Logistique

- Jeudi soir je ferme les TP
- Inscrivez-vous avant jeudi pour le projet
  - Même titre pour 2 personnes dans le même groupe
- Les soutenances c’est vendredi 8h30 – 11h45 puis 13h30-15h
  - Votre présence est requise pendant toutes les soutenances
  - Temps de passage: 8 min de présentation, 5 min de questions

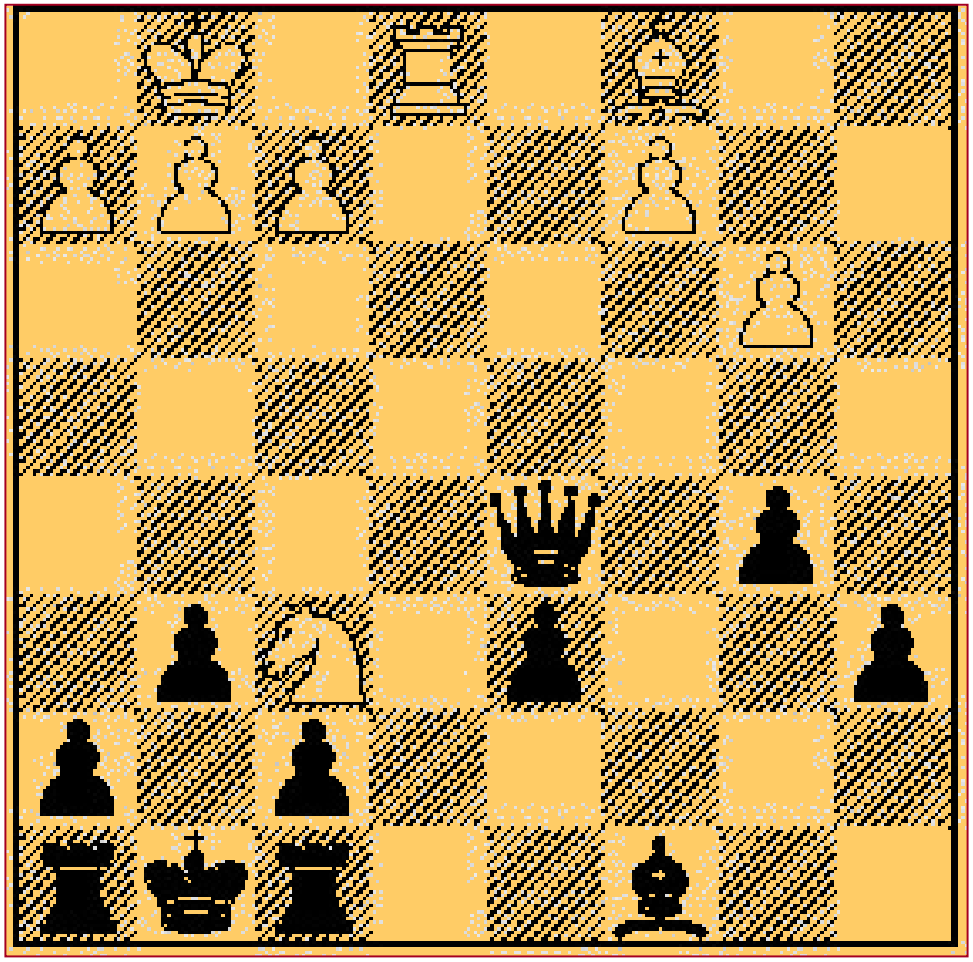
3EL05

Chapitre 5
Complexité et cognition

Contenu

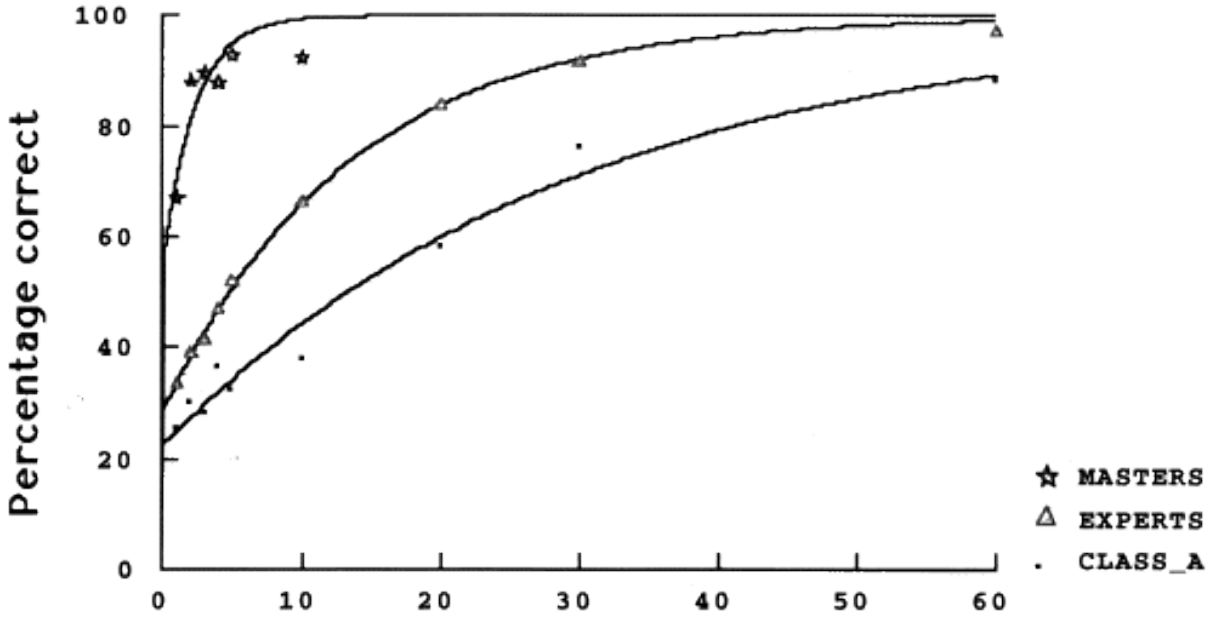
- Structures
- Inattendu
  - Simplicité
  - Complexité causale
- Surprise et entropie de Shannon

Structures



Structures

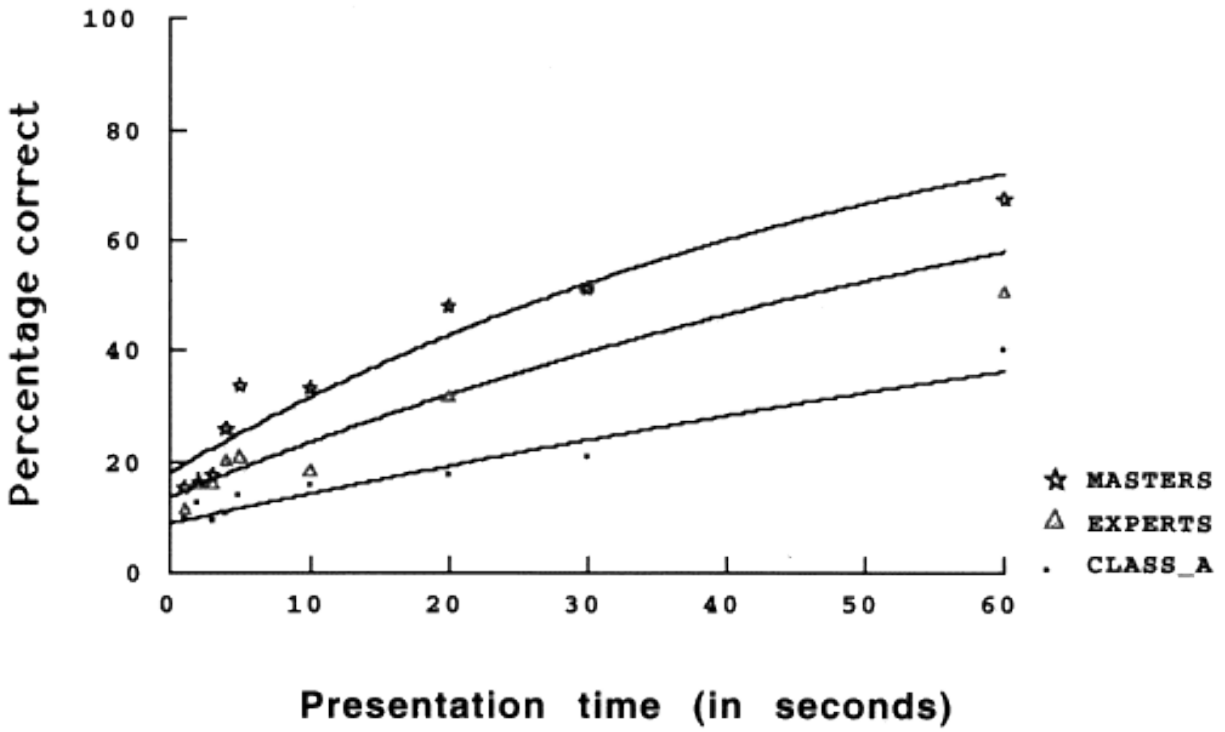
Nineteen game positions were selected from various chess books with the following criteria: (a) the position was reached after about 20 moves; (b)
White is to move; (c) the position is "quiet" (i.e., is not in the middle of a sequence of exchanges); (d) the game was played by (Grand)masters, but is obscure. The mean number of pieces was 25.



« Five seconds or sixty? Presentation time in expert memory »
Fernand Gobet and Herbert A. Simon
***Cognitive Science* 24(4), 2000, 651-682**

Structures

Ten random positions were created by assigning the pieces from a game position to random squares on the chessboard.



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Structures

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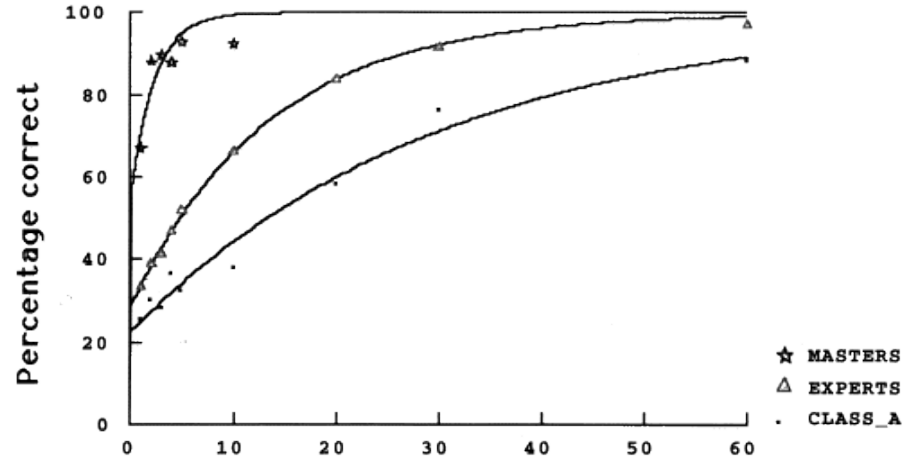
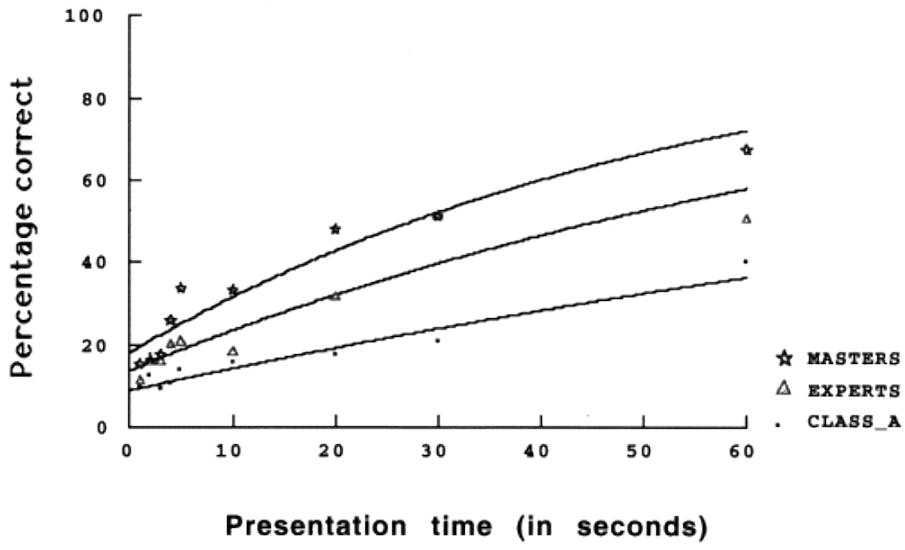
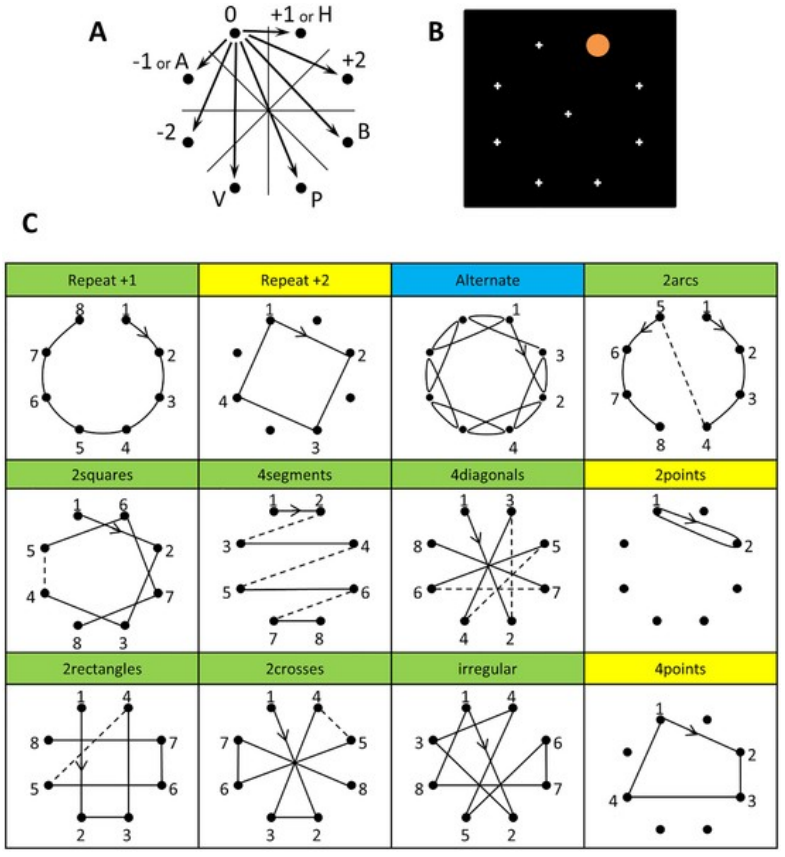


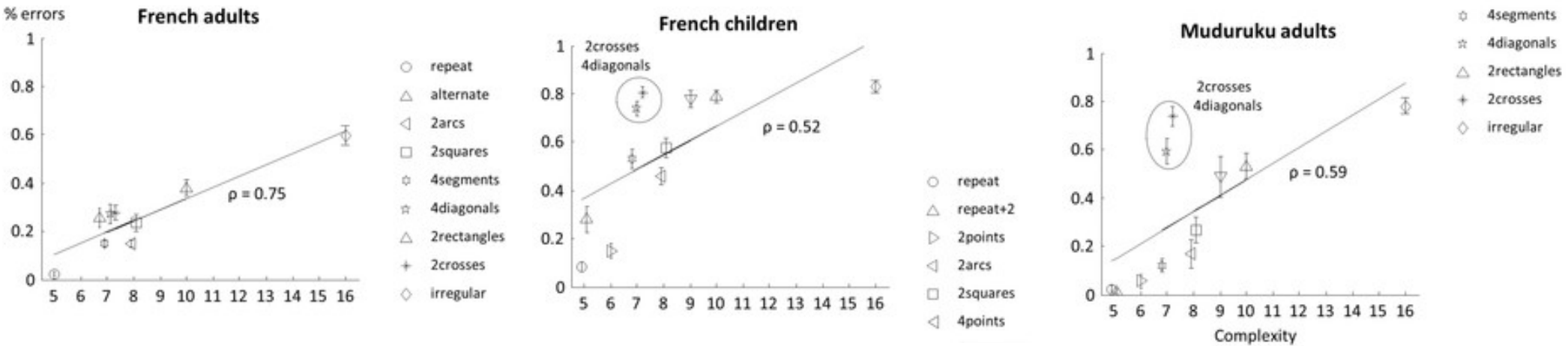


Complexité et sciences cognitives



Amalric et al, *The language of geometry: Fast comprehension of geometrical primitives and rules in human adults and preschoolers*, PLOS Comp Bio 2017

Complexité et sciences cognitives



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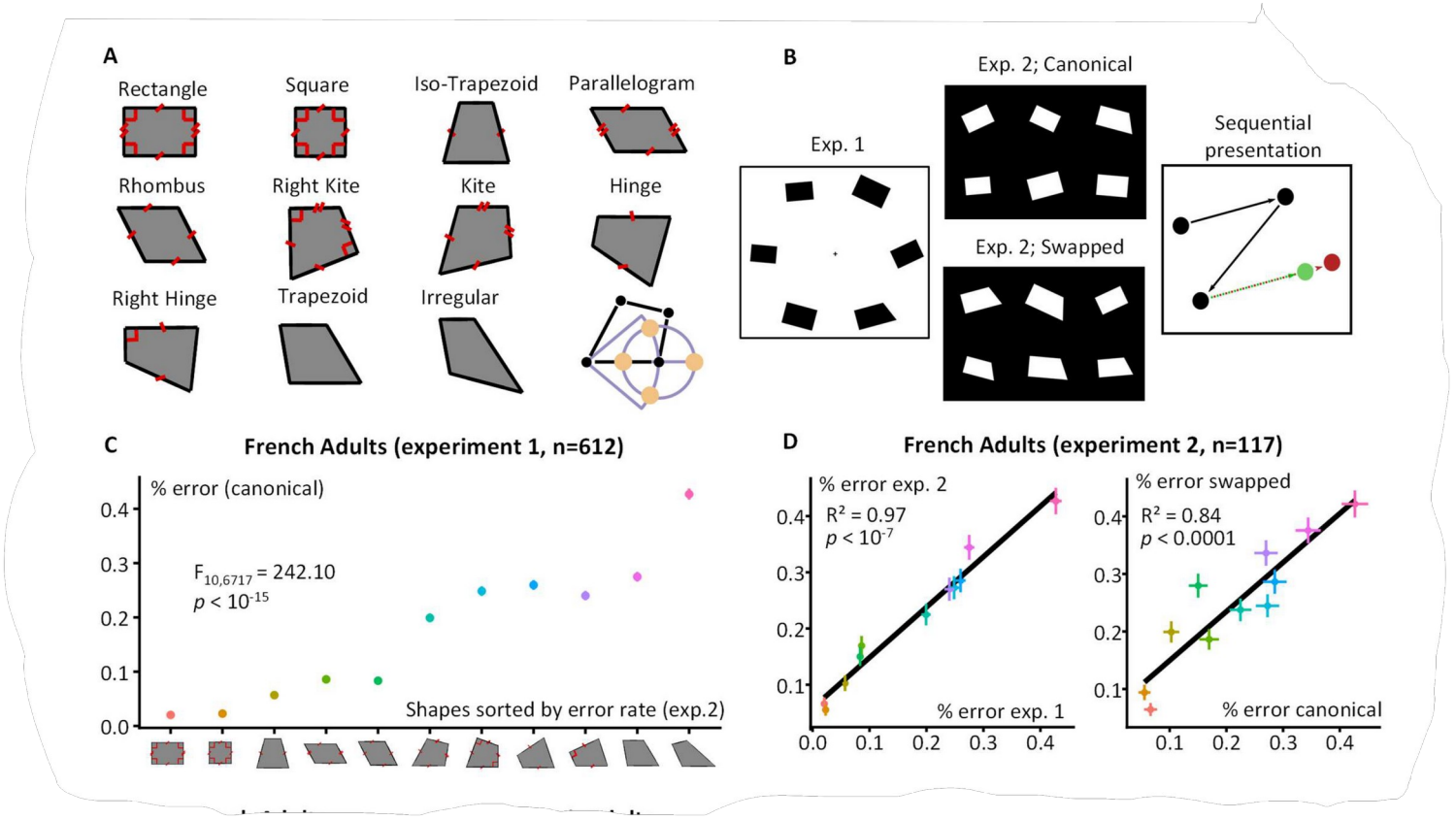
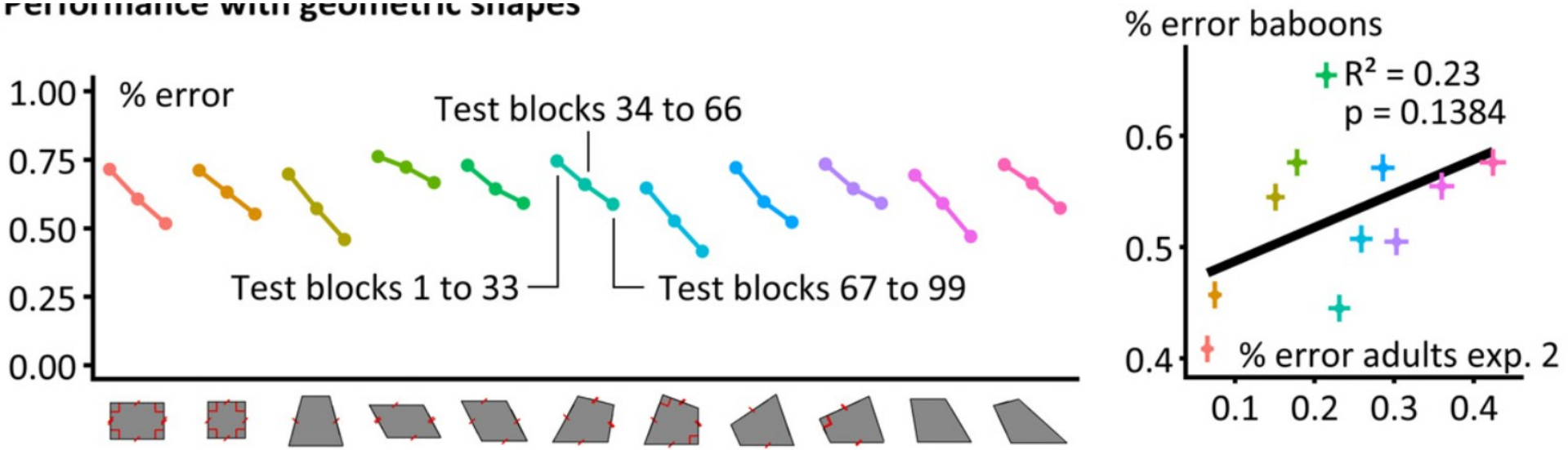
Complexité et sciences cognitives



Sablé-Meyer et al, *Sensitivity to geometric shape regularity in humans and baboons: A putative signature of human singularity*, PsyArXiv 2020

Complexité et sciences cognitives



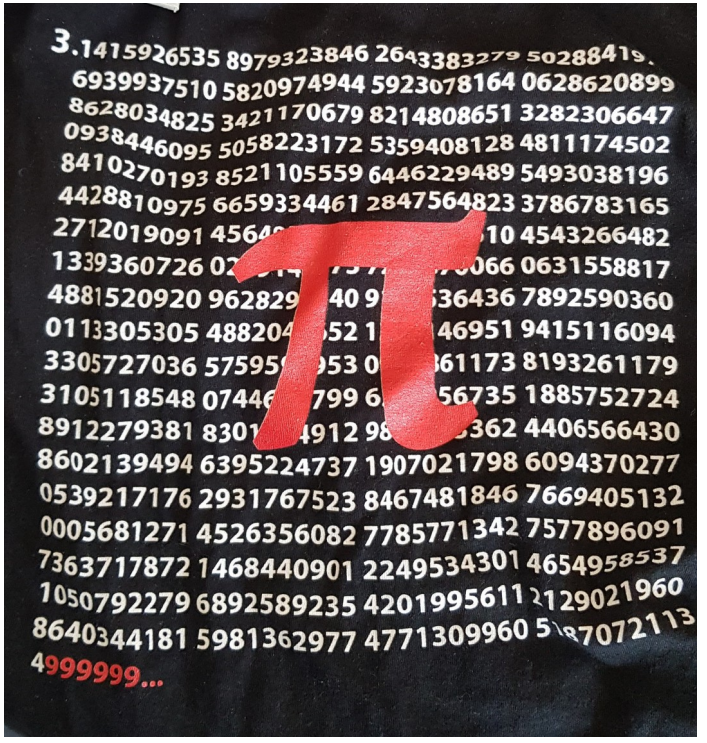
Sablé-Meyer et al, *Sensitivity to geometric shape regularity in humans and baboons: A putative signature of human singularity*, PsyArXiv 2020

L’inattendu

- Soit un tirage de loto (6 nombres entre 1 et 99)
- Lequel est le plus inattendu/i
  - 1, 2, 3, 4, 5, 6
  - 42, 65, 2, 96, 22, 81

L’inattendu

Famous physicist Richard Feynman was allegedly amazed at the occurrence of 6 nines at 762nd position in π’s decimal expansion.



His surprise is…

- legitimate because there is no regularity in pi’s decimal expansion
- unfounded because any series of 6 numbers would have been equally likely at this position.

L’inattendu

You travel far away from home and…
you bump into someone you know.

The event is certainly tweetworthy!

What would make you feel the urge to share the event even more?

- ❑ if the person is famous
- ❑ if the person is a close friend/colleague of yours
- ❑ if you meet them in a hard-to-reach place

L’inattendu

L’inattendu est une différence positive entre la *complexité causale* et la *complexité descriptive*

$$U(s) = C_w(s) - C_d(s)$$

complexité ex-ante

complexité ex-post

L’inattendu

- Calculer 2 complexités :
  - La complexité causale
  - La complexité descriptive
- Chacune utilise une machine différente :
  - Comment cet évènement a-t-il pu être généré par la machine “monde réel” ?
  - Comment cet évènement peut-il être décrit avec ma machine subjective ?

L’inattendu

- Pour le loto :
  - La complexité causale
    Chaque tirage est équiprobable, il faut $6\log_2(99) \approx 39.8$ bits pour le générer
  - La complexité descriptive dépend du tirage
    - Pour 42, 65, 2, 96, 22, 81 c’est presque $6\log_2(99)$ bits
    - Pour 1, 2, 3, 4, 5, 6 c’est beaucoup moins, peut-être $\log_2(6) + C(\text{”compter”})$

L'inattendu

the occurrence of 6 nines at 762nd position in π's decimal expansion

- Pour les décimales de π :
  - La complexité causale
    Chaque suite est équiprobable, il faut
    bits pour la générer
  - La complexité descriptive

$$C(\pi) + C(9) + C(6) + C(762)$$

$$\approx 15.3 \text{ bits}$$

Si vous êtes scientifique,
cette complexité est faible

Complexité et entropie

N_1 red balls

N_2 blue balls

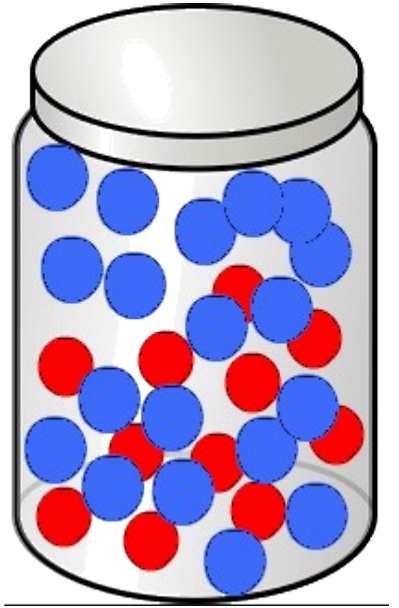
$N = N_1 + N_2$

One draw: s

n_1 red balls

n_2 blue balls

$n = n_1 + n_2$



Color of balls is unknown ex-ante

Ex-ante complexity:

Ex-post complexity

Surprise:

Complexité et entropie

N_1 red balls

N_2 blue balls

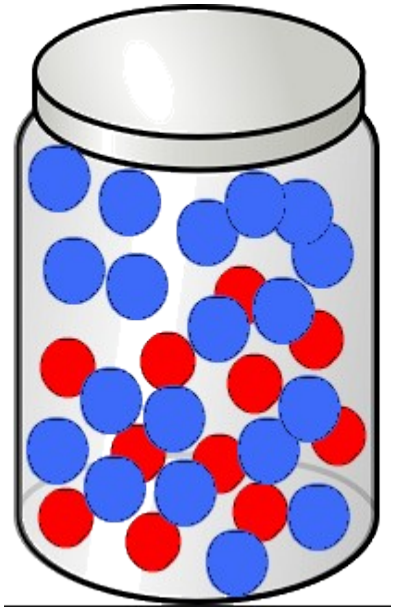
$N = N_1 + N_2$

One draw: s

n_1 red balls

n_2 blue balls

$n = n_1 + n_2$



Color of balls is unknown ex-ante

Ex-ante complexity: $C_w(s) = n \log(N)$

if $N >> n$ or if balls are put back

Ex-post complexity: $C(s) = n_1 \log(N_1) + n_2 \log(N_2)$ (if order is 'random' or ignored)

Surprise: $U(s) = C_w - C = -n\,[(n_1/n) \log(p_1) + (n_2/n) \log(p_2)]$

Cross-entropy

where $p_i = N_i/N$ prob. of drawing a ball with colour i

When $n_i/n = p_i$, we have $U(s)/n = H(s)$

$U(s)/n - H(s) = KL(s)$

average unexpectedness ≥ entropy

Complexité et entropie

$$I(s) = -\log_2(p(s))$$

Claude Shannon

$$p(s) = 2^{-K(s)}$$

Ray Solomonoff

Shannon, *A mathematical theory of communication*, The Bell System Technical Journal 1948

L’inattendu

Vous rencontrez quelqu’un dans un endroit loin de chez vous...

$$U(s) = C_w(s) - C_d(s)$$

- Est-ce un endroit où passe beaucoup de monde ?
- Est-ce que cette personne avait une raison évidente d’être là ?

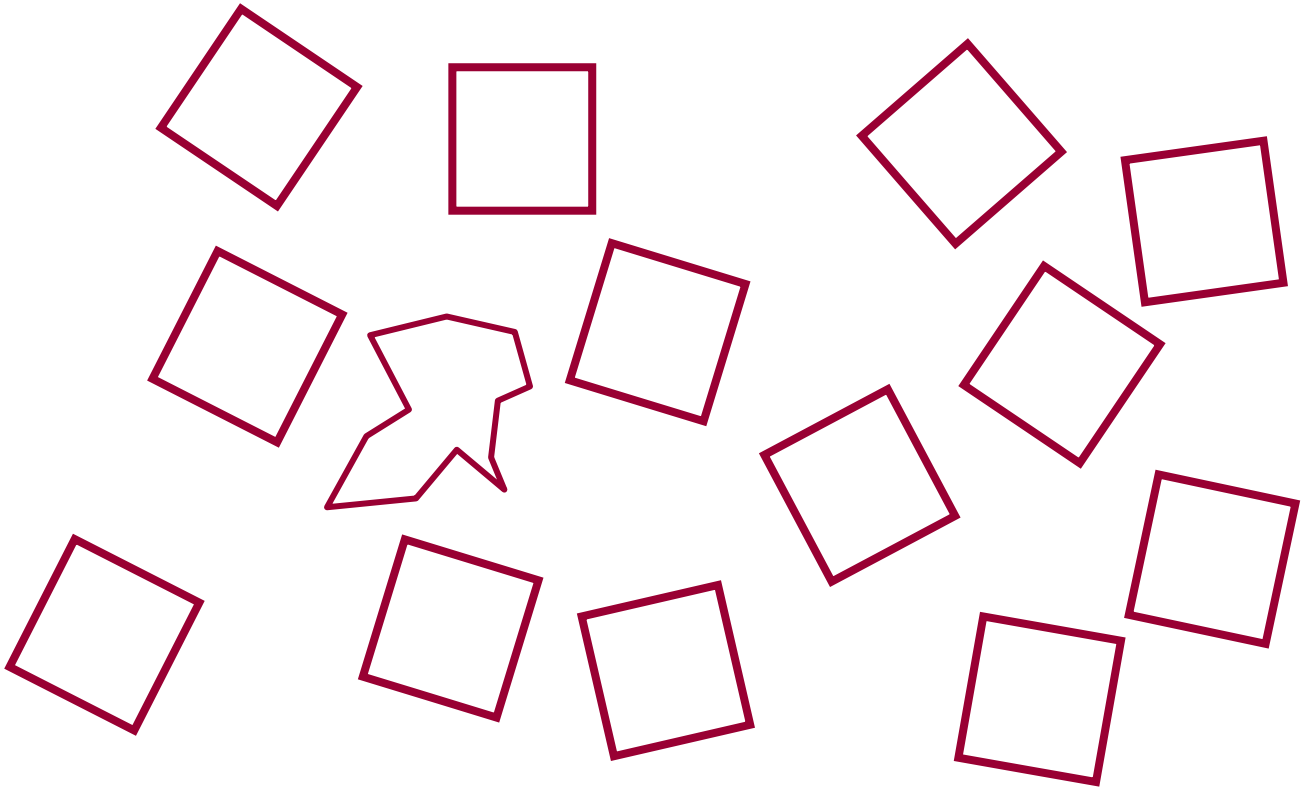
- Cette personne est-elle facile à décrire pour vous ?
- En haut de votre liste de personnes importantes ?
- Connue de nombreuses autres personnes ?

Les tours de magie

Complexité causale élevée : comment expliquer qu'un lapin se retrouve dans un chapeau ?

Complexité descriptive faible : Un lapin. Dans un chapeau.

Les anomalies



Les coïncidences

Lincoln was elected to Congress in 1846, Kennedy was elected to Congress in 1946.

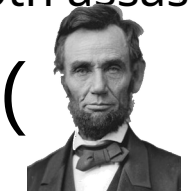
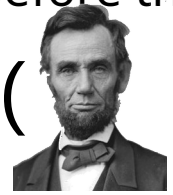
Lincoln was elected president in 1860, Kennedy was elected president in 1960.

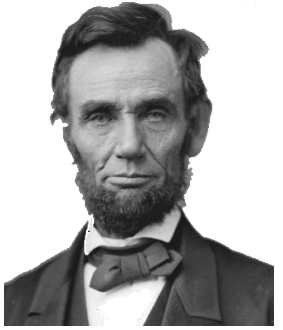
Both presidents have been shot in the head in presence of their wives.

Both successors were named Johnson, born in 1808 and 1908.

Kennedy was shot in a car named Lincoln

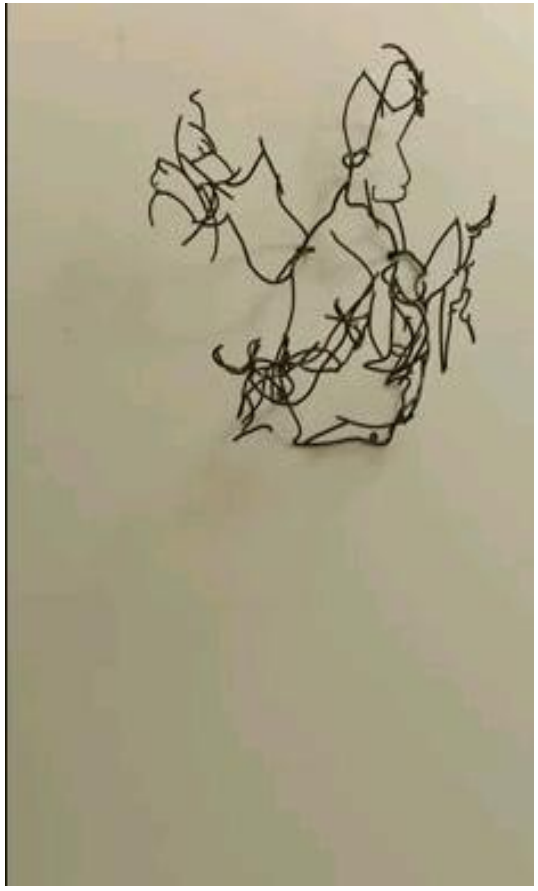
Both assassins were assassinated before their trials

C() + C() - C( , )



Solution: Probability has virtually nothing to say about coincidences.
Coincidences are explained by *complexity drop*. Each element x_i common to the two situations requires $2 \times C_w(x_i)$ bits to be generated (e.g. the complexity of choosing the vice president's name). But it needs to be described only once → hence the compression.
The 100 year shift costs less to be described than, say, 84.
Famous people cost less on the description's side as well (much less than e.g. two obscure Guatemalan presidents).
Related topic: Analogies correspond to minimal complexity.

L’esthétique

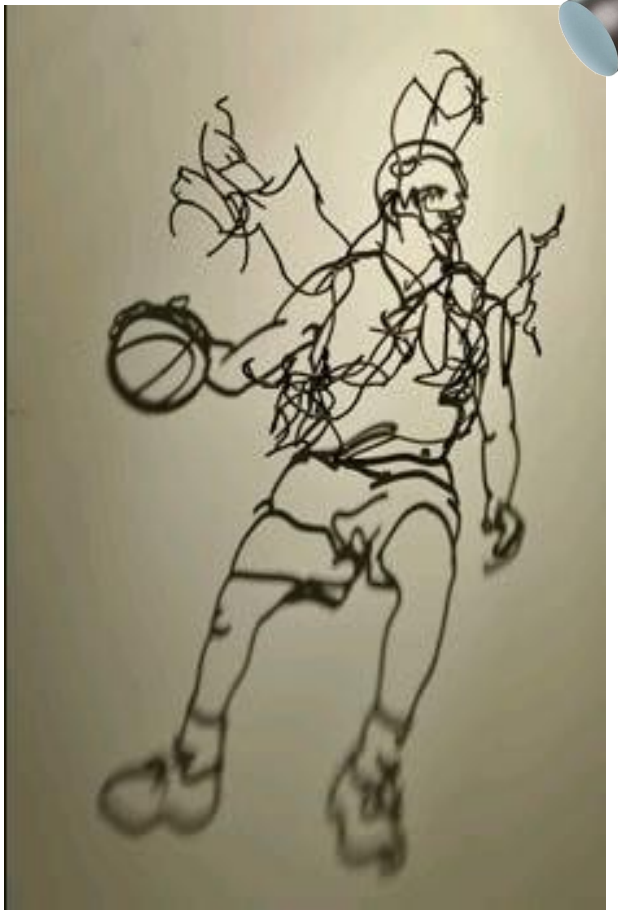


Complexité *ex-ante* de l’ombre

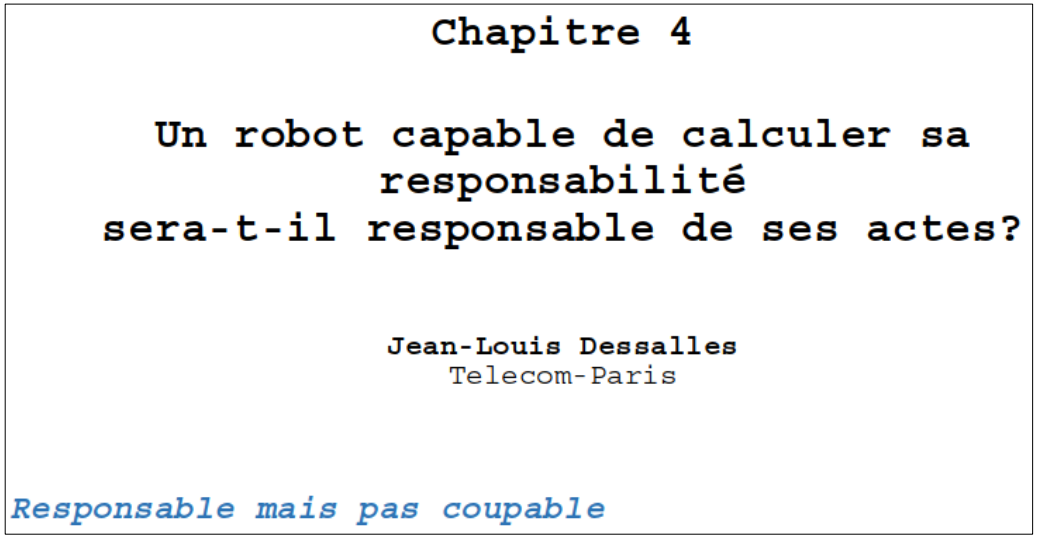
vs

Complexité *ex-post* de l’ombre

Larry Kagan



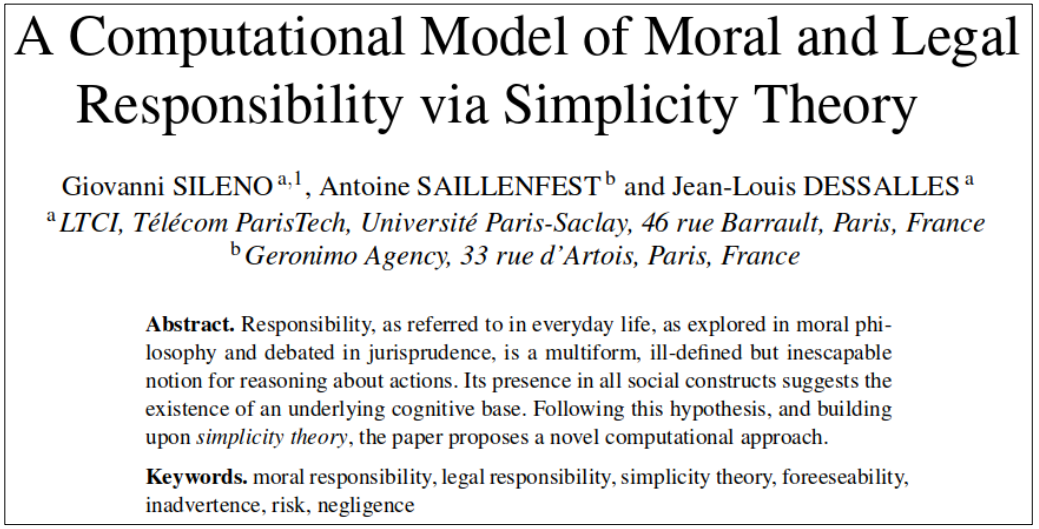
Complexité, responsabilité et culpabilité


Chapitre 4

Un robot capable de calculer sa responsabilité sera-t-il responsable de ses actes?

Jean-Louis Dessalles
Telecom-Paris

Responsable mais pas coupable


A Computational Model of Moral and Legal Responsibility via Simplicity Theory

Giovanni SILENO [a,1], Antoine SAILLENFEST [b] and Jean-Louis DESSALLES [a]
[a] *LTCI, Télécom ParisTech, Université Paris-Saclay, 46 rue Barrault, Paris, France*
[b] *Geronimo Agency, 33 rue d'Artois, Paris, France*

Abstract. Responsibility, as referred to in everyday life, as explored in moral philosophy and debated in jurisprudence, is a multiform, ill-defined but inescapable notion for reasoning about actions. Its presence in all social constructs suggests the existence of an underlying cognitive base. Following this hypothesis, and building upon *simplicity theory*, the paper proposes a novel computational approach.

Keywords. moral responsibility, legal responsibility, simplicity theory, foreeseability, inadvertence, risk, negligence

Dessalles, J.-L. (2021). In G. Aïdan & D. Bourcier (Eds.), *Humain non-Humain - Repenser l'intériorité du sujet de droit*, 47-56. Paris: Librairie LGDJ.

L’attendu

$$U(s) = C_w(s) - C_d(s)$$

Cas où U(s) < 0 ?

Conclusion

- La complexité explique de nombreux phénomènes cognitifs, avec un minimum de modélisation
- Le cerveau humain est-il capable de calculer une forme de complexité ?

Opinion

Symbols and mental programs: a hypothesis about human singularity

Stanislas Dehaene, [1,2,*] Fosca Al Roumi, [1] Yair Lakretz, [1] Samuel Planton, [1] and Mathias Sablé-Meyer [1]

2022

Conclusion du cours

- La complexité et l’information algorithmique infusent :
  - Les mathématiques
  - L’apprentissage automatique
  - Les sciences cognitives
- Découvrir la complexité m’a causé une chute de complexité (= j’ai mieux compris le monde)
- J’espère que pour vous aussi