

# H24 : An agent-based model to investigate the effects of social segregation around the clock on social disparities in dietary behaviour

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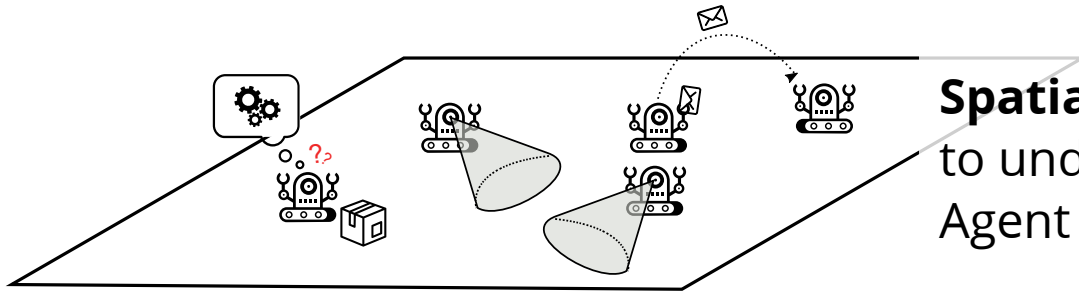
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# Modelling human behaviours

## Modelling territories



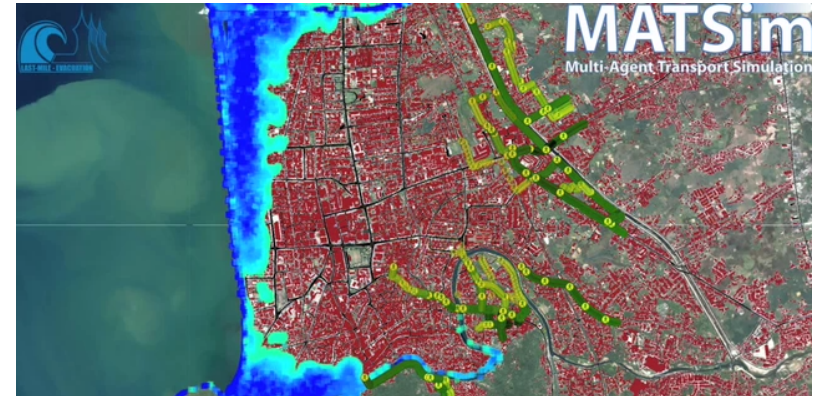
**Spatial** representation of individuals to understand their **behaviours** with Agent Based Model

Keep it Simple

Segregation of stores <sup>a</sup>		Segregation of households <sup>a</sup>					
Grid position <sup>b</sup>		Grid position <sup>b</sup>					
		Left side vs right side		Left side vs right side			
Left side vs right side		Random	Random	High-income	Low-income	Low-income	High-income
Random	Random	1		4			4 <sup>c</sup>
All stores	No stores	2		5			8
Healthy stores	Unhealthy stores	3		6 <sup>d</sup>			7 <sup>c</sup>
Unhealthy stores	Healthy stores	3 <sup>c</sup>		7			6 <sup>c</sup>

[Auchincloss et al., 2011]

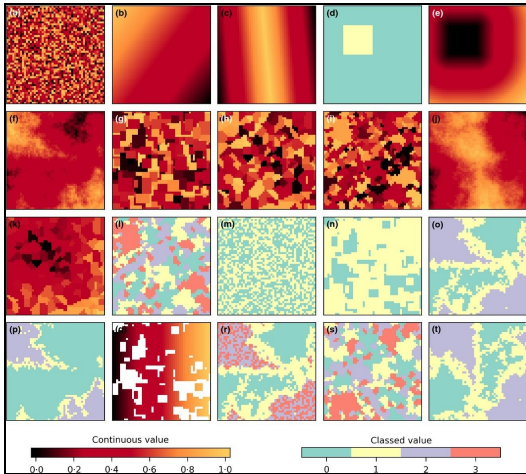
Keep it Detailed



[Nagel, Auhhausen et al.]

# Spatial representation in ABM

Abstracting the characteristics of space  
Between simplistic simplification and singularity



*Neutral Landscape Model*  
Thomas R. Etherington

Space as an input parameter

ex: SpaceMatters project with population density grids as varying initial spatial conditions [Raimbault et al., 2017]

... What about time?

- Spatio-temporal heterogeneity
- Constraints on interaction

	Compact	Polycentric	Discontinuous
	<b>European Reference</b>		
	Vienna (Austria)	Liege (Belgium)	Augsburg (Germany)
	<b>Examples of generated grids</b>		
	<b>Corresponding meta-parameters</b>		
$\alpha$	1.707024718	1.525077587	1.853205966
$\beta$	0.00568899	0.00764774	0.10796615
$n$	3	2	1
$N$	1753.09434	4629.16844	12905.6414

*Space Matters*  
J. Raimbault et al.

# Thematical challenge

Place /neighbourhood effects :

- matter when exploring human behaviors in health, education, voting etc.
- hard to prove because people (i) adapt to each other, (ii) sort themselves between places and (iii) only live once, which makes alternative spatial scenarios impossible to observe.

Interactions between people & places remain often static in statistical models

- either without including people's daily trajectories
- or with people's daily trajectories but without including place's daily trajectories

Need ABM to explore people's and place's daily trajectories and their impact on human behaviours

# Objectives

Explore effects of segregation around the clock on extent of social disparities in human behaviours

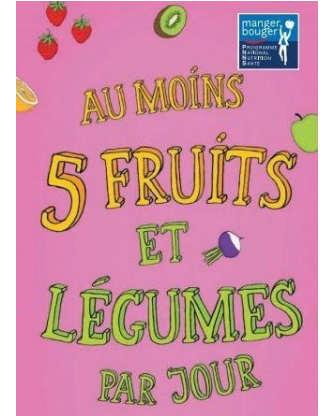
Are social disparities in human behaviours greater...

(i) when night locations are spatially segregated rather than randomly attributed ?

(ii) when day locations are taken into consideration besides night locations ?

	Random locations	Survey-based locations
Night only (ie. residence)	Scenario 1	Scenario 2
Night & day	Scenario 3	Scenario 4

# Diet behaviours



## National nutrition policies

eg. Programme National Nutrition Santé (PNNS) in France since 2001

## Convergent findings about social disparities in fruit and vegetable consumption

### Compliance with French Nutrition and Health Program Recommendations Is Strongly Associated with Socioeconomic Characteristics in the General Adult Population

AURÉLIE MALON, PharmD; VALÉRIE DESCHAMPS, PhD; BENOIT SALANAVE, MSc; MICHEL VERNAY, PhD; EMMANUELLE SZEGO, MSc; CARLA ESTAQUIO, MSc; EMMANUELLE KESSE-GUYOT, PhD; SERGE HERCBERG, MD, PhD; KATIA CASTETBON, PhD

*J Am Diet Assoc* (2010)

### Socioeconomic Differences in Fruit and Vegetable Consumption among Middle-Aged French Adults: Adherence to the 5 A Day Recommendation

CARLA ESTAQUIO, PhD; NATHALIE DRUESNE-PECOLLO, PhD; PAULE LATINO-MARTEL, PhD; LUC DAUCHET, MD, PhD; SERGE HERCBERG, MD, PhD; SANDRINE BERTRAIS, PhD

*J Am Diet Assoc*. (2008)

## Pioneer research using ABM to explore social disparities in diet, but only in the context of (simplistic) residential segregation

### An Agent-Based Model of Income Inequalities in Diet in the Context of Residential Segregation

Amy H. Auchincloss, PhD, MPH, Rick L. Riolo, PhD, Daniel G. Brown, PhD, Jeremy Cook, BA, Ana V. Diez Roux, MD, PhD

*Am J Prev Med* (2011)

### An agent-based simulation of persistent inequalities in health behavior: Understanding the interdependent roles of segregation, clustering, and social influence

Brent A. Langellier\*

*SSM - Population Health* (2016)

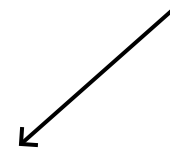
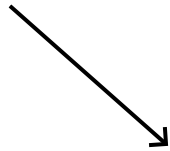
# (French) data

## Diet dynamics

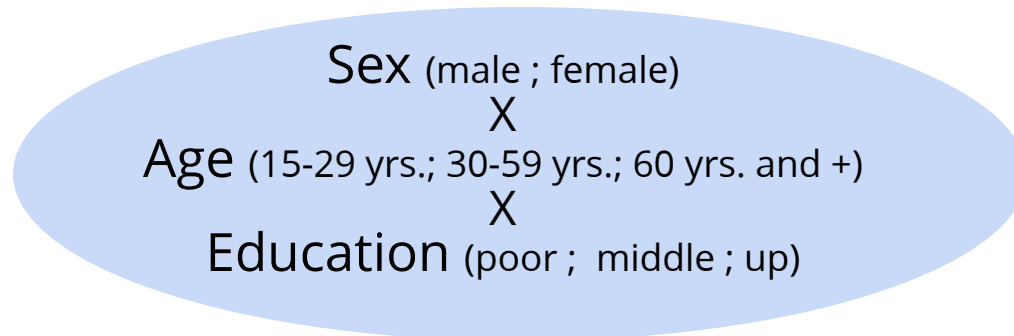
Baromètres Santé Nutrition  
(1996 ; 2002 ; 2008)

## Spatio-temporel locations

Night (ie. residence) : 2012 census  
Day & evening : 2010 origin-destination survey



*explored with same **sociodemographic groups (18)***



# Population generation

## Spatial grid

Ile-de-France

8540 inhabited cells (1km X 1km)

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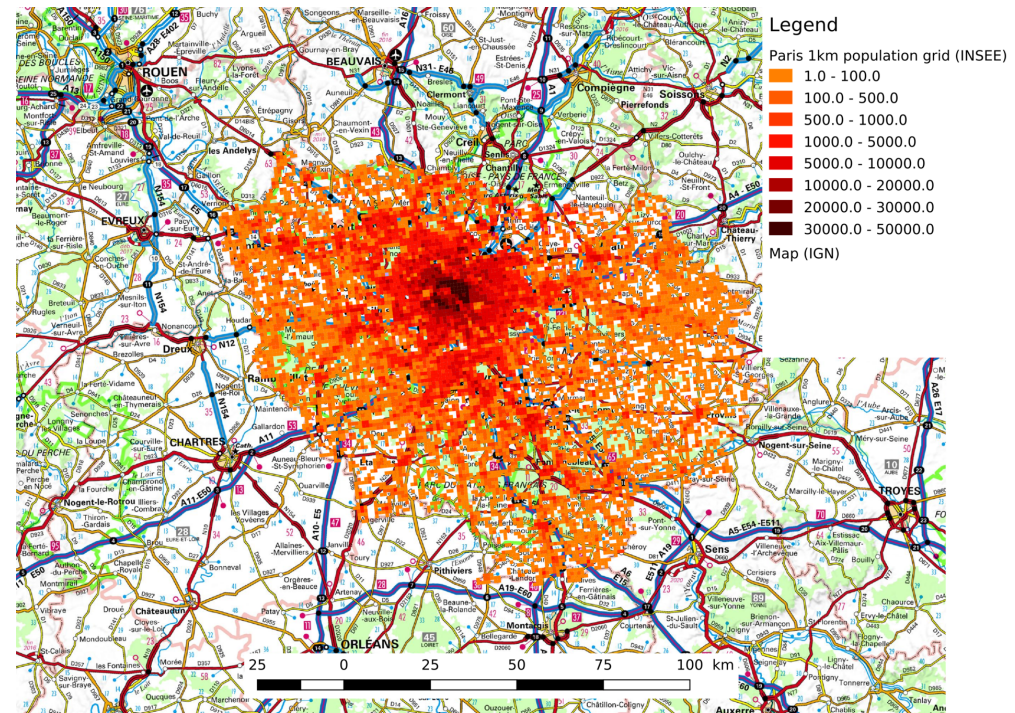
## Agent

8,16 millions of agents  
with sociodemographic attributes  
with night/day/evening cells

68 % in a 'day' cell  $\neq$  the 'night' cell

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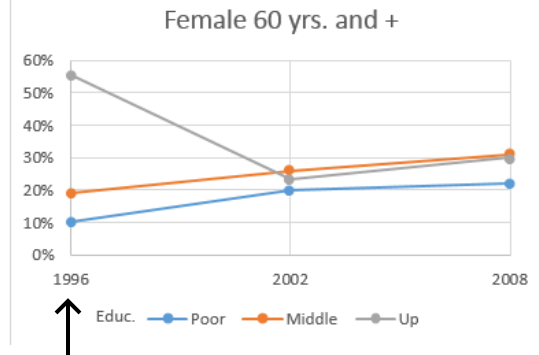
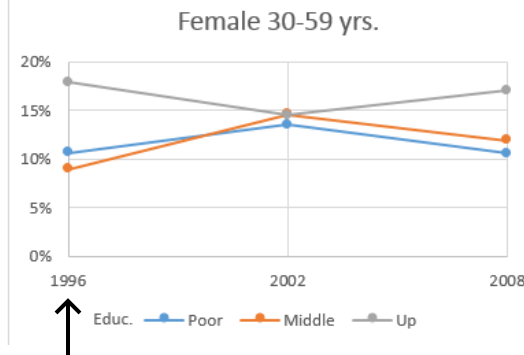
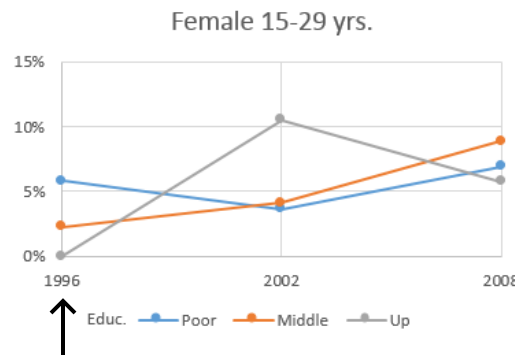
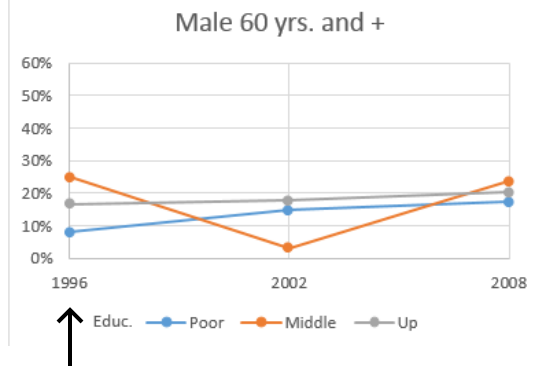
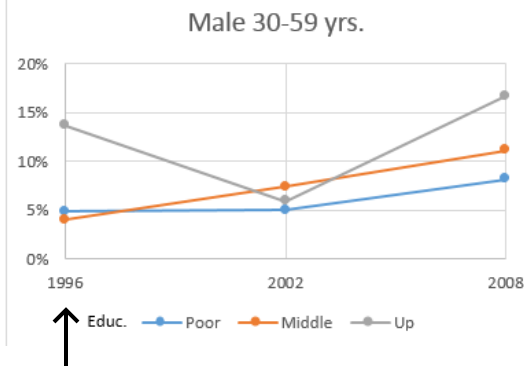
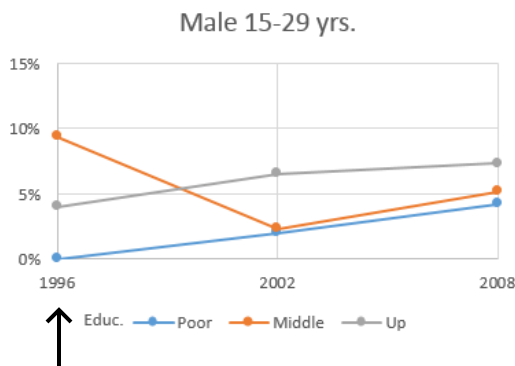
Agent diet opinion and behaviour initially defined  
according to sociodemographic category





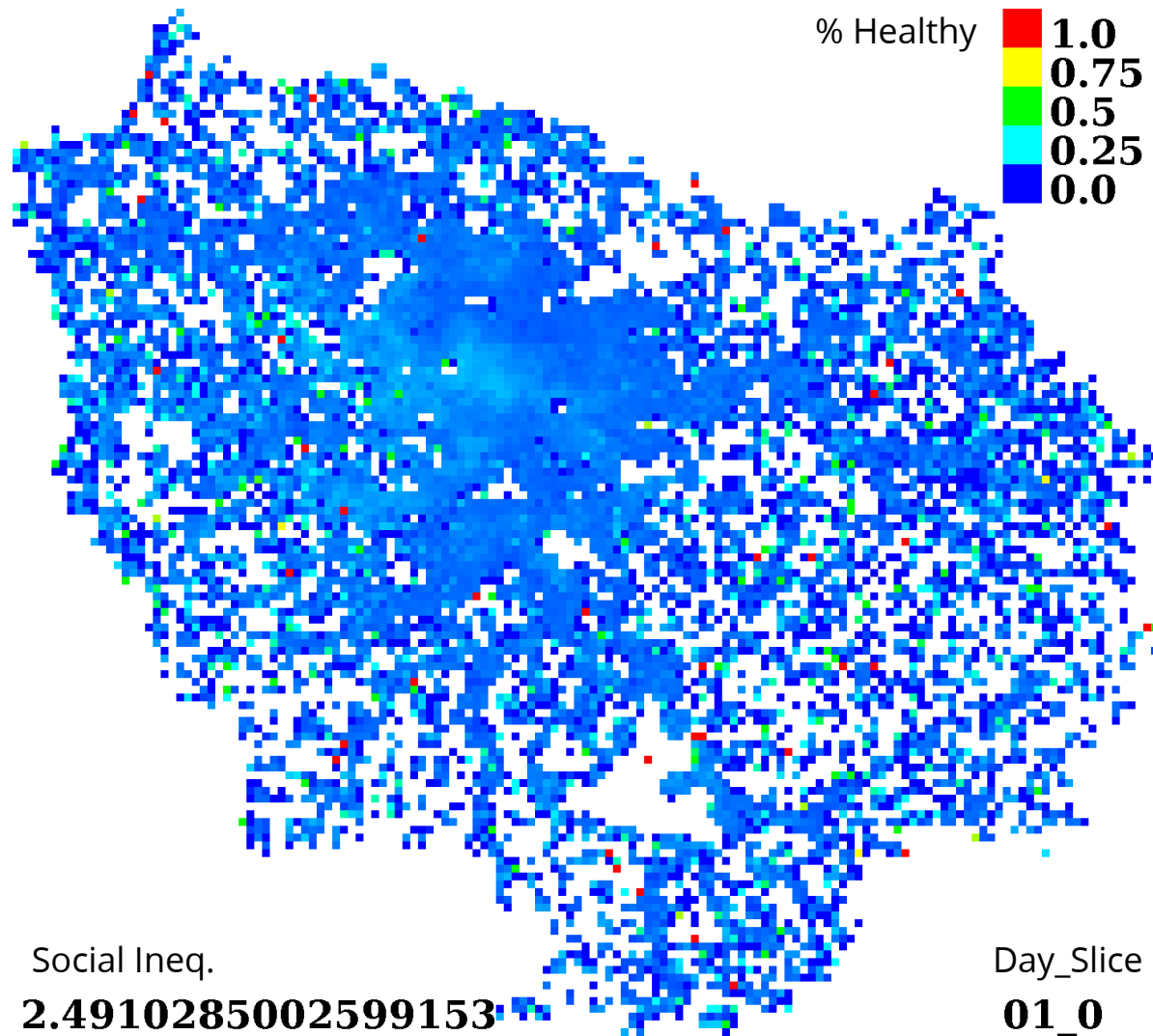
# Initial dietary behavior

From 1996 data : 5-a-day fruit and vegetable consumption



Source : Baromètres Santé Nutrition (1996 ; 2002 ; 2008)

# Initial dietary behavior



# Model structure

Scenarios 1 & 2:

1 time slice per day

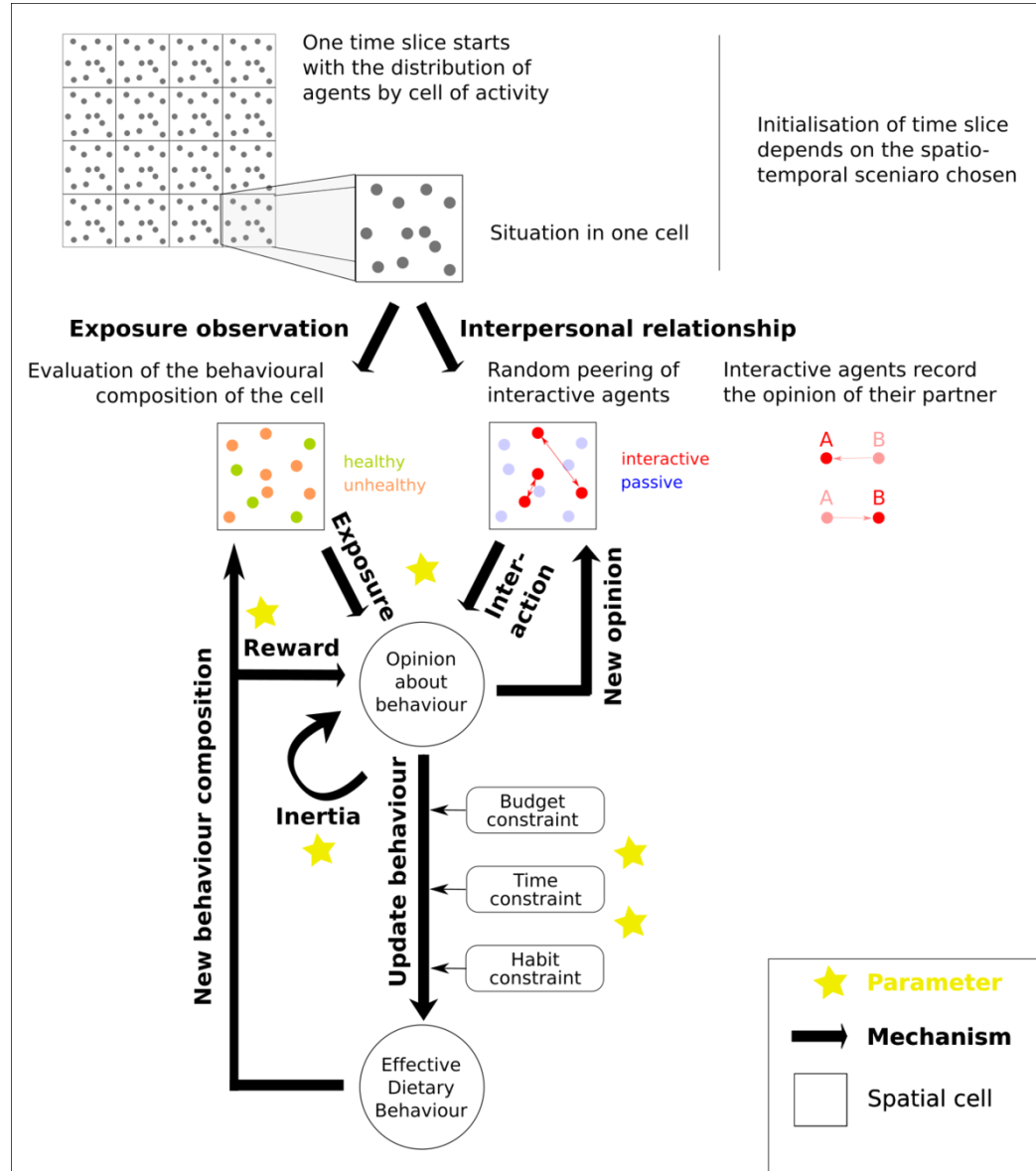
Scenarios 3 & 4:

3 time slices per day

Spatial interactions

Modelling **opinion** change

Modelling **behaviour** change under constraints



# Parameter expectations

Parameter	Mechanism	Range	if min	if max	Influence on 5-a-day
Interaction	Spatial Interaction	[ 0 ; 1 ]	Observation of cell behaviour only	Observation of partner opinion only	+
Reward	Behaviour-Opinion	[ 0 ; 1 ]	No Feedback from behaviour	Healthy behaviour strengthens opinion	+
Inertia	Opinion-Behaviour	[ 0 ; 1 ]	Opinion depends on influences only	Stable opinion	?
Switch Proba	Opinion-Behaviour	[ 0 ; 1 ]	No change of behaviour	Behaviour matches opinion	+
Constraint	Opinion-Behaviour	[ 0 ; 1 ]	No constraint	Constraint prevents behaviour switch	?

# Evaluation protocol

optimisation using evolutionary algorithms (EA)

## A - Exploring behavior of standalone model

**space** : one cell with 100 people

**method** : maximise diversity using pattern exploration algorithm

**expected patterns** : Consistent dynamics of the model in terms of opinion diffusion and behaviour change

## B - Invalidate behavior by falsification, an inverted calibration

**space** : 8540 cells

**method** : minimise distance to data using multi-objective evolutionary algorithm (EA)

**expected patterns** : random scenario cannot produce coherent data and inequality between education groups

# Model 50hh - 50uu

Parameter	Mechanism	Range	Expected influence	Significant coefficient
Interaction	Spatial Interaction	[ 0 ; 1 ]	+	
Reward	Behaviour-Opinion	[ 0 ; 1 ]	+	+
Inertia	Opinion-Behaviour	[ 0 ; 1 ]	?	
Switch Proba	Opinion-Behaviour	[ 0 ; 1 ]	+	
Constraint	Opinion-Behaviour	[ 0 ; 1 ]	?	

Multiple R-squared: 0.0828

# Model 50hm - 50um

Parameter	Mechanism	Range	Expected influence	Significant coefficient
Interaction	Spatial Interaction	[ 0 ; 1 ]	+	+
Reward	Behaviour-Opinion	[ 0 ; 1 ]	+	
Intertia	Opinion-Behaviour	[ 0 ; 1 ]	?	
Switch Proba	Opinion-Behaviour	[ 0 ; 1 ]	+	+
Constraint	Opinion-Behaviour	[ 0 ; 1 ]	?	

Multiple R-squared: 0.3023

# Model 90hh - 10uu

Parameter	Mechanism	Range	Expected influence	Significant coefficient
Interaction	Spatial Interaction	[ 0 ; 1 ]	+	
Reward	Behaviour-Opinion	[ 0 ; 1 ]	+	
Inertia	Opinion-Behaviour	[ 0 ; 1 ]	?	+
Switch Proba	Opinion-Behaviour	[ 0 ; 1 ]	+	
Constraint	Opinion-Behaviour	[ 0 ; 1 ]	?	

Multiple R-squared: 0.2611



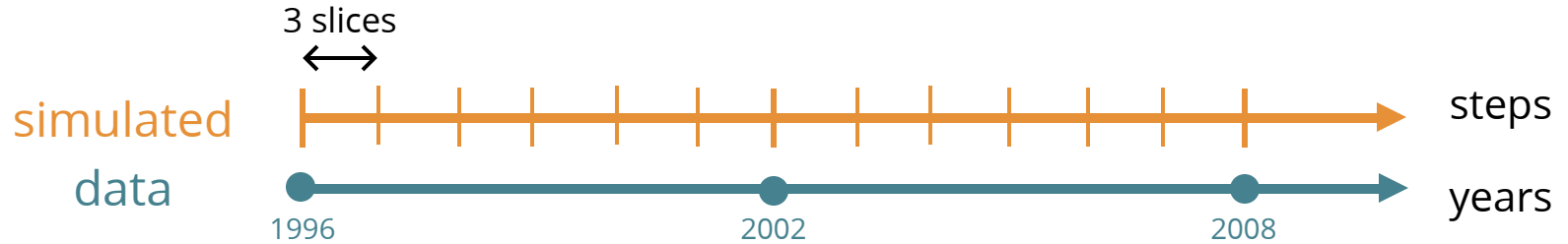
# Model 10hh - 90uu

Parameter	Mechanism	Range	Expected influence	Significant coefficient
Interaction	Spatial Interaction	[ 0 ; 1 ]	+	+
Reward	Behaviour-Opinion	[ 0 ; 1 ]	+	
Intertia	Opinion-Behaviour	[ 0 ; 1 ]	?	
Switch Proba	Opinion-Behaviour	[ 0 ; 1 ]	+	
Constraint	Opinion-Behaviour	[ 0 ; 1 ]	?	

Multiple R-squared: 0.149

# Aggregated output

Specification of a simulation run:



## Observables

**Obs. 1** : Distance to data  $MSE ( \%healthy_{age-sex} \%healthy_{age-sex} )$   
2002, 2008

**Obs. 2** : Social inequality  $SI = \sum_{i=1}^2 \sum_{j=1}^3 \frac{ShareHealthy_{i,j,e=3}}{ShareHealthy_{i,j,e=1}} \times \frac{N_{i,j}}{N}$

*for each category of age (i) & sex (j)*
*ratio between more (3) & less (1) educated*
*weighted by sex & age category*

\_\_\_\_\_  
 measure inequality between extreme education groups at equal age and sex category

# Model Evaluation

3 objectives to minimize :

**Obj. 1.** : MSE sum for **random** scenario

$$\sum_{i \in (2002, 2008)} MSE_i$$

**Obj. 2.** : MSE sum for **mobility** scenario

**Obj. 3.** : The difference between social inequality in mobility scenario and in simpler scenario

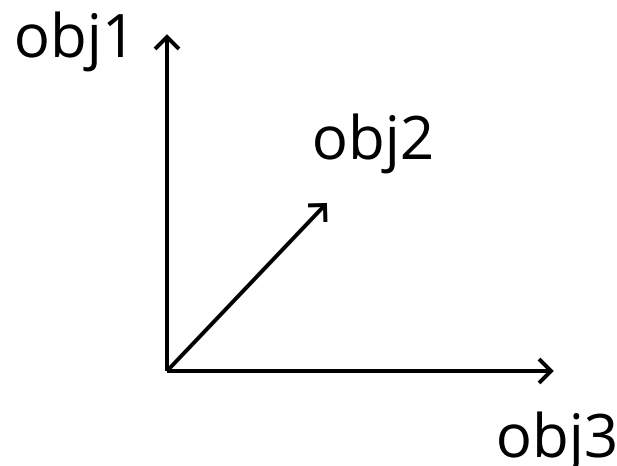
$$\Delta(SI_{random}, SI_{mobility})$$

Exceptionation ?

min obj. 1

min obj. 2

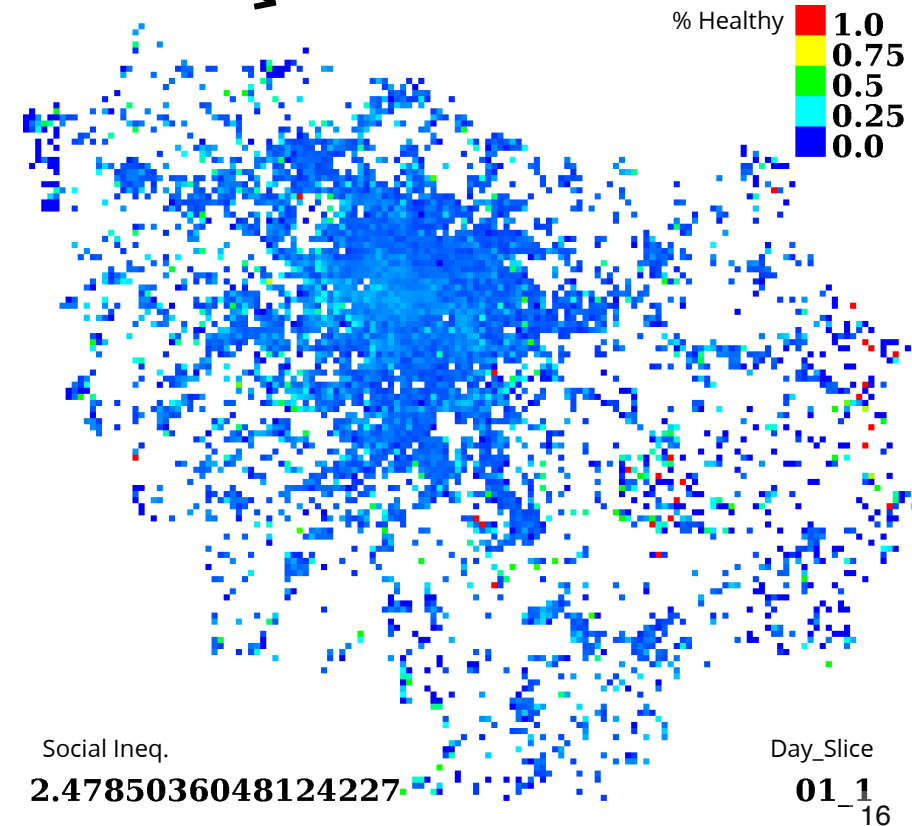
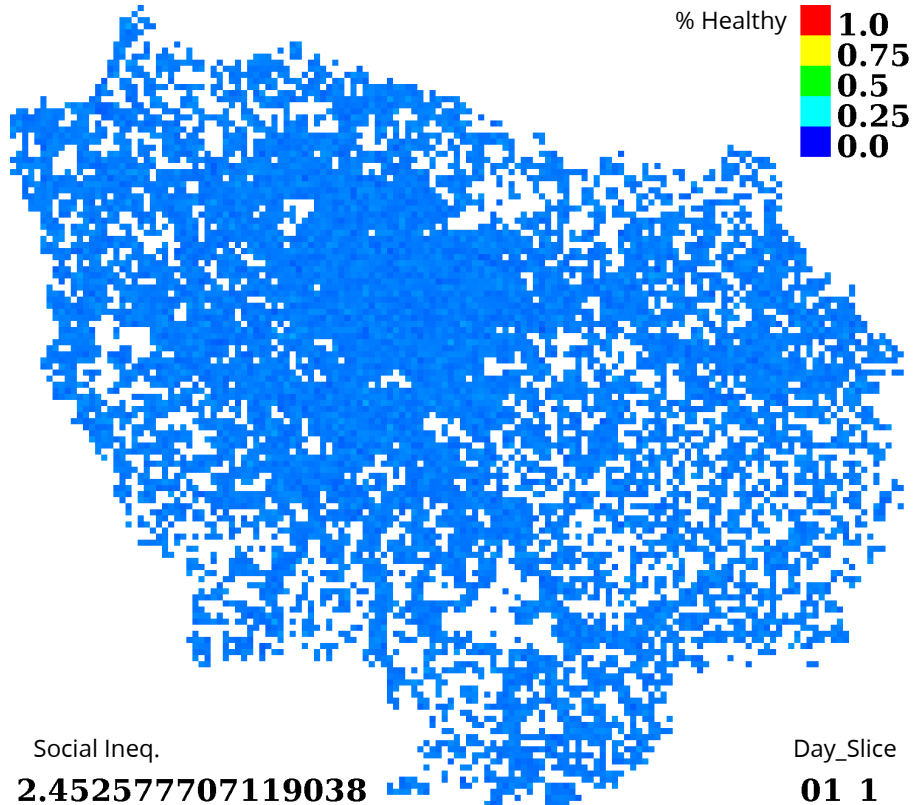
high obj. 3



# Preliminary results

Parameter	Mechanism	Value
Interaction	Spatial Interaction	0,5
Reward	Behaviour-Opinion	0,5
Inertia	Opinion-Behaviour	0,5
Switch Proba	Opinion-Behaviour	0,5
Constraint	Opinion-Behaviour	0,2

	Random locations	Survey-based locations
Night only (ie. residence)	<b>Scenario 1</b>	
Night & day		<b>Scenario 4</b>



# Conclusion & Perspectives

An original approach in (health) geography

An inter-disciplinary team with challenges in each domain :

- thematic point of view
- data analysis : EGT, nutrition, etc.
- in software engineering : ~ 8 millions moving agents !
- in exploration : High Performance Computing with dedicated evolutionary algorithms
- in epistemology : Validation of realistic model ?

# Thank you!

**Présentation**

Modèles simu → individus de l'espace pour comprendre comportements humains (CS)

au hasard? spatiale + spécifique

intro: Traditionnellement, Espace/Territoire repris soit trop abstrait, soit trop 1.1

↓

Espace & interactions localisées

↓

Space Matters ⊕ Population synthétique

↓

Place Matters & interactions Rapport individus & territoire avec plus (H) localisation + temporalité

INTEO en jeu méthode ABM SMS \* en jeu thématique

↓

Objets ↓

⑤ Nutrition Présentation Q? Données

↓

Choix Modèle

↓

Espace \* INSEE

• Residence

• EGT Mobilité

↓

scénarios

↓

⑤ Effets lieux: Souvent \* statiques & sans mobilité ni simultanés

- scolaire
- vote
- santé
- économique

**Représentation Territoires dans les modèles de simu**

Modèle

↓

Population

↓

Op.

↓

Comp.

scénario

↓

contraintes

↓

1 step = 1 an + critères eval emplo

↓

Résultats → attentes / objectifs \*

↓

Carton Survey

↓

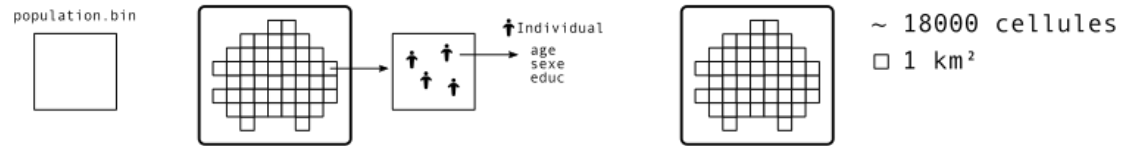
Local. Active

↓

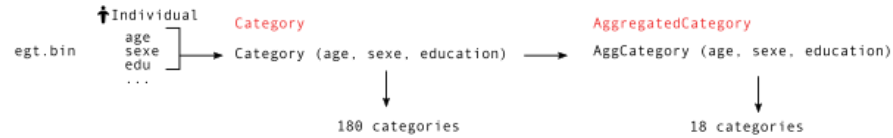
\* Distribution ABM \*

Calo: Sum

# Bonus 1: Synthetic Population Generation

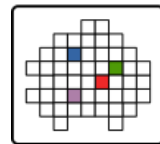


Transform EGT category to Agregated harmonized category

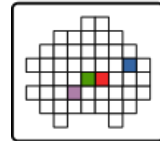
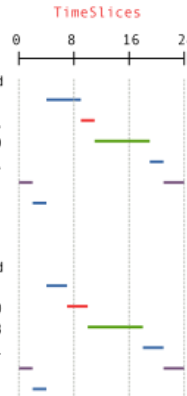


Residence  
Loisir Jour  
Travail  
Loisir Nuit

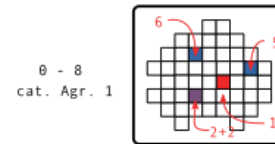
overlapping FLOW by TimeSlices, by AggCat on Cell



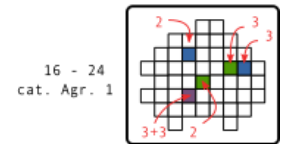
Flow	AggCat id	lieu	start	end
	(2.1.3) 1	R	4	9
	(2.1.3) 1	LJ	9	11
	(2.1.3) 1	T	11	19
	(2.1.3) 1	R	19	21
	(2.1.3) 1	LN	21	2
	(2.1.3) 1	R	2	4



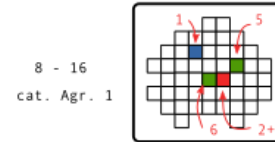
	Cat id	lieu	start	end
	(2.1.3) 2	R	4	7
	(2.1.3) 2	LJ	7	10
	(2.1.3) 2	T	10	18
	(2.1.3) 2	R	18	21
	(2.1.3) 2	LN	21	2
	(2.1.3) 2	R	3	4



0 - 8  
cat. Agr. 1

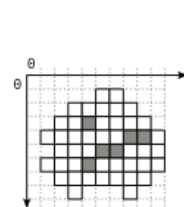


16 - 24  
cat. Agr. 1



8 - 16  
cat. Agr. 1

list moves by TimeSlices, by Cell, by AggCat



cat. 1 Agr. -	Move (dest,poids)
0 - 8	(((4,3),6), ((8,4),5), ((4,6),4), ((6,5),1))
8 - 16	(((4,3),1), ((5,5),6), ((7,4),5), ((6,5),4))
16 - 24	(((4,3),2), ((8,4),3), ((5,5),2), ((7,4),3), ((4,6),2))

cat. 1 Agr. à Cat 18 Agr.	Move (dest,poids / sum-slice)
0 - 8	16 + ... = sum-slice1
8 - 16	16 + ... = sum-slice2
16 - 18	12 + ... = sum-slice3

# Bonus 2: Formal Model

$$influence\_partner_{i,j,c} = opinion_{j,c}$$

$$influence\_cell_{i,c} = \frac{n\_healthy\_neighbours_c}{n\_all\_neighbours_c}$$

$$rewardedOpinion_{o_{i,t}} = opinion_{i,t} \quad \text{if } i \text{ is unhealthy at time } t$$
$$\min(1, (1 + healthyDietReward) * opinion_{i,t}) \quad \text{otherwise}$$

$$newOpinion_{o_{i,t}} = inertiaCoefficient \times rewardedOpinion + (1 - inertiaCoefficient) \times$$
$$(interpersonalInfluence \times influence\_partner_{i,c} +$$
$$(1 - interpersonalInfluence) \times influence\_cell_{i,c})$$

$$y_i = maxProbaToSwitch - n_i * constraintStrength$$

$$x_i = f(y_i, o_i) = \max(0, y_i * (2 * newOpinion_i - 1)) \quad \text{if } i \text{ is unhealthy at time } t$$
$$\max(0, y_i * (-2 * newOpinion_i + 1)) \quad \text{if } i \text{ is healthy at time } t$$

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$i$  = agent

$c$  = cell

$n_i$  = number of constraints of agent  $i$

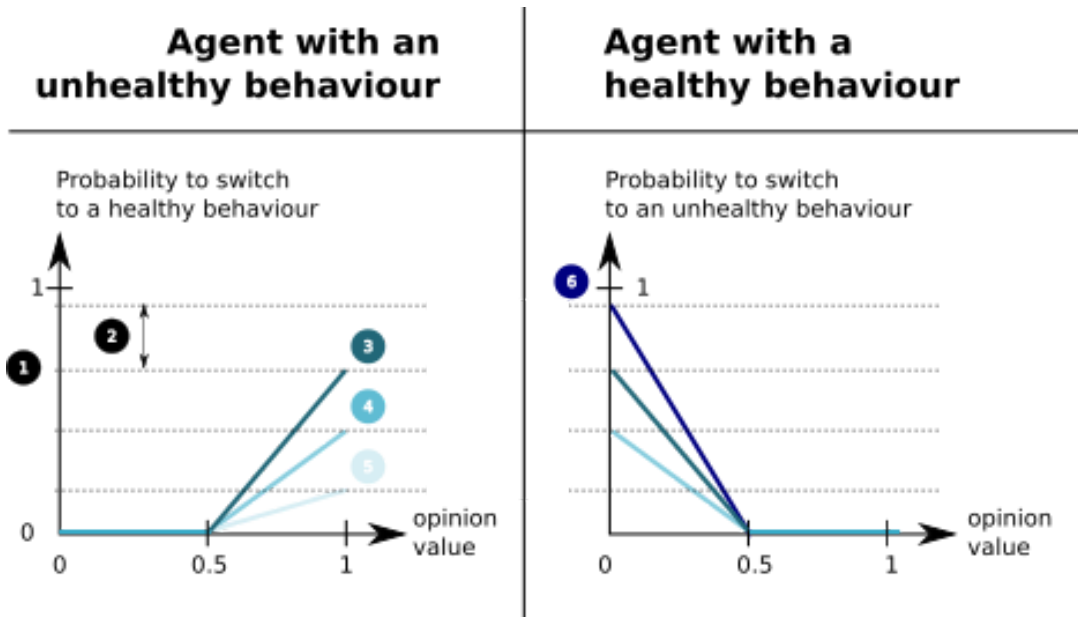
$j$  = interacting partner

$x_i$  = switch probability

Free parameter



# Bonus 3: Switching mechanism



## Parameters of the model

- 1 maxProbaToSwitch
- 2 constraintStrength

## Opinion value scale



## Alternative functions for categories of agents

- 3 Agent with no constraint (or 1 slowing + 1 accelerating constraints)
- 4 Agent with 1 slowing constraint
- 5 Agent with 2 slowing constraints
- 6 Agent with 1 accelerating constraint