Conductome

# ¿Por qué personas ”buenas” toman decisiones ”malas”?


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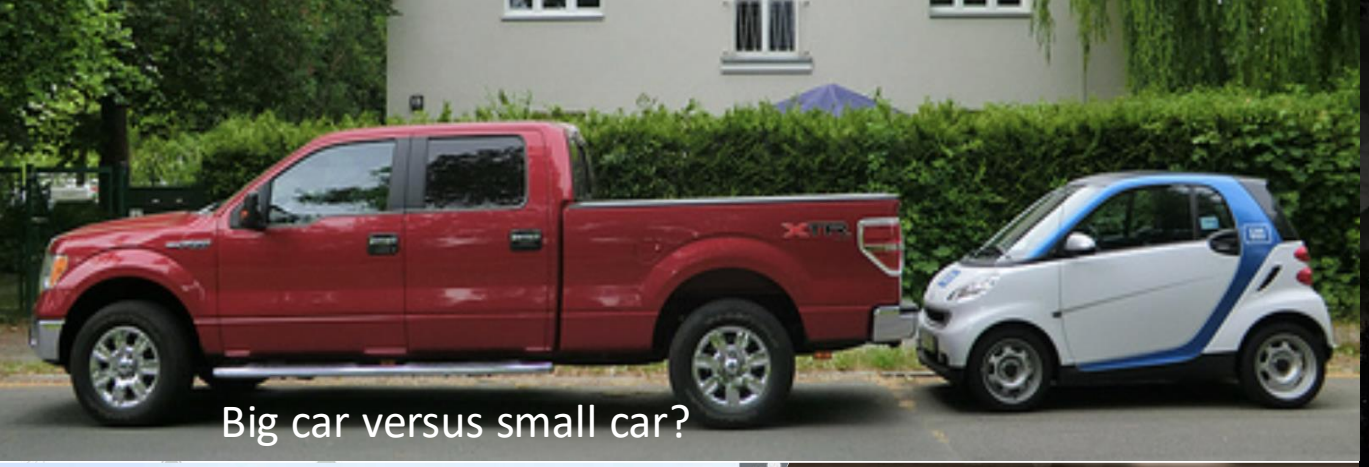
Evento FUTUROSICN 27 de octubre 2022

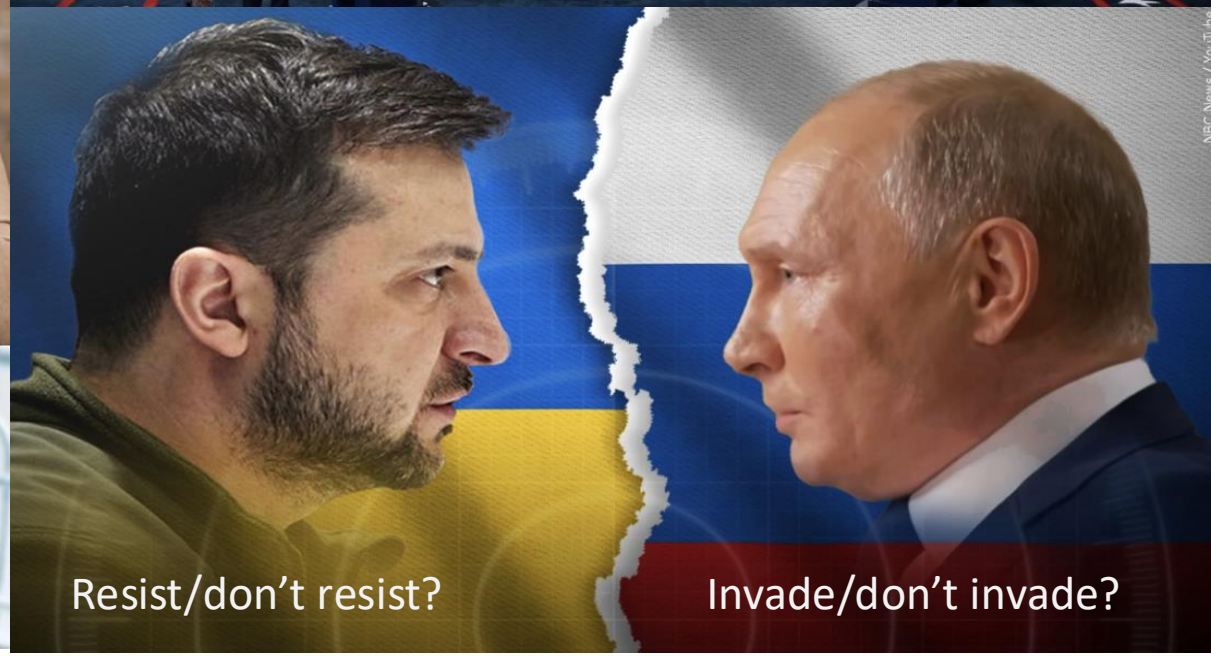

Big car versus small car?

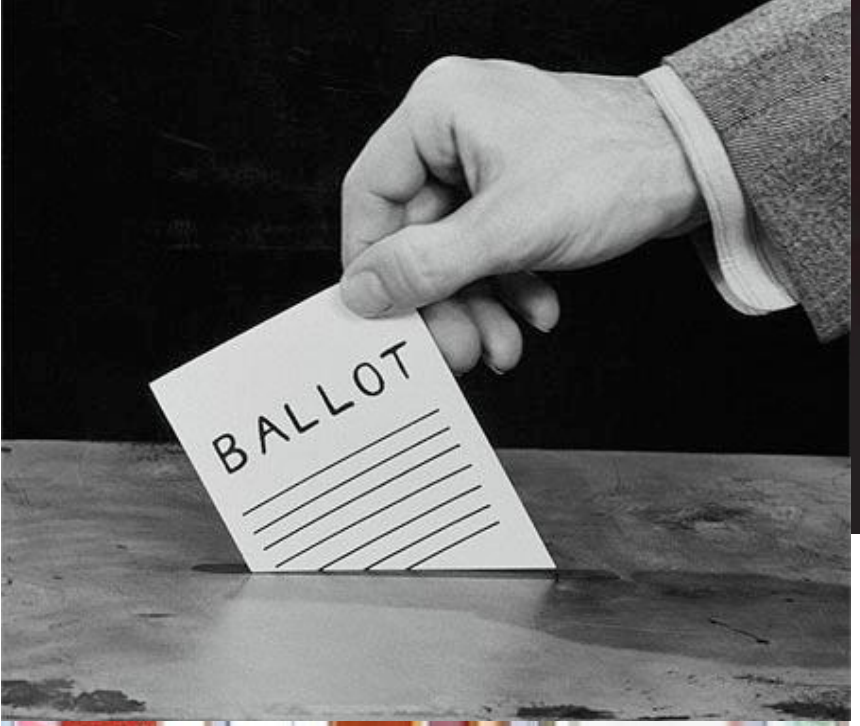

No Mask
Masks


Stairs versus escalator?


Hamburger versus salad?


Netflix or gym?


Resist/don’t resist?
Invade/don’t invade?

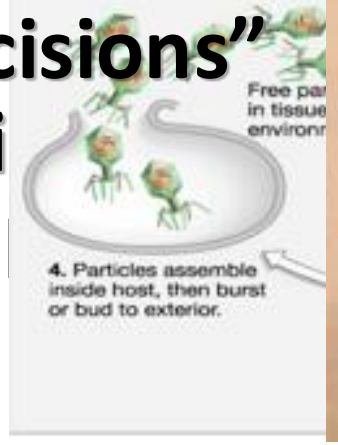



**All Complex Adaptive Systems...**

**make “decisions”**

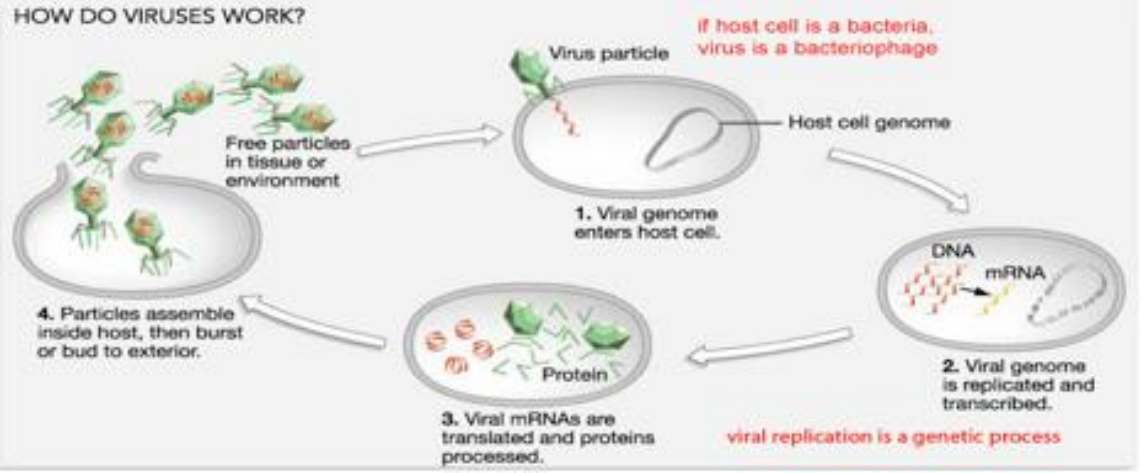
**h at the indi**

**d collective**





There are “good” decisions
and there are “bad” ones




# What is a decision?

**A selection between alternatives implying a change of state**

- **Associated with an action not a thing**
- **Associated with a “behaviour” or “strategy”**
- **How do we enumerate the alternatives?**
- **How do we weight the alternatives?**
  - **What factors should be taken into account?**
  - **Time scales and multi-objectivity**
  - **“Racional” versus “irracional”**
- **“Emotional” versus “logical”**
- **Explicit versus implicit**
- **Individual versus group level**

# What goes into a decision?

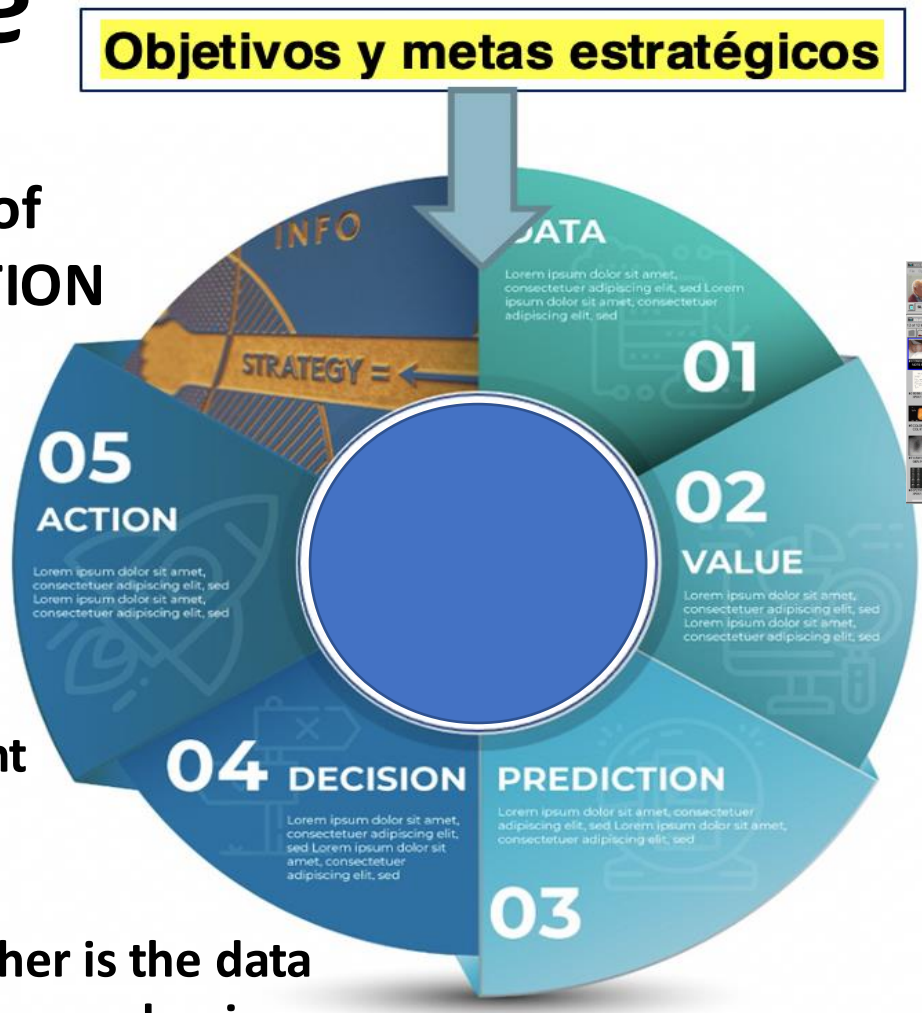
## *The Decision Cycle*

**The most important component of the Decision Cycle is the PREDICTION MODEL on which it is based**

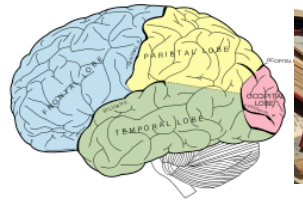
**The principal purpose of all living systems and the principal purpose of science - medicine, public health - is to… PREDICT**

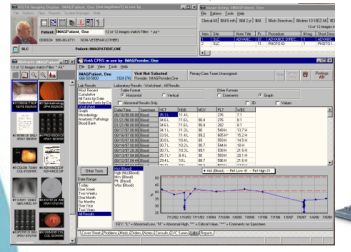
**An organism in this sense can be thought of as a synergistic set of prediction models.**

**What differs from one organism to another is the data that enters in the model, the data storage mechanism, the data processors and the prediction algorithm.**

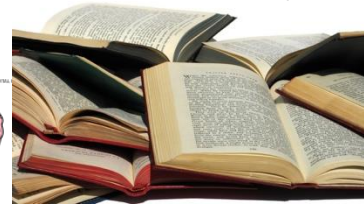



Human brain
10-100 Terrabytes





All the books in the world 30-50 Terrabytes



In electronic form
1 zettabyte

# What is predictable?
# The Physical World?

1) I drop an object. What happens?

Drops to the floor 100% Stays suspended in midair 0%

2) I drop 2 objects of different masses at the same time.
Which hits the floor first?

The heavier 0% The lighter 0% Both at the same time 100%

3) I push this object. What happens?

It moves 100% It stays still 0%

Phenomenology: everyday experience Newton's laws

# What is predictable?
# Human decision making?

**1) You haven't drunk water (not any liquid) in three days. Someone offers you a litre of water versus a box of cornflakes. Which do you choose?**

**Water 100% Cornflakes 0%**

**2) There's a dangerous fire in the auditorium and the alarm sounds. I invite you to stay to the end of my talk. What do you do?**

**Run 100% Stay 0%**

**3) You are very hungry. Someone offers you a meal of 1500 calories. You can choose between carnitas, enchiladas suizas and frijoles negros; o just celery (7.5kg). Which do you choose?**

**Carnitas etc. 100% Celery 0%**

# What is predictable?
# Human decision making?

**4) You haven't drank water (nor any liquid) in three days. Someone offers you a litre of Coca-cola versus a litre of Pepsi. Which do you choose?**

**Coca cola 70%** **Pepsi 30%**

**5) There's a dangerous fire in the auditorium and the alarm sounds. You get to the exit but note that someone you don't know is trapped. Do you go back to help risking your own life or keep running?**

**Go back 50%** **Keep running 50%**

**6) You are very hungry. Someone offers you a meal of 1500 calories. You can choose between carnitas, enchiladas suizas y frijoles negros; or barbacoa, chicharrón and arroz. Which do you choose?**

**Carnitas etc. 50%** **Barbacoa etc. 50%**

# What is predictable?
# Human decision making?

**1) Who among you will be obese in 20-30 years?**

**2) Who among you will be diabetic in 30-40 years?**

**3) Who among you will die before you get to 70 due to bad lifestyle?**

**and many more**

**These will all be states that result from our decision making**

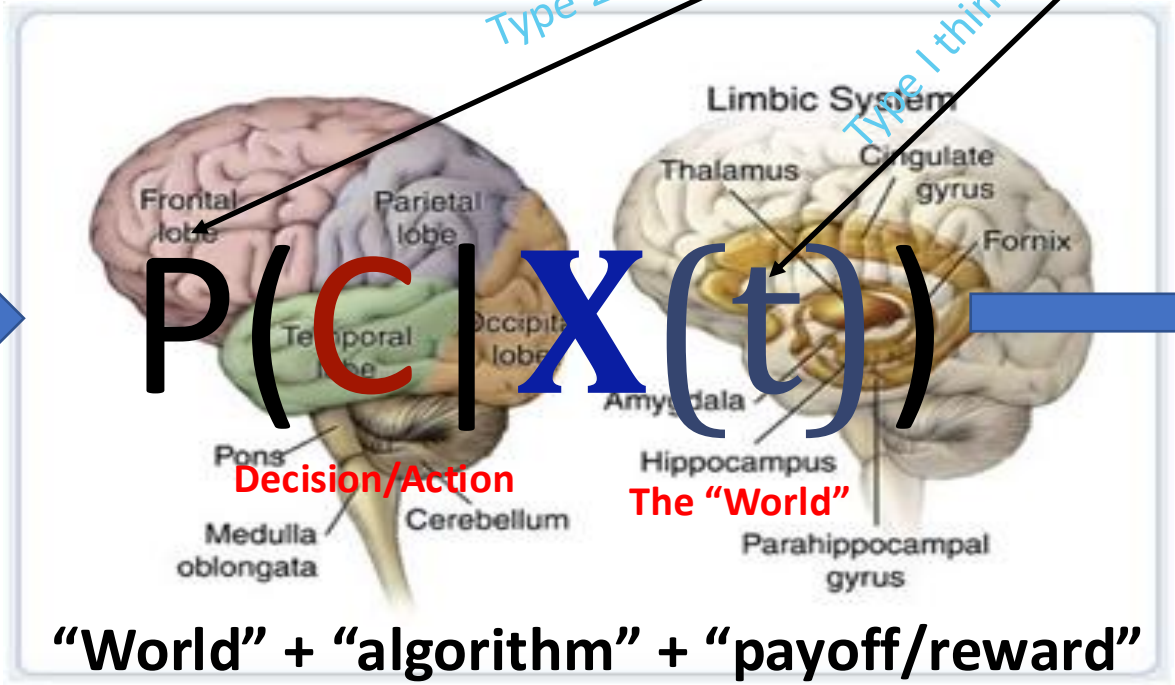
# This is the Conductome

Data + Meaning + Value →
Prediction + Decision + Action

Type 2 thinking

Type I thinking

Data +
Meaning
+ Value




Prediction
+ Decision
+ Action

There are many alternative for any decision and many possible actions

# Did it work?

DMV → PDA is evaluated to be good or bad according to one (or more) performance criteria – payoff/reward


# $P(C|X(t))$ can represent:

i) **Our internal model** of reality and its perception.

ii) **An external model** of reality based on observation and data

- In either case it is a **statistical inference** that is based on an **ensemble** of **"events"** (real – "**external**" ensemble or imaginary - "**internal**" ensemble)
- The "**external**" is objective and empirical – we count events and relations between effects and their potential causes and use frequencies
- The "**Internal**" is subjective and associated with our **mental model** of the world where we use Bayesian beliefs.

# Hypotheses

That human conduct/behavior can be ***predicted*** and ***explained*** (probabilistically)

a) Both transversally and longitudinally (though certain behaviors are more predictable and explainable than others)

b) With a Bayesian probability P(C |**X**), where C is the conduct/behavior of interest and **X** are the ”predictors/explainers” (though **X** is exceedingly ***multifactorial*** (multi-disciplinary) and dynamic – from genes to politics)

c) That there is an “internal” Conductome that is constructed by an organism, and which determines its behaviour; and an “external” Conductome that we will try to construct from data

d) With Machine Learning models being the most appropriate to construct P(C |**X**)

## Caveats

We don’t have a good definition of what is a conduct/behavior
We don’t have a good taxonomy of behaviors
We don’t have data sets that cover the gamut of explainers (though we are trying - and making progress!)
We don’t have much idea about the myriad causal and non-causal relations between the **X**

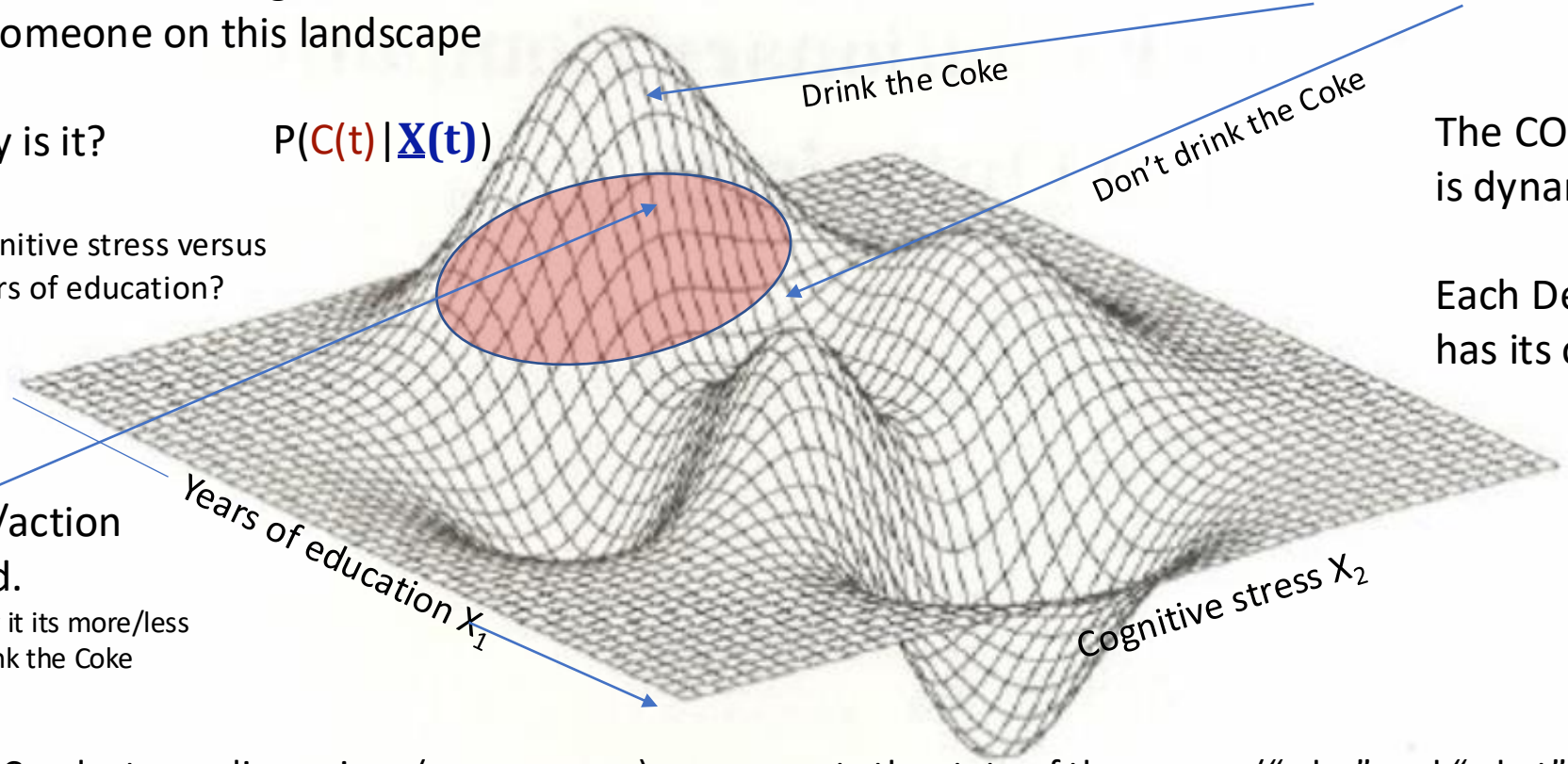
# Concepts – The CONDUCTOME Landscape

Conduct/behavior change means moving someone on this landscape

How do we move someone from here to here?

How easy is it? $P(C(t)|\mathbf{X(t)})$

Reduce cognitive stress versus
5 more years of education?




Decision/action threshold.

Above/below it its more/less likely you drink the Coke

The CONDUCTOME Landscape is dynamic and adaptive.

Each Decision/Action/Conduct has its own Landscape

($X_1$, $X_2$) – Two Conductome dimensions (among many) – represents the state of the person ("who" and "what" - old/young, happy/sad,…) and/or environment ("where" and "when" - at home/work, in Mexico/France,…)

# An Example (EXTERNAL) Conductome

Behaviour C = No exercise on weekdays

| Question | Answer | Number of people with X | Number of people who do not exercise and X | Number in population | Number not exercising on weekdays | % who do not exercise | % who do not exercise and X | Predictive model weight (score) | Statistical reliability (Epsilon) | Cause or consequence |
|---|---|---|---|---|---|---|---|---|---|---|
| What chores do you do? Childcare | Yes | 41 | 29 | 292 | 120 | 41.10% | 70.73% | 0.38 | 3.86 | Cause |
| How regular is your bedtime schedule? | 1 - 2 hrs | 17 | 14 | 292 | 120 | 41.10% | 82.35% | 0.67 | 3.46 | Both |
| Do you exercise on the weekend? | No | 182 | 97 | 292 | 120 | 41.10% | 53.30% | 0.06 | 3.35 | Both |
| What time do you go home from work? | 15:00 | 32 | 22 | 292 | 120 | 41.10% | 68.75% | 0.34 | 3.18 | Cause |
| How many hours do you sleep on weekdays? | 4-5 hours | 65 | 39 | 292 | 120 | 41.10% | 60.00% | 0.18 | 3.1 | Consequence |
| Approximately how many free hours do you have a day on weekdays?: I don't know | Yes | 24 | 17 | 292 | 120 | 41.10% | 70.83% | 0.39 | 2.96 | Cause |
| Where do you eat during the week?: Position 2 | In street stalls | 9 | 8 | 292 | 120 | 41.10% | 88.89% | 0.9 | 2.91 | Both |
| What chores do you do?: Wash the bathroom | Yes | 172 | 89 | 292 | 120 | 41.10% | 51.74% | 0.03 | 2.84 | Cause |
| What chores do you do?: Shake | Yes | 158 | 82 | 292 | 120 | 41.10% | 51.90% | 0.03 | 2.76 | Cause |
| What type of vehicle is transported from home to work? and How long does each one last approximately IN MINUTES?: Metro: Value | 60 min | 11 | 9 | 292 | 120 | 41.10% | 81.82% | 0.65 | 2.75 | Cause |
| How do you get your snacks?: I buy it at a stall | Yes | 50 | 30 | 292 | 120 | 41.10% | 60.00% | 0.18 | 2.72 | Both |
| What chores do you do on the weekend?: Childcare | Yes | 60 | 35 | 292 | 120 | 41.10% | 58.33% | 0.15 | 2.71 | Cause |
| Where do you have breakfast? Select in order of frequency: Position 1 | In the kitchen at work | 27 | 18 | 292 | 120 | 41.10% | 66.67% | 0.3 | 2.7 | Both |

These are just the most statistically significant predictors from a small subset of the predictors/explainers **X**.

> 1.96 ~ 95% confidence interval

**Applications to obesity and metabolic disease**

Population of 292 academic and non-academic workers of the UNAM in 2019.

Some predictors/explainers are other conducts where some are more ”voluntary” than others; some are environmental factors;

# Another Example (EXTERNAL) Conductome

Conductome

## Applications to obesity and metabolic disease

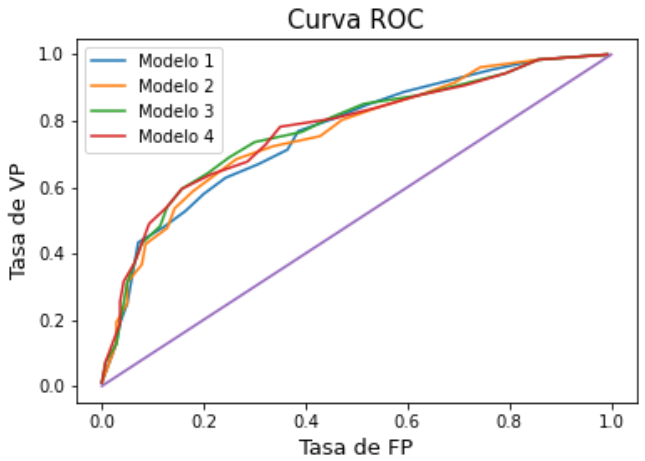
Population of 636 undergraduate students from various Mexican universities in 2022

Over 1000 questions in multiple questionnaire that cover a large gamut of areas and disciplines:

Negative emotions (EN), such as stress, anxiety and depression; Delay of gratification (RG); ThreeFactorEatingQuestionaire; Locus of control - food control (LCA); Locus of control exercise (LCE); Exercise attitudes and beliefs (EC); Obesity attitudes and beliefs (CO): What students believe regarding obesity; Self-efficacy food (AA); Self-efficacy exercise (AE); Motivation (M) for weight control; Food (A) : Options that most help the student to take care of their weight with respect to food. University (Uni.): Section where your condition, stress, health, etc. during the both before and after COVID-19 are indicated; Diseases (Enf.) : Diseases that the student suffers or has suffered; Figure (F): What the student thinks about their body; Obesity (O): Section where the student is asked if he has been diagnosed with obesity; Belongings (P): Objects or services that the student possesses; Work (T): Questions about the student's work. Habits (V): Section on habits of the student; Housing (Viv.) : Questions about the student's housing.

## Behaviour C = Exercise > 2.5 hours weekly

| | item | answer given | N | Nc | Nc/N | Nx | Nxc | Ncx/Nx | Epsilon | Score |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | How do you consider your physical condition? | Good | 530 | 278 | 0.52 | 173 | 142 | 0.82 | 7.80 | 1.52 |
| 2 | Do you exercised regularly? | Yes | 517 | 278 | 0.54 | 390 | 278 | 0.71 | 6.94 | 0.91 |
| 3 | How do you consider your health ? | Very good | 528 | 277 | 0.52 | 75 | 62 | 0.83 | 5.24 | 1.56 |
| 4 | How do you consider your physical conditin? | Very good | 530 | 278 | 0.52 | 52 | 46 | 0.88 | 5.20 | 2.04 |
| 5 | Three_Factor_Eating_Questionaire: On a scale of 1 to 8, where 1 means “not restrict my eating” (eat what I want, wherever I want) and 8 means “restrict my eating” (constantly limit myself and never eat it): Which number would best describe you? | ´7-8 | 297 | 151 | 0.51 | 33 | 31 | 0.94 | 4.95 | 2.74 |
| 6 | Locus_of_control_exercise: My lack of initiative prevents me from exercising | Dos not describe me at all | 215 | 103 | 0.48 | 53 | 43 | 0.81 | 4.84 | 1.46 |
| 7 | Locus_of_control_exercise: My lack of will prevents me from exercising | Dos not describe me at all | 215 | 103 | 0.48 | 47 | 38 | 0.81 | 4.52 | 1.44 |
| 8 | Locus_of_control_exercise: Although I try, I never manage to exercise | Dos not describe me at all | 215 | 103 | 0.48 | 83 | 60 | 0.72 | 4.45 | 0.96 |
| 9 | Locus_of_control_exercise: After I finish my activities I don't have time to exercise | Dos not describe me at all | 215 | 103 | 0.48 | 34 | 29 | 0.85 | 4.36 | 1.76 |
| 10 | How much do you think you eat ? | Recomended amount | 521 | 277 | 0.53 | 252 | 168 | 0.67 | 4.29 | 0.69 |
| 11 | Self-efficacy_exercise: Sticking to an exercise routine. How confident are you that you can stick to your routine despite these situations? Without the support of family or friends. | ´9-10 | 215 | 103 | 0.48 | 70 | 51 | 0.73 | 4.18 | 0.99 |
| 12 | Gratification_delay_frequency_responses: Select the response that most characterizes you. I have always tried to eat healthy because it is a good decision for the future | Always | 297 | 151 | 0.51 | 61 | 47 | 0.77 | 4.09 | 1.21 |
| 13 | Locus_of_control_exercise:My lack of organization prevents me from exercising | Dos not describe me at all | 215 | 103 | 0.48 | 43 | 34 | 0.79 | 4.09 | 1.33 |
| 14 | Locus_of_control_exercise: My inconstancy prevents me from exercising | Dos not describe me at all | 215 | 103 | 0.48 | 45 | 35 | 0.78 | 4.01 | 1.25 |
| 15 | Locus_of_control_exercise: My homework prevents me from exercising | Dos not describe me at all | 215 | 103 | 0.48 | 31 | 26 | 0.84 | 4.01 | 1.65 |
| 16 | Do you or any member of this household have: Cleaning services? | Yes | 521 | 278 | 0.53 | 165 | 113 | 0.68 | 3.89 | 0.78 |
| 17 | Do you eat healthy ? | Yes | 521 | 277 | 0.53 | 375 | 236 | 0.63 | 3.79 | 0.53 |
| 18 | Locus_of_control_exercise: My responsibilities prevent me from exercising | Dos not describe me at all | 215 | 103 | 0.48 | 32 | 26 | 0.81 | 3.78 | 1.47 |
| 19 | Self-efficacy_exercise: Sticking to an exercise routine. How confident are you that you can stick to your routine despite these situations? After recovering from an illness that prevented you from continuing to exercise. | ´9-10 | 215 | 103 | 0.48 | 48 | 36 | 0.75 | 3.76 | 1.10 |



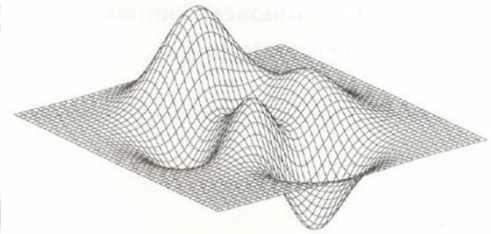

Highly predictive classifier models can be deduced. These models are ***highly multi-factorial***. More than 20% of the total number of features are predictive at the 95% confidence interval.

Conductome

These CONDUCTOMEs represent

$$P(A_k \mid \mathbf{S}(\{s_{Ii}(t)\}), \mathbf{O}(\{o_{Ii}(t)\}), \mathbf{E}(\{e_i(t)\}))$$

Probability for a subject S in a state $(\{s_{Ii}(t)\})$ and in an environment $\mathbf{E}(\{e_i(t)\})$ to take an action $A_k$ (potentially involving an object $\mathbf{O}(\{o_{Ii}(t)\})$).



We are using an ***external*** ensemble

This is a behavioural approach. We get BIG, DEEP data and we correlate observed actions with subject, object and environment state variables.

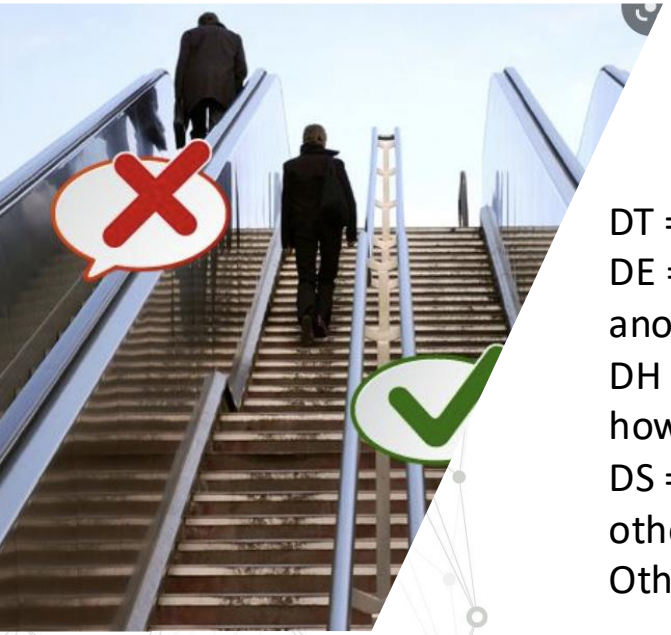
It doesn't give us the WHYs though! Or, at least only very indirectly.

A true understanding of the WHYs requires a better understanding of the ***internal*** ensemble.

***WHY does someone take the escalator versus the stairs?***

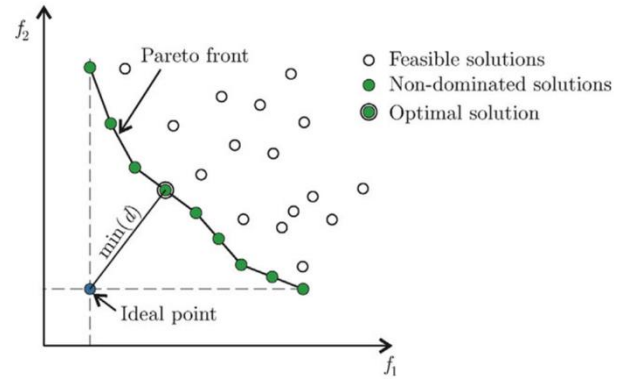
# When is a decision “good” versus “bad”?

We need a metric to measure it.
Rational decision making implies that there is a unique utility function that we optimize



What is the utility function here?

DT = the time difference between taking the stairs and taking the elevator?
DE = the difference in physical energy expended in one route versus another?
DH = the relative perceived health benefit of one versus the other (think how this can change pre-COVID versus post-COVID!)?
DS = the socialization benefit in the case you would take one versus the other with coworkers?
Others?




# How do we balance these tradeoffs and make our decision?

# How do we make decisions?

For a potential utility we assign a value function $v_i$
For $N_v$ value functions we have: $\mathbf{V} = (v_1, v_2, \ldots, v_{Nv})$
Every action $A_k$ leads to a change: $D\mathbf{V}(A_k) = (Dv_1(A_k), Dv_2(A_k), \ldots, Dv_{Nv}(A_k))$

A decision is "good" versus "bad" with respect to a given value function $v_i$ if $Dv_i(A_k) > 0$ ("good" decision) versus $Dv_i(A_k) < 0$ ("bad" decision).

It is not possible to have $Dv_i(A_k) > 0$ for all $v_i$. E.g., in the stairs-elevator situation if the elevator was slow where $DT(\textit{stairs versus elevator}) > 0$ but $DE(\textit{stairs versus elevator}) < 0$. "You can't have your cake and eat it".

$D\mathbf{V}(A_k)$ can take different values depending on where the measurement is made – pre-action versus post-action.

Post-action, $D\mathbf{V}(A_k)$ represents the real or perceived payoffs of the action, i.e., they are outcomes.

For a pre-action evaluation $\langle Dv_i(A_k) \rangle$ represents the predicted value change due to the action. Although $\langle \ldots \rangle$ could in some circumstances be calculated objectively, in general it comes from an ***internal*** prediction model for estimating what the change in value will be.


$$P(A_k \mid \langle \mathbf{DV}(A_k) \rangle) = P(A_k \mid \langle Dv_1(A_k) \rangle, \langle Dv_2(A_k) \rangle, \ldots, \langle Dv_{Nv}(A_k) \rangle)$$

The probability to take the action $A_k$ is conditioned by the predicted payoffs from the action along a set of value functions.

To evaluate the probability of the action then the person needs a prediction model for each value function

$$P(Dv_i(A_k) \mid \mathbf{S}(\{s_{Ii}(t)\}, \{e_i(t)\}), \mathbf{O}(\{o_{Ii}(t)\}, \{e_i(t)\})$$

In other words, we predict what the probability is for a change in the value function $v_i$ given the subject, object and environment states. Thus, for example, in the stairs-elevator example – if the subject is in a "very tired" state, then the probability for a large perceived increase in effort, DE, to take the stairs would be higher than in the "non-tired" state, with the consequence that the probability function will be such that $P(\textit{take the stairs} \mid \langle DE(\textit{take the stairs}) \rangle_1) < P(\textit{take the stairs} \mid \langle DE(\textit{take the stairs}) \rangle_0)$, where $\langle DE(\textit{take the stairs}) \rangle_1$ is the predicted effort for taking the stairs given that the subject is in the state 1 = "very tired" and $\langle DE(\textit{take the stairs}) \rangle_0$ is the predicted effort for taking the stairs given that the subject is in the state 0 = "not tired".
The predicted change in $v_i$ we then take to be

$$\langle Dv_i(A_k) \rangle = F(P(Dv_i(A_k) \mid \mathbf{S}(\{s_{Ii}(t)\}, \{e_i(t)\}), \mathbf{O}(\{o_{Ii}(t)\}, \{e_i(t)\}))$$

for a given function F( ) that maps the probability function for the value function changes conditioned on the subject, object and environment states into an "expected" change.

# Conclusions

1) Basically, all major human problems are consequences of human conduct
2) Decision making and behaviour are immensely multifactorial
3) Data-centric “omic” approaches have revolutionized micro-biology
4) Such approaches can and should be applied to human conduct, although human conduct is a lot more multifactorial, multi-scale and multi-disciplinary than any phenomenon in micro-biology
5) The CONDUCTOME is a conceptual and theoretical framework within which data-centric (external ensemble) prediction models – CONDUCTOMES – can and have been constructed
6) It is a huge challenge to understand what these models are telling us
7) It is an even bigger challenge to understand the “internal ensemble” models that, in reality, govern our conduct
8) Our hypothesis is that a human decision is a meta-model, where the final decision depends on the predicted payoffs from multiple prediction models, one for each objective
9) The CONDUCTOME project and team have data from over 7500 participants and 1000s of variables, from the micro to the macro, and are always looking for collaborations – we are drowning in data.
10) All this work has been in collaboration with a large, interdisciplinary team who I am immensely grateful to, as well as several funding bodies. (See chilam.c3.unam.mx/en/projects/about-conductome)

**THANK YOU**

conductome.unam.mx
chilam.c3.unam.mx