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Simulating the impact of cognitive biases on the mobility transition*

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Abstract. Climate change is becoming more visible, and human adaptation is required urgently to prevent greater damage. One particular domain of adaptation concerns daily mobility (work commute), with a significant portion of these trips being done in individual cars. Yet, their impact on pollution, noise, or accidents is well-known. This paper explores various cognitive biases that can explain such lack of adaptation. Our approach is to design simple interactive simulators that users can play with in order to understand biases. The idea is that awareness of such cognitive biases is often a first step towards more rational decision making, even though things are not that simple. This paper reports on interactive simulators of potential factors of resistance, and illustrates their explanatory power on various scenarios. These simulators can be played online, with the goal to provide users with food for thought about how mobility could evolve in the future. Work is still ongoing to design a user survey to evaluate their impact.

Keywords: Mobility · Agent-based modelling · Cognitive biases.

1 Introduction

In recent decades, the average daily distance traveled by the French population has increased considerably (5 km in the 1950s vs 45 km in 2011 [23]), as has the number of personal cars (11,860 million in 1970 [4] vs 38,3 million in 2021 [7, 13]). The evolution of mobility is therefore an essential question, for the climate crisis but also for public health, knowing the negative impact of sedentary lifestyle [4], road accidents, or air and sound pollution [19]. Indeed, each year 40000 deaths are attributable to exposure to fine particles (PM2.5) and 7000 deaths for nitrogen dioxide (NO₂), i.e. 7% and 1% of the total annual mortality [11]; this report also concludes that the 2-month lockdown of spring 2020 in France saved 2300 and 1200 deaths by reducing exposure to particles and nitrogen dioxide respectively. This shows that public policies and individual behaviour changes can have an impact on public health, for instance setting temporary cycling lanes during the pandemics [20]. However, aside from such emergencies, public policies take time

* Supported by the French National Research Agency (ANR), project SWITCH.

to set up and are not always well accepted. Many of these temporary cycling lanes were thus returned to cars after the lockdowns [3].

Indeed, despite feeling more and more concerned about climate change, citizens are often reluctant to constraining public policies that could slow it down. As a result, mobilities evolve very slowly, for instance in France a large proportion of commuting is still done by car, even for very short journeys [6]. Some reasons for this inertia are well-known: lack of alternatives (limited public transports, cost of newer cars...); difficulty of changing habits [5, 16]; or individualism [10]. Yet another possible explanation is the influence of cognitive biases in human reasoning: [12] show that people tend to “stick” to the car, even when it is more costly than metro or bus, and explain this deviation from rational behaviour by the influence of cognitive biases.

Cognitive biases are heuristics that facilitate reasoning in situation of uncertainty or danger [22]. They are often useful, but can also lead to mistakes with potentially serious consequences [21]. They were shown to be important to consider when simulating human evacuation in wildfires [1], to inform buildings safety design and procedures [15]. Research shows that becoming aware of one’s biases can help overcoming them in decisions [18]; they thus propose debiasing interventions (game or video) and show their positive impact. We suggest that interactive simulation could be used as another debiasing intervention; indeed it has been successfully used previously to explain various complex phenomena, for instance the mechanisms of the pandemic [8].

We propose to use interactive simulators to **raise awareness about cognitive biases** and their influence on our mobility decisions in the face of climate change. This article describes agent-based simulators illustrating how two cognitive biases (reactance and halo) can explain resistance to the adoption of soft mobility. A serious game has been proposed previously to simulate the role of habits in mobility decisions [2], but it is implemented with the GAMA simulation platform and cannot be played online; it is also more complex and based on realistic geographical data from an actual town. On the contrary, our simulators are intended to be played online without guidance with a philosophy more similar to that of the CovPrehension collective [8]. We therefore implemented them in Netlogo [24] and willingly kept them relatively simple to facilitate exploration and discovery. This work is part of a larger project aiming at simulating the transition of cities towards more sustainable mobility. All simulators described in this paper are already available to play online, but have not yet been evaluated.

2 Reactance bias in mobility

Reactance is defined as a tendency to react inversely to persuasion attempts when they are felt as coercive. The individual might thus strengthen their non-compliant opinion or intention in order to assert their undangered free-will. Persuasive messages can therefore agonize their receivers and have an effect contrary to that intended. This bias could cause mixed reactions to communication campaigns in favour of soft mobility or ecology: part of the population might get

angry at these attempts to force them into a constraining behaviour, and react by asserting their right to behave as they want.

2.1 Conceptual model

Opinion diffusion model. Our conceptual model is interested in how agents react to an official message. We consider opinions about one single fact (for instance “it is necessary to commute by bike rather than car”) modelled as a real number on a continuum from 0 to 1 representing the degree of agreement about that fact. Each agent has its own opinion about this fact, that differs from the other agents’ opinions.

When 2 agents meet, they “share” their opinions, and as a result, each agent tends slightly towards the opinion of the other. Concretely, we compute the new opinion as an asymmetrical average where one’s own opinion weighs more (exact weight value configurable in the code) than the received opinion. If letting the agents interact for a while, resulting opinions tend towards a compromise in the middle of the continuum.

Confirmation bias. In a first model, agents can be endowed with a confirmation bias. In that case, when interacting, they only adjust their opinion if the other agent agrees with them; on the contrary they discard opinions that do not confirm theirs. As a result, opinions can only be reinforced, and tend towards the extremes. After a number of interactions, two groups of opposite opinions emerge, the population is polarised.

Reactance bias. Based on this basic model of opinion diffusion, we have designed a new model where an official messenger broadcasts a persuasive message (such as a campaign for ecology, soft mobility, or physical activity for health) to the population. When agents meet the messenger, they are confronted to its opinion.

Additionally, agents can be susceptible or not to the reactance bias. Non-susceptible agents will get gradually persuaded by the message, as above. Susceptible agents might trigger the reactance bias based on a distance condition: when exposed to another opinion, the agent evaluates its distance with its own current opinion. If this distance is small enough, the new opinion is acceptable, and the agent tends towards it (asymmetrical weighed average, as above). On the contrary, if this distance is over a certain (configurable) threshold, the agent activate the reactance bias: in this case it adjusts its opinion away from the official message, reinforcing its disagreement.

Message targets. Based on this model, for given message content and reactance triggering threshold, agents can fall in one of three different categories:

- Already convinced agents, whose opinion match the content of the message;
- In-target agents, or positive target: they are not convinced yet, but can still be. Either they are not susceptible to the reactance bias, or they are but the message falls close enough to their own opinion to be acceptable and not trigger the bias.

- Off-target agents, or negative target: they can never be convinced with the current message, because they are susceptible and their current opinion is far enough to trigger reactance bias. They will therefore react in the opposite direction.

2.2 Simulator

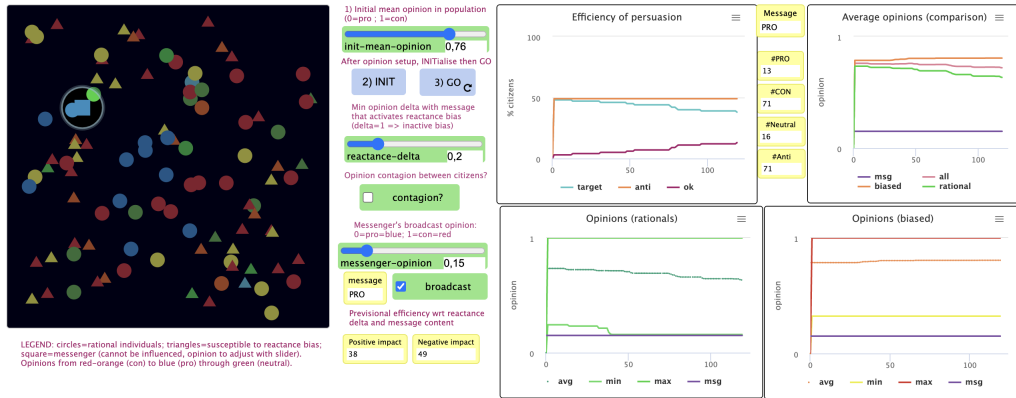


Fig. 1. Interface of the reactance bias simulator

Population initialisation The simulator¹ interface is shown in Figure 1. The user can choose the desired initial average opinion in the population (0-1 range) by using a slider. When pressing the “INIT” button, the population is created with opinions distributed on a Gaussian centered around that mean, and a variance of 0.25. Opinions are kept bounded between 0 and 1 at all times. Each agent’s opinion is visually represented by a colour on a gradient between blue (value 0) and red (value 1), with undecided agents ranging from yellow to green.

Each agent has another attribute determining if it is sensitive to the reactance bias. This is visualised by their shape: circle agents are “rational”, *i.e.* they do not have the reactance bias; triangle agents are susceptible to the bias, *i.e.* they might activate it when the conditions are fulfilled (message too far from what they can accept). Once the population is created, the user can start the simulation with the “GO” button: the agents then start moving around the window randomly, and can meet other agents or the messenger (represented by a square). The simulation stops automatically when the broadcast message has no impact anymore (*i.e.* its positive target is empty).

¹ <https://nausikaa.net/wp-content/uploads/2023/02/reactance-v2-en.html>

Input parameters At runtime, the user can modify a number of parameters, regarding both the message and the mechanics of opinion diffusion. First, they can use a slider to choose the value (on the opinion continuum) of the message and use a switch to suspend or resume broadcast. The messenger is shown as a coloured square (same opinion colour gradient) while broadcasting, and hides when broadcast is suspended.

The mechanics of opinion diffusion can be influenced in two ways. First, a contagion switch allows to decide if standard agents (other than the messenger) also share their opinion with each other. If enabled, agents can be influenced both by the messenger and their neighbours. If disabled, only the messenger can influence the agents' opinions. Second, a slider allows to configure the opinion delta that triggers the reactance bias (for the triangle susceptible agents). Concretely, if the value is set to 1, it means that only opinions distant by more than 1 from one's own opinion will trigger the bias, so it is in fact disabled. The smaller the value, the easier it is to activate the bias, and the harder it is for the messenger to persuade without agonising its target.

Outputs and feedback The interface displays useful information in various forms:

- When the user selects the opinion delta triggering the bias, and the content of the message, two monitor boxes update in real time the resulting size of the targets: the positive target are those agents who can be persuaded, while the negative target is made up of those agents who will react reversely due to the reactance bias. The user should try to minimise the size of the negative target so that the message does not have the inverse effect. When the size of the positive target reaches 0, the message has no impact anymore and the simulation stops.
- The top left graph illustrates the efficiency of the persuasive message. The blue line is the percentage of agents that are in the target; it decreases with time as these agents become convinced. The pink line is the percentage of convinced agents; it increases with time as the messenger persuades more agents. Finally the orange line is the percentage of agents that cannot be convinced; it does not change as long as the user does not modify either the message content or the reactance threshold.
- The top right graph compares the official message (purple line) with the average opinion of three groups: the total population (pink line), the rational population not susceptible to reactance (green line), and the biased population (orange line).
- At the bottom, two graphs further detail the opinion dynamics in the rational population (left) and the biased population (right), by showing the minimal and maximal opinion in addition to the average. This allows to see the full range of opinions in each group, and how homogeneous they are. If the persuasion is efficient, these lines should converge towards the message.

2.3 Scenarios

We have run some scenarios demonstrating explanatory power of our simulator.

Scenario 1: baseline We initialised the population with an average opinion of 0.8, and the message with a content at 0.2, so quite distant. We set the reactance delta to 1 to disable the bias, and toggle off the opinion contagion between agents to isolate the effect of the messenger. We then start broadcast and let the messenger move around and try to persuade citizens. The opinion dynamics graph (Figure 2) shows that all average opinions gradually converge towards the official message.

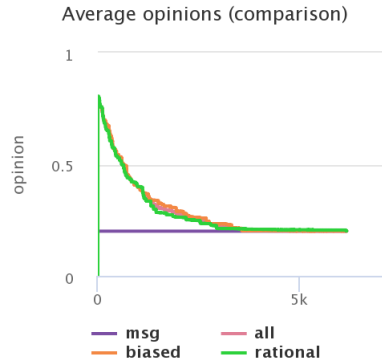


Fig. 2. Average opinion dynamics without reactance bias: convergence

Scenario 2: reactance We initialised the population and messenger with the same values as above, and still toggled contagion off, but now set the reactance delta to 0, so that all susceptible agents trigger the bias. As a result, we observe that the two groups (rational vs biased) react differently (Figure 3). The average rational opinion converges to the message while the average biased opinion diverges away from it.

Scenario 3: gradual persuasion We now set the initial opinion to 0.75 and the reactance delta to 0.25 so that only some agents trigger the bias. The idea here is that the messenger will try to progressively bring the average opinion to 0.25 again, but in order not to agonize citizens who disagree, it will start with a softer message of 0.5 and progressively change the content towards 0.25. At 0.5, some biased agents are close enough to let themselves be persuaded, while the most extreme opinions will become even more extreme. As the average opinion becomes close enough to 0.5, the messenger can decrease the content of the message to 0.4, then 0.3 and finally 0.25. As shown on Figure 4, the average opinion diverges less since only some agents trigger the bias while some others are drawn gradually towards the official message.

This is in line with classical persuasion strategies of “putting a foot in the door” or inciting people to doing small gestures rather than requesting a big

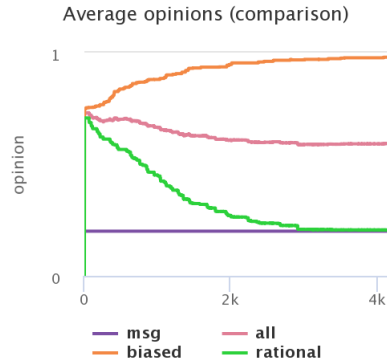


Fig. 3. Average opinion dynamics with reactance bias: divergence

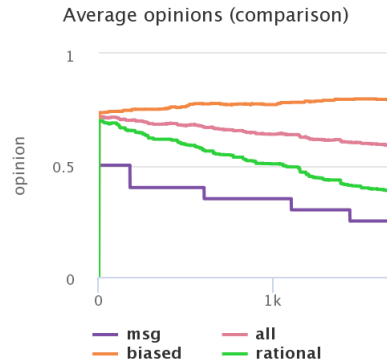


Fig. 4. Progressively adapting the content of the message to avoid triggering reactance

change that is more likely to discourage or agonize them. It applies for instance to energy saving gestures to fight global warming (switch your devices off rather than in standby); mobility change (take your bicycle once a week); or resuming physical activity (take the stairs instead of the lift, get out of the bus one stop early to walk, etc).

Scenario 4: inter-individual contagion In the first scenarios, there was no contagion between citizens, so that only the messenger would influence other citizens. If we now toggle contagion on, the result is much more variability in opinions, since citizens can be influenced by their neighbours (whatever their opinion) while the messenger is away in another part of the window. If there are many biased agents with very strong opposite opinions, they might cancel the official message faster than it can be spread.

This is similar to the effect of social networks, where people can always connect to others who also disagree with the official speech, thus reinforcing their own opposition, until they might fall in a spiral of conspiracy theories. It forces the authorities to find efficient communication strategies to fight fake news and disinformation.

2.4 Discussion

In conclusion, this simulator shows that the further a broadcast message is from their current beliefs, the more individuals risk activating a reactance bias that consists in asserting their free will by adopting the action contrary to the recommendations (*e.g.* “I will commute by car if I want”). The recommendations must be more progressive so as not to antagonize citizens.

This is in line with classical persuasion strategies of “putting a foot in the door” or inciting people to doing small gestures rather than requesting a big change that is more likely to discourage or agonize them. It applies for instance to energy saving gestures to fight global warming (switch your devices off rather than in standby); mobility change (take your bicycle once a week); or resuming physical activity (take stairs instead of lift, get out of the bus one stop early to walk, etc).

The simulator also shows the difficulty of fighting against online disinformation and fake news (with the opinion contagion option). The idea is that it is dangerous to lose citizens who will build increasing distrust and resentment towards official communication, affecting all further interactions.

It could be gamified by letting the user create several messengers, counting the total time and resources invested, and matching it to results in terms of percentage of the population actually convinced.

Finally, the way we modelled reactance as triggered by a distance between opinions could be debated. In particular, another idea would be to model reactance to repetition: the more a message is repeated (echo chamber) the more it might trigger adverse reactions from people who get tired of it.

3 Halo bias in mobility

The halo bias consists in ignoring certain negative aspects in the evaluation of an object, when they are inconsistent with a positive first impression. This bias thus allows to preserve that position impression. With respect to mobility, it could thus lead to ignoring new inconvenients of one’s usual mobility mode, for instance an increase in petrol price or traffic jams, in order to avoid a costly questioning of one’s habits.

3.1 Conceptual model

Rational multicriteria decision model The model is based on an existing model of rational multi-criteria evaluation of modes of mobility [14] in which 4 modes

of travel (car, bike, bus, walking) are evaluated on the basis of 6 criteria (time, cost, comfort, safety, ecology, praticity) and their priority for each individual. Concretely each individual is defined with their personal priorities for the 6 criteria (for instance one individual can be very focussed on ecology but not care about comfort so much, while another will have a big priority on time but not focus on price too much). These priorities are supposed to be static.

Each mode is marked on each criteria depending on the context (town setting, weather...). For instance bicycle and walking are always very ecological while car is not at all; their safety depend on cycling lanes or speed limit; their comfort depend on temperature while car or bus are always more comfortable; etc. These marks can evolve with the evolution of the environment (new public policies, time of day, weather...).

Each agent then computes the global mark of each available mobility, as a weighed average of the mark and priority of all 6 criteria. This ensures that different agents, with different priorities, might rate the same mobilities differently in the same context. Agents are fully rational, and choose the mobility mode with the best global mark. As a result, when the urban planning evolves (*e.g.* new cycling lanes, petrol price increase), citizens adapt their mobility choice.

Halo bias model Our model enriches this rational decision model with the halo bias. Concretely, agents have 6 priorities for the 6 criteria, and can be susceptible to the halo bias or not. Non-susceptible agents use the rational decision algorithm as described above. Susceptible agents might trigger the halo bias when re-evaluating their current mobility. The triggering condition is based on the distance between the **value** of this mobility on a criteria, and the **priority** of that criteria for the agent. If this distance is bigger than a certain delta, then the agent activates the halo bias and ignores this criteria altogether, by setting its priority to 0 when computing the new mark. This leads agents who have adopted a certain mode of mobility to ignore the criteria on which their current mode is poorly rated, in order to maintain a positive overall view. The idea is that it is less costly to question one's priorities than to change one's mobility mode. The halo bias does not influence the evaluation of the other modes.

Finally, agents also have a level of satisfaction or happiness, computed as the mark of their current mobility. It is expected that rational agents will switch to a different mobility when they grow unhappy with theirs, while biased agents will ignore the negative criterion in order to restore satisfaction without having to change mobility.

3.2 Simulator

Initialisation The initial urban planning (scores of the 4 modes on the 6 criteria) is empirically initialised to values matching a standard town: bike and walk are more ecological than bus, while the car is not at all; car and bus are more comfortable (eg less exposed to the weather) than bike or walk; walk is the slowest mode; etc. The exact initial values are visible and configurable in the code.

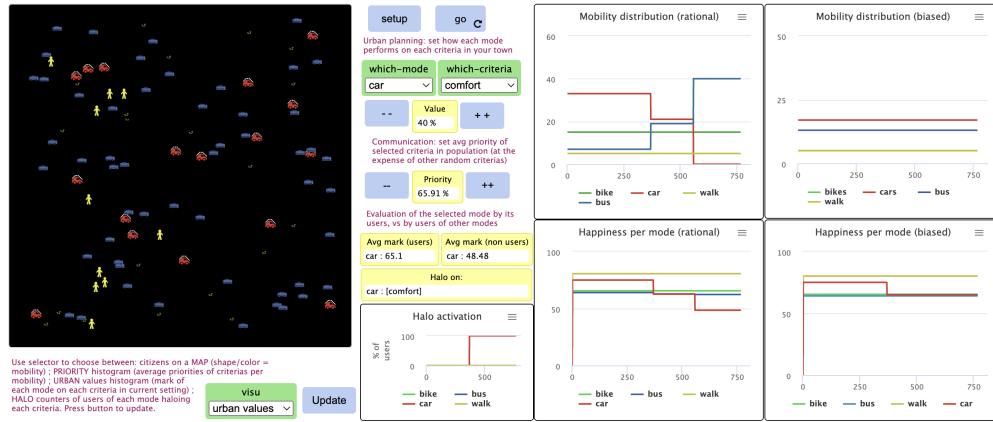


Fig. 5. Screenshot of the halo bias simulator interface

The population is then initialised with a believable distribution of citizens on the 4 modes (50% cars, 20% bikes, 20% bus, 10% walk), and their initial priorities are set so that their rational choice in the current urban setting is indeed their chosen mode, but with some random variability so that not all users of each mode have exactly the same priorities. Again, this is configurable in the code, although our goal to visualise the impact of a bias does not require this distribution to match reality exactly.

Finally, half agents are susceptible to the halo bias, while the other half is not. The triggering threshold is set to 15: this means that when the score of the current mobility mode on a given criterion (rated between 0 and 100%) falls at least 15 points below the priority of that criterion for the agent (also rated between 0 and 100%), this agent will activate the halo bias and start ignoring this criterion altogether. The halo bias does not influence the evaluation of the other available modes, which are rated rationally.

User interactions The interface (Figure 5) of the simulator² allows the user to:

- Modify the **urban planning** of the virtual town, by directly setting the score of each mobility mode on each criterion (what a different urban design would do, such as increasing the frequency of buses or decreasing the maximum authorized speed on roads). All changes are possible in the interface, even though some of them are semantically impossible (*e.g.* no urban policy can make walking not ecological), so it is down to the user to choose wisely.
- Modify the **priority** of each criterion in the population (what a communication campaign could do). Again, reality is not that simple, no advertising campaign can ensure that ecology suddenly gets maximal priority for everybody, but this option allows to explore what could happen as a result.

² <https://nausikaa.net/wp-content/uploads/2023/01/switch-halos-en.html>

Outputs and visualisation The interface has three parts. On the left, a dropdown menu below the main window allows the user to choose between four visualisation options. On the main map, the agents are shown with the shape and color indicating their mobility mode (bicycle - green; bus - blue; walk - yellow; car - red). Agents are also surrounded by a white halo when they activate the halo bias. The other options are various histograms to visualise at a glance: **values** of each mode on each criteria in the current urban setting, showing which mobility is favoured; average **priorities** of each criteria among users of each mode, illustrating the different user profiles; counters of users of each mode putting each criteria in **halo** (and thus ignoring it), allowing to spot the "weak" criterias for each mode (discrepancy between value and priority).

On the centre, the user can select a mode and a criteria in the dropdown menus, which automatically displays the up-to-date **value** of that mode on that criteria in the current town (then editable with the buttons), as well as its up-to-date mean **priority** in the population. Under the parameters, additional monitors also display: the average mark for that mode among its users; its average mark among users of other modes; and the list of criteria put in halo by its users (details can be seen on the halo histogram on the left). These two marks can differ because users of different modes have different priorities (which can be visualised on the priority histogram), but also because of the halo bias activated by biased citizens when evaluating their own mobility mode.

Finally, on the right of the interface, 4 graphs display the evolution of mobility distribution (top) and average happiness (bottom) of rational (left) vs biased (right) users of each mode (one colour line per mode). This provides the user with feedback about the impact of their actions (urban planning or communication) on these indicators.

3.3 Scenarios

Various scenarios can be tested to illustrate the potential of this simulator.

Urban planning to encourage soft mobility. We start the simulation with the default settings, then use the urban planning buttons to progressively decrease the score of car on the time criterion (meaning that the travel time by car increases). This simulates the current trend in many towns where more space is being dedicated to bicycles or buses at the expense of car facilities (driving lanes, parking spots), which increases traffic jams or time to park. The same effect could also result from a slower speed limit (30 instead of 50 km/h) that slightly increases the total trip time.

As a result of the new setting, rational car drivers decrease their mark. They may then switch to another faster mode (such as the bus or bicycle) depending on their other priorities. We indeed observe an increase in the modal part of bus, which is closest to the priority profile of car drivers, since it preserves comfort. On the contrary, biased car drivers activate a halo on the now negative time criterion, to preserve their positive opinion of car. They continue driving

to work, and their satisfaction even increases as a result of ignoring the most negative aspect.

Ecological crisis. We start the simulation with the default initialisation again, and this time use the communication buttons to increase the average priority of ecology for the population. This is meant to simulate the current energy shortages and ecological focus in European media. The resulting mobility switch is shown in Figure 6. Among the rational citizens, the first change happens when citizens usually commuting by bus switch to the more ecological bicycle, or to a lesser extent to walking (being much slower, it only attracts citizens with a very low priority for time). Car drivers had a lower priority for ecology at the start, so it takes longer before ecology actually impacts their decisions. When it does, they switch to the bus, which better fulfills the ecological requirement, while maintaining some level of comfort and safety (which are the next most important criteria for them).

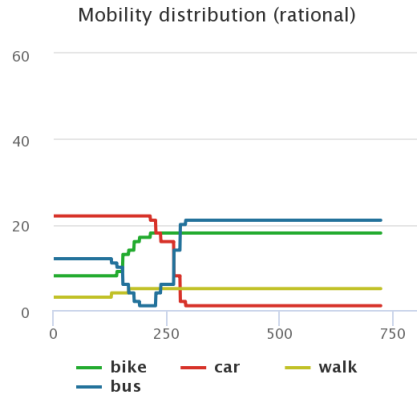


Fig. 6. Rational mobility switch after ecology awareness campaign

Among biased users, things are a bit different (see Figure 7). Car drivers have the biggest gap between the high priority of ecology and its low value for their mode. As this gap grows bigger, it becomes more and more obvious to them that their current mode is not in agreement with their new priority. This gap grows to the point when it triggers the halo bias among all susceptible car drivers. As a result, they drop the ecology criterion in their evaluation, maintain a high satisfaction with the car, and keep driving. This might feel counter-intuitive initially, because increasing the priority of ecology leads some citizens to eventually ignore it, but it is in line with the mechanics of the halo bias. On the contrary, most users of other modes do not trigger the halo bias, because their mode mark on ecology is close enough to their priority for ecology (which was already high). Therefore, they keep using their mode if it is ecological

enough, or switch to a better mode: we observe in particular that bus users switch to bike or walk.

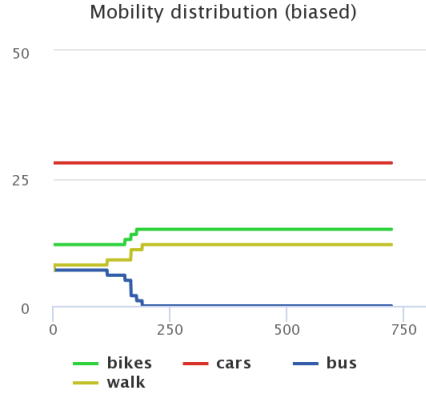


Fig. 7. Biased mobility switch after ecology awareness campaign

3.4 Discussion

Realistic initial values. We have initialised the town and the population with believable but empirical values (initial urban planning and priorities). Real statistics could be found (for instance from INSEE for France) but it is not the goal of this work to get to that level of detail. Besides, exact figures differ for different towns or different time periods. The focus of this simulator is to illustrate the mechanism and impact of the halo bias, and as such it does not require to calibrate these values that precisely.

Concrete actions. We have investigated the impact of “positive” communication, trying to reinforce the priority of ecology for the population. But cars still benefit from a very positive global opinion, as conveyed by advertisement: car manufacturers often advertise their cars as related to positive values such as autonomy, safety, or adventure. It would be interesting to also study actions to restrain such (often misleading) communication.

User actions are still very abstract. The simulator could be made more playful and immersive by matching the abstract actions (increasing the value or priority of a given criteria) to actual concrete actions modifying public policies or communication (*e.g.* “advertise about road safety”, “raise awareness about climate change”, “make the town centre pedestrian only”, “make public transport free”, “increase petrol price”...). However it is hard to be exhaustive when listing such actions, and several actions can have the same concrete effect on underlying values, so the current interface offers more expressive and abstraction power.

Cognitive biases and coping strategies. Our agents can use two strategies to restore cognitive consonance between their mobility and their priorities: modifying their choice of mobility, or their priorities (putting a halo on the negative criteria). This is similar to the coping strategies that are activated by individuals when they feel negative emotions. According to Lazarus [17], coping strategies against negative emotions fall into two categories: either they address the stimulus itself when possible (problem-focussed coping) or they address the individual's evaluation of the stimulus when it is not controllable (emotion-focussed coping). For instance, "denial" is a strategy often triggered when someone is faced with bereavement: the negative stimulus cannot be controlled and is too intense, so the individual might react by denying its reality and refusing to believe that their relative actually died. Here agents who deal with a cognitive dissonance between their current mobility choice and their growing ecological priority might also feel that they have no control on the problem (choice of mobility), because they (believe that they) depend on their car (there might indeed be no alternative, or it would be too costly). Since they cannot or do not want to resolve the gap by changing mobility, a less costly strategy consists in denying the importance of ecology. As a result, they reappraise their current mobility without that criterion, which restores their positive opinion of it, and their satisfaction.

4 Conclusion

This paper introduced interactive simulators of the impact of cognitive biases on mobility inertia despite climate change. These simulators are published online and can be played autonomously by users. Even though we illustrated their explanatory power on various scenarios, we have not yet conducted a real evaluation. Short-term future work will be dedicated to evaluating the actual impact of each simulator on users via an online survey. Psychological validity will be harder to assess, since human behaviour is subject to interpretation, and many different causes can explain the same result.

It is therefore important to reassert that the goal of our simulators is not to teach any definitive explanation to mobility inertia, but rather to give users food for thought, and let them explore scenarios. Besides, in the absence of debriefing we cannot expect much learning to happen [9]. Making people think however is just as essential in these times of constant change, with new mobilities emerging and requiring adaptations. Another important aspect of the mobility transition that requires thinking is equity: it is easy to forget people along the way, who cannot afford the transition for various reasons (limited fitness, budget, or time). The goal of these simulators and the overarching project is to support prospective thinking about what the mobility of tomorrow could look like. Imagining a better future could be the first step before making it a reality.

References

1. Adam, C., Gaudou, B.: Modelling human behaviours in disasters from interviews: application to melbourne bushfires. *Journal of Artificial Societies and Social Simulation* **20**(3) (2017)
2. Adam, C., Taillandier, F.: A serious game to raise awareness about the impact of mobility habits. In: *GAMA days* (2022)
3. Barbarossa, L.: The post pandemic city: Challenges and opportunities for a non-motorized urban environment. an overview of italian cases. *Sustainability* **12**(17), 7172 (2020)
4. Biswas, A., Oh, P.I., Faulkner, G.E., Bajaj, R.R., Silver, M.A., Mitchell, M.S., Alter, D.A.: Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Annals of internal medicine* **162**(2), 123–132 (2015)
5. Brette, O., Buhler, T., Lazaric, N., Maréchal, K.: Reconsidering the nature and effects of habits in urban transportation behavior. *Journal of Institutional Economics* **10**(3), 399–426 (2014). <https://doi.org/10.1017/S1744137414000149>
6. Brutel, C., Pages, J.: La voiture reste majoritaire pour les déplacements domicile-travail, même pour de courtes distances. *Insée Première* **835**, 19 (2021), <https://www.insee.fr/fr/statistiques/5013868>
7. CCFA: L'industrie automobile française, analyse et statistiques 2019. Tech. rep., Comité des constructeurs français d'automobiles (2019)
8. CovPrehension collective: Understanding the current covid-19 epidemic: one question, one model. *RofASSS (Review of Artificial Societies and Social Simulation)* (2020)
9. Crookall, D.: Serious games, debriefing, and simulation/gaming as a discipline. *Simulation & gaming* **41**(6), 898–920 (2010), <https://journals.sagepub.com/doi/pdf/10.1177/1046878110390784>
10. Epprecht, N., Von Wirth, T., Stünzi, C., Blumer, Y.B.: Anticipating transitions beyond the current mobility regimes: How acceptability matters. *Futures* **60**, 30–40 (2014)
11. *et al.*, S.M.: Impact de la pollution de l'air ambiant sur la mortalité en france métropolitaine. Tech. rep., Santé Publique France (2021), <https://www.santepubliquefrance.fr/determinants-de-sante/pollution-et-sante/air/documents/enquetes-etudes/impact-de-pollution-de-l-air-ambiant-sur-la-mortalite-en-france-metropolitaine.-reduction-en-lien-avec-le-confinement-du-printemps-2020-et-nouvelle>
12. Innocenti, A., Lattarulo, P., Paziienza, M.G.: Car stickiness: Heuristics and biases in travel choice. *Transport Policy* **25**, 158–168 (2013)
13. INSEE: Données sur le parc automobile français au 1er janvier 2021. Tech. rep., Ministère de la Transition Ecologique (2021), <https://www.statistiques.developpement-durable.gouv.fr/donnees-sur-le-parc-automobile-francais-au-1er-janvier-2021>
14. Jacquier, A., Adam, C.: Choice of mobility: an agent-based approach. In: *Spatial Analysis and Geomatics (SAGEO)*. pp. 127–138 (2021)
15. Kinsey, M., Gwynne, S., Kuligowski, E.D., Kinateder, M.: Cognitive biases within decision making during fire evacuations. *Fire technology* **55**(2), 465–485 (2019), <https://link.springer.com/article/10.1007/s10694-018-0708-0>
16. Lanzini, P., Khan, S.A.: Shedding light on the psychological and behavioral determinants of travel mode choice: A meta-analysis. *Transportation research part F: traffic psychology and behaviour* **48**, 13–27 (2017)

17. Lazarus, R.S., Folkman, S.: Stress, appraisal, and coping. Springer publishing company (1984)
18. Morewedge, C.K., Yoon, H., Scopelliti, I., Symborski, C.W., Korris, J.H., Kassam, K.S.: Debiasing decisions: Improved decision making with a single training intervention. *Policy Insights from the Behavioral and Brain Sciences* **2**(1), 129–140 (2015). <https://doi.org/10.1177/2372732215600886>
19. Pastorello, C., Mellios, G.: Explaining road transport emissions: A non-technical guide. Tech. rep., European Environment Agency (2016), <https://www.eea.europa.eu/publications/explaining-road-transport-emissions>
20. Rérat, P., Haldimann, L., Widmer, H.: Cycling in the era of covid-19: the effects of the pandemic and pop-up cycle lanes on cycling practices. *Transportation research interdisciplinary perspectives* **15**, 100677 (2022)
21. Trivers, R.L., Newton, H.P.: The crash of flight 90: doomed by self-deception? *Science Digest* pp. 66–67,111 (November 1982), https://roberttrivers.com/Publications_files/T&Newton1982article-2.pdf
22. Tversky, A., Kahneman, D.: Judgment under uncertainty: Heuristics and biases: Biases in judgments reveal some heuristics of thinking under uncertainty. *science* **185**(4157), 1124–1131 (1974)
23. Viard, J.: *Éloge de la mobilité: essai sur le capital temps libre et la valeur travail*. Eds de l’Aube (2011)
24. Wilensky, U.: Netlogo. <http://ccl.northwestern.edu/netlogo/>, Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL (1999), <http://ccl.northwestern.edu/netlogo/>