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In the Leviathan Model, the average opinion is higher when vanity is weaker with lower valued agents

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Abstract. In the Leviathan model, agents form opinions about each other. During dyadic meetings, they directly influence each other, or talk about peers through gossip. Speakers highly valued by their listeners are more influential. Moreover, they are subject to a vanity process; if an agent feels undervalued, then he decreases his opinion about the despising agent and on the contrary he increases his opinion about a compliment-giver agent. This model produces several different patterns depending on the parameter values, but the average opinion is always negative whatever the emerging pattern. As a consequence, the gossips tend to be mostly negative. Since this is not in complete accordance with the social-psychology literature indicating that both mostly negative and positive gossip can be observed, we investigate the changes to operate to obtain also mostly positive gossips. We found that when the vanity process is less triggered by agents held in low esteem, the average opinion significantly increases. We check that with this modification, the model still yields the same patterns.

1 Introduction

The recently proposed Leviathan model [1] considers individuals forming and maintaining opinions about each other, including themselves through processes of opinion propagation and vanity. The opinion propagation includes a part which can be interpreted as gossiping. From its simple virtual dynamics of individual interaction emerges a collection of patterns such as “dominance”, “equality”, “hierarchy”, “elite” or “crisis”. One striking emerging effect is that in these patterns, the average opinion is always negative [1]. As a consequence, gossiping is mainly negative. At first, this sounds in accordance with the observations that gossip is more often negative [2]. But a recent study surveying a group of working nurses in a hospital shows the opposite [3]: negative gossip is quite rare in this group.

This paper aims at modifying the Leviathan model in order to get a more positive average opinion and consequently more positive gossips. With this aim, we tested two modifications of the vanity process, which, in the original model, applies with all interlocutors:

- Vanity is weaker with lower agents: An agent is subject to weaker vanity when discussing with an agent that he considers lower than himself;

- Vanity is weaker with higher agents: An agent is subject to weaker vanity when discussing with an agent that he considers higher than himself.

We found that when the vanity is weaker with lower agents, the average opinion tends to be significantly more positive. Moreover, the same patterns as in the original model are observed. Two of them show a highly positive opinion on average. However one pattern has probably been modified in deep by the change vanity process.

The paper is organised as follows. We start by a description of the dynamics and the emerging properties of the model. We describe the impact of vanity process modifications on the number of positive opinions and on the patterns. We then propose some theoretical explanations of the main result. Finally, we discuss our result and identify some complementary studies to make.

2 The model and the experimental design

The agent dynamics of the Leviathan model, inspired by Hobbes [4] and more recent studies from social-psychologists [5-10] [11] is presented in the next subsection. The following subsection describes the different patterns emerging from the interactions [1].

2.1 The Leviathan model: The agent dynamics

We consider a set of N agents, each agent i is characterised by her list of opinions about the other agents and about herself: $(a_{i,j})_{1 \leq i,j \leq N}$. We assume $a_{i,j}$ lies between -1 and +1, or it is undefined (equal to nil) if the agent i never met j and nobody has talked to i about j yet. At initialisation, we suppose that the agents never met, therefore all their opinions are undefined. When opinions change, we always keep them between -1 and +1, by truncating them to -1 if their value is below -1 after the interaction, or to +1 if their value is above +1. The individuals interact in uniformly and randomly drawn pairs (i, j) and at each encounter, we apply two processes: the opinion propagation and vanity. We follow the people's interactions considering a time range called iteration. We assume one iteration, i.e. one time step $t \rightarrow t + 1$, is $N/2$ random pair interactions (each individual interacts N times on average during one iteration).

We now describe the processes with more details.

2.1.1 Opinion propagation with highly valued agents being more influential

The strength of the propagation of opinion is ruled by a parameter ρ multiplied by a coefficient $p_{i,j}$. This function implements the hypothesis that if i has a high opinion of j , then j is more influential on i . It is a logistic function (with parameter σ) of the difference between the opinion of i about j ($a_{i,j}$) and the opinion i about herself ($a_{i,i}$). If $a_{i,j} = \text{nil}$ (j is unknown to i), we assume that i has no opinion because he has not met or hear about j . At the first meeting, we suppose that the a priori about j is neutral and we set $a_{i,j} \leftarrow 0$. Let us also observe that, at the initialisation, an agent has no opinion

about herself thus we also set $a_{i,i} \leftarrow 0$ at the first discussion. Then we compute the propagation function $p_{i,j}$, which rules the intensity of the opinion propagation from j to i :

$$p_{ij} = \frac{1}{1 + \exp\left(-\left(\frac{a_{ij} - a_{ii}}{\sigma}\right)\right)}$$

$p_{i,j}$ tends to 1 when $a_{i,j} - a_{i,i}$ is close to 2 (i values j higher than herself), and tends to 0 when it is close to -2 (i values j lower than herself). When σ is small, p_{ij} rapidly changes from 0 to 1. When σ is large, this change is progressive.

This propagation coefficient of influence is computed to determine the influence a speaker has onto a listener about the opinion the listener has of oneself, of the speaker and of their peers.

2.1.2 Vanity and opinion influence between protagonists due to direct contact

Let us assume that agents i and j have been drawn. During their first meeting, agent i and agent j don't know each other and their opinions are nil. Then, they instantaneously become 0 which is the neutral opinion. This initiates the meeting dynamics between i and j .

Then, i and j talk about themselves: i talks about herself and j , while j talks about herself and i . This direct exchange called face-to-face implies influence of each of them on what they think about themselves and the other, and a vanity process applied only by the listener to the talker.

This vanity process expresses that agents tend to reward the agents that value them more positively than they value themselves and to punish the ones that value them more negatively than they value themselves. The vanity equation considering the reaction of i to what j says about i has the following form:

$$v_{ij} = \omega(a_{ji} - a_{ii} + \text{Random}(-\delta, +\delta))$$

This vanity is added to the influence i received from j regarding what she thinks about j to compute the updated opinion of i about j : a_{ij} . The agent i compares her self-opinion a_{ii} to the opinion j tells about her a_{ji} . If the perceived opinion of the other (j) is higher than her self-opinion, i increases her opinion of j (reward). Else i decreases her opinion of j (punishment). This particular reaction of i aims to increase or decrease the future influence of j in order to protect or enhance herself. The parameter ω rules the importance of the vanity process.

The influence of j on the opinion i has on i and j is controlled by the propagation coefficient $p_{i,j}$ (see 2.1.1) and a parameter ρ .

The modification of i 's opinion of i is assumed as simply depending on the difference between the opinion of i about herself and the opinion of j about i . The modification of i 's opinion of j is assumed on the difference between the opinion of i about j and the opinion of j about j (influence) and on the vanity v_{ij} .

Moreover, an agent i has no direct access to the opinions of another one (j) and can misunderstand her. To take into account this difficulty, we consider the perception of the agent i as the value a_{jz} more or less a uniform noise drawn between $-\delta$ and $+\delta$ (δ is a model parameter). This random addition then corresponds to a systematic error the agents make regarding the others' opinions. That can be seen as a noise that distorts the perception that i has about j 's opinions. The parameter δ rules the amplitude of this noise.

During the interaction, the procedures $\text{face-to-face}(i,j)$ and $\text{face-to-face}(j,i)$ are successively applied. The face-to-face can be formally described in pseudo-codes as follows (example given for $\text{face-to-face}(i,j)$):

Face-to-face(i,j)

if $a_{ii} = \text{nil}$, $a_{ii} \leftarrow 0$

if $a_{ij} = \text{nil}$, $a_{ij} \leftarrow 0$

$a_{ii} \leftarrow a_{ii} + \rho p_{ij} (a_{ji} - a_{ii} + \text{Random}(-\delta, +\delta))$

$a_{ij} \leftarrow a_{ij} + \rho p_{ij} (a_{jj} - a_{ij} + \text{Random}(-\delta, +\delta)) + v_{ij}$

The gossip follows the face-to-face.

2.1.3 Gossip: individuals discuss about those they know

During an encounter, we have seen that agent j propagates to i her opinions about herself (j) and about i . It also propagates to i her opinions about k agents randomly chosen among her acquaintances through gossip (or about all her acquaintances if there are fewer than k).

The agent i modifies her opinion about the individual z that j talked using the same “influence mechanism” than the one used in the face-to-face. She applies the propagation coefficient p_{ij} multiplied by the influence parameter ρ to the difference between what j told about z and what she thinks of z . More formally, the process can be written in pseudo-code as follows:

Gossip(i, j)

Repeat k times:

Choose randomly z taking into account $a_{jz} \neq \text{nil}$, $z \neq j$

If $a_{iz} = \text{nil}$, $a_{iz} \leftarrow 0$

$a_{iz} \leftarrow a_{iz} + \rho p_{ij} (a_{jz} - a_{iz} + \text{Random}(-\delta, +\delta))$

2.1.3 Summary

Finally, the model has 6 parameters:

- N , the number of individuals;
- σ , the reverse of the sigmoidal slope of the propagation coefficient;

- k , the number of acquaintances an individual talked about during a meeting – they are randomly chosen among her acquaintances;
- δ , maximum intensity of the noise when someone is alluded to;
- ω , the coefficient of the vanity process;
- ρ , the parameter controlling the intensity of the coefficient of the influence.

The following algorithm describes one iteration: $N/2$ random pairs of individuals are drawn, with reinsertion, and we suppose that each individual influences the other during the encounter. The update is synchronous: every opinion changes occurring during a meeting are computed on the same value of opinions taken at the beginning of a pair meeting.

```

Repeat  $N/2$  times:
  Choose randomly a couple  $(i,j)$ 
  Save the opinions which are going to change in temporary variables to ensure
the update during the  $i$  and  $j$  meeting is synchronous
  Face-to-face( $i,j$ )
  Face-to-face( $j,i$ )
  Gossip( $i,j$ )
  Gossip( $j,i$ )

```

2.2 The Leviathan model: Emerging properties

This section aims to remind what we know from emerging properties of the Leviathan model. We have already said a bias to negativity of the whole population emerges from the agent dynamics: the average opinion is negative, sometimes very strongly [1]. This is due to a difference between the opinion an agent has of herself and the average opinion of this agent in the population. This difference is driven by the noise during the conversation and the asymmetrical property of the influence (the agents are more influenced by the ones they value high than by the others). It corresponds to a bias of oneself for herself which is called positivity bias [12]. In other words, everyone thinks themselves better on average than the others. Such a bias can be amplified by the vanity for example, leading to a negative average opinion as an emerging process. Indeed the difference for agents between their opinion of themselves and the average opinion of them in the population leads them to be always disappointed in the interactions. Then, because of the vanity process, they continuously punish their interlocutors by decreasing their opinion of them. Such a punishment leads to a negative average opinion for the whole population. This is typically what occur in the crisis or the equality patterns we present now.

Indeed the dynamics not also reproduces biases but shows a striking variety of patterns representing structures of opinions. This variety can be described by five main patterns and several of them often take place in a single simulation. This section describes them shortly.

In a first set of patterns, when the opinion propagation is strong (high value of ρ), the agents tend to all have the same opinion about each agent (the differences are due

to the randomness). If we call, for sake of simplicity, reputation¹ the average opinion about an agent, the distribution of reputations gives a good description of these patterns. There are generally more negative than positive reputations. For some patterns the number of reputations decreases progressively when getting more positive, giving the idea of a hierarchy. For other patterns, there is a single or a couple of agents that have a strongly positive reputation, while all the others have a very negative one. Agents with a positive reputation can be identified as leaders. These consensual leaders characterise two patterns emerging from the dynamics: (1) the absolute dominance or (2) a multiple-leaders hierarchy. There is one pattern without leaders: (3) the “crisis” in which each agent has a very negative opinion of all the others and of herself.

The second set of patterns emerges when vanity is strong. In these patterns there is no consensus about each agent who can be highly valued by some agents and lowly valued by others; we identified two main patterns “equality” and “elite”. In (4) equality, each agent has a positive opinion about herself; she is connected by strong positive mutual opinions with a small set of agents and has very negative opinions about all the others. All agents have a similar number of positive (and negative) links. The (5) elite pattern shows two categories of agents: the elite and second category agents. The elite agents have a positive self-opinion and are strongly supported by a friend, but they have a very negative opinion of all the other elite agents and of all the second category agents. The second category agents have a very negative self-opinion, they have a very negative opinion of all the other second category agents and their opinion about the elite agents is moderately positive.

3 Modifying vanity for getting more positive opinions

This section describes our study. It begins by presenting our hypothesis and the experimental design allowing the study by simulations. A following subsection relates to the relevance of our hypothesis regarding the cause of the sign of gossiping while a next one investigates how the change in vanity impacts the emerging structures of opinions. A last subsection gives some explanations about our results.

3.1 Hypothesis and experimental design

In the original model, the vanity process does not depend on the relative value of the interlocutors; a flattery or an offense coming from a highly valued agent has the same effect as if it came from a lowly valued agent. It was choice for simplicity because it seems that the difference of value can weaken or strengthen the vanity, depending on the circumstances. We know the coupling of such a function to the influ-

¹ Reputations is understood in this paper as a consensus, inspired by the Emler’s definition of reputation [13]: “consensus among knowledge informations as to the attributes of targets”. We do not claim modelling “reputations” and other more relevant studies are more relevant for this issue than ours.

ence function with a sigmoidal coefficient based on the level of esteem for the talker implies a strong tendency of people to have a negative opinion of others.

We investigate the behaviour of the model with different variants of the vanity: the first one corresponds to the original model (same vanity process whatever the value difference); in the second one, vanity is weaker when discussing with lower valued agents; and in the third one vanity is weaker when discussing with higher valued agents :

- Constant vanity (CV) means that the vanity is applied to everyone with the same strength (as in the original model) ;
- Weaker vanity for lower valued (WLV) means that the strength of the vanity is weaker when discussing with lower valued agents; this is obtained by multiplying the vanity equation by the sigmoid function p_{ij} ;
- Weaker vanity for higher valued (WHV) means that vanity is weaker when discussing with higher valued agents; this is obtained by multiplying the vanity equation by the function $1 - p_{ij}$.

We now present the experimental design as well as how some values are measured and aggregated to build indicators of the dynamics.

The model includes 6 parameters and it is difficult to make an exhaustive study in the complete parameter space. In addition to the study of coefficient ω , we decided to study with more attention the influence of parameters k and σ because they have been poorly studied previously. We also decided to vary the noise δ , but not as much as k and σ . Also ρ varies poorly since it has been tested in details in [1]. In particular, we know from this first study that in the plane defined by parameters ρ and ω the transitions between patterns take place on right lines of origin (0,0). We fix N , the number of agents to 40, in order to make tractable results of our study and $\omega=1$. We vary the other parameters as follows:

- k , the number of acquaintances about which the pair of agents discuss in the opinion influence takes the values 1, 2, 3, 4, 5, 10, 15, 20, 25 and 30;
- δ , the intensity of noise disturbing the evaluation of other's opinions takes two different values: 0.1 and 0.3;
- σ , ruling the slope of the logistic function determining the propagation coefficients takes the values 0, 0.01, 0.02, 0.06, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8;
- ρ , ruling the intensity of the opinion propagation coefficient takes three values: 0.05, 0.5, 1;

For each set of parameter values, we run the model for 201 000 iterations (one iteration corresponding to $N/2$ random pair interactions), and we repeat this for 30 replicas. From iteration 30 000 to 200 000 every 10000 iterations, we measure a group of values allowing us to make conclusions about the impact of on the vanity variants on the average opinion and on the patterns. The measured values over times of 30 replicas are averaged to form one indicator. The indicators are presented in more details in in the next sections.

3.1 Average proportion of positive opinions

To study how modifications of vanity impact the number of positive gossip corresponding to positive opinions, we consider the average proportion of positive opinions over the 30 replicas for each set of parameters. Figure 1 shows this indicator averaged over the tested values of δ and ρ , for the various values of k and σ and the three variants of vanity process, on the left for constant vanity, in the middle for weaker vanity with higher valued agents (WHV), on the right weaker for lower valued agents (WLV). From these figures, we notice that for WLV the proportion of positive values is much higher than for the other variants and for some values of k and σ , the positive opinions represent more than 50 % (thus a majority) of the opinions while for other vanity variants, they always represent a minority (less than 25 %). Indeed we see onto the two left graphs that the average rate is mainly from 0 to 0.125 (in very light blue), or at most from 0.125 to 0.25 (in light blue) for low values of k and/or high values of σ . Differently, on the right graph (weaker vanity with lower valued) we observe the average rate of positive opinions is often between 0.37 to 0.5 (light green), especially for large values of k and σ , and goes up to [0.5,0.625] for low values of σ (in dark green). The results averaged over every other tested parameter values do not change the conclusion we can draw: for the weaker vanity with lower valued, the number of positive opinions is significantly higher.

These experiments suggest that the weaker vanity with lower valued produces populations where positive opinions are a majority or a minority while they are always a minority when vanity is constant or weaker with higher valued agents. The next section is dedicated to the impact of the changes of the vanity process on the patterns.

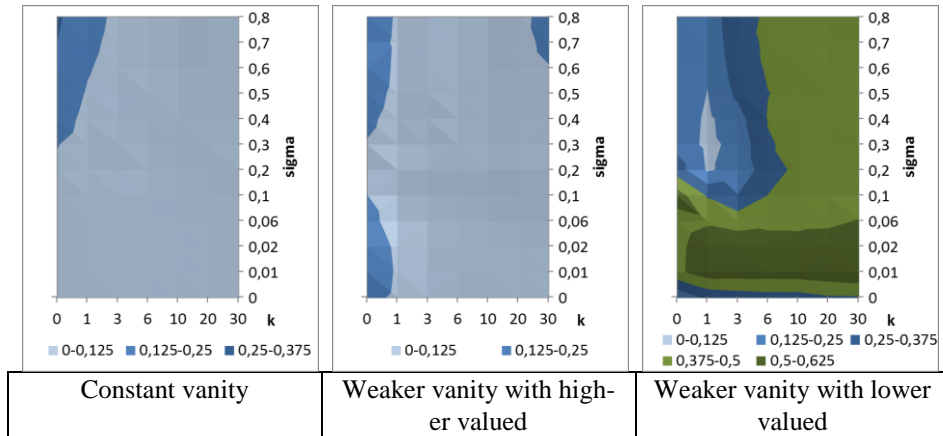


Fig. 1. Average proportion of positive opinions (over time and replicas) for the three variants of the vanity process. On abscissa are values of the number of acquaintances gossiped about k and on ordinate are the tested values for the sigmoid parameter σ . The meaning of the colours is given at the bottom of each graph under the abscissa

3.2 Impact of vanity modifications on patterns of opinions

We consider a new indicator: the average over all the agents of the difference between their maximum and their minimum opinions. We call this measure “dispersion of opinions”. It varies from 0 to 2. Figure 2a on the left shows that the opinion dispersion is smaller for large ρ (ie propagation strength) whatever the vanity variant and higher for small value of $\rho=0.05$. A large noise, such as $\delta=0.3$, tends to increase the dispersion but the effect of ρ remains, especially for weaker vanity with lower valued agents (in green). This confirms it still exists two different areas that we can distinguish by the level of consensus about each agent and then probably our two different sets of patterns (see 2.2 for more details).

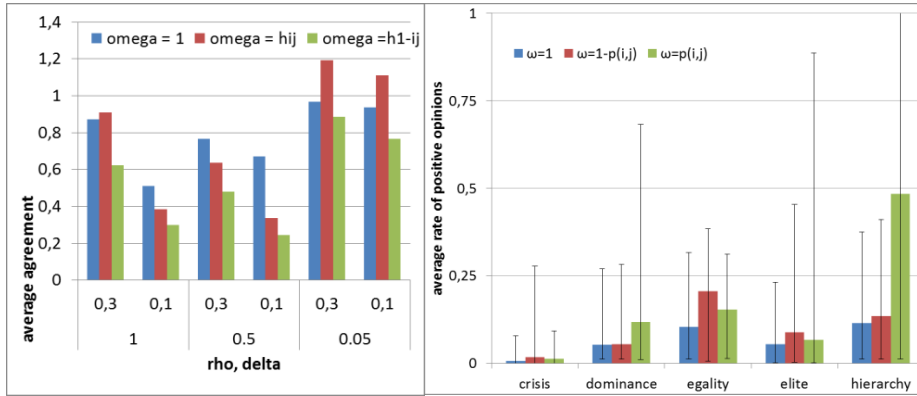


Fig. 2. a on the left, average opinion dispersion with on abscissa, from the bottom to the top, three values of ρ (1, 0.5, 0.05) and two values of δ (0.1 and 0.3). The level of agreement is still mainly driven by the propagation coefficient ρ : to this regards, the three various behave very similarly – **b on the right**, average percentage of positive opinion for the various vanity variants and the different patterns (the error bars represent the minimum and maximum variations)

We applied the diagnosis presented in [1] to define if already identified emerging patterns of opinions are still observable with the new vanity variants. Figure 2b on the right presents the average part of positive opinions of the diagnosed patterns. Firstly we observe that the five patterns are still diagnosed whatever vanity variant. Secondly this is clear the “hierarchy” is more positive for weaker vanity with lower valued agents and shows strong variations in its proportion of positive opinions. The other structures remain almost unchanged by the vanity variant but “elite” and “dominance”, show strong variations of the proportions of positive opinions for the variant WLW, which would require more investigation. However, this is out of the scope of this paper.

3.3 An explanation of the impact of the various forms of vanity

In order to get an intuition about the effect of the various forms of vanity, we consider the simple case $\sigma = 0$ (the sigmoid function p_{ij} is then either 0 or 1) for which we

can clearly identify who is going to be punished or rewarded, and $k=0$. Then, at the first meeting when everyone has an opinion valued at 0, the following table n°1 describes what occur and how the value of a_{ij} changes due to the vanity (d is a positive number comprised between 0 and δ); we suppose that the opinion of i about j is 0, and of i about himself is also 0.

Table n°1. Evolution in the face-to-face of the opinion of i about j (a_{ij}) for various forms of vanity and $\sigma = 0$, $k=0$; d is a positive number comprised between 0 and δ

Vanity heuristic	$a_{ij} = 0; a_{ji} =$	$a_{ii} = 0; a_{ji} =$	p_{ij}	$\omega =$	$a_{ij}(t+1)$
h1	-d1	-d2	0	1	-d2
		d2	0	1	d2
	d1	-d2	1	1	(d1-d2)
		d2	1	1	(d1+d2)
h1-ij	-d1	-d2	0	1	-d2
		d2	0	1	d2
	d1	-d2	1	0	d1
		d2	1	0	d1
hij	-d1	-d2	0	0	0
		d2	0	0	0
	d1	-d2	1	1	(d1-d2)
		d2	1	1	(d1+d2)

These observations point out why weaker vanity with lower valued agents causes agents to see each other more positively than the other variants of vanity. In any case, the lowest opinion of i of j is higher for this variant since it is $(d1-d2)$ while it is $-d2$ for the other variants.

Overall, at the very beginning, dispersion of opinions is smaller. More generally, the constant vanity process leads to cycles of mutual opinion increase or decrease that are stopped only by the limits of opinion values (+1 or -1) in the original model. When vanity is weaker with lower valued agents, the cycles of mutual opinion decrease are strongly attenuated when one of the protagonists is much lower than the other. This can often stop the usual escalations driving many agents to get very low opinions (close to -1).

Moreover, the initial analysis of the Leviathan model shows that the average negative opinion is due to tendency of the agents to have a higher self-opinion than the average opinion on them. Indeed, this difference leads them to be disappointed on average by the opinions of the others, and thus to decrease their opinion about them by vanity. When the vanity is weaker for lower-valued agents, this process is attenuated for such agents.

Therefore, overall the opinions tend to be less negative. .

4 Discussion - conclusion

The Leviathan model includes a dynamics of the esteem based on a coupling between a vanity process and an opinion propagation process. The two processes occur during a direct experience a listener and a speaker have of each other during a meeting. The opinion propagation rules also the indirect experience listeners and speakers have of the others through gossiping. Both these mechanisms make people changing their opinions of each other. The original Leviathan model exhibits a strong tendency of opinions to be negative, and hence a strong dominance of negative gossiping. Whereas the literature in social psychology has shown that gossiping can be either majorly negative [2] or positive [3] without explaining why.

We investigate variants of the vanity process that could lead to more positive average opinions and we observe that majority weaker vanity with lower valued agents leads to much larger proportions of positive opinions than with the other variants of vanity, whereas the opinions can still be majorly negative for some parameters. On the contrary, a constant vanity or a weaker vanity with higher valued agents always leads to a majority of negative opinions.

From these observations, we conclude that with a weaker vanity with lower valued agents, the positivity bias (self-opinion higher than the average opinion on the agent) has a weaker effect and does not always leads to a global negativity. It is then, among the tested form for vanity, the only one in accordance with both of the sociopsychological cited studies on gossip. This is also consistent with those about self-esteem values mainly showing that low self-esteem people do not truly dislike themselves; they view themselves positively, just less positively than do high self-esteem people [14].

Dynamic patterns of behaviour of the population emerging from this model [1] have been identified. They are still diagnosed for each of the different vanity variant we consider. With a weaker vanity with lower-valued agents, the hierarchy pattern, is significantly positive on average and shows strong variations. This makes this pattern richer than it was from the original model in which it remains majorly negative. Despite their average level of positivity close in every vanity dynamics conditions, the dominance and elite patterns can be very positive with this vanity variant. We suspect nevertheless that the dominance and elite patterns could be modified with this vanity variant and this would require deeper investigation.

We do not claim that changing vanity is the only way for observing both more positive than negative gossips. Indeed, the positivity bias and a tendency to a global negativity exist also in absence of vanity when the dynamics is only driven by the propagation of opinions. Investigating the change of biases in this case is one of our future goals.

More generally, we think that this model can suggest new views on current issues in social psychology, as well as being improved by incorporating more results from this science.

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