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Efficient promotion strategies in hierarchical organizations

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ABSTRACT

The Peter principle has recently been investigated by means of an agent-based simulation, and its validity has been numerically corroborated. It has been confirmed that, within certain conditions, it can really influence in a negative way the efficiency of a pyramidal organization adopting meritocratic promotions. It was also found that, in order to bypass these effects, alternative promotion strategies should be adopted, as for example a random selection choice. In this paper, within the same line of research, we study promotion strategies in a more realistic hierarchical and modular organization, and we show the robustness of our previous results, extending their validity to a more general context. We also discuss why the adoption of these strategies could be useful for real organizations.

1. Introduction

Promotion strategies are fundamental for a hierarchical organization, this being a scientific group, a company, a public administration, a cluster of computers, or a group of animals. They are important for one to understand the dynamics of a pyramidal system and eventually provide ways to improve its efficiency. It is not strange that physicists are also working in this direction. In fact, in recent years, physicists have started to collaborate with economists and social scientists in order to get a more quantitative understanding of social science mechanisms [1–6]. Actually, it is by now largely accepted that, even in social sciences, simple schematic models and computer simulations inspired by statistical physics are able to take into account unexpected collective behaviors of large groups of individuals, discovering emergent features that are independent of their individual psychological attributes, which are very often counterintuitive and difficult to predict simply by following common sense. Along these lines, by means of an agent-based simulation approach [7–11], we study here the effects of the Peter principle [12] within a very general context in which different promotion strategies are investigated in order to maximize the global efficiency in a given hierarchical system. In a previously published paper [13], we have already studied this phenomenon within a pyramidal organization, showing its validity under certain conditions, and we have tested several strategies in order to bypass its negative effects. In this paper, we investigate in deeper detail a more complex modular organization, also endowed of new realistic features, in order to test these different promotion strategies under the Peter hypothesis and their influence in maximizing the global efficiency of the system, considering also the individual expectations of its members in terms of career progressions. In particular, we study the gain in efficiency due to both the organization topology (modular or pyramidal) and the introduction of a variable percentage of random promotions after a meritocratic transient. The paper is organized as follows. In Section 2, after a brief summary of our previous results, we present the details of the more realistic new model adopted in the present paper, and we compare the old pyramidal topology with the new modular one. In Section 3, we describe the new simulation results. Then a general discussion is addressed in Section 4, where the real applicability of these strategies is also presented, and finally some conclusions are drawn in Section 5.

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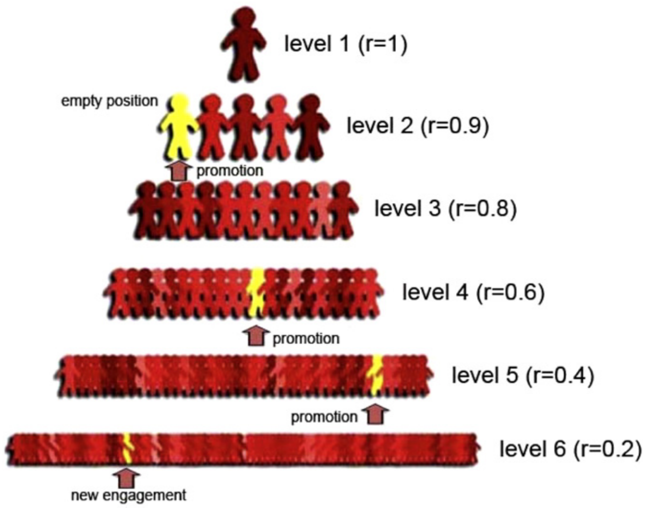


Fig. 1. Schematic view of the simple pyramidal model studied in our previous paper [13]. Beside each level, the corresponding value of responsibility (increasing linearly from the bottom to the top) is also reported. We show in yellow the empty positions for which promotions are required. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2. The extended hierarchical organization model

We present in this section the details of the new hierarchical organization model adopted in this paper, in order to test in more realistic situations the effects of the Peter principle and the possible strategies to contrast it. However, before illustrating the new model, we summarize the results obtained in our previous paper [13].

2.1. Previous results about the pyramidal model

In our previous paper, we studied the schematic pyramidal model shown in Fig. 1. The main features of this model are summarized below.

(1) We considered a hierarchical pyramidal organization with 160 positions divided into six levels. Each level has a different number of members (which decreases, climbing the hierarchy) with a different responsibility, i.e., with a different weight on the global efficiency (see below) of the organization. The members of the organization have only two features: an age (ranging from 18 to 60 years) and a degree of competence (ranging from 1 to 10, and indicated by a color with intensity proportional to the competence). As initial conditions we selected ages and competences following normal distributions with, respectively, average 25 (with standard deviation 5) and average 7 (with standard deviation 2).
(2) At each time step, members with an age over the retirement threshold (fixed at 60 years) or with a competence lower than the dismissal threshold (fixed at 4) leave the organization (their color becomes yellow), and someone from the level immediately below (or from outside for level 6) will be chosen for promotion; see Fig. 1.
(3) Four different competing strategies of promotion have been proposed. The first strategy consists in promoting the best worker, the second in promoting the worst, the third considers the promotion of a random worker, and the fourth alternates the promotion of the best and the worst.
(4) For each promotion at the upper level, two different mechanisms of competence transmission have been considered. (1) Common Sense (CS): if the features required from one level to the upper are sufficiently stable, the new competence at the upper level is correlated with the previous one and the agent maintains his/her competence with a small error. (2) Peter hypothesis (PH): if the features required from one level to a higher one can change considerably, the new competence at the higher level is NOT correlated with the previous one, so the new competence is again randomly assigned from a normal distribution, as happens in a new engagement.
(5) A parameter, called the global efficiency, E, is calculated by summing the competences of the members level by level, multiplied by the level-dependent factor of responsibility, ranging from 0 to 1 and linearly increasing on climbing the hierarchy. The result is normalized to its maximum possible value $Max(E)$ and to the total number of agents N, so that the global efficiency (E) can be expressed as a percentage. Therefore, if C_i is the total competence of level i, the resulting expression for the global efficiency is

$$E(\%) = \frac{\sum_{i=1}^{6} C_i r_i}{Max(E) \cdot N} \cdot 100, \quad (1)$$

with $Max(E) = \sum_{i=1}^{6}(10 \cdot n_i) \cdot r_i / N$, where n_i is the number of agents at level i.

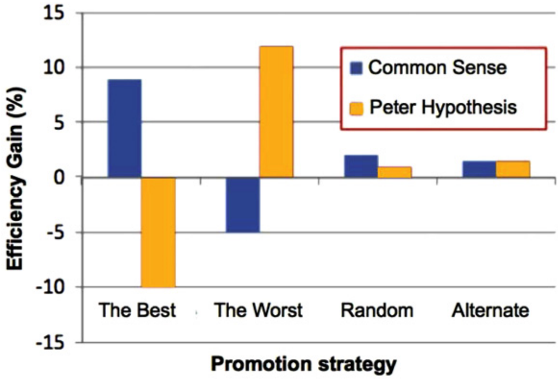


Fig. 2. A schematic summary of the results found in our previous paper [13]; see the text.

The main results found in our previous paper are summarized in the histogram of Fig. 2, where the asymptotic efficiency gain, calculated with respect to a common but arbitrary initial state and averaged over many different realizations of the initial conditions, is reported as a function of the hypothesis adopted and of the promotion strategy applied. In particular, we found the following.

(1) Promoting the best member is a winning strategy only if the CS hypothesis holds, otherwise is a losing one; for this reason, we also define the strategy "The best" coupled with the Peter hypothesis as "naively" meritocratic.
(2) In contrast, if the PH holds, the best strategy is that of promoting the worst member.
(3) But if one *does not know* which of the two hypotheses holds, then adopting a random promotion strategy, or alternating the promotion of the best and the worst, always results in being a winning choice.

The previous results are neither straightforward nor immediately intuitive, since at a first sight they seem to contradict common sense; moreover, they were obtained through a very simple toy model which could seem a very peculiar example. Therefore, although the paper was very successful and appreciated also for its simplicity – it was quoted by several blogs and specialized newspapers, among which were the MIT blog, the New York Times, and the Financial Times, and it was also awarded the IG Nobel prize 2010 for "Management" [14] – further investigations within a more realistic model were certainly desirable.

2.2. The new hierarchical tree model

In order to test the robustness and the general validity of the increase in efficiency triggered by random strategies, we improved our agent-based model by introducing several new features which provide a more realistic scenario.

First of all, we consider a more complex topology for modeling a schematic modular organization, i.e., a hierarchical tree network with $K = 5$ levels, where each agent (node) at levels $k = 1, 2, 3, 4$ (excluding the bottom level with $k = 5$) has exactly L first subordinates (i.e., first neighbors at level $k + 1$), which will fill that position when it becomes empty. An analogous structure has been used in a recent paper concerning a Dilbert–Peter model of organization effectiveness [15]. We can call L the *coordination number* of the network. This means that, at variance with the pyramidal schematic model of our first paper, in this case promoted agents follow the links to ascend through levels. On the other hand, neglecting the links and promoting agents from the entire level k to the next level $k - 1$, one recovers the pyramidal model as a particular case. For a given value of K and L, the total number N of agents of such a hierarchical network is given by

$$N = \frac{L^K - 1}{L - 1}. \tag{2}$$

In the following, we fix $K = 5$ and vary L. In this case, each agent with $k < 5$ has exactly $N_k = (L^{6-k} - L)/(L - 1)$ subordinates in all the levels below. In Fig. 3, we show four examples of hierarchical tree networks with $K = 5$ levels and an increasing coordination number L: for $L = 3$, we obtain a network with $N = 121$ agents; for $L = 4$, $N = 341$; for $L = 5$, $N = 781$; and for $L = 6$, $N = 1555$. The responsibility value is 0.2 for the bottom level and it increases linearly, like in the previous model, with step 0.2 for each level up to the top one, whose responsibility value is 1. Such a modular structure is surely more suitable than the simple pyramidal one to describe realistic sales divisions in large corporations or project teams in government institutions [15].

The second main improvement concerns the time units adopted in the simulations. In our previous model, we adopted one year as the time unit; therefore all the dynamical features of the algorithm (retirements, dismissals, promotions, or new engagements) were updated at the end of each year. Now, we increase the time resolution by using one month as the unit. This means that the age of all the agents increases by one unit (one year) every 12 time steps, but all the dynamical features are now updated every month. In such a way we will be able to follow the dynamics of the organization over a more realistic and detailed time scale.

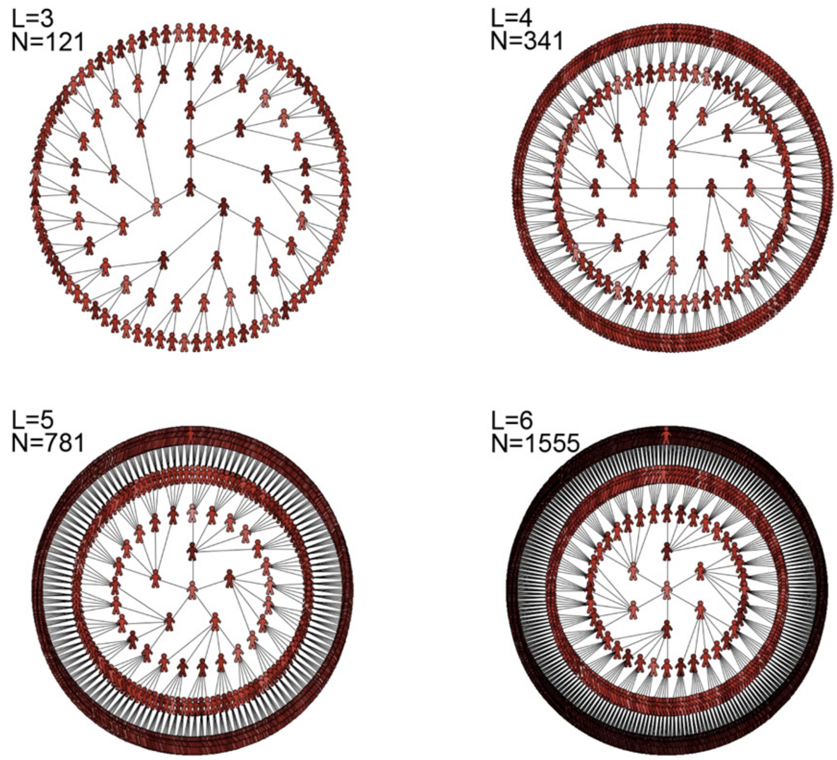


Fig. 3. Hierarchical tree networks with different coordination number L and size N: for $L = 3$ and $N = 121$, for $L = 4$ and $N = 341$, for $L = 5$ and $N = 781$, and for $L = 6$ and $N = 1555$.

In order to make the dynamics independent of the initial conditions, instead of studying gains and losses with respect to an arbitrary initial state for the organization (with an arbitrary value of the initial global efficiency, as done in [13]), we will refer here to a *relative global efficiency* $E_r(\%)$, calculated with respect to a fixed transient during which a naively meritocratic strategy (i.e., promotions of ''The best'' coupled with the Peter hypothesis) is always applied. The introduction of such a transient also allows us to simulate organizations which have already reached their stationary state, since we are not particularly interested in newly founded companies but in existing average-size companies. Another important improvement concerns the details of random promotions. Since it is understandable that a real company would initially be hesitant in adopting *tout court* random promotions as a long-term strategy, it is worthwhile investigating how much randomness is effectively needed in order to see *as soon as possible* some relevant improvement after the meritocratic transient. Therefore we introduce a new ''Mixed'' strategy, in which a different increasing percentage of random promotions with respect to ''The best'' one is considered. Of course a ''Mixed'' strategy with 0% of random promotions corresponds to a full ''The best'' strategy, while a ''Mixed'' strategy with 100% of random promotions corresponds to a full ''Random'' strategy.

Finally, as already anticipated, we have also considered the possibility to promote a member from one level to the next without considering the links of the hierarchical tree, in order to reduce the new model to that one considered in [13]: this last mode of promotion is, from here on, called *global mode*, and it refers to the old pyramidal topology, while the *neighbors mode* is the promotion mode which follows the links of the full modular network.

3. New simulation results

We present in the following the results of simulations performed with the new hierarchical model just introduced. First of all, let us try to reproduce the old results shown in Fig. 2 within this new model, focusing our attention (i) on the influence of the topology on those results and (ii) on the competition between the ''Random'' strategy and ''The best'' strategy under the Peter hypothesis of competence transmission.

3.1. Comparison between the old and the new model

In Fig. 4, we plot the time evolution of the relative global efficiency $E_r(\%)$ for the hierarchical tree networks shown in Fig. 3, but in the 'global' mode, i.e., without considering the links: it is a situation equivalent to the old pyramidal topology shown in Fig. 1, only with a different increasing size. For each network, we adopt a mixed strategy of promotions, with an increasing percentage of random promotions and coupled with the Peter hypothesis (PH). Results are averaged over

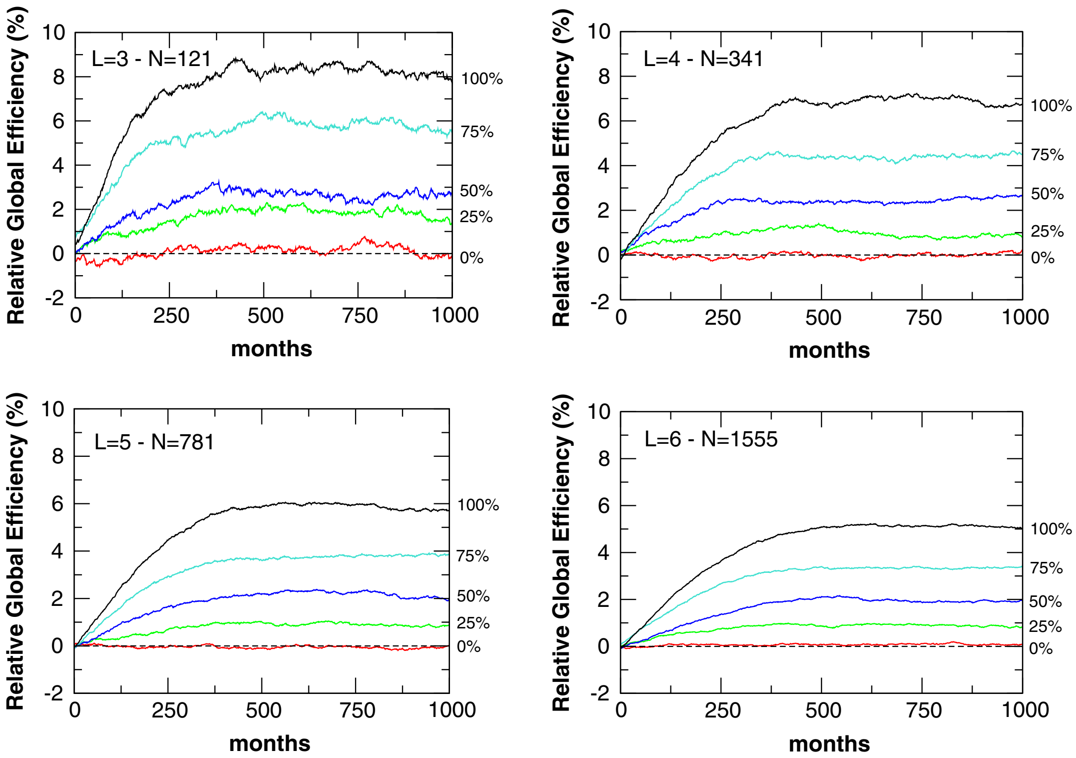


Fig. 4. Time evolution of the relative global efficiency $E_r(\%)$ for four hierarchical tree networks with increasing coordination numbers, after a meritocratic transient (not reported in the panels). An average over 30 realizations was done. For each plot, assuming the Peter hypothesis for competence transmission, a mixed strategy of promotion was adopted with an increasing percentage of random promotions with respect to "The best" strategy—reported beside the panels. The simulations were performed in 'global' mode, i.e., each network is reduced to a simple pyramid in which an empty position at level k can be filled by any agent at level $k + 1$, as in the old model [13].

30 events, i.e., runs with different realizations of the initial conditions. As previously mentioned, each simulation starts with a meritocratic transient of 1000 months (not plotted in Fig. 4), which is long enough to reach a stationary state for the global efficiency. Immediately *after* the transient, the various percentages of random promotions are introduced, and for the next 1000 months we report, in each panel of Fig. 4, the relative global efficiency $E_r(\%)$ for the corresponding organization, calculated as the difference between the actual absolute efficiency $E(\%)$ and the efficiency $E_{trans}(\%)$ calculated by averaging along the stationary state of the transient. In other words, $E_r(\%)$ measures the gain or loss in efficiency with respect to the 'naively' meritocratic regime (whose reference value, corresponding to $E_r(\%) = 0$, is indicated with a dashed line in all the plots).

We immediately see that an increase in the percentage of random promotions (reported on the right at the end of each curve) yields a gain in efficiency for all the organizations, although in general the asymptotic values of $E_r(\%)$ slightly diminish by increasing the size of the organization. Fluctuations in the time evolution are also strongly suppressed by increasing the size of the system, since they go from values around $\pm 0.3\%$, for the $L = 3$ case, to values below $\pm 0.1\%$ for the $L = 6$ case. In any case these fluctuations do not affect the general trend of the global efficiency and therefore the conclusions of our analysis.

If one focuses on the difference between the 100% curves (full "Random" strategies) and the 0% ones (full "The best" strategies), this result confirms what previously shown in Fig. 2, where the difference in efficiency (about 8%) between the cases "Random" + PH and "The best" + PH is comparable with that one obtained here for the $L = 3$ organization, the more similar in size with the old pyramidal model. It is interesting to notice that the increase in efficiency triggered by the random promotions (also if they are present in a small percentage) is sudden and relevant immediately after the meritocratic transient, even if the system reaches its stationary state only after 20 years (240 months).

In Fig. 5, we illustrate simulations analogous to those presented in Fig. 4, where the time evolution of the relative global efficiency $E_r(\%)$ has been calculated for the same four hierarchical tree networks shown in Fig. 4, but applying the mixed strategy of promotions (again coupled with the Peter hypothesis) in 'neighbors' mode, i.e., promoting people by following the links for climbing the hierarchy. The results show that the global efficiency is quite sensitive to the topology of the organization, whose effect seems to be that of shrinking the gap of gain between the full "Random" strategy efficiency (100% curve) and the meritocratic one (0% curve), for all organization sizes (for the $L = 3$ network the gap shrinks from the 8% of Fig. 4 to 4%, even if it stays quite constant increasing L). This would mean that, for a given organization, a hierarchical tree topology with modules, groups, and subordinates would allow one to reduce the effectiveness of random strategies in

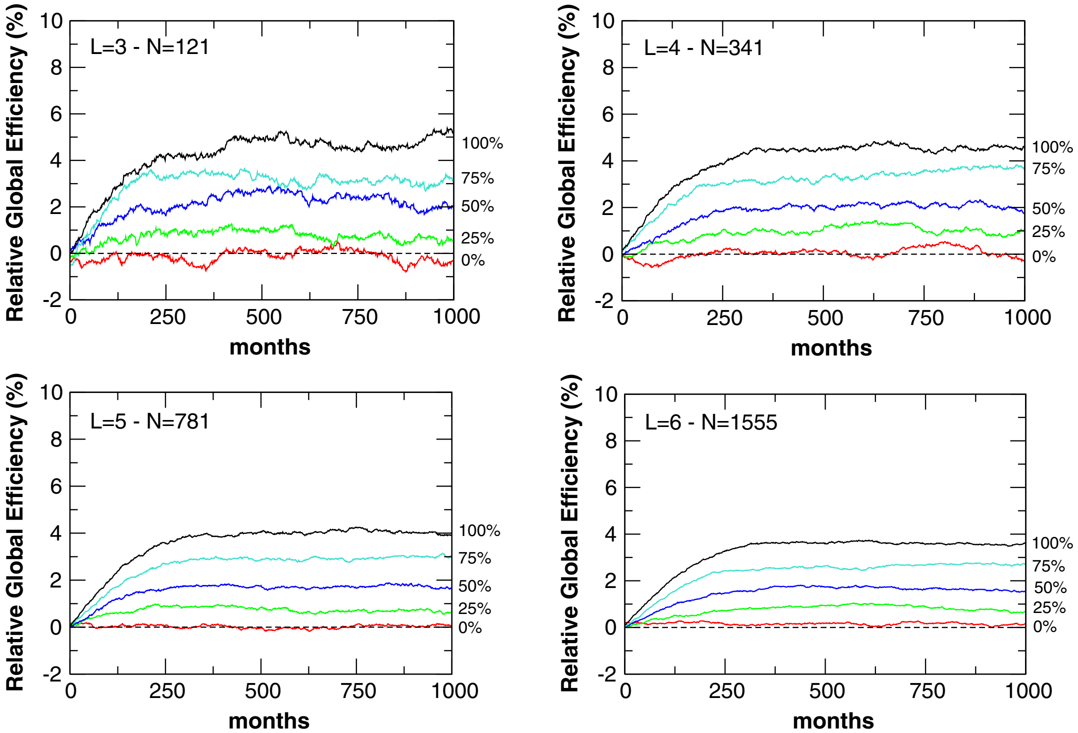


Fig. 5. We show here simulations analogous to those shown in Fig. 4 but obtained with promotions in 'neighbors' mode, i.e., an empty position at level k can be filled only from first-neighbor agents at level $k+1$.

mitigating the effects of the Peter hypothesis with respect to the simple structure with global promotions among levels. But this is only one half of the story. In fact, if one observes the absolute values of the transient efficiency $E_{trans}(\%)$ (not reported in the figure), it results that, regardless of L, it is always greater by about 3% in 'neighbors' mode with respect to the 'global' mode. This can be explained by considering that, during the meritocratic transient, the strategy of promoting each time the agent with the highest competence penalizes organizations with pyramidal topology ('global' mode): in fact, in this case, the selection of the best agent at level k is performed on a statistical sample with many more agents (L^{k+1} to be precise) than in the case of a network topology in 'neighbors' mode (where the selection is performed only over the L first neighbors); therefore, the probability of promoting an agent with competence close to the maximum possible value (10) is very much higher. And since each promotion implies a random change of competence, as imposed by the Peter hypothesis, such a statistical effect produces, in the long term, a lower (in absolute value) transient efficiency for the pyramidal topology. On the other hand, the hierarchical tree networks in 'neighbors' mode shows a greater transient efficiency but reduces the gain in efficiency due to the introduction of random promotions after the transient, as observed in Fig. 5 (we will discuss this effect in more detail in the next section).

Finally, as shown in Fig. 6, we perform a final test in order to verify the consistency of the new model with the old one also when the Common Sense hypothesis for competence transmission is adopted after a meritocratic transient, again as a function of an increasing percentage of random promotions and for both the 'global' and the 'neighbors' modes. We consider here only the $L = 4$ network, representing an organization with five levels and a total of 341 members, and compare the behavior already shown in Fig. 5 for this network under the Peter hypothesis (PH, top panels) with the analogous results obtained now under the Common Sense hypothesis (CS, bottom panels). It clearly appears, in agreement with the results of Fig. 2 for the limiting cases of 0% and 100% of random promotions, that the evolution of the relative global efficiency $E_r(\%)$, averaged over 30 events, shows a sudden decrement in the CS regime when even a small percentage of randomness is introduced into the promotion strategy. This confirms the effectiveness of promoting the best members when the new competence requested at level k is correlated with the old one requested at level $k+1$. In this case, the modular structure of the organization ('neighbors' mode, right bottom panel) reduces the negative effects with respect to the pyramidal one ('global' mode, left bottom panel); therefore, a complex topology with project teams, managers, and subordinates is again also recommended for a real hierarchical organization if the Peter hypothesis does not hold.

3.2. Robustness of the random strategy gain

In order to better compare the total efficiency gain which takes into account the contributions of both the topology and the random promotions, it is more convenient to represent the results of the upper panels of Fig. 6, concerning an $L = 4$ network,

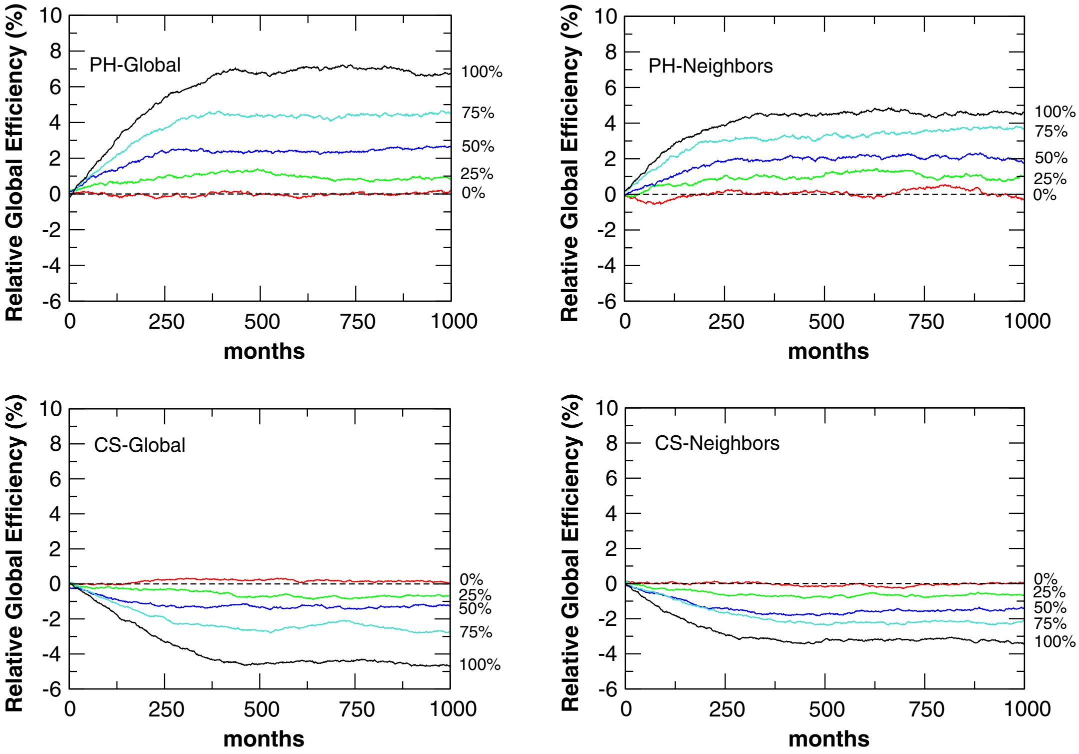


Fig. 6. Time evolution of the relative global efficiency (averaged over 30 events) for the $L = 4$ hierarchical tree network. In the first row we report, for comparison, the same plots of Figs. 4 and 5 for the $L = 4$ network, while in the second row we show analogous plots but with the Common Sense (CS) hypothesis of competence transmission for both 'global' (left) and 'neighbors' (right) modes. As expected, in this case, the introduction of a percentage of random promotions after the meritocratic transient yields a decrease in efficiency, according to the results of Fig. 2, but this decrement is less in the case of the "neighbors mode"; see the text.

in the form of a histogram, as shown in Fig. 7. Here, the global efficiency in the 'global' mode (on the left) corresponds to the asymptotic efficiency gain due to the introduction of random promotions after the meritocratic transient, while the global efficiency in the 'neighbors' mode (on the right) is calculated by taking as reference value the average transient efficiency $E_{Gtrans}(\%)$ in the 'global' mode (put equal to 0), and by adding the gain in efficiency $E_{Ntrans}(\%) - E_{Gtrans}(\%)$, evaluated at the end of the transient and due to the modular topology (a gain which depends on the statistical effect previously explained and which remains here around 3%), to the asymptotic gain in efficiency due to random promotions. Fluctuations around the average stationary values are not visible in this representation, but they remain very small and of the same order of those of the previous figures for the case when $L = 4$.

Within this new visualization it becomes evident that the modular complex structure ('neighbors' mode) is more convenient for a real organization (in terms of efficiency) not only when the Peter hypothesis (PH) holds and one adopts the strategy of promoting the best members (as happens during the transient), but also when one adopts a percentage of random promotions less than 100% (again under the PH). Only on applying the full "Random" strategy does the global efficiency seem to no longer depend on the topology. With this last figure as reference, let us now test the robustness of the random strategy gain with respect to the introduction of new realistic features to our model. Of course we will introduce one feature at the time, keeping all the others fixed, in order to better emphasize the influence on the organization for a given modification.

Simulations with age-dependent competences

In the previous section, as well as in our previous paper [13], the competence of the various agents was considered fixed in time at the top of their respective possibility. But in a more realistic situation one can imagine that the competence of a young employee would improve until a certain age and then would slowly diminish until retirement. Furthermore, very often employees are frustrated by a lack of promotion opportunities, and individual efficiency decreases when an increase in age does not match with a proper career progression: such an effect is known as the *Prince Charles syndrome*, and it has also already been studied computationally [16].

It is therefore interesting to explore if the effectiveness of the random promotion strategy holds when a competence variable in time with the age and the position of the agents is introduced in our new model. In particular, we introduced an increment of competence in time for each agent during the first part of his/her career in the organization, regardless of the level, up to an age of 38 years, and a decrement of competence during the remaining part of career which, however, further decreases climbing the hierarchy in order to take into account the Prince Charles syndrome (at the same age, the

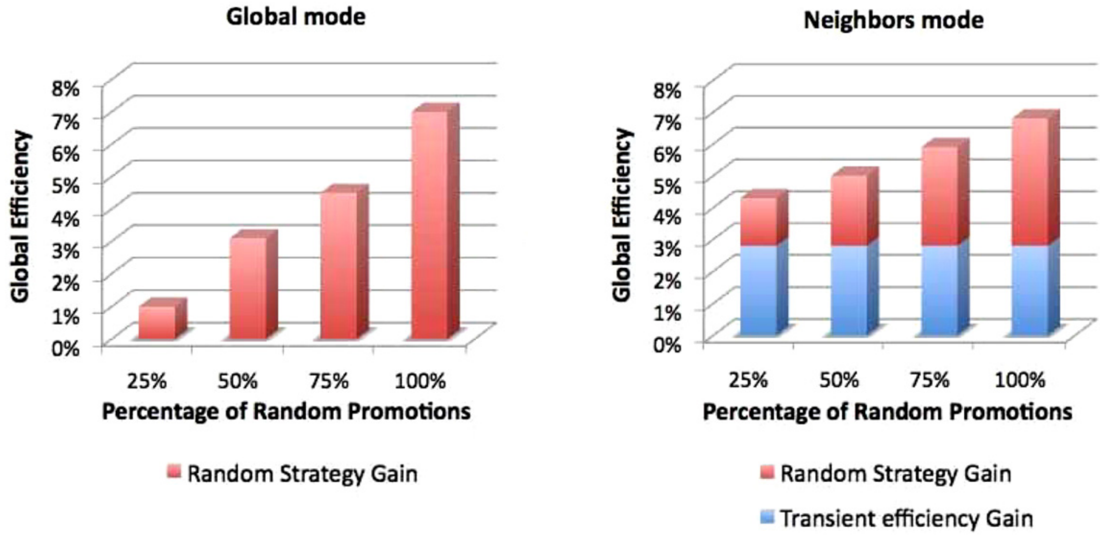


Fig. 7. Global efficiency gain for the $L = 4$ hierarchical tree network for an increasing percentage of random promotions in both 'global' and 'neighbors' modes. The different contribution due to the transient dynamics, with meritocratic promotions, and to the introduction of random strategies, is emphasized (see the text).

higher the level is, the greater the motivation is to carry out one's own work with efficiency). In Fig. 8, we plot the global efficiency gain for an $L = 4$ network, in both 'global' and 'neighbors' modes, as function of an increasing percentage of random promotions (under the PH) and for two different steps of increment/decrement of competence. In the two upper panels we fix an annual competence increment of $+0.02$ and an annual decrement of $-0.02/r_k$, r_k being the responsibility of level k (which increases linearly with the levels, as reported in Fig. 1), while in the lower panels the annual increment is $+0.05$ and the annual decrement $-0.05/r_k$; in both cases, from a comparison with Fig. 7, it clearly appears that this new feature does not sensitively affect the global efficiency, regardless of the topology. Actually, apart from a small general loss of $\sim$2% observed in the lower plots, the gain induced by random promotions tends to be confirmed for both the pyramidal and the modular structures of the organization.

Organizations with nonlinear responsibility

In all the previous simulations, as already observed, the responsibility of the five levels of the organization varies linearly from 0.2 to 1, but of course this is an arbitrary criterion and one could ask how the response of the system to the introduction of random promotions could be affected by changing it. Actually, since the responsibility of managers within a hierarchical organization could be likely considered to be correlated to the total number of their subordinates at the lower levels, it is probably more realistic to adopt a nonlinear scale for the responsibility. In this respect we did some simulations in which the responsibility r_k of an agent at level $k < 5$ is equal to the total number of his/her subordinates at all the levels below, i.e., $N_k = L^{6-k} - L/L - 1$. For $k = 5$, we put $r_k = 1$. The results are reported in Fig. 9 for $L = 3$ and $L = 4$ organizations, in both 'global' and 'neighbors' modes, and under the Peter hypothesis of competence transmission. Again, also in this case, we observe a positive reaction of the asymptotic global efficiency to the adoption of random strategies, with a total gain that is independent of the topology only for full random promotions, while for a percentage of randomness smaller than 100% the contribution of topology becomes important and privileges the 'neighbors' mode, i.e., a modular structure with respect to a pyramidal one. Comparing the lower panels of Fig. 9 with those of Fig. 7, apart from a slight decrease (~ -1%) in transient efficiency for the 'neighbors' mode, the results are very similar; therefore, the choice of responsibility scale does not appear to affect the global efficiency of the system and the gain due to random promotions so much.

Mixed hypothesis for the transmission of competences

Let us now consider a situation that is probably very common in real organizations, where often neither the Common Sense hypothesis nor the Peter hypothesis of competence transmission is always satisfied, individually, for *all* positions. Rather, we can suppose that, in many real cases, some particular positions in the hierarchy will require, for the promoted agent, a small change in the task to perform with respect to the previous level (CS), while other positions could require very different skills (PH). In order also to take into account these situations, in the next simulations we consider the possibility of having two different kinds of position randomly distributed over the organization, one satisfying the PH and the other one the CS, but with a different probability. In Fig. 10, the behavior of the asymptotic global efficiency is reported for the usual $L = 4$ organization (with linear responsibility scale) in both 'global' and 'neighbors' modes, now as function of an increasing percentage of PH positions. As always, each simulation starts with a meritocratic transient characterized by the promotion of the best members, after which we apply here a full (100%) random strategy of promotions. Notice that, at variance with the previous simulations, here both $E_{Ntrans}(\%)$ and $E_{Gtrans}(\%)$, and then the gain in efficiency $E_{Ntrans}(\%) - E_{Gtrans}(\%)$ due to the topology, may change depending on the percentage of PH positions, since the latter is a structural feature which also affects

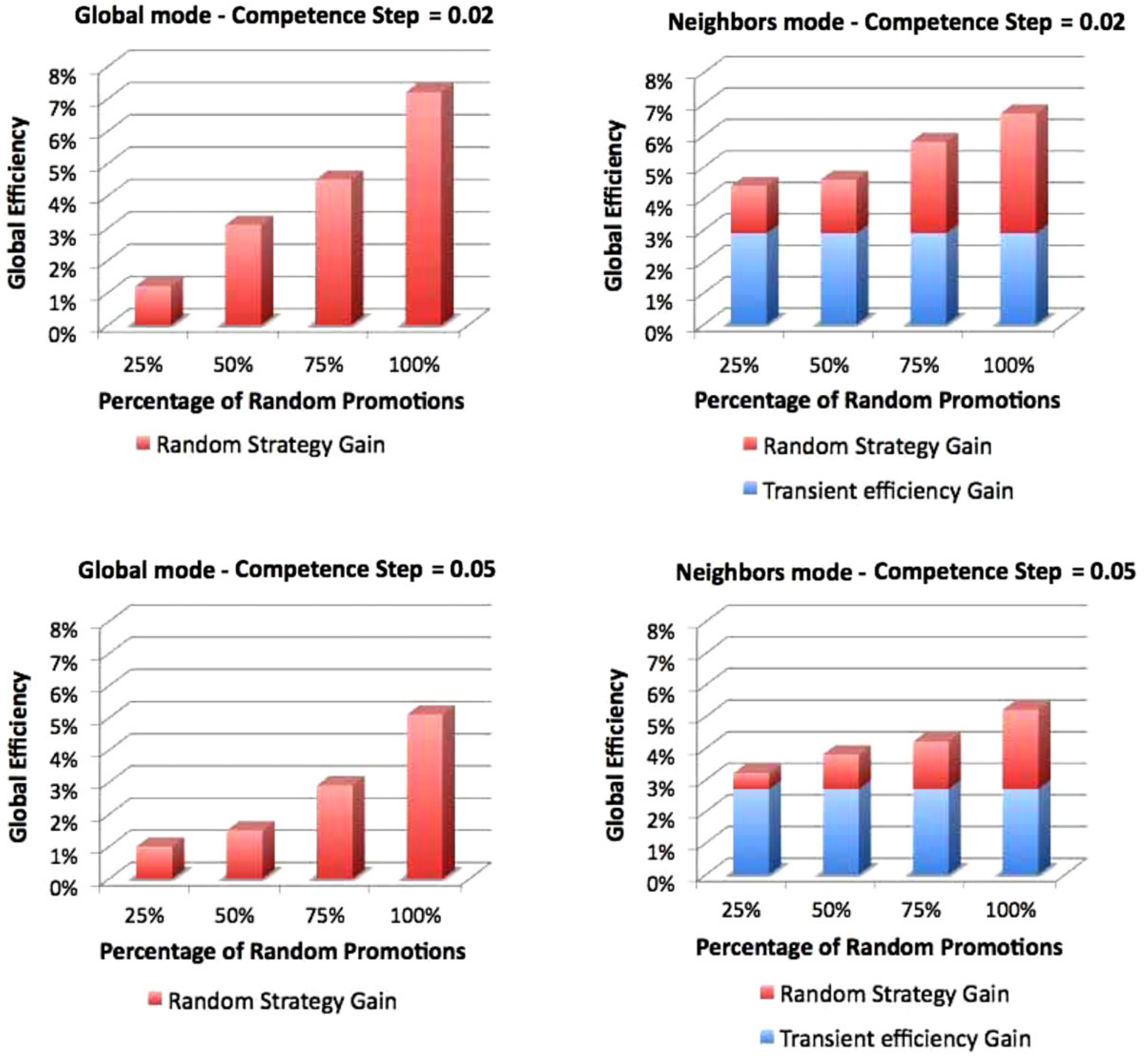


Fig. 8. Global efficiency gain (averaged over 30 events) for the $L = 4$ hierarchical tree network for an increasing percentage of random promotions in both 'global' (left side) and 'neighbors' (right side) modes. In these simulations, we introduced an annual increment of competence ($+0.02$ and $+0.05$) for each agent during the first part of his/her career (regardless of the level) up to an age of 38 years, and an annual decrement of competence ($-0.02/r_k$ and $-0.05/r_k$) during the remaining part of the career (see the text for more details).

the transient dynamics. Furthermore, $E_{Ntrans}(\%) - E_{Gtrans}(\%)$ can now also be negative when the percentage of PH positions is lower than 50%, since in that case the Common Sense hypothesis prevails in the organization and the meritocratic transient benefits the 'global' pyramidal topology with respect to the 'neighbors' one (for the same statistical effect which favors the modular structure when the Peter hypothesis holds).

From Fig. 10, we see that, for any topology, the application of the 100% random promotion strategy produces positive effects only for organizations with more than 50% of PH positions, while in the other cases promoting the best members continues to be a winning strategy. This definitively clarifies that adopting random promotions is not *always* a recommended strategy, but *only* when in a given organization the Peter hypothesis holds for the majority of positions.

Time-dependent size of the organization

Our last test concerns the introduction of the possibility to change in time the size of the organization. Actually, in the previous simulations, the total number of active positions in the organizations was kept fixed in time, but this constraint could be considered not very realistic since companies can decrease or increase the number of their employees in time following periods of crisis or expansion. Therefore, we tried to explore the effects of the introduction of a given percentage of random promotions in a contracting or in an oscillating modular $L = 4$ organization (in 'neighbors' mode, under the Peter hypothesis) after a meritocratic transient during which the size is held constant in time. The results of the simulations are shown in Fig. 11. First of all, we let the organization contract in time by dismissing its members with a rate of 3 positions every 12 months, as shown in the left top panel, where the percentage of active positions (i.e., the level of occupancy) is

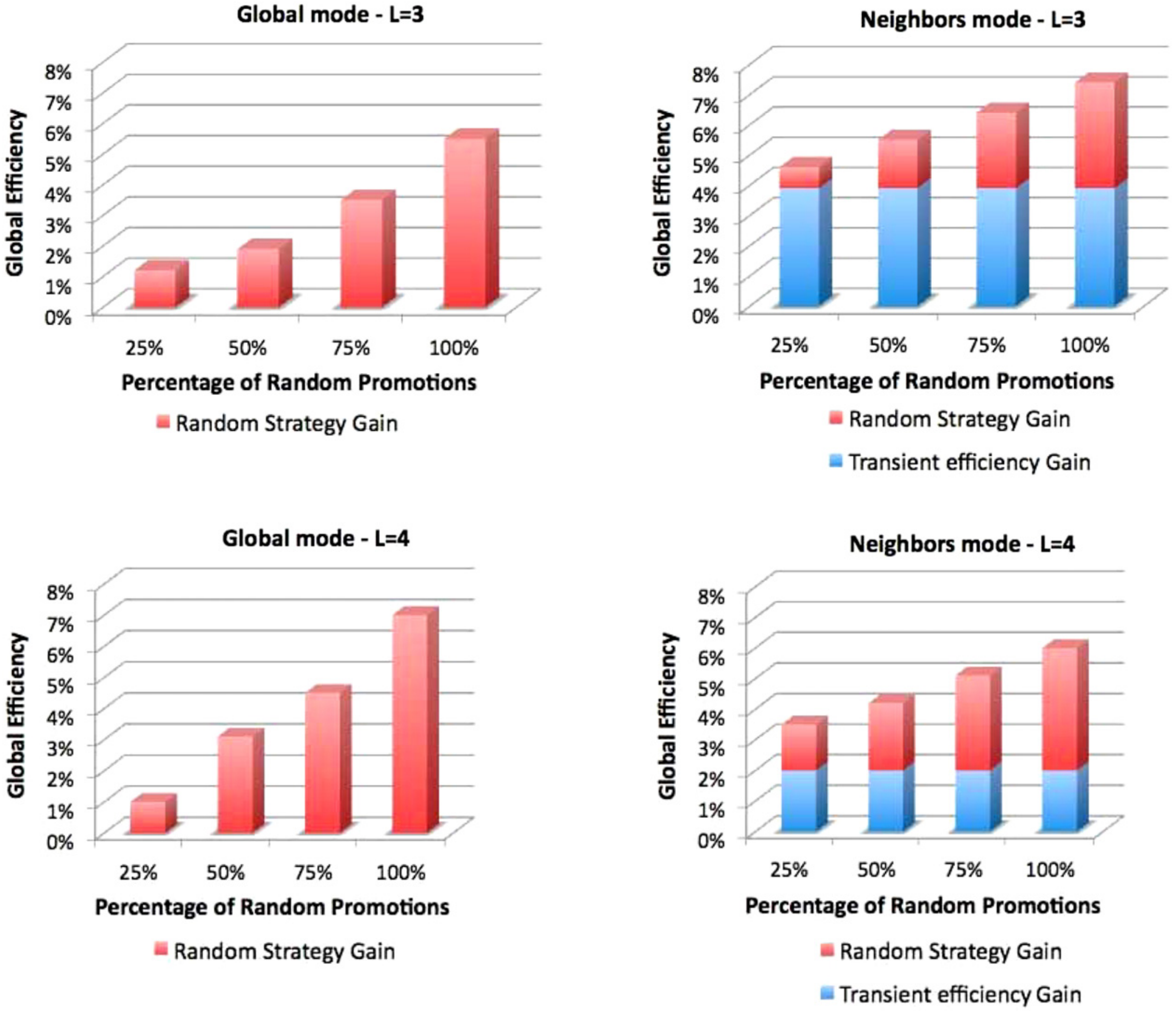
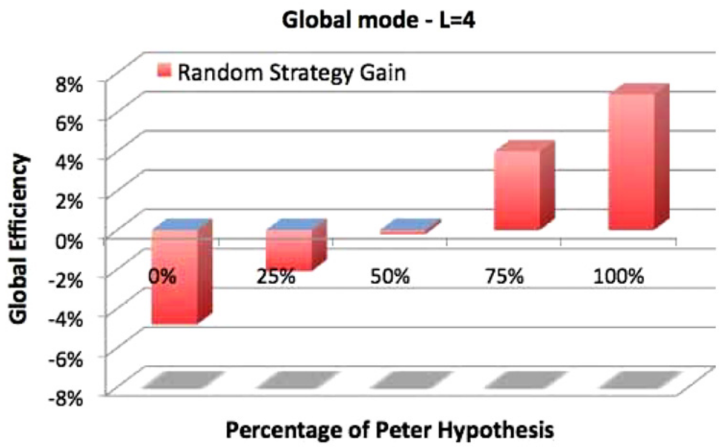


Fig. 9. Global efficiency for the $L = 3$ and $L = 4$ hierarchical tree networks (averaged, respectively, over 30 and 20 events), for an increasing percentage of random promotions in both 'global' and 'neighbors' modes of the Peter hypothesis. In order to make the responsibility increment from the bottom to the top level more realistic, in these simulations we adopted, instead of the usual linear scale, a nonlinear one; see the text for more details.

plotted as a function of time; correspondingly, in the panel below, we plot the behavior of the relative global efficiency for three different percentages of random promotions. The introduction of even a small percentage of random promotions quickly also enhances the relative efficiency during a period of crisis. The same behavior can be found in the plots on the right side of Fig. 1, where we let the number of active positions of the organization oscillate in time with a dismissal rate of 5 positions every 3 months, as shown in the top panel. Again, random strategies (and in particular the full 100% one) seem still to be more effective than the others, as shown in the panel below. In general, we also see that the effect of reducing the size improves the efficiency while an expansion reduces it, until, with an occupancy under 40%, even the meritocratic strategy with 0% random promotions improves the efficiency of the organization (but, in any case, less than the random one). Therefore these simulations also further confirm the robustness of the full random strategy, which can be definitively considered as the more effective for any complex organization, pyramidal or modular, for which the Peter hypothesis applies.

4. General discussion

In this section, we will try to summarize the results of our simulations presented previously and discuss possible applications in real cases. In all the examples we have presented, a common feature strongly emerges: the efficiency of an organization increases significantly if one adopts a random strategy of promotion with respect to a simple meritocratic promotion of the best members. This fact, already shown in our previous paper [13] for a very simple pyramidal model and under a minimum number of assumptions, has proven to be very robust and persistent even in a new hierarchical tree model and under many different kinds of realistic improvement.



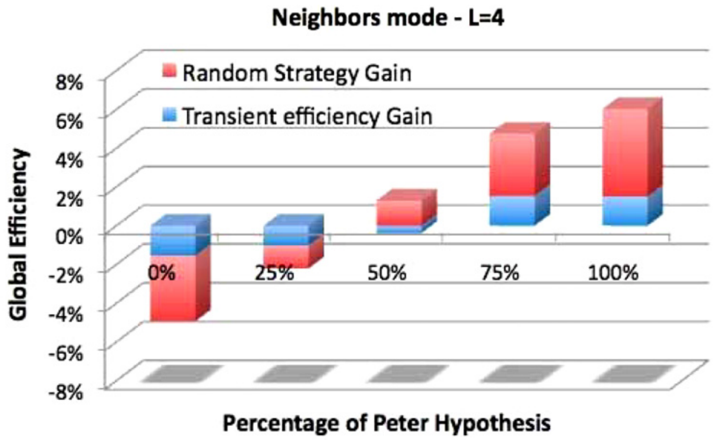


Fig. 10. Global efficiency (averaged over 30 events) for the $L = 4$ hierarchical tree network in both 'global' and 'neighbors' modes and with a full (100%) random strategy. In these cases we simulate an organization in which a certain percentage of positions are characterized by the Peter hypothesis (indicating no correlation between competences before and after the promotion at those positions), while the remaining ones are characterized by the Common Sense hypothesis (indicating a strong correlation between competences before and after the promotion at those position). See the text for further details.

Actually, the finding of the effectiveness of random promotions is not completely new. In fact, we have recently discovered that some years ago two researchers at the Dallas School of Management, Texas (US), published a study of management in real companies through computer simulations and found that the promotion of best performers may actually degrade the overall organizational performance when compared with just promoting a random member of the group [17]. But, since they introduced random promotions as a baseline control system, they were very surprised by this unexpected result, which in any case was not connected at all to the Peter principle and, as far as we know, they did not return to the subject with further investigations. In contrast, in our simulations the random strategy has been introduced from the beginning as a real alternative strategy to the meritocratic one, and the increase of efficiency triggered by random promotions has been identified as an emergent feature which comes out because of the cooperative effect of many promotion events under the Peter hypothesis. In this respect, our new results corroborate the fact that one does not need a full random strategy to obtain an increase of efficiency: in many cases, a choice of only 50% of agents selected in a random way for promotion results in being enough to obtain a consistent increment in the efficiency. Furthermore, in all cases discussed, the random strategy improves the efficiency of the system consistently, revealing a very persistent robustness.

4.1. Considerations about the first 20 years

The simulations presented in the previous section were performed for a period of 1000 months (about 83 years). This period could seem too long to be considered realistic also for a real organization which wants to establish a long-term strategy of promotions. But, on the other hand, the improvement in efficiency induced by the random strategy after the transient has been shown to be rapid and substantial since the very beginning (1% after 3 years, 2% after 6 years, and so on) and usually the global efficiency reaches a stationary state after just 20 years. In order to discuss this point in deeper detail, we emphasize in Fig. 12 the initial part of the efficiency time evolution for a hierarchical organization with

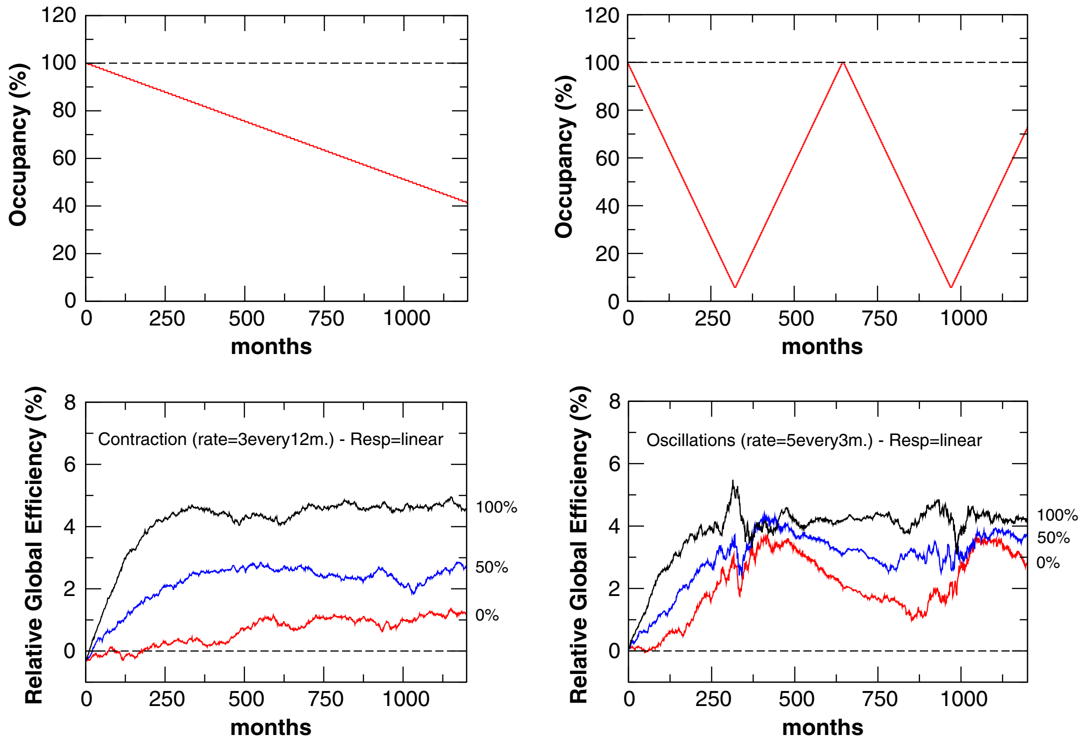


Fig. 11. In the bottom panels we show the time evolution of the relative global efficiency for the $L = 4$ hierarchical tree network (averaged over 30 events), for an increasing percentage of random promotions in the 'neighbors' mode of the Peter hypothesis. The novelty is the introduction of the possibility, for the organization, to change in time its number of active positions. A contracting organization and an oscillating organization have been considered, respectively, in the left and in the right panels. Fluctuations in efficiency are visible especially in the right panel, due to the sudden inversion of tendency in the size oscillation.

$K = 5$, $L = 4$ and $N = 341$, considering an increasing percentage of random promotions for both a pyramidal ('global') and a modular ('neighbors') topology under the Peter hypothesis of competence transmission. In particular, we focus on a period of 240 months (20 years), and we also perform an average over 30 different realizations in order to diminish the effect of fluctuations. The simulations strongly indicate that, regardless of the topology and of the percentage of random promotions, in the first 20 years the global efficiency reaches values which are equal to about 75–80% of the asymptotic values shown in the upper panels of Fig. 6. In Tables 1 and 2, we report detailed information concerning all the relevant quantities which characterize the organization considered in Fig. 12 during the 20 years.

In particular, in Table 1, we report (from left to right), for both 'global' (top) and 'neighbors' (bottom) modes and for each percentage of random promotions, the following quantities: (i) the gain in efficiency accumulated during the meritocratic transient (calculated with respect to the 'global' mode, which therefore has gain equal to 0%); (ii) the further gain in efficiency due to the adoption of a random strategy after the transient (corresponding to the maximum values reached in Fig. 12); (iii) the total number of dismissals (N_d); (iv) the total number of retirements (N_r); and (v) the total number of promotions (N_p). On the other hand, in Table 2, we report, again for both topologies and for all percentages of random promotions, the total number of agents who terminated their career (due to dismissal or retirement) at each of the five levels of the organization, i.e., respectively (from left to right), N_5, N_4, N_3, N_2, N_1.

Looking at these tables, we immediately notice something strange. In fact, from the last three columns of Table 1, one sees that, while the total number of dismissals and retirements in the 20 years is almost the same regardless of the topology, the number of promotions is quite different in the two cases, and it results in being always greater in the 'neighbors' mode (i.e., for a modular organization) of about 30 units on average. Such a result sounds paradoxical because, at first glance, the total number of promotions, N_p, should be strictly correlated with the total number of dismissals and retirements at levels 4, 3, 2, and 1 (quantified by N_4, N_3, N_2, N_1). Actually, from Tables 1 and 2, it results that, for each percentage of random promotions and for both topologies,

$$N_p = N_4 + (N_3 \cdot 2) + (N_2 \cdot 3) + (N_1 \cdot 4), \tag{3}$$

since every dismissal or retirement causes, in turn, a cascade of promotions depending on the level at which it occurs (the more numerous the higher the level). On the other hand, it is also evident that, regardless of the topology,

$$N_d + N_r = N_5 + N_4 + N_3 + N_2 + N_1. \tag{4}$$

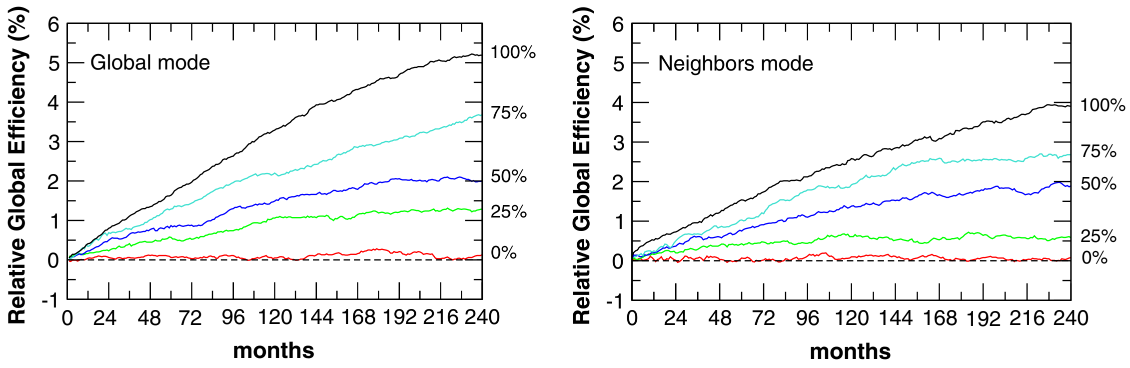


Fig. 12. A magnification of the initial evolution of Figs. 4 and 5 that shows an immediate increase of the efficiency since the beginning of the adoption of a random strategy with respect to a meritocratic one with the Peter hypothesis; see the text for further details.

Table 1
With reference to the simulations plotted in Fig. 12, we report, from left to right, the percentage of random promotions in 'global' mode (upper panel) and in 'neighbors' mode (lower panel); the gain in efficiency accumulated during to the meritocratic transient (calculated with respect to the 'global' mode); the further gain in efficiency due to the adoption of a random strategy after the transient; the total number of dismissals; the total number of retirements; and the total number of promotions. See the text for further details.

	Trans. Eff. Gain (%)	Rnd. Eff. Gain (%)	N_d	N_r	N_p
Global mode — % of rnd prom. (%)					
0	0.00	0.36	22	206	84
25	0.00	1.01	22	205	94
50	0.00	2.37	20	206	96
75	0.00	3.80	24	209	111
100	0.00	5.25	23	204	116
Neigh. mode — % of rnd prom. (%)					
0	2.70	0.14	22	203	135
25	2.70	1.12	24	204	136
50	2.70	1.42	23	204	138
75	2.70	2.83	25	201	144
100	2.70	3.70	25	202	146

Table 2
With reference to the simulations plotted in Fig. 12, we report, from left to right, for both 'global' (upper panel) and 'neighbors' (lower panel) modes and for all percentages of random promotions, the total number of agents who terminated their career at each one of the five levels of the organization.

	N_5	N_4	N_3	N_2	N_1
Global mode — % of rnd prom. (%)					
0	167	44	12	4	1
25	161	46	14	4	2
50	158	48	14	4	2
75	155	54	17	5	2
100	146	56	17	6	2
Neigh. mode — % of rnd prom. (%)					
0	133	61	21	8	2
25	134	63	22	7	2
50	132	63	23	7	2
75	128	64	25	6	3
100	128	65	24	7	3

Therefore, comparing Eqs. (3) and (4), the explanation of why N_p is so sensitive to the topology, while N_d and N_r are not, seems to lie in the different role played by the bottom level 5, since only in this level does a dismissal or a retirement not translate into a promotion but implies a new external engagement. Actually, the value of N_5 in the 'neighbors' mode is always lower than the corresponding value in the 'global' mode (see Table 2) and such a decrease, of about 30 units, corresponds to the number of agents who, in a modular organization, are more likely to be promoted to the next levels with respect to a pyramidal structure (as reported in the last column of Table 1).

The solution of this puzzle becomes clear if one looks at the ages of agents at level 5, which (during the dynamics) are normally distributed around 40 years regardless of the topology, and those at other levels. In fact, it results that, in a modular organization ('neighbors' mode), members of levels ≤ 4 are on average quite older than those of the bottom level 5, while the same does not happen in a pyramidal topology ('global' mode). Such a strange statistical effect can be explained with an argument similar to that used in Section 3.1, since in 'neighbors' mode the choice of the candidate to be promoted is carried out on a much smaller sample (of the order of a few units) than in the 'global' mode, so it is very likely that the tails of the age distribution will almost always excluded, and the age of the promoted members will be closer to the average, i.e., 40 years old. This implies a greater number of retirements at levels ≤ 4 with respect to level 5 in 'neighbors' mode (despite the fact that the total number N_r is similar for both topologies) and this, in turn, implies the observed greater number of promotions N_p for the modular topology.

In conclusion, it seems that the mere fact of adopting a modular structure, instead of a pyramidal one, increases not only the efficiency of the organization in a meritocratic regime of promotions (see the first column of Table 1), but also the probability of career advancements for its members. Therefore it seems that a complex hierarchical and modular topology is convenient from both a global and an individual point of view. Finally, we notice that the total number of promotions N_p grows even further also by increasing the percentage of random promotions for both topologies, thus definitively confirming the advantage of using a random strategy for any kind of organization (if the Peter hypothesis holds).

4.2. Real applications of random promotion strategies

Let us now discuss the possibility of real applications of a random promotion strategy. A frequent objection to the adoption of a random promotion strategy, by a company or a public administration, concerns the possible negative psychological feedback of employees to a denied and expected promotion. It is true that, for the sake of simplicity, we did not consider any possibility of this kind in our simulations. But, on the one hand, in a very big company it is very likely that the employees completely ignore the promotion strategies of their managers; therefore, these effects could have a very minimal influence on their work. On the other hand, we think that the most important point which emerges from our work is the necessity to distinguish promotions from rewards and incentives for the good work done. Actually, if the best employees understandably expect a prize for their work, such a prize, which from an individual perspective is necessary for the purpose of preventing a decrease in competence (see also the Prince Charles syndrome), does not necessarily have to coincide with a promotion. On the contrary, receiving an increase in salary, or more responsibility or more freedom in the time schedule, could be very often a much more appreciated reward for excellent performance. Thus we explicitly suggest accompanying random promotions with prizes/rewards to the best members, in order to prevent psychological side effects. In fact, it is not difficult to understand that if someone is the best for a certain role, it is much better to try to keep him/her in that position instead of risking changing his/her task or role, a change that, if the Peter hypothesis holds, could expose the company to the risk of a decrease in efficiency. For example, it is surely much better to keep an excellent surgeon in his/her position instead of promoting him/her to be the main director of the hospital, which is a managerial role: in so doing, we risk having a double loss, i.e., a less competent new director and a less competent new surgeon!

But, once it is established that for a given organization the meritocratic strategy is a losing one if the Peter hypothesis holds, why should random promotions be better? Of course, an immediate answer is that promoting people at random prevents the change of role of the best members with certainty, thus circumventing the Peter effect. On the other hand, it is not easy to understand this result analytically in detail, since the effect is a cooperative emergent feature of the numerical simulations. We suspect that such an effect could have many similarities with the Parrondo paradox [18], where the noise has a constructive role. Also, in physics, there are many examples where noise has a positive influence [19–23], and actually this was what stimulated us in trying this possibility to bypass the Peter principle. However, apart from physics, there are other analogies in nature in favor of this strategy, and one of them is certainly natural selection. In fact, during evolution, natural selection proceeds through random mutations and not through something like top-down meritocratic promotions. If a random mutation results in giving a great advantage for some species, then it is maintained and reinforced, and never changed or removed on purpose. Moreover, mixing genes is surely positive for species health and survival.

In addition to these arguments, a random strategy of promotions also has other advantages which provide further benefits. In fact, random selection can favor the emergence of hidden skills of the less competent employees, which otherwise could have had very few probabilities to be appreciated. A famous example in this direction, extracted from another field, is the case of the well-known opera singer Maria Callas. The great turning point in her career occurred in 1949 in Venice, when she was chosen, by chance and all of a sudden, to substitute for the main singer, who had fallen ill [24], in a role she had never interpreted, in the opera "I Puritani". Something similar also happened to the famous orchestral conductor Arturo Toscanini, who debuted as a conductor at the age of 19 years old just by chance, when he was forced to substitute for the official conductor who abandoned the orchestra (in which Toscanini played as musician) during a tour of South America [25].

But there are also other justifications for the practical use of random selection of candidates. Not infrequently, especially in public administration, the meritocratic regime does not represent the main criterion chosen for promoting people: relatives or friends with very minimal competence are often preferred for promotion to higher levels, without any relation to competence. In this case, a random selection of candidates may have the merit of disrupting this very bad practice which certainly decreases the organizational efficiency more than any meritocratic promotion. In this respect, Phedon

Nicolaides [26], after reading our first paper, recently expressed his personal point of view on our proposal by considering a random choice for the committees that should select employees for promotion. In our opinion, this could also be a successful strategy, although we have not done any simulation in this direction.

At this point, it would be interesting to put into practice and test our proposal in the real world to have some experimental proof, beyond simulations, of its validity, and we hope to collaborate with private companies in this respect in the near future. Of course, in order to do so, our proposal needs to be adapted to real organizations, with a given topology, which could differ from case to case. But we have recently discovered that, as far as we know, there is at least a well-known case where a strategy similar to what we propose has been put into practice with success. This is the case of the SEMCO company in Brazil [27]. In the 1980s, this company was saved from bankruptcy by Ricardo Semler, who took the role of CEO, substituting for his father. Semler, by adopting a very innovative way of management based on task rotation, on a system of rewards, and on a very limited role of hierarchy, invented a new strategy which revealed itself to be very successful, and increased the number of employees from 90 to 3000. Today, Semler is one of the new gurus of management who gives lectures at the Harvard Business School and in other prestigious institutions around the world. The new Semco way is not exactly equivalent to what we propose, but it is very similar in many respects and provides an interesting example of how new ways of management, apparently eccentric and not based on a simple and naively meritocratic regime, are not only possible but, above all, convenient. Finally, before closing this discussion, we would like to mention another possible application of our random strategy to political elections. When democracy was invented in olden times in Athens [28], political representatives were sorted at random and not elected. An election system based on a refined lottery was adopted in the past for choosing the Doge in Venice [29], and similar systems were adopted in the past in other parts of Italy. So it would be quite interesting to see if a random selection of political representatives would really improve the efficiency of a parliament. This idea has also regained some strength recently with the proposal in this direction of popular juries, that should control the work of politicians, by Ségoléne Royal in France [30], or with the proposal of Barnett and Carty for a radical reform of the House of Lords by a random election [31]. Stimulated by these examples, we have started to work in this direction with numerical simulations. Our results seem very encouraging, and favor the adoption of a random choice of representatives for enhancing the efficiency of a parliament, but they will be reported elsewhere [32].

5. Conclusions

We have explored in a more realistic model of hierarchical organization, within an agent-based simulation approach, the negative effects of the Peter principle and possible strategies to contrast them. Our results confirm the robustness of our previous findings, providing further support to our claim that a random strategy seems to be a very simple and interesting way to increase the efficiency of any real organization for which the Peter hypothesis of uncorrelated competence transmission holds. As discussed in the paper, random selection should not necessarily be completely random to be successful, since even 50% of random selection already provides a good advantage with respect to a full "naively" meritocratic regime of promotions. On the other hand, it is also true that no psychological effects of random promotions have been taken into account in our simulations and that these could be non-negligible for real organizations. We will certainly consider them in future studies, but, anyway, we believe that random selection with different possible refinements (as suggested for example in [26]) could be an interesting promotion strategy to improve the performance of a hierarchical organization, not only to contrast the Peter principle effects but also nepotism and corruption. In general, a rotation of tasks, which is a very similar possibility to the one we propose, has already been applied successfully at least in one real case, i.e., the SEMCO company [27]. We therefore believe that our study is not merely an academic out-of-the-world proposal and that it could have useful and relevant practical implications. In this respect, an experimental test in a real system is very welcome and we hope to present soon, in a future study, some first concrete results in this direction.

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