Normal = Normative?
The Role of Intelligent Agents in Norm Innovation

Marco Campennì[1,2], Giulia Andrighetto[1], Federico Cecconi[1], and Rosaria Conte[1]

[1] LABSS - Istituto di Scienze e Tecnologie della Cognizione - CNR, via S. Martino della Battaglia 44, 00185 Rome, Italy (http://labss.istc.cnr.it)
[2] University of Modena and Reggio Emilia, Italy

Abstract. In this paper the results of several agent-based simulations, aiming to test the role of normative beliefs in the emergence and innovation of social norms, are presented and discussed. Rather than mere behavioral regularities, norms are here seen as behaviors spreading to the extent that and because the corresponding commands and beliefs do spread as well. On the grounds of such a view, the present work will endeavour to show that a sudden external constraint (e.g. a barrier preventing agents from moving among social settings) facilitates norm innovation: under such a condition, agents provided with a module for telling what a norm is can generate new (social) norms by forming new normative beliefs, irrespective of the most frequent actions.

1 Introduction

Traditionally, the scientific domain of normative agent systems presents two main directions of research. The first is focused on intelligent agent architectures, and in particular on normative agents and their capacity to decide on the grounds of norms and the associated incentive or sanction. The second is focused on much simpler agents and the emergence of regularities from agent societies.

Very often, social scientific study of norms goes back to the philosophical tradition that defines norms as regularities emerging from reciprocal expectations [22, 5, 15]. Indeed, interesting sociological works [23] point to norms as public goods, the provision of which is promoted by 2nd-order cooperation [18, 19]. This view has inspired the more recent work of evolutionary game-theorists [17], who explored the effect of *punishers* or *strong reciprocators* on the group's fitness, but did not account for the individual decision to follow a norm.

No apparent contamination and integration between these different directions of investigation has been achieved so far. In particular, it is unclear how something more than regularities can emerge in a population of intelligent autonomous agents and whether agents' mental capacities play any relevant role in the emergence or innovation of norms.

In this paper, we will concentrate on *one* of these capacities, norm recognition. We will simulate agents endowed with the capacity to tell what a norm is, while observing their social environment.

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One might question why start with norm recognition. After all, isn't it more important to understand *why* agents observe norms? Probably, it is. However, whereas this question has benn answered to some extent [10, 9] the question how agents tell norms has received poor attention so far. Furthermore, the account for the reason why agents observe the norms sheds poor light on our problem: norms need to have emerged, before they are complied with for any reason.

In this paper, we will address the antecedent phenomenon, norm innovation, postponing the consequent, norm compliance, to future studies. In particular, we will endeavour to show the impact of norm recognition on norm innovation. More precisely, we will observe agents endowed with the capacity to recognize a norm (or a behavior based on a norm); generate by herself new normative beliefs and transmit them to other agents by communicative acts or direct behaviors.

We intend to show whether a society of such normative agents allows norms to emerge or innovate. (By norm innovation, we mean the process by means of which the (set of) norm(s) shared within a (sub-)population changes in all or in part at any given time). Hence, we intend to investigate not only how norms come into existence, but also how they are maintained or replaced by other norms. The notion of norms that we refer to [11] is rather general. Unlike a *moral* notion, which is based based on the sense of right or wrong, norms are here meant in the broadest sense, as behaviors spreading to the extent that and because (a) they are prescribed by one agent to another, (b) and the corresponding normative beliefs spread among these agents.

Again, one might ask why not to address our moral sense, our sense of the right or wrong. The reason is at least twofold. First, our norms are more general, including moral and social norms. Secondly, and moreover, agents can deal with norms even when they have no moral sense: they can even obede norms they believe to be injust. But in any case, they must know what a norm is.

2 Existent Approaches

Usually, in the formal social scientific field, that is in utility and (evolutionary) game theory [5, 15, 25, 26, 28], the spread of new norms and other cooperative behaviors is not explained in terms of internal representations. The object of inquiry is usually the conditions for agents to converge on given behaviors, which proved efficient in solving problems of coordination [22] or cooperation [4], independent of the agents normative beliefs and goals [6]. In this field, no theory of norms based on mental representations (of norms) has yet been provided.

Game theorists essentially aimed to investigate the dynamics involved in the problem of norm convergence. They consider norms as conditioned preferences, i.e. options for action preferred as long as they are believed to be preferred by others as well [5]. Here, the main role is played by sanctions: what distinguishes a norm from other cultural products like values or habits is the fact that adherence to a social norm is enforced by sanctions [16, 3] and the utility function, which an agent seeks to maximize, usually includes the cost of sanction as a crucial component.

In the field of multi-agent systems [14, 21, 27], instead, norms are explicitly represented. However, they are implemented as built-in mental objects. This alternative approach has been focused on the question as to how autonomous intelligent agents decide on the grounds of their explicitly represented norms. Even when norm emergence is addressed [24], the starting point is some preexisting norms, and emergence lies in integrating them. When agents (with different norms) coming from different societies interact with each other, their individual societal norms might change, merging in a way that might prove beneficial to the societies involved (and the norm convergence results in the improvement of the average performance of the societies under study). Lately, decision making in normative systems and the relation between desires and obligations has been studied within the BDI framework, developing an interesting variant of it, i.e. the so-called Belief-Obligations-Intentions-Desires or BOID architecture [7].

In none of these approaches, including the last one, it is possible for an agent to tell that a given input is a (new) norm. On the contrary, obligations are hardwired into the agents' minds when the system is off-line. Unlike the game-theoretic model, multi-agent systems certainly exhibit all of the advantages deriving from an explicit representation of norms. Nevertheless, they overshadow one of the advantages of autonomous agents, i.e. their capacity to filter external requests. Such a filtering capacity affects not only normative decisions, but also the acquisition of new norms. Indeed, agents take decisions even when they decide to form normative beliefs, and then new (normative) goals, and not only when they decide whether to execute the norm or not [12].

Despite the undeniable significance of the results achieved, these studies leave some fundamental questions still unanswered, such as how and where norms originate, how agents acquire norms, and more specifically, how agents tell that something is a norm. Our feeling is that the question how norms are created and innovated has not received so far the answer it deserves the role of norm-recognition has been insufficiently perceived.

3 Objectives

Some preliminary simulations, discussed in [1], compared the behavior of a population of normative agents provided with a norm recognition module and a population of social conformers whose behavior is determined only by a rule of imitation. The results of these simulations show that under specific conditions, i.e. moving from one social setting to another, imitators are not able to converge on one behavior, even if this is common to different settings, whereas normative agents are.

In this paper we want to find out the sufficient (even if not necessary) conditions for existing norms to change. In particular, we want to show if a simple cultural or material constraint can facilitate norm innovation. To see this, we imagined a simple case in which subpopulations are isolated in different contexts for a fixed period of time. The methaphor here is any physical catastrophe or political upheaval that divides one population into two separate communities. The recent European history has shown several examples of this phenomenon.

4 Norm Innovation

Norms are highly adaptable artifacts, emerging, evolving, and decaying. If it is relatively clear how legal norms are put into existence, it is much less obvious how the same process applies to social norms. How do new social norms and conventions come into existence? Some simulation studies about the selection of conventions have been carried out, for example Epstein and colleagues' study of the emergence of social norms [15], and Sen and Airiau's study of the emergence of a precedence rule in the traffic [25]. However, such studies investigate which one is chosen out of a set of alternative equilibriums. A rather different sort of question concerns the innovation of social norms when no alternative equilibriums are available for selection.

We propose that a possible answer might be discovered while examining the interplay of communicated and observed behaviors, and the way they are represented into the minds of the observers. If any new behavior α is interpreted as obeying a norm, a new normative belief will be generated and a process of normative influence will be activated [13]. Such a behavior will be more likely to be replicated than would be the case if no normative belief were formed [2]. As shown elsewhere [9, 2], when a normative believer replicates α, she will be likely to influence others to do the same not only by ostensibly exhibiting the behavior in question, but also by explicitly conveying a norm. People impose new norms on one another by means of deontics and explicit normative valuations and propose new norms (implicitly) by means of (normative) behaviors. Of course, having formed a normative belief is necessary but not sufficient for normative influence: we will not answer the question *why agents do* so (a problem that we solve for the moment in prbabilistic terms), but we address the question how they can influence others to obey norms. They can do so if they have formed the corresponding normative belief, if they know how one ought to behave.

5 Normative Architecture

We consider a norm as a social behavior that spreads trough a population thanks to the diffusion of a particular belief, i.e. the normative belief. A normative belief, in turn, is a belief that a given behavior, in a given context, for a given set of agents, is either forbidden, obligatory, permitted, etc. Thus, for a norm-based behavior to take place, a normative belief has to be generated into the minds of the norm addressees and the corresponding normative goal has to be formed and pursued. Our claim is that a norm emerges as a norm only when it is incorporated into the minds of the agents involved [10, 11]; in other words, when agents recognize it as such. In this sense, norm emergence and stabilization implies its *immergence* [8] into the agents' minds.

5.1 Norm Recognizer

Our normative architecture (EMIL-A) (see [2] for a detailed description) consists of mechanisms and mental representations allowing norms to affect the behaviors of autonomous intelligent agents. EMIL-A is meant to show that norms not only regulate the behavior but also act on different aspects of the mind: recognition, adoption, planning, and decision-making. Unlike BOID in which obligations are already implemented into the agents' minds, EMIL-A is provided with a component by means of which agents infer that a certain norm is in force even when it is not already stored in their normative memory. In this situation the norm has not already been incorporated into schemata, scripts, or other pragmatic structures [5]; hence, agents are not facilitated by any of these. Actually, the norm needs to be found out, and only thereafter, stored. To implement such a capacity is conditioned to modeling agents' ability to recognize an observed or communicated social input as normative, and consequently to form a new normative belief. In this paper, we will only describe the first component of EMIL-A, i.e. the norm recognition module. This is most frequently involved in answering the open question we have raised, i.e. how a new norm is found out and we claim that to answer this question is particularly crucial in norm emergence, innovation and stabilization.

Our Norm Recognizer (see Fig. 1) consists of three layers and a link to the normative board, which is part of the agents long term memory. The normative board contains normative beliefs and normative goals, ordered by *salience*. With salience we refer to the degree of activation of a norm: in any particular situation, one norm may be more frequent than others, its salience being higher. The difference in salience between normative beliefs and normative goals has the effect that some of these normative mental objects will be more active than others and they will interfere more frequently and with more strength with the general cognitive processes of the agent.

In the higher layer, actions (α) presented as deontics (D) or normative valuations (V) are stored; in the lower layer, instead, actions are stored only if they have already been stored at the higher level, i.e., if they have been received by the agent as deontics or normative valuations. We identify six possible modals: assertions (A), i.e. generic sentences pointing to or describing states of the world; behaviors (B), i.e. actions or reactions of an agent, with regard to another agent or to the environment; requests (R), i.e. requests of action made by another agent; deontics (D), partitioning situations between good/acceptable and bad/unacceptable (we further distinguish deontics into three types: obligations, forbearances, permissions); normative valuations (V), i.e. assertions about what it is right or wrong, correct or incorrect, appropriate or inappropriate (i.e. *it is correct to respect the queue*).

Aiming to decide which action to produce, the agent will search through the normative board: if more than one is found out, the most salient norm will be chosen. Once received the input, the agent will compute the information in order to generate/update her normative beliefs. Every time a message containing a deontic (D) or a normative valuation (V) is received, the relative action will be stored as a (possible) norm. This will sharpen agents' attention: further messages with the same content, especially when observed as open behaviors, will be processed and stored at the same level. Beyond a certain normative threshold (which represents the frequency of corresponding normative behaviors observed, e.g. n% of the population), they will generate a new normative belief.

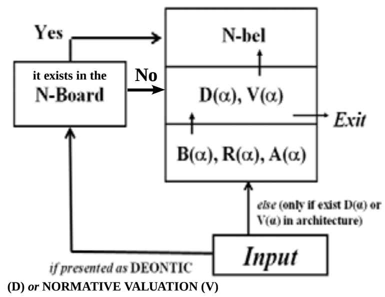


Fig. 1. The norm recognition module (in action): on the right side of the figure, from the bottom the *Input* and the two layers of the module (layer 0 and layer 1) plus the normative belief (generated or recognized); on the left side, the normative board. Vertical arrows in the block on the right side indicate the process regulating the generation of a new normative belief. The input action (α) can match with a norm present in the normative board (see the arrows path on the left side of the figure); or a new normative belief can be formed if the agent receives an input action (α) (at least one time as deontic or normative valuation) for a given number of times (as fixed by the normative threshold; see the arrows path on the right side of the figure). If the agent receives no other occurence of the same input action (α), after a fixed time t action α exits from the higher level and the process is finalized (see *Exit*).

6 The Model

In our simulation model, the environment consists of four scenarios, in which the agents can produce three different kinds of actions. We define two context-specific actions for every scenario, and one action common to all scenarios. Therefore, we have nine actions. Suppose that the first context is a postal office, the second an information desk, the third our private apartment, and so on. In the first context the action *stand in the queue* is a context-specific action, whereas in the second a specific action could be *occupy a correct place in front of the desk*. A common action for all of the contexts could be, *answer when asked*. Each of our agents is provided with a personal agenda (i.e. a sequence of contexts), an individual and constant time of permanence in each scenario (when the time of permanence is expired, the agent moves to the next context) and a window of observation (i.e. a capacity for observing and interacting with a fixed number of agents) of the actions produced by other agents. Norm Recognizers are also provided with the three-layer architecture described above, necessary to analyze the received information, and a normative board in which the normative beliefs, once arisen, are stored. The agents can move across scenarios: once expired the time of permanence in one scenario, each agent moves to the subsequent scenario following her agenda. Such irregular flow (each agent has a different time of permanence and a different agenda) generates a complex behavior of the system, tick-after-tick producing a fuzzy definition of the scenarios, and tick-for-tick a fuzzy behavioral dynamics.

We have modeled two different kinds of environmental conditions. In the first set of simulations, agents can move through contexts (following their personal agenda and in accordance with the personal time of permanence). In the second set of simulations, from a fixed time t, agents are obliged to remain in the context they have reached, till the end of the simulation: in this case agents can explore the contexts exchanging messages with one another and observing others' behaviors. When they reach the last context at time t, they can interact with same-context agents till the end of the simulation.

At each tick, the Norm Recognizers (NRs), paired randomly, interact exchanging messages. These inputs are represented on an ordered vector, consisting of four elements: the source (x); the modal through which the message is presented (M); the addressee (y); the action transmitted (a).

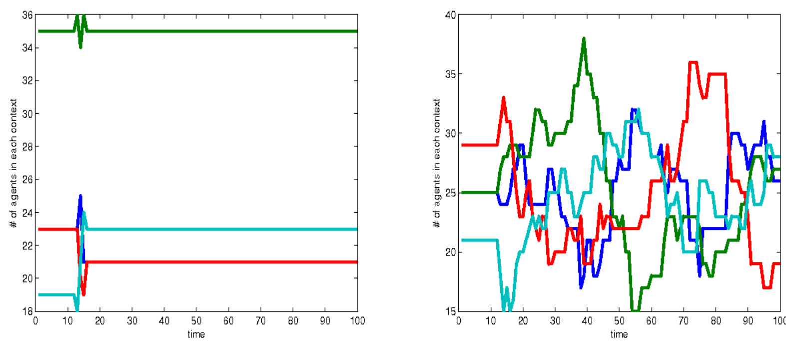
Codifying the input in such a way allows us to (a) access the information even later, if necessary; (b) recognize the source, a piece of information that might be useful to store inputs from recognized authorities; (c) account for a variety of information, thanks to the modals' syntax; (d) compute the received information in order to generate a new normative belief. NRs produce different behaviors: if the normative board of an agent is empty (i.e. it contains no norms), the agent produces an action randomly chosen from the set of possible actions (for the context in question); in this case, also the modal by means of which the action is presented is chosen randomly. Vice versa, if the normative board contains some norms, the agent chooses the action corresponding to the most salient among these norms. In this case the action produced is presented with one of these modals: deontic (D), normative valuation (Vn) or behavior (B). This corresponds to the intuition that if an agent has a normative belief, there is a high propensity (in this paper, this has been fixed to 90%) for her to transmit it to other agents under strong modals (D or Vn) or open behavior (B). We run several simulations for different values of the threshold, testing the behaviors of the agents in the two different experimental conditions.

7 Results and Discussion

We briefly summarize the simulation scheme. The process begins by producing actions (and modals) at random. The process is synchronic. The process is more and more complex runtime: agent i provides inputs to the agent who precedes her (k=*1*), issuing one action and one modal. Action choice is conditioned by the state of her normative board. When all of the agents have executed one simulation update, the whole process restarts at the next step.

7.1 Simulations' Results

Figure 2(a) and Figure 2(b) show the trend of simulation in terms of number of agents in each context runtime in both cases (the first with the external barrier, the second without it).



(a) with barrier

(b) without barrier

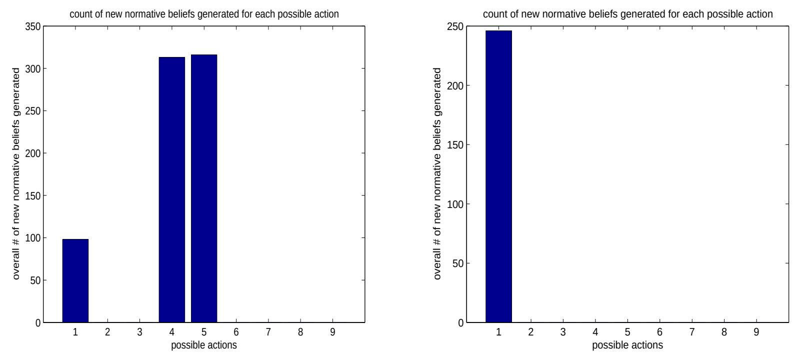
Fig. 2. Number of agents in each context runtime - with (left) and without (right) external barrier

First of all we present the results obtained when imposing the external barrier. Then, we present the results obtained when no barrier was imposed; finally we compare the former with the latter results.

Figure 3(a) shows the overall number of different new normative beliefs generated at the end of the simulation: as we can see, in the barrier condition, agents form more than one normative belief, whereas in the no barrier condition they form one normative belief only.

Figure 4 shows the trend of new normative beliefs generation runtime for a certain value of the norm threshold, which is a good implementation of our theory: each line represents the generation of new normative beliefs corresponding to an action (i.e. each line corresponds to the sum of different normative beliefs present in all of the agents). To be noted, a normative belief is not necessarily universally shared in the population. However, norms are behaviors that spread thanks to the spreading of the corresponding normative belief. Therefore, they imply shared normative beliefs.

Figures 7(a) and 7(b) are very similar (even if in the no-barrier variant, we find some noise in the chromatic definition of different contexts). In these figures, we cannot appreciate significant chromatic differences pointing to the normative



(a) with barrier (b) without barrier

Fig. 3. Overall number of new normative beliefs generated for each type of possible action - with (left) and without (right) external barrier

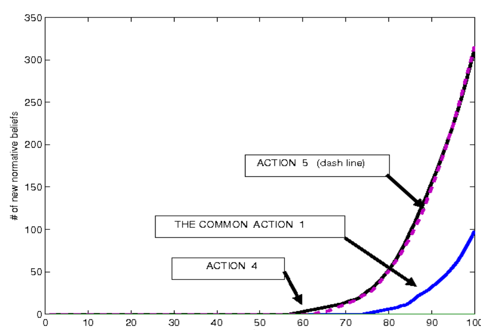
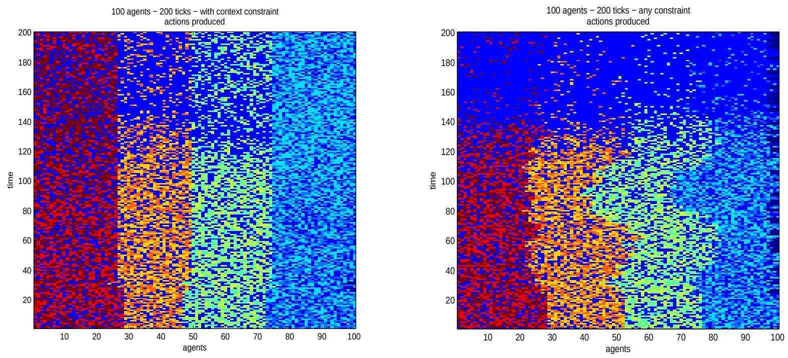


Fig. 4. New normative beliefs generated runtime - with external constraint



(a) with barrier (b) without barrier

Fig. 5. Chromatic representation of the actions generated by the NRs. A different action corresponds to each color: the dark blue color represents the action common to the 4 scenarios; on axis X we find the number of agents (100) and on axis Y the number of simulation ticks (200) - with (left) and without (right) external barrier

beliefs acting on the effective behaviors: we cannot distinguish the chromatic effect corresponding to the agents' convergence on a specific norm. This is due to the length of these simulations, which is not sufficient to include the latency time of norms. In the previous study, indeed, we showed that for a normative belief to affect behavior, a certain number of ticks has to elapse, which we might call *norm latency*. Indeed, if we run longer simulations, we can appreciate the consequences of the results of our investigation: in Figures 5(a) and 5(b) we can observe two chromatic effect: (a) more or less at the same time both in the barrier (left) and no barrier (right) condition, a convergence on the common action (dark blue) is forming, much more homogeneous in (5.b) than in (5.a); (b) however, in the barrier condition, other areas of convergence are also emerging (e.g. a light blue in the last column).

This corresponds to what is shown in Figure 4 and Figure 6 on one hand, and Figure 3(a) and Figure 3(b) on the other: with external barrier, we can see that the higher overall number of new normative beliefs generated does not correspond to the common action (action 1) and the trend of new normative beliefs generated runtime shows the same results. With no external barrier, instead, only normative beliefs concerning action 1 are generated.

8 Concluding Remarks

We show that the model allows new norm, to emerge, despite another norm had previously emerged. More interestingly, the new norms do not correspond to the common action. Some rival norms now compete in the same social settings. Obviously, they will continue to compete, unless some further external event or

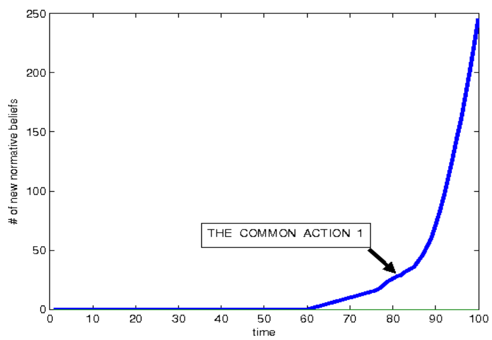
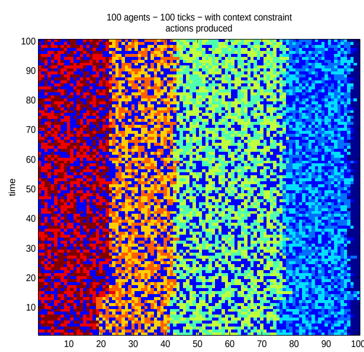
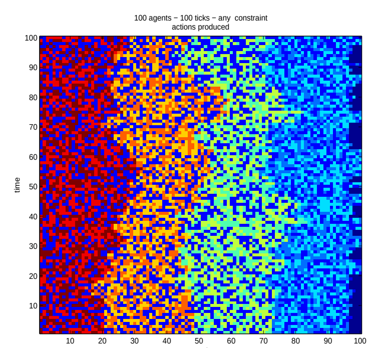


Fig. 6. New normative beliefs generated runtime - without external barrier



(a) with barrier



(b) without barrier

Fig. 7. Chromatic representation of the actions generated by the NRs. A different action corresponds to each color: the dark blue color represents the action common to the 4 scenarios; on axis X we find the number of agents (100) and on axis Y the number of simulation ticks (100) - with (left) and without (right) external barrier

change in the population (e.g. the barrier removal) will cause agents to start migrating again. It would be interesting to observe how long the rival norms will survive after barrier removal, whether and when one will out-compete the others, and if so, which one. It should be observed that, as we observe a latency time for a normative belief to give rise to a new normative behavior, we also expect some time to elapse before a given behavior disappears while and because the corresponding belief, decreasingly fed by observation and communication, starts to extinguish as well. We might call such a temporal discrepancy *inertia of the norm*. Both latency and inertia are determined by the twofold nature of the norm, mental and behavioral, which reinforce each other, thus preserving agents' autonomy: external barriers do modify agents' behaviors, but only through their minds.

More than emergence, our simulation shows a norm innovation process; in fact, Figure 4 shows that, starting around tick=60, two normative beliefs appear in the normative boards and the overall number of these two new normative beliefs generated is three times higher than the overall number of normative beliefs concerning the common action 1 (Figure 3(a)). Analogously, in Figure 5(a) some areas of homogeneity start to appear beyond the dark blue one.

We might say that, if stuck to their current location by external barriers, norm recognizers resist the effect of majority and do not converge on one equilibrium only. Rather, they will form as many normative beliefs as there were competing beliefs on the verge of overcoming the normative threshold before the agents had been stuck to their locations. No such effect is expected among agents whose behavior depends only from the observation of others.

In sum, is statistical frequency sufficient for a norm to emerge? Beside action 1, common to the four contexts, other norms seem to emerge in our simulation.

Hume seemed to doubt it [20].

Normative agents can recognize a norm; infer the existence of a norm by its occurrences in open behavior under certain conditions (see the critical role of previous deontics); and finally spread a normative belief to other agents.

Future studies are meant to investigate on the effect of barrier removal and the inertia of normative beliefs.

Acknowledgments

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