



## Collective Decision-making in Social Spiders: Dragline-mediated Amplification Process Acts as a Recruitment Mechanism

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Amplification mechanisms involved in group cohesion and coordination of several individuals' activities are a major research topic in social arthropod biology. In this paper, we investigate how recruitment processes can be mediated by the use of silk draglines in the case of social spiders. Our intent is to demonstrate how a behavioural feature common to all spider species can induce positive feedback, potentially leading to collective decision-making in a social context. Dragline-mediated amplification mechanisms are investigated in a simulated "Y" choice set-up. Numerical experiments involve two distinct models: a simplified one, devoted to the exploration of the most basic amplifying properties of the system, and a more complex simulation platform, taking into account the geometrical properties of a growing network (two-dimensional web). The effect of hypothetical subpopulations, as well as variations in silk attractivity in the case of mixed populations (originating from multiple nests) are also discussed. Results fit experimental data and demonstrate that spiders' behaviour exhibits very strong amplifying properties that can play a crucial part in the organization of social life.

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### 1. Introduction

Collective decision-making is a key aspect of group-living animals' biology. In its simplest and most common expression—activity focusing—it allows individuals to capitalize on each other's actions, drawing benefits from cooperative effects. In social arthropods, the scale factor between an individual's size or cognitive abilities and the achievements of the colony is particularly impressive. In a variety of ecologically relevant problems the mechanisms underlying collective decision processes are just beginning to be uncovered (e.g. Deneubourg & Goss, 1989;

Théraulaz *et al.*, 1991; Bonabeau *et al.*, 1996a; Bonabeau *et al.*, 1997).

Examples can be found in the way honey bees or trail-laying ants select a food source (Pasteels *et al.*, 1987; Camazine & Sneyd, 1991; Traniello & Robson, 1995), army ants produce their network (Deneubourg *et al.*, 1989; Franks *et al.*, 1991) or termites and bees build regular structures (Deneubourg, 1977; Camazine, 1991; Théraulaz & Bonabeau, 1995; Bonabeau *et al.*, 1998).

Some behaviours involved in collective decision-making are best investigated in simple and constraining experimental set-ups, creating artificial conditions where most parameters are known and controlled by the observer. One of

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the most effective and common of these set-ups is the “Y” maze, confronting the animal with a binary choice. It is in this kind of simplified environment that the emergence of trail networks in ants have been successfully studied (Aron *et al.*, 1990; Deneubourg *et al.*, 1990; Detrain *et al.*, 1991; Beckers *et al.*, 1992a, b, 1993; Fourcassie & Deneubourg, 1994). These studies have produced a convincing model of the collective decision process, covering both the behavioural and dynamical levels, by combining experimental results and real-data-fed simulations.

Social spiders obviously encounter some of the problems social insects do when it comes to collective activities: they are small animals, with limited individual abilities, sometimes living in huge groups of many thousands, a situation in which they probably benefit from some cooperative effects (Pasquet & Krafft, 1992; Saffre *et al.*, 1997). They simply appear to have evolved a social organization entirely different from that found in social insects. For example, we do not know of any social spider exhibiting a clear-cut division of labour (see e.g. Krafft, 1971; Buskirk, 1981; Avilés, 1997).

Recently, collective decision-making in social spiders was investigated in simple experimental set-ups (Furey *et al.*, unpublished data). Collective emigration behaviour with binary choice was initiated in groups of *Anelosimus eximius*, a neotropical species, under field conditions in French Guiana. Experimental set-ups comprised small trees. These were chosen so as to exhibit a forked shape, providing access to two equivalent web foundation sites. Groups of spiders were placed in plastic cups suspended from a thread guy line. This guy line rose approximately to half a metre where it split, giving the animals leaving the cup an equal choice between the two separate branches. In most of the experiments, all spiders ended up on the same branch, suggesting strong interactions between conspecifics. Two categories of groups were used, single and mixed colonies (50:50 distribution from two distinct colonies). No differences in final choice between mixed or single groups were observed.

The way social spiders deal with binary choices is somewhat different from what can be expected from other trail-following arthropods. Unlike them, they are able to short-circuit an open “Y”

set-up by the use of their dragline, each individual providing its followers with a potential escape route because of the non-continuous aspect of the attachment pattern (Saffre *et al.*, 1999), thus allowing them to avoid the initial choice point.

What is at the centre of this paper is that the evolution of the silk network itself reflects the choices that are made by the spiders, in a way that can influence their conspecifics’ behaviour. If spiders do use each other’s draglines as escape routes, then we are facing a potential amplification mechanism that can result in a collective decision process.

In order to study the dynamics of such a process, we designed a set of theoretical models (Monte Carlo simulations). We started from a very simple basic scenario (1D) devoted to the exploration of the amplifying properties of the dragline-following behaviour. We subsequently developed a web simulation (2D), taking into account the spatial characteristics of the growing network, as well as the capacity of the spiders to cross small gaps in the web.

## 2. Basic Scenario Simulation (1D)

### 2.1. DESCRIPTION OF THE MODEL

This first Monte Carlo simulation does not take into account the spatial structure of the network, but only the orientation and distribution of the potential escape routes along the axis leading to the initial choice point. The spiders follow a very simple course of action as they move along (Fig. 1). All individuals follow one another in a sequential order, the second one entering the set-up only after the first one has left. As a result of this arbitrary choice on our part, no time variable has to be taken into account (the unit is the number of spiders), and obviously, no direct interaction between two individuals is possible.

The first spider’s only escape route corresponds to the terminal bifurcation point (initial “Y” choice), so it has 50% chances of choosing either side [Fig. 2(a)]. A new escape route is then added upstream [Fig. 2(b)]. To obtain its position along the vertical axis, we assume that each spider has a constant probability  $p_a$  of attaching its dragline per space unit. This rule is derived

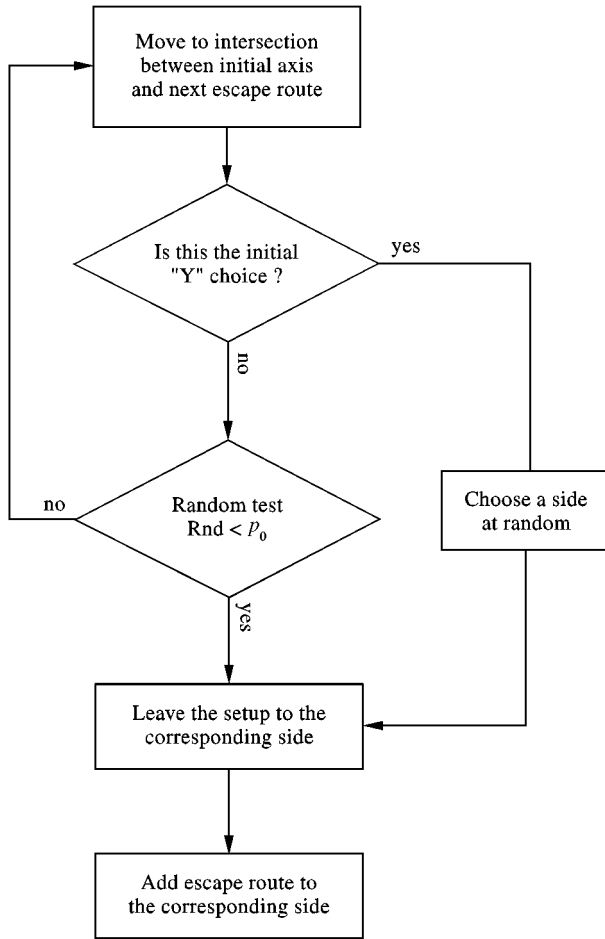


FIG. 1. Spider's algorithm in the simplified model.

from experimental data and results in an exponential distribution of the intervals between two consecutive attachment points (Saffre *et al.*, in press). As in this first model spiders are dimensionless, the distance between attachment points is of no importance, and only the exponential pattern, which determines the distribution of branching points, has to be taken into account. Obviously, the side to which the newly added exit thread leads is the same as for the chosen exit, rendering the growth of the corresponding material structure.

Once the first spider has passed, there is a chance that the chosen escape route could be a conspecific's dragline. Each time an individual encounters such an exit thread, it has a probability  $p_0$  to follow it. If it does not, it resumes its walk along the initial axis until the next one. Obviously, if the second spider ignores the first

one's dragline, it will also encounter the terminal bifurcation [Fig. 2(c)]. Again, a new escape route is added to the corresponding side [Fig. 2(d)].

The amplification process results from the opportunity for an individual to use a predecessor's dragline as a shortcut, avoiding the initial "Y" choice in the process [Fig. 2(e)]. As each spider is contributing to the growth of the branching points sequence, one side gains the advantage [Fig. 2(f)–(i)].

From this description, it is clear that in this simplified simulation, given the experimental nature of the dragline attachment pattern, only one parameter remains to be investigated: the probability  $p_0$ , which reflects the tendency of the spiders to leave the initial axis.

## 2.2. RESULTS FOR HOMOGENEOUS POPULATIONS

An even distribution of the population between both sides is extremely unstable, due to the sequential and local aspects of the choice process (irreversibility: only one positive decision allowed per spider). Of course, from one simulation to the other, it is either the left or right side that benefits from the amplification process, which results in a U-shaped frequency distribution of the population fraction on any one side. From now on, by convenience, we will always present data for the left branch, and speak of asymmetrical distribution between sides, referring to the outcome of the individual simulations.

As the use of conspecifics' draglines is the basis of the amplification mechanism, it is clear that the value of  $p_0$  has a strong influence on the decision process. For  $p_0 = 0$ , draglines are never used as shortcuts, and all spiders will encounter the initial choice point and choose at random to follow the left or the right branch. In this case, the total population will be statistically distributed evenly between both sides (no decision). For  $p_0 = 1$ , only the first explorer will reach the initial bifurcation. All other spiders will use the dragline of their immediate predecessor to short-circuit the "Y" set-up and all will end up on the same side, irreversibly determined by the first explorer's random choice (decision is immediate).

For  $0 < p_0 < 1$ , a decision is always made, since the amplification mechanism is active, but the rate of the process does vary (Fig. 3). One way

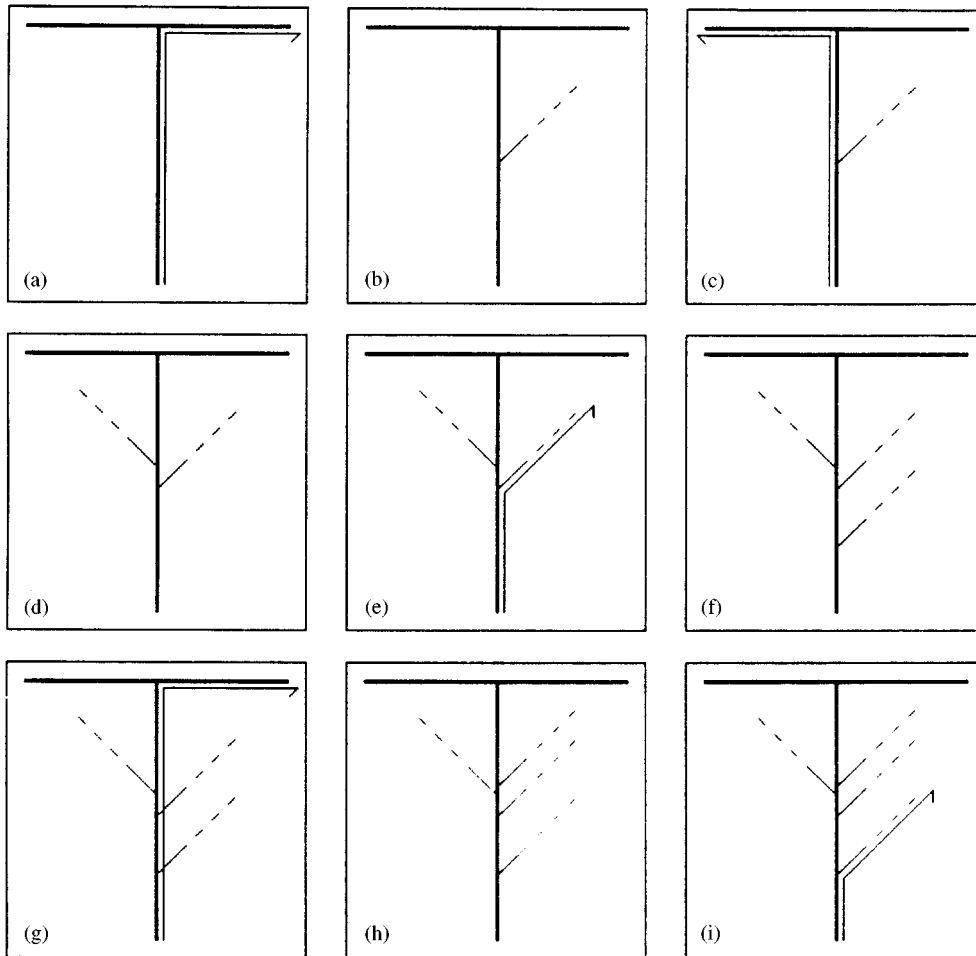


FIG. 2. Typical evolution of a branching points sequence in the simplified model.

to describe the underlying dynamics is to express the number of explorers that are necessary for a decision to be made ( $v$ ) as a function of  $p_0$ . In fact,  $v$  is the number of spiders for which the frequency distribution diagram of the population on one side ceases to be monomodal. A trivial calculation shows that  $v = 2$  is theoretically reached for  $p_0 = 1/3$ .

The analysis of the simulated experiments (Fig. 4) which covered values of  $p_0 < 0.35$ , shows that the best fit ( $r^2 = 0.99$ ) is obtained using an expression linking  $v$  to a power of  $p_0$ :

$$v = kp_0^{-\alpha}, \quad (1)$$

where  $k = 0.63$  and  $\alpha = 1.63$ .

The fairly high value of  $\alpha$  indicates that the relation between  $v$  and  $p_0$  is nonlinear, and that even a small increase in  $p_0$  can result in a substan-

tial reduction of the critical number of explorers for which the decision emerges ( $v$ ).

Comparison with field data shows that the best fit between theoretical and experimental distributions is obtained for  $p_0 \sim 0.1$ , in the absence of any interfering factor [Fig. 5(a)]. For higher values of  $p_0$ , the amplification process is too strong to account for the presence of “no choice” situations (<80% of the spiders on the “winning” side), although it should be remembered that these only represent three of 19 field experiments, and that random fluctuations could be responsible for them (Furey *et al.*, unpublished data).

### 2.3. INFLUENCE OF SUBPOPULATIONS

As little is known of inter-individual variability in social spiders behaviour, it appeared to us that

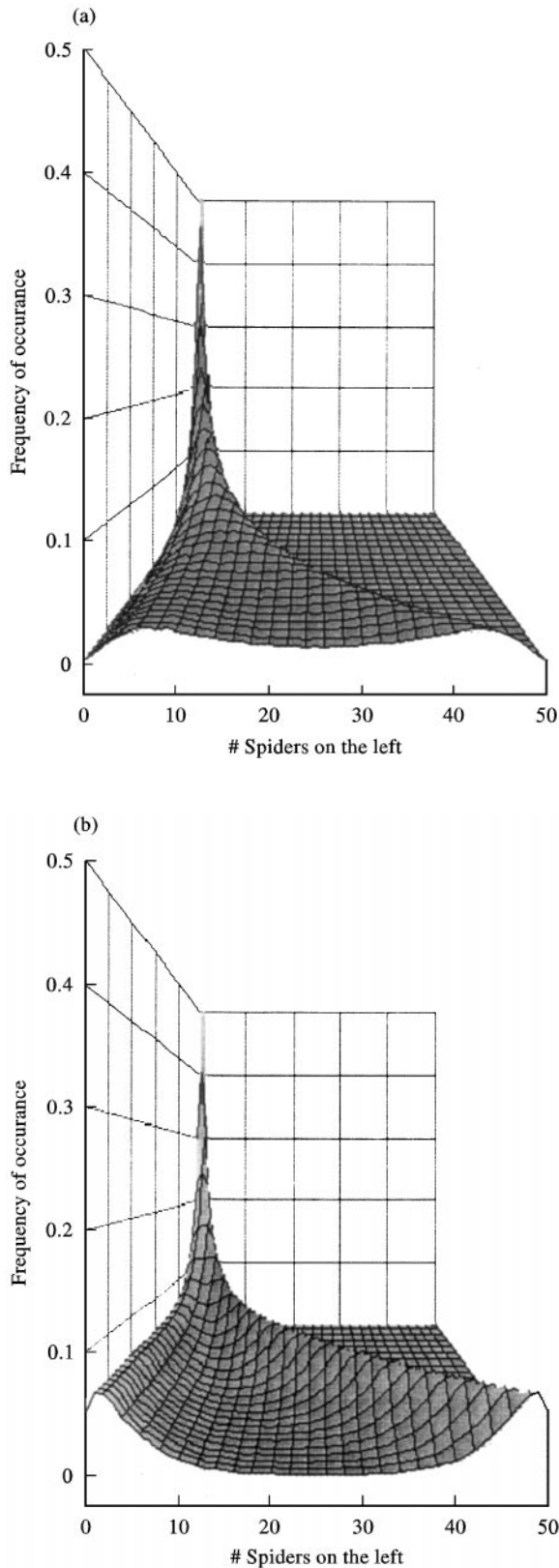


FIG. 3. Evaluation of the population on the left branch as a function of the number of explorers ( $n = 10^5$ , front = 50th) for  $p_0 = 0.1$  (a) and  $p_0 = 0.2$  (b).

considering the case of a population divided into subcategories could be relevant. There is no evidence allowing us to disregard the possibility that the probability to follow a dragline could vary from one spider to the other. It is known that in insect societies division of labour is widely based on a distribution of response thresholds (Page & Robinson, 1991; Bonabeau *et al.*, 1996b) and that, in trail-laying ants, the fact that all individuals do not necessarily react to a given stimulus in the same way does affect collective responses (George *et al.*, unpublished data).

Practically, we ran a set of simulations where the spiders were divided into two statistically equal subpopulations respectively responding to a potential escape route with a probability of  $p_0/2$  and  $3p_0/2$ . Spiders belonging to each subcategory followed one another in a random order.

There are no noticeable differences between the patterns corresponding to the homogeneous population scenario and to the subpopulations scenario, as shown in Figs 4 and 5(b) ( $k = 0.58$ ;  $\alpha = 1.69$ ;  $r^2 = 0.99$ ). This suggests that in an exploratory recruitment involving a multiplication of potential escape routes through time, a variability between individuals has little or no effect on the collective decision process.

2.4. RESULTS FOR MIXED POPULATIONS

Social spider colonies also differ from many insect societies in the way they react to conspecific intruders (Hölldobler & Wilson, 1991). It

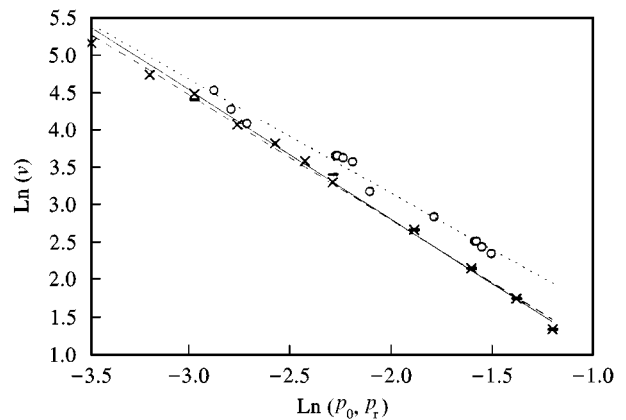


FIG. 4.  $\text{Ln}(v)$  as a function of  $\text{Ln}(p_0)$  for homogeneous population ( $\times$ ), for subpopulations ( $---$ ), and as a function of  $\text{Ln}(p_r)$  for mixed populations ( $\circ$ ).

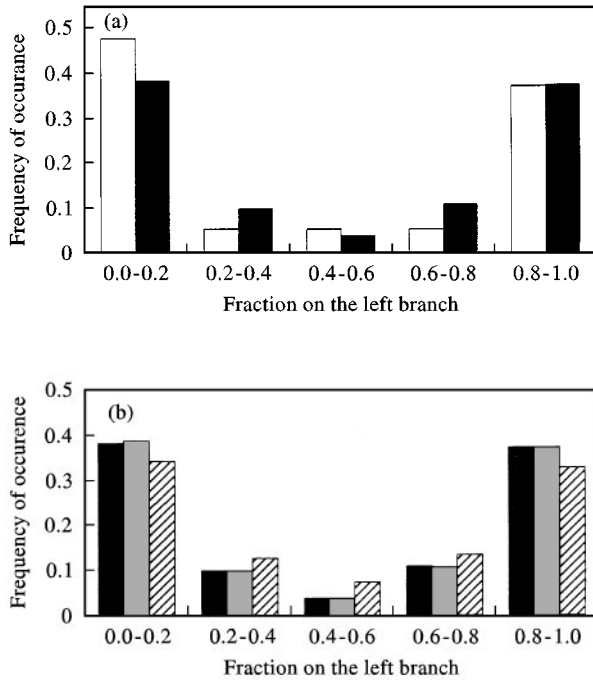


FIG. 5. Comparison between simplified model (filled,  $n = 10^5$ ) and experimental data (a), and between the three scenarios of the simplified model: homogeneous population (filled,  $n = 10^5$ ,  $p_0 = 0.1$ ), subpopulations (dotted,  $n = 10^5$ ,  $p_0 = 0.1$ ) and mixed populations (dashed,  $n = 10^5$ ,  $p_r = 0.1$ ) (b).

would seem they exhibit no explicit agonistic behaviour towards them (see e.g. Krafft, 1971, 1975; Furey & Riechert, 1999). However, the fact that social spiders do not kill or expel intruders does not necessarily mean that they cannot identify them as such. It has been shown for example that the introduction of a non-nestmate increases nearest-neighbour distance in *A. eximius* (Pasquet *et al.*, 1997). It is also known that silk contains pheromones (Prouvost & Trabalon, 1997). These can be attractive for conspecifics (Evans & Main, 1993) or used by males to locate mates (Clark & Jackson, 1995). So it is possible that silk could also carry some information about an individual's origin (for a more detailed discussion, see Furey *et al.*, unpublished data). To what extent would the ability to discriminate between the dragline of a nestmate and that of another spider affect the collective decision process in a mixed population?

We considered the same course of action that we used in the basic scenario, except that this time, when a spider encounters a possible escape route, it has a different reaction following the

origin of the dragline. It should be noticed that this scenario differs from the subpopulations scenario in that the probability to take an escape route does not vary as a function of some intrinsic property of the spider, but of a combination between its origin and that of the encountered dragline. As a result, the probability to exit may change from one branching point to the other, for any given individual.

In this case, another random test is performed whenever an exploring spider encounters a dragline that has not been laid by a nestmate. We define  $p_1$  the probability for a spider to consider foreign silk as a valid escape route and  $p_2 = p_0 p_1$  the probability that an individual leaves the initial axis using a foreign dragline when it encounters one.

We repeated the “Y” experiment with a mixed population composed of a statistically equal number of spiders coming from each colony, following one another in a random sequence. Again, for extreme values of  $p_1$ , the situation is trivial. For  $p_1 = 0$ , spiders of different origin simply ignore one another: sometimes foreign colonies will end up on the same side of the set-up, sometimes not. For  $p_1 = 1$ ,  $p_2 = p_0$  and the situation is in no way different from the basic scenario.

For intermediate values, the decision process will follow its course, pushing the entire population to select one side of the set-up. However, it will be slowed down by the fact that part of the explorers will be more or less reluctant to follow the other part's escape routes: the lower  $p_1$ , the higher the number of explorers that is necessary ( $v$ ) before a common decision emerges within the mixed population.

We tried to fit the resulting data using the same expression that proved effective for the basic scenario:

$$v = k p_r^{-\alpha} \quad (2)$$

with  $p_r$  being a probability resulting from the combination of  $p_0$  and  $p_1$ , generalized to mixed populations issued from  $N_c$  different colonies:

$$p_r = p_0 \frac{1 + (N_c - 1)p_1}{N_c}. \quad (3)$$

The analysis of the data (Fig. 4) shows that the best fit ( $r^2 = 0.98$ ) is obtained for values

of  $k = 1.23$  and  $\alpha = 1.49$ . This suggests that it is simply the mean attractivity ( $p_r$ ) of all available escape routes (nestmates and non-nestmates draglines) that determines the average number of explorers that is necessary for a collective decision to be made. The lower  $\alpha$  and higher  $k$  compared with those we obtained for homogeneous populations, suggests that amplification, if still present, is weaker, and consequently results in a less asymmetrical distribution [Fig. 5(b)]. However, these differences are too small to be statistically significant (Student test, NS). Also, it should be emphasized that for values  $p_1$  very close to zero, the values of  $v$  given by eqn (2) are underestimates, even if  $p_0$  is high. Obviously, for  $p_1 = 0$ ,  $v$  should be infinite to reflect the absence of any coordination between non-nestmates and the resulting survival of the central peak (trimodal distribution, whatever  $p_0$ ,  $k$  and  $\alpha$ ).

The most biologically significant result of the simulations dealing with mixed populations is that they clearly demonstrate that even a reasonably low attractivity of foreign silk (low values of  $p_1$ ) has little effect on the collective decision process, provided that the tendency to leave the initial axis ( $p_0$ ) is not too low. For example, in the case of a group issued from two different nests, with  $p_1 = p_0 = 0.2$ , giving a spider a probability  $p_2 = 0.04$  of leaving the initial axis when encountering a foreign dragline, the model predicts that a common decision still emerges for populations approaching 30 individuals ( $v = 29$ ). Further calculations show that for values of  $p_0$  higher than 0.2, amplification is strong that even values of  $p_1$  lower than 0.1 can lead to a final distribution with 100 individuals that is even more asymmetrical than the one observed experimentally for homogeneous populations (Furey *et al.*, unpublished data).

Given what we know of the way social spiders react to intruders, it seems very unlikely that they exhibit any strong avoidance behaviour towards foreign silk, even though they could prefer that produced by a nestmate. So, the model could explain why there is no significant difference between homogeneous and mixed groups in the field (Furey *et al.*, unpublished data). For the population tested (200 individuals), and given the size of the experimental set ( $n = 19$ ), the asymmetry would still be strong enough to hide any

discriminative pattern, at least for reasonable values of  $p_1$ .

### 3. Web Simulation (2D)

#### 3.1. LIMITATIONS OF THE 1D SIMULATION

Although the 1D simulation we used in the basic and mixed population scenarios appears to mimic quite accurately the dynamics of the “Y” choice experiment, it does not take into account the evolution of the silk structure itself. The web built by the spiders in the exploratory process is merely represented by a growing sequence of branching points, reflecting the choices made by other individuals. Whenever a spider has left the initial axis using another’s dragline, it is not allowed to “change its mind”; it is irreversibly routed towards the corresponding site.

If spiders were points without dimension, they would indeed be trapped by a one-dimensional thread, but they are not. Even if they are denied the ability to turn back along the same thread (which appears a reasonable simplification since they exhibit a strong tendency to climb up rather than down) they can still “jump” from one escape route to another, potentially switching sides in the process. As the opportunity to leave a dragline obviously depends on the possibility to reach another one, given the radius of a spider, a simulation that is to take this case into account requires an accurate modelling of the evolving geometrical properties of the growing network.

#### 3.2. DESCRIPTION OF THE MODEL

This simulation takes place in a two-dimensional continuous space. For computational purposes, a grid is superimposed, the mesh size of which is adjusted to a spider’s mean diameter (10 mm). Each spider is injected at the basepart of the vertical branch of the “Y” set-up, and moves from cell to cell, in a sequence corresponding to the orientation of the thread it is climbing along. Each time the spider enters a new cell, all draglines passing through it are checked, with a probability  $p_0$  of being chosen as the new circulation route. The order of testing depends arbitrarily on the threads age (oldest first, newest last). If the spider chooses to switch threads, the cell sequence is modified to render the new orientation

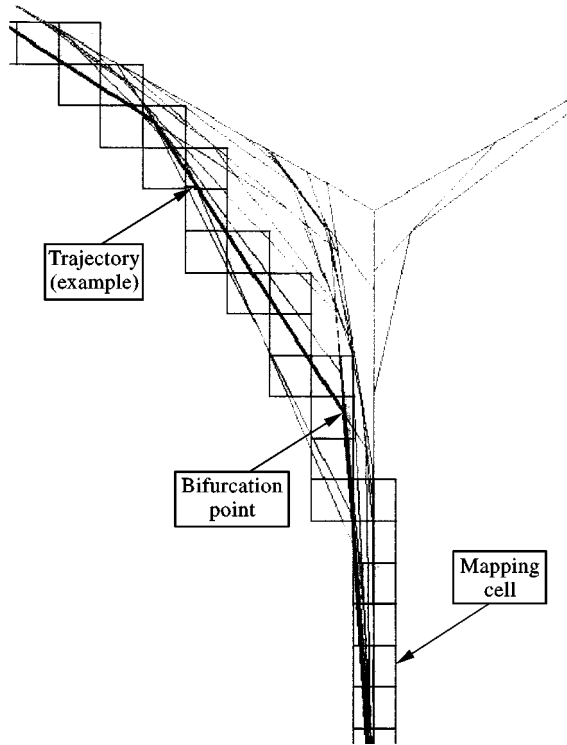


FIG. 6. Example of spider's trajectory in the web simulation.

of its displacement (Fig. 6). When the spider exits the set-up, the network is updated with its own dragline, the position of anchor points being a function of the trajectory and of the experimental attachment pattern. The network itself is continuous: the grid is only used as a mapping technique, minimizing search time for locally accessible threads.

### 3.3. RESULTS

This more realistic model gives puzzling results. The overall pattern of the decision process is unchanged: there is still a transition from an equal distribution between both sides to an asymmetrical one, for all values of  $p_0 > 0$ . But the bifurcation diagram [Fig. 7(b)] shows that the evolution of the phenomenon is nevertheless quite different from that we found in the basic scenario [Fig. 7(a)]. The decision process is slower (quite understandably, since a spider's first choice is not irreversible anymore), which results in the distribution being paradoxically further from the experimental data than the one we obtained with the simplified model.

It also appears that the ratio between the "losing" and "winning" sides no longer tends towards

zero, and that the lower the value of  $p_0$ , the higher the asymmetry in the population distribution after 100 spiders have left the theoretical set-up. This can only be explained in terms of saturation effects: as the network density on one side increases, so do the opportunities of switching from one thread to the other. As the probability of doing so is a function of  $p_0$ , it is clear that higher values of this parameter result in the saturation effect appearing sooner in the process. This in turn leads to a lower asymmetry in the spiders' distribution, as the probability of ending up on the "losing" side no longer tends towards zero, maintaining a residual activity on the corresponding branch.

The two-dimensional model was also used to study the correlation between asymmetries in the webbing surface (defined as the number of cells containing at least one thread) and in the population distribution. On that point, it appeared that it was able to reproduce experimental results

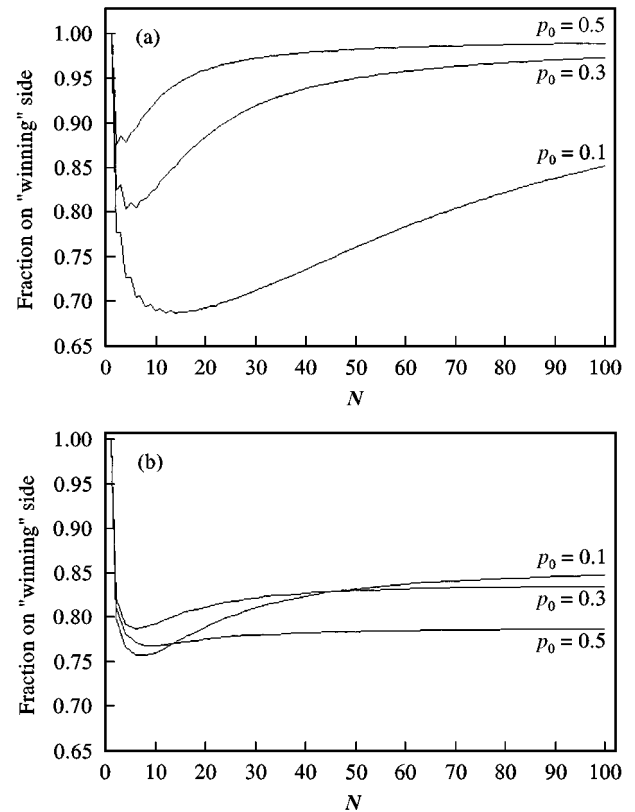


FIG. 7. Bifurcation diagram: population fraction on the "winning" branch as a function of the number of explorers ( $N$ ) in the simplified model (a,  $n = 10^5$ ) and in the web simulation (b,  $n = 10^4$ ).

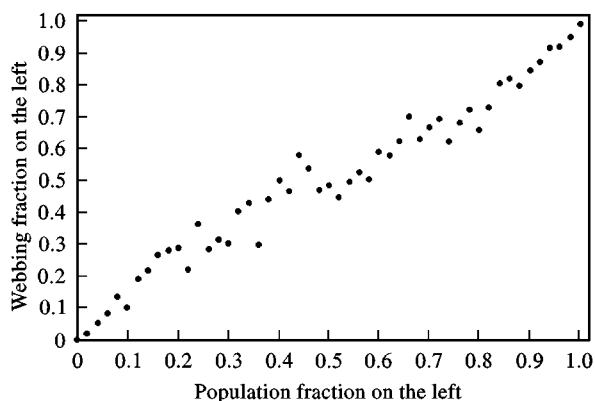


FIG. 8. Webbing surface fraction on the left branch as a function of population fraction on the same branch in the web simulation ( $p_0 = 0.1$ ).

with accuracy. Indeed, there is a strong correlation in these asymmetries, which can appear trivial, considering the very logic of the exploratory recruitment process. Yet the size of the theoretical dataset compared to the experimental results allowed us to go further in the analysis.

As shown in Fig. 8, the correlation between webbing surface fraction and population fraction on one side is not precisely linear. In fact, it is better for extreme values than for a more or less even distribution between both sides ( $< 80\%$  on the “winning” side). Simulation results indicate that the asymmetry in webbing surface is lower than the asymmetry in population distribution for these intermediate values. Once again, the effect is too weak to be of any significance for the interpretation of the experimental data, yet it is strong enough to be unquestionable on the theoretical level.

For now, we have no clear-cut explanation for this aspect of the amplification mechanism. It can only be assumed that it is related to the network’s local density, which was not taken into account yet, as our results only involve webbing *surface*. It is possible that below some critical point in the collective decision process, local inhomogeneities in the network density could make it appear symmetrical, although it is not from a more refined point of view (relative amount of silk on each side). Yet, this hypothesis has still to be verified.

#### 4. Discussion

The simulations clearly show that spiders’ basic dragline-laying behaviour can induce

strong amplification processes, resulting in collective decision abilities for social species. Even in the absence of any explicit recruitment process, either based on chemical trails or vibratory communication, geometrical constraints inherent to dynamical networks can result in information exchange and activity coordination within a population of mutually tolerant spiders.

The fairly good adequation between the basic scenario (1D) and the experimental results obtained in the field (Furey *et al.*, unpublished data) suggests that the sequential aspect of the population transfer along a single axis is enough to produce a strongly biased population distribution in the “Y” set-up. The existence of subpopulations as tested in the model (spiders exhibiting extreme values of  $p_0$ , following one another in a random order) would statistically not affect the amplification process. Nevertheless, it is possible that a collective decision could be achieved more or less efficiently as a result of variations in a given subpopulation frequency, or in the case of  $p_0$  being correlated with other behavioural features (activity level, etc.).

The patterns obtained in the real web scenario (2D) are very close to those we found in the 1D scenario, which confirms the efficiency and robustness of the amplification process. The differences in the distributions resulting from the two models are small enough to be experimentally unnoticeable (given all possible perturbation causes). Nevertheless, they are quite interesting from a theoretical point of view: for example, simulations suggest that higher values of  $p_0$  would finally result in a less biased distribution for increasing populations, due to saturating effects. This could act as an implicit population density control mechanism, facilitating splitting for large colonies that have grown beyond optimal size. In fact, the underlying dynamics could easily be compared to those involved in exploratory recruitment (Aron *et al.*, 1990) and collective nest-moving in social insects like ants (Hölldobler & Wilson, 1991; Verhaeghe *et al.*, 1992). If social spider foundation strategy partly relies on budding like it has been suggested (Lubin & Robinson, 1982; Vollrath, 1982), it seems interesting, from an ecological point of view, to conduct an experimental study about the influence of group size on the population transfer dynamics.

The influence of silk-bound pheromones on the collective decision process is quite puzzling. It is well known that most animal species have evolved recognition systems allowing them to discriminate between kin and non-kin (Sherman *et al.*, 1997). Given the high degree of inbreeding found in spider societies (see e.g. Avilés, 1997), we could have imagined some level of segregation between individuals belonging to distant colonies. But experimental results show that the final population distribution is not significantly different for mixed groups (Furey *et al.*, unpublished data). What simulations have taught us is that even if there is only a very low attractivity of foreign silk it has little effect on the amplification process. So the numerical results prevented us from concluding to the absence of any colony-specific pheromone on the basis of our experimental data. They show that if foreign silk is not explicitly repulsive (which seems very unlikely as social spiders exhibit no agonistic behaviour towards unfamiliar conspecifics), it is possible to obtain an asymmetrical population distribution with individuals that are able to identify silk of their own colony. They can even exhibit a strong preference for nestmates' draglines without affecting the global pattern in the binary choice experiment, provided that the total population exceeds a few dozen spiders. This unintuitive phenomenon simply results from the overwhelming influence of the amplification mechanism, inherent to the sequential aspect of the intersections encountering process. In fact, the juxtaposition of pheromone use and web building produces unusual responses, because chemical communication and mechanical constraints are narrowly interlaced, which is not the case in many other social arthropods.

We now intend to investigate another aspect of the amplification process, which is the potential influence of external inhomogeneities on the evolution of the population transfer. For example, air flow or asymmetrical light conditions could cause perturbations in the collective decision process. They could make it faster by inducing an initial bias in favour of one side, or on the contrary slow it down if spiders are facing contradictory information. As the ecological implications of these environmental factors for trap-building predators are obvious, chances are

they play an important part in each individual's choice.

Another part of our future work will consist in the exploitation of the web simulation platform in the overall context of communal web building, with a special interest in the interplay between geometrical properties of the supporting structure and spider's behaviour. Preliminary results have demonstrated that irregular web design is extremely sensitive to constraints imposed by the physical environment. We intend to test a variety of theoretical set-ups in order to study how the global response of the colony is affected, and to what extent does the final shape of the network reflect changing external conditions. As the web simulation platform accurately models the evolution of the web, including the spatial orientation of threads, their length, the number of intersections, etc., we should be able to define a set of criteria for a quantitative description of the network's properties (silk density profile, connection level, etc.). We think that this theoretical approach can provide important clues for the understanding of natural irregular webs, in particular those of social species.

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