environment».

Heuristics **co-evolve** with their Environment.

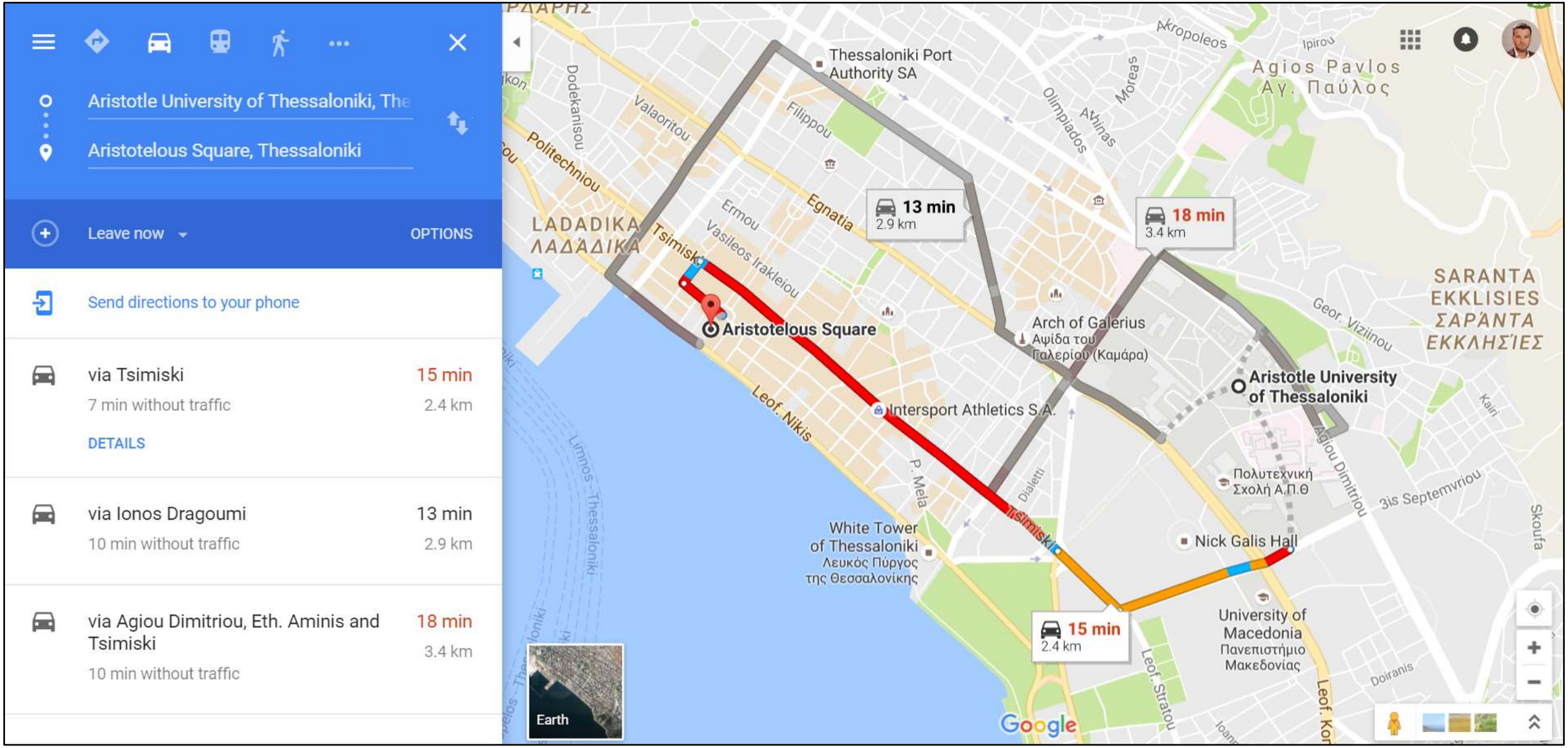
Is Rationality related to Interconnectedness ?

Information Diffusion in Networks and Decision Making

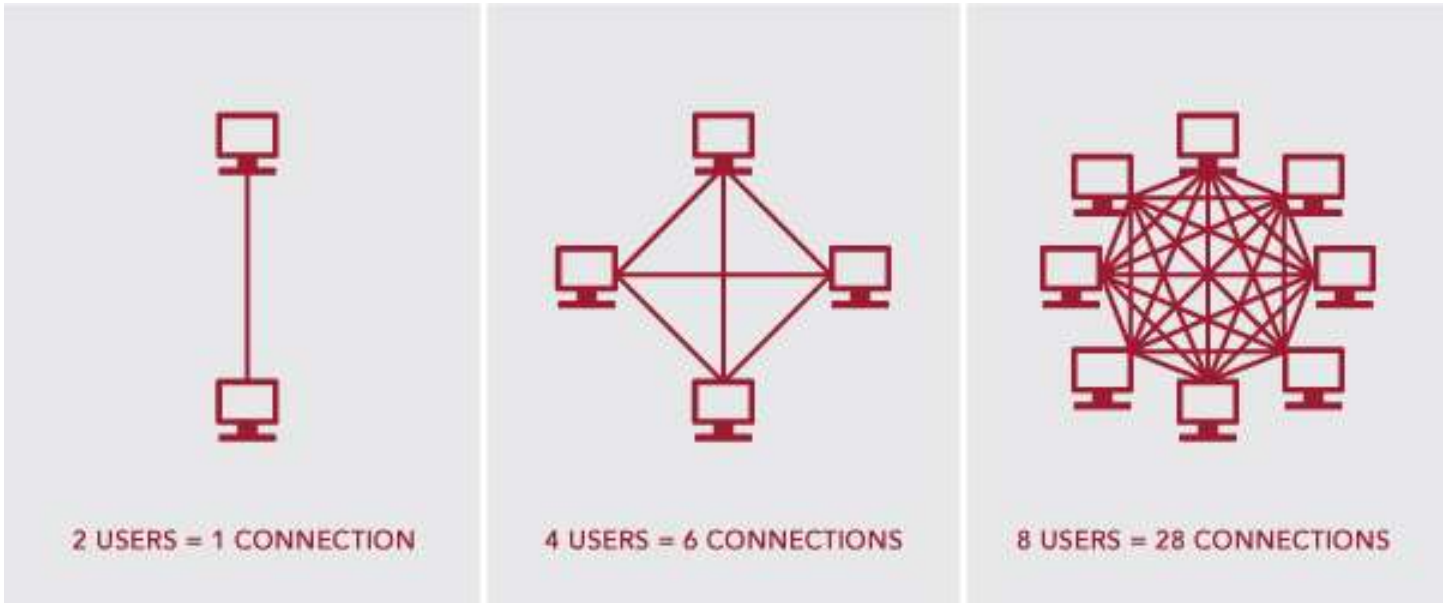


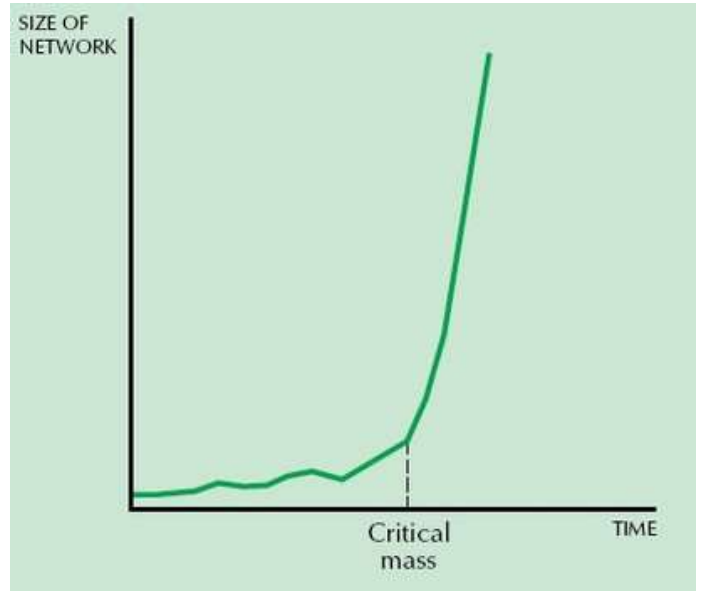
Higher Interconnectedness expands the bounds of rationality of the Agents

Access to Web = Better real time Decision Making



Network Effect and Metcalfe's law





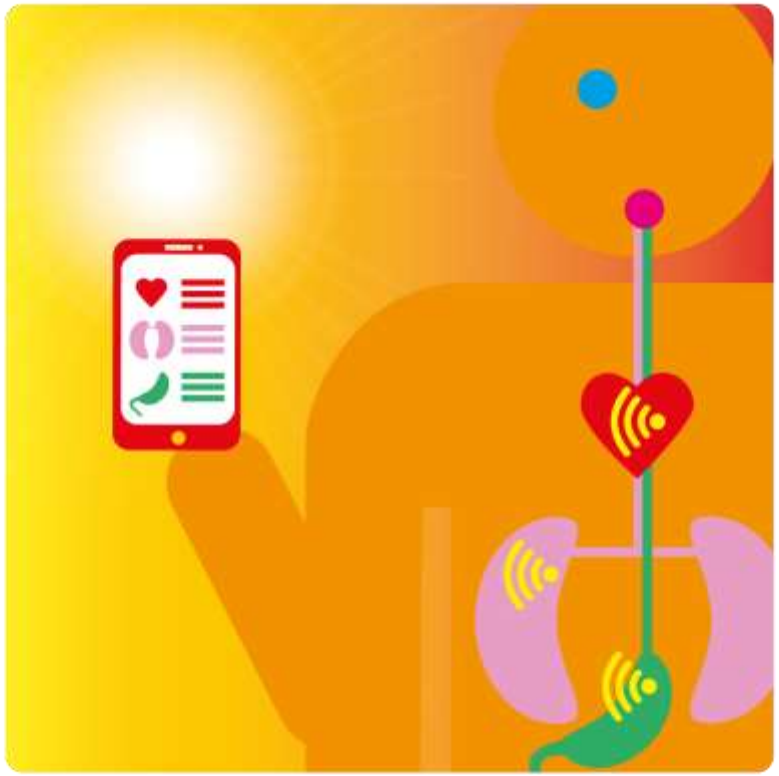
The more «users» **joining the Network** ,

the more **Value** they **give and eventually gain from the Network**

- The **Value** that you gain from being in the Network depends **critically** on the number of **interconnected** users: **Value of the Network** $\propto N^2$ **(Metcalfe's law)**

- Network Effect becomes significant after a certain threshold, called **«Critical Point»**

Internet of Things

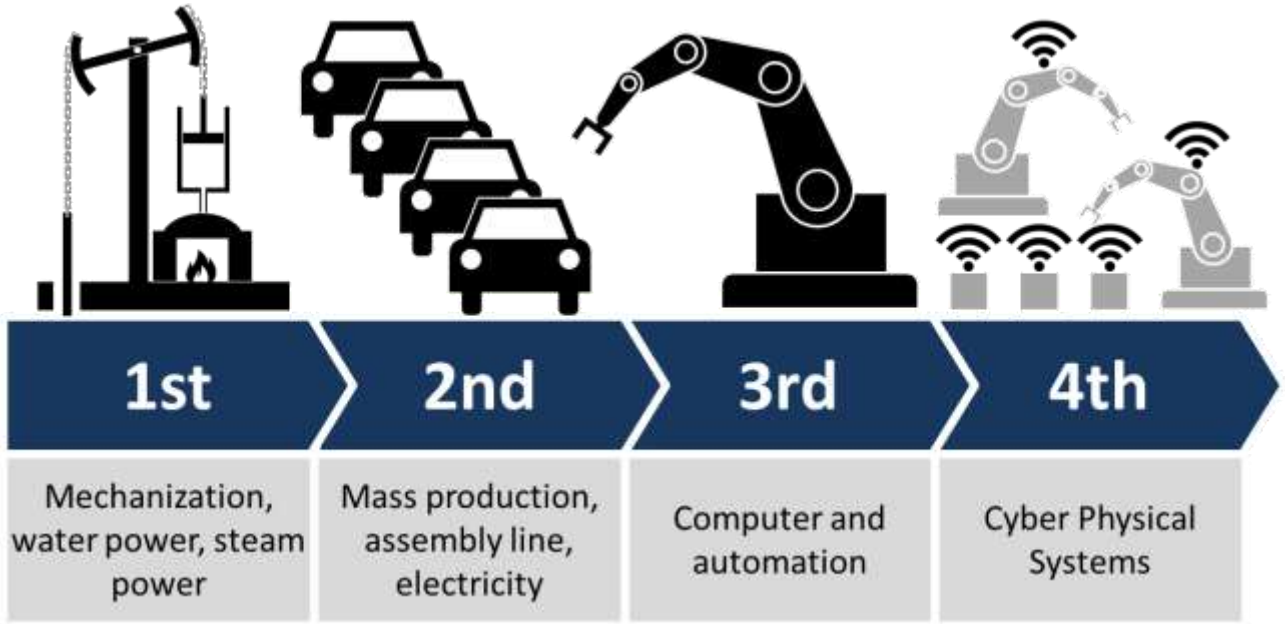


Internet of Things: Living beings (People) and non-living entities (Things) **interact and decide in real time**, forming a **Complex Adaptive System**, allowing their

«Harmonious Symbiosis»

Examples: SMART Ecosystem, SMART Industry/Value Chain, SMART Health System

4th Industrial Revolution



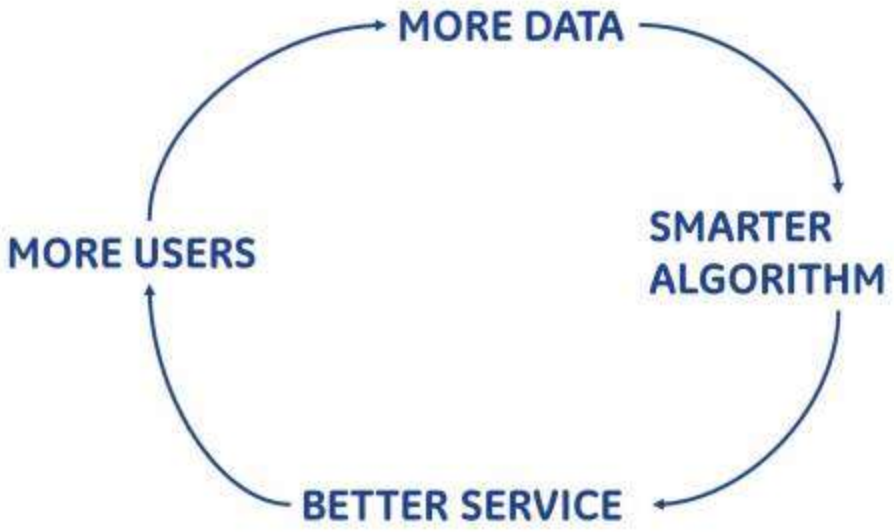
IBM
Watson Internet of Things

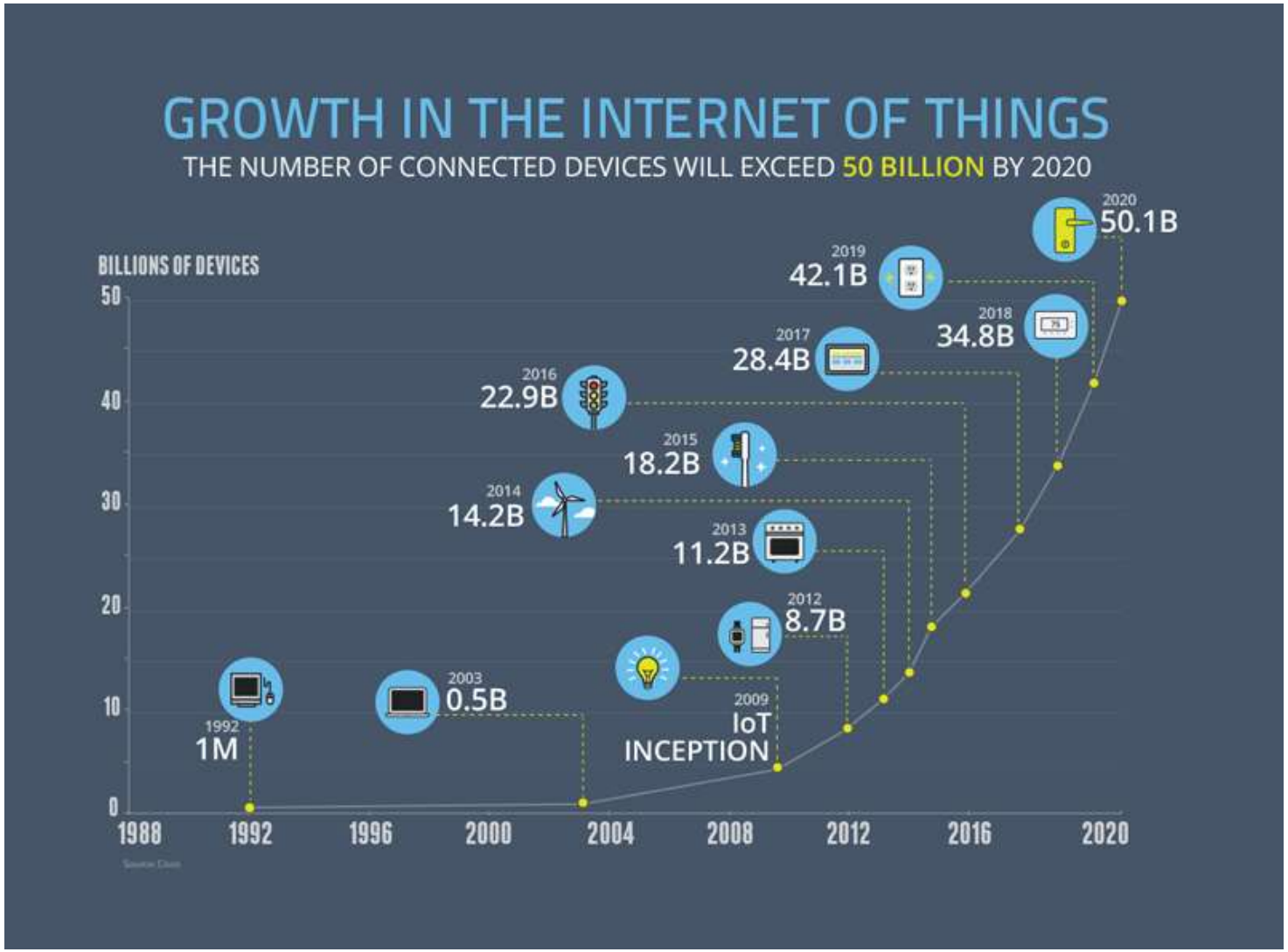
intel inside

GE imagination at work

Cyber-Physical Systems: Interconnected «Mechatronics» (**Mecha**nical and Elec**tronic** devices) augmented with **communication capabilities** based on computer algorithms

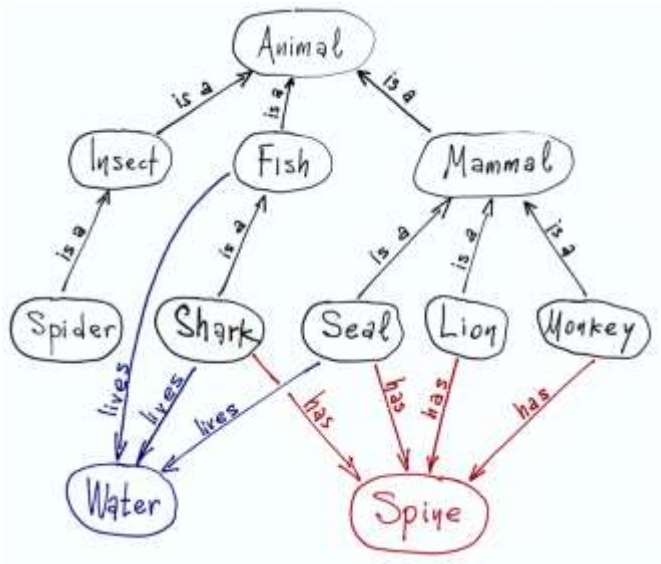
More Users Generate More Data





Semantic Processing and Significance

- How **data** can help me to take **rational Decisions effectively** ?
- What is the **Meaning** of data (**Semantic Information**)
  and what is their **Significance** (**Pragmatic Information**) ? ⇨ **Complexity reduction**



- **Semantic Networks:** A Network of Semantic Relations between Concepts
- **Ontology:** A Semantic Network together with the relevant **Inference Rule** **(Semantic Web)**
- **Linked Data:** **Structured** data by **interlinking** them in order to become more useful when questioning (making a Query) and take Decisions.

Concluding Remarks

- A higher level of **Interconnectedness** will allow better Decision-Making
  4th Industrial Revolution – Internet of Things

- Considering Software aspects, **Semantic Information processing** is needed, in order to **deal with Big Data effectively in real time**.
  Semantic Web

- When more and more people and/or devices become interconnected, the damage of a potential **Information/Knowledge Warfare** increases
  Cyber-Security

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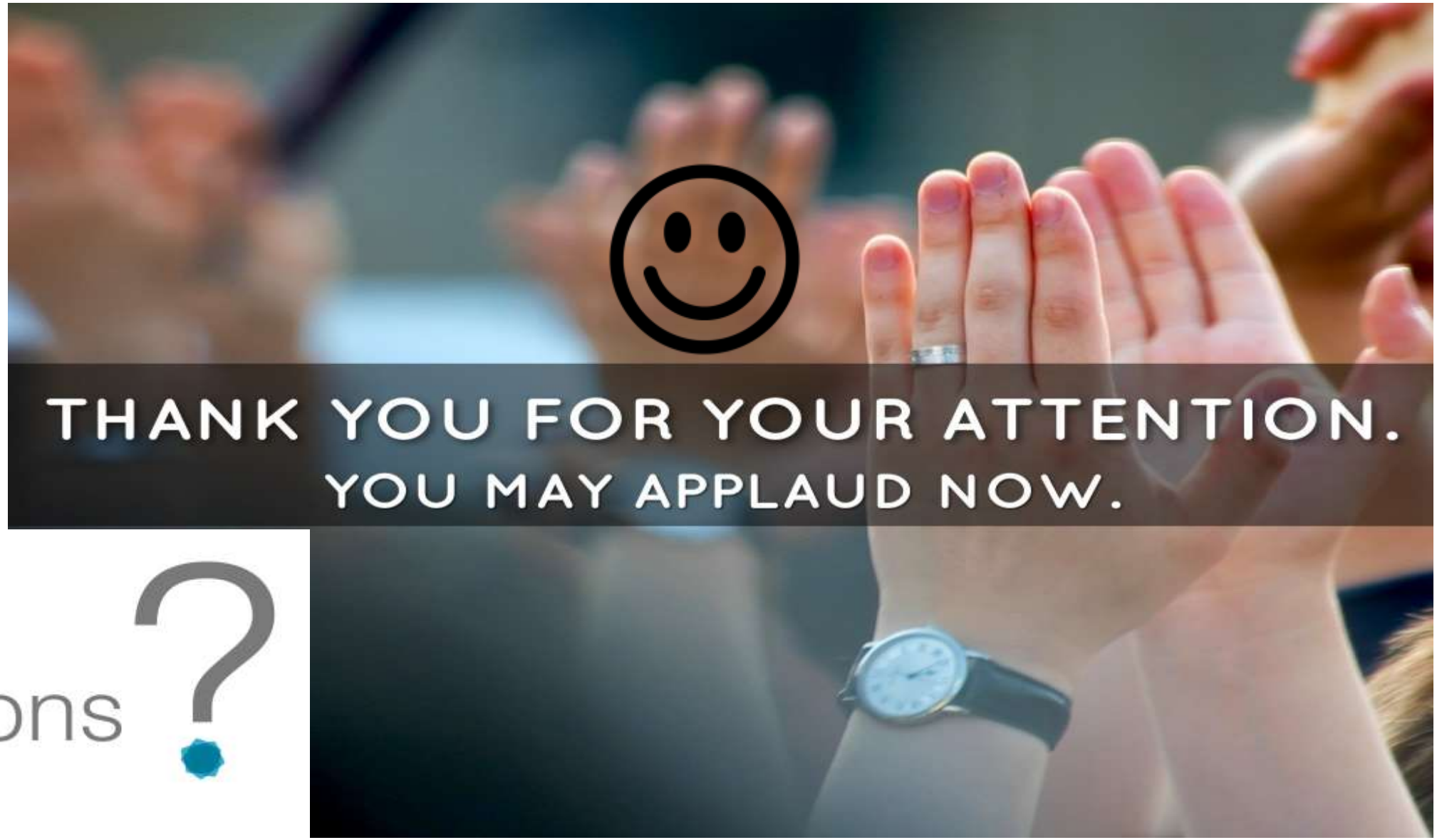

Any questions ?

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Thanks

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Summer school and Conference