Modeling Explicit and Implicit Ties within an Organization: A Multiple Model Integration

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ABSTRACT: *We present a simulation designed to capture the impact of both explicit authority ties and implicit socialization ties on the performance of an organization adapting to a turbulent world. We present a summary of three key models which informed our approach. We then outline and describe the operation of our resulting simulation. Using an experiment which manipulated both the authority network structure and the stress each organization placed on socialization, we show that socialization has a non-linear impact on peak organizational performance and on the performance of top management. We also demonstrate that the authority structure has some impact on the performance of both the organization in toto, as well as on top management.*

1. Introduction

An organization is a group of people assembled in order to complete one or more tasks. Organizations must adapt to dynamic conditions to survive. One method organizations use to adapt over time is turnover. March (1991) demonstrates that this strategy should be effective in dynamic environments, arguing that an organization should attempt to ignore its own understanding of the environment when hiring new actors because new actors bring new information. Morgan and Carley (2011) examined what effect adding a selective hiring function to March's Mutual Learning Model might have by integrating a model of social reflexivity. Drawing from Morgan, Morgan, and Ritter's (2010) work on social reflexivity in combat units, Morgan and Carley (2011) confirmed that the more random the selection method – the more effective the turnover strategy is in confronting a dynamic environment.

These models (March, 1991 and Morgan & Carley, 2011) do not address, however, how organizational hierarchies or structures influence performance. Many organizations exhibit multiple levels of hierarchy. Further, one can argue that hierarchy, itself, is a response to a dynamic environment. Sub-units pay attention to key issues relevant to their tasks and report to management as and when necessary.

The Garbage Can Model (Cohen, March, and Olsen, 1972) examines organizational decision-making in terms of the flows of information, people, and problems. Carley (1986a, 1986b) extended the Garbage Can Model with hierarchical ties, using it to model naval operations.

There is a rich body of work that considers the role of both formal and informal ties (Selznick, 1948; Oh, Chung, and LaBianca, 2004). Although it is possible to consider representing explicitly both formal and informal ties via multiplex networks (with multiple ties of authority, friendship, and acquaintance, among others, represented at once), modeling even a reasonably large organization via such explicit ties quickly becomes infeasible. Further, how formal and informal ties operate to transfer information remains an open research question. Instead, we see the Hierarchical Garbage Can Model (adapted from Carley, 1986a) as a method of representing formal ties, and the Mutual Learning Model (March, 1991) as a method of representing informal ties. Combining these models provides us a tractable method of representing an organization with both kinds of ties.

2. The Simulations

In this section, we will review the assumptions, constraints, and products of each of the pre-existing models. We will briefly review each to illustrate the processes used in the integrated model. The three models being integrated are March's Mutual Learning Model (March, 1991), the Hierarchical Garbage Can (Carley, 1986), and the Participation Model (Morgan, Morgan, and Ritter, 2010). In previous work, Morgan and Carley (2011) integrated the Mutual Learning Model and the Participation Model but we will outline the original model.

2.1 The Mutual Learning Model - Modeling Implicit Connections

The Mutual Learning Model (March, 1991) is an intellective agent-based model from the organizational literature. It posits that there is an external environment, represented as a *c*-tuple of values either 1 or -1 that organizations must adapt to in order to perform well. March suggests that organizations with a more accurate understanding of the external environment will perform better than organizations that do not. Organizations do not directly perceive the environment, but instead infer the characteristics of the environment from their members, learning from high-performing members to construct what is referred to as the organizational code. The organization begins with a blank organizational code (all 0s), and thus has no inherent bias. Each member of the organization is an agent and has their own *c*-tuple of values – which represents their views on the environment. Once the organization has inferred a particular bit attribute of the environment, it socializes its members to agree with its stances. Since the organization may infer from its members incorrectly, this socialization can inhibit the performance of individuals, but the socialization mechanism is necessary to develop the distinct views of high performers.

Without turnover, the Mutual Learning Model quickly reaches equilibrium – where all agents and the organization have identical values in their respective *c*-tuples – and thus no further learning or socialization will occur. If the environment continues to change after equilibrium is achieved, the organization will be unable to adapt to these changes and the organization's performance will degrade.

March presented turnover as a mechanism for combating this degradation of performance, showing that even modest turnover allows the organization to maintain performance as the environment continues to change. March cautions, however, that turnover is only effective when the organization selects individuals essentially at random from all aspects of the environment that can feasibly change. We add the caution 'that can feasibly change' because, for example, tax laws may change but all accountants are likely to need basic math skills.

Although this model is insightful and influential in the organizational literature, it presents an organization as a collection of individuals without formal ties. The organization has no inherent structure, and organizations are structured, more or less effectively, in order to cope with a changing environment. Further, organizations are composed of individuals, which often find it difficult to hire individuals at random as opposed to picking actors much like themselves, phenomena often described as homophily, or preference for same. For a discussion of homophily, please see McPherson and Smith-Lovin, 1987.

2.2 The Hierarchical Garbage Can - Modeling Explicit Authority Connections

The Hierarchical Garbage Can (Carley, 1986a) is an emulative agent-based model based on the theoretical work of Padgett (1980) and implemented in a tool called GARCORG (Carley, 1986b). The model posits that an organization has multiple tiers with its lowest tier, team members, dedicated to detecting change in the environment. Each higher tier has access to the insights of the lower tiers, although access to the findings of lower tiers may be blocked either due to access constraints or a perceived lack of salience from the higher tiers.

Each team member is responsible for paying attention to a particular issue, but the organization may not be able to effectively access a team member's findings or discount the importance of the issues to which a team member is assigned. Because the Hierarchical Garbage Can does not characterize an external environment, these assessments are made based on the flow of information higher levels are able to perceive from the team member, and can result in the removal even of a high performing worker due to structural flaws in the organization. Areas where team members are routinely replaced are labeled as problem spots, and indicate an area of the organization that deserves attention.

This model explicitly represents formal authority ties and presents a useful account of structural flaws in organizations. However, the role of implicit ties in organizations can moderate the organization's performance through the actions of boundary spanners (Oh, Chung, and LaBianca, 2004). Nevertheless, implicit ties within the organization can be difficult or impossible to discern, and the information transference capabilities of the differing kinds of informal ties are not well known. Thus, the Mutual Learning model presents a method of representing these informal ties in aggregate. Individuals do not have specific characteristics in the Hierarchical Garbage Can Model (other than the spot they fill in the organization) and thus the hiring or transfer of individuals was an aspect of the process not considered in the original model.

2.3 The Participation Model – Introducing Actor Bias

The Participation Model (Morgan, Morgan, and Ritter, 2010) is a mathematical model designed as an overlay. This model is focused on the behavior of individuals and how their behavior changes due to influence of fellow team members, team leaders, and the objects of their behavior. The work focused on the highly variable performance of small combat teams, and drew on a survey of relevant sociological and psychological literature to suggest a reflexive mechanism to moderate behavior of individuals across many contexts. These contexts may involve both positive and negative actions towards objects. Their results showed a pattern consistent with documented historical records, with the reflexive mechanism decreasing overall combat performance while reliably increasing the variation in results.

Morgan and Carley (2011) applied this work to the Mutual Learning Model, using the bias mechanism to influence hiring of individuals. Whereas the original work focused on the physical distance between actors, this work focused on the social distance between actors based on their shared perceptions of the environment. As March (1991) predicted, the social reflexivity mechanism tends to decrease the efficacy of turnover as a mechanism to confront changes in the environment. Further work has revealed that the more introspection that is applied to the hiring process, the less effective the turnover mechanism.

3. The Integrated Simulation, the Unified Hierarchical Model

In this section, we describe the integrated simulation, which takes aspects of each of these models. This model is an intellective agent-based simulation. Since both the Mutual Learning and the Hierarchical Garbage Can model the operation of organizations and present quite different pictures of the workings of an organization, the integration was not entirely straightforward. A larger aim of this work is to develop a method for integrating multiple models related to similar phenomena, even models that concern the same phenomena at different granularities. Critical to this integration approach is to identify key assumptions of each model and allow the operation of the other models to inform these assumptions. All assumptions of each model must be either assumed by the final integrated model or explained by the inter-operation of those models. We will summarize the assumptions and processes of each model at the conclusion of this section in Table 3.1.

Like the Mutual Learning Model, this model supposes both an environment with multiple aspects and an organization attempting to optimize its performance within that environment. Each aspect, as in the Hierarchical Garbage Can, is matched to a team member. Above team members, there are team leaders, group leaders, and a single CEO actor. As in the Hierarchical Garbage Can, we have four tiers, although four tiers do not represent a strong commitment of the model but instead is intended to present a sufficiently deep organization to allow substantial structural variation. Every member of the organization is a staff member. All staff members have their own perception of environment. Every staff member must have at least one tie to the next higher level of the organization (except the CEO), but may have additional authority links (i.e., a team leader may report to multiple group leaders, and a team member may report to multiple team leaders).

As environment bits change, team members in charge of that issue have an opportunity to perceive the change in the environment. If the team member becomes aware of the change, higher levels of the management hierarchy also become immediately aware of the change, subject to their ability to access their subordinates work or their interest in that work. Thus, with this mechanism and the one that follows, changes in the environment tend to cause changes in the organizational code.

After the previous process concludes, the Mutual Learning Model mechanisms are used to develop an organizational understanding of the environment and to socialize actors. Staff members are evaluated based on the portion of the organizational code they are responsible for – and are replaced if that portion of the organization's code is incorrect for more than a consecutive number of turns defined by a grace period. New staff members will be hired by one or more team leaders using the work developed in Morgan and Carley (2011), including at least one team leader with oversight for that position.

Based on this description, we can characterize both the original models and the new model, which we do in Table 3.1.

Table 3.1 Shared model characteristics between the Mutual Learning Model (MLM), the Hierarchical Garbage Can (HGC), the Participation Model (Par), and the new simulation, the Unified Hierarchical Model (UHC)

Characteristic	MLM	HGC	Par	UHC
Org in an environment	♦			♦
Environment changes over time	♦			♦
Org learns from agents	♦			♦
Org socializes agents	♦			♦
Agents leave Org at random	♦			
Org replaces agents at random	♦	♦		
Org has explicit authority ties		♦		♦
Team members generate info		♦		♦
Information travels along ties		♦		♦
Information transfer has error		♦		♦
Org removes under-performers		♦		♦
Org can have structural flaws		♦		♦
Explicit access constraints to info		♦		
Context moderates agent action			♦	♦
Dyad distance moderates action			♦	♦
Spatial distance moderates action			♦	
Social distance moderates action				♦
Agents implement homophily bias				♦
Committee makes hiring choice				♦
Org accuracy measured over time	♦			♦
CEO accuracy measured over time				♦
Structural Flaws tracked over time		♦		♦

In the remaining sub-sections, we will describe in more algorithmic detail the initialization, operation, and outcomes of the new integrated model. Throughout these sub-sections, we will define the usage and purpose of each of the following variables, summarized in Table 3.2.

Table 3.2 Summary of key variables in the Unified Hierarchical Model

	Purpose
c	Environmental complexity – and also indicates the number of team members the organization possesses, $c > 0$
m	Team leaders in the organization, $c \geq m > 0$
g	Group leaders in the organization, $m \geq g > 0$
r	The probability of having multiple authority ties, $1 > r > 0$
s	The length of the simulation in turns, $s > 0$
l	Grace period (in turns) before an organization terminates a team member that is underperforming, $s \geq l > 0$
t	Probability that environment bits flip value from turn to turn. $1 > t > 0$
p	Probability that a responsible team member will perceive a change in the environment, $1 > p > 0$
u	Supervisor capacity for updates per turn, $c > u > 0$
a	Informs the probability of the organization learning from high performers, $1 > a > 0$
o	Probability that staff members change their bits to match the organizational code, per bit, $1 > o > 0$

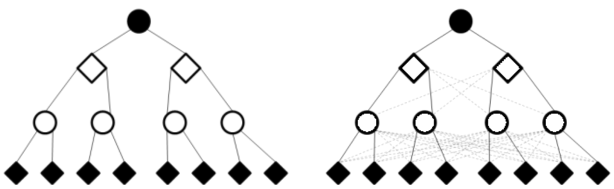
3.1 Initialization

To initialize the simulation, the modeler must make several decisions. They must determine how complex the environment is – that is, how many aspects of the environment are likely to change over time. We label the quantity of these aspects as c.

In this work, we assume that each aspect of the environment has a corresponding team member that is responsible for tracking that aspect, so c represents both the complexity of the environment and the number of team members the organization will possess.

The modeler must also decide on the number of group managers (g) and the number of team leaders (m). There must be at least one group manager and one team leader. It is possible for there to be any number of team leaders and group managers, but we will assume an upper bound of the quantity of staff members of the tier below. So m should not exceed c, and g should not exceed m.

Finally, some staff members report to multiple people. This possibility is informed by the quantity r, which should range between 1 (inclusive) and 0 (exclusive). When determining whether an agent should have an additional authority tie, assuming that the agent does not already report to every actor in the higher tier, the probability of a new authority tie (i.e., of an additional "reports-to" relationship) is equal to r raised to the power of the number of current authority ties the actor has. Thus, every staff member (except the CEO) will form at least one authority tie, but team members and team leaders may form additional authority ties. If $r = 1$, then every team member will report to every team leader and every team leader will report to every group leader. Figure 3.1 compares an organization with a very small r value to an organization with $r = 1$.



$a = .01$, $c = 8$, $m = 4$, $g = 2$ $a = 1$, $c = 8$, $m = 4$, $g = 2$

Figure 3.1 The redundancy variable indicates the probability that an actor will have multiple "report-to" relationships in the organization

3.2 Operation

Once initialized, the simulation must proceed through a number of turns, defined by the quantity s. Each turn is composed of several phases:

1. Environment Changes
2. Formal Authority Information Transfer
3. Organizational Inference
4. Implicit Socialization
5. Turnover

Phase 1, *environment changes*, addresses changes in the external environment. Each environmental bit has a probability, t, of flipping in value. This probability should be between 0 and 1. Conventionally, t should be set towards the lower range, indicating that any particular aspect of the environment is more likely to maintain its current state rather than change.

Phase 2, *formal authority information transfer*, handles the direct transfer of information among staff members along the explicit authority ties. For each environment bit that changed in Phase 1, the team member responsible for that aspect has a probability, p, of recognizing that the environment has changed. If the team member observes the change, he reports it to all of his team leaders. Each manager (team leaders, group leaders, and the CEO) has a capacity, u, for receiving updates. If that capacity is exceeded, the update is ignored. Otherwise, the manager updates their own understanding of the world and passes along the update to their superiors. Figure 3.2 illustrates this mechanism.

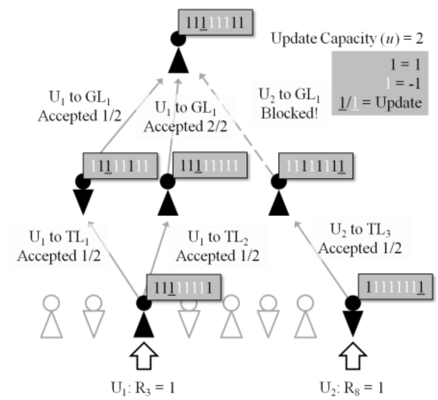


Figure 3.2 Supervisors have limited capacity for updates. Staff Member 8's update was blocked at the Group Leader level.

In Phase 3, *organizational inference*, the organization refines its organizational code based on the individual perceptions of its staff members. The organization identifies all high-performing staff and generates a probability, per environment bit, that the organization will infer that the staff's majority opinion is correct. This probability is informed both by the quantity, a, and the level of consensus for the correct setting of that bit among high performers. Higher values of a indicate an organization willing to take more risks, whereas lower values of a indicate a more conservative firm profile.

In Phase 4, *implicit socialization*, the organization socializes actors to agree with its stance on each bit. This stance may be at odds with the environment and may even defy the information they previously transmitted in Phase 2! The probability of socialization per aspect is defined by the quantity o. Higher values of o indicate an organization that stresses socialization, focusing on making sure that new hires rapidly transition into useful members of the staff. Lower values of o indicate an organization with a longer view, allowing individuals more time to mature into the organization.

In Phase 5, *turnover*, the organization replaces under-performing staff. Team members are replaced if the aspect of the organizational code for which they are responsible is incorrect for longer, consecutively, than a defined grace period. This grace period is captured by the quantity l, and should be shorter than the total length of the simulation, s. Staff members are replaced, using the method described in Morgan and Carley (2011), by a committee of three team leaders who have an implicit bias towards new hires similar to themselves. The committee is first populated by team leaders which have management authority over the position. If there are not enough team leaders to form a committee of three, then the committee includes other group leaders and, if necessary, the CEO.

3.3 Outcomes

In this simulation tool, there are several outcomes of interest. We retain the Mutual Learning Model's organizational performance metric, measuring the accuracy of the organizational code. We also track and report the CEO's performance, measured as the accuracy of their personal code against the environment as a related but distinct measure. Referencing the Hierarchical Garbage Can, we will keep track of the organization's minimum, maximum, and average number of rehires across all team member positions per turn. Because we are also interested in the effect of an organizational hierarchy on hiring, we track the average number of individuals examined per opening per turn.

4. Virtual Experiment

In this section, we will discuss a virtual experiment that examines the tradeoffs between two different authority structures with three levels of implicit socialization.

In this experiment, we keep the number of mid-level managers (team leaders and group leaders) constant, but vary their proportions. We define two structures, represented here as ACME and ZENO. ACME has ten team leaders but only two group leaders. ZENO has six team leaders and six group leaders. We expect information to travel differently through these structures.

In ACME, environment changes will usually be successfully communicated to team leaders. Group leaders may, by contrast, be overwhelmed by the updates they receive from their team leaders. Updates to the CEO will often be successfully transmitted.

In ZENO, more updates from team members will escape the capacity of their leaders. However, nearly all updates received by team leaders will also be successfully related to group leaders. The CEO's understanding may lag, as this actor has too many group leaders to pay attention to them all. ZENO is likely to be a less efficient organization because the group leader level seems likely to have a great deal of spare capacity, and may even have a few "empty-suits", group leaders without any team leaders reporting to them.

Some research (Oh, Chung, and LaBianca, 2004) suggests that inter-group socialization, in moderation, improves performance, but that socialization can be over-emphasized and thus harm performance. Consequently, we examine the interplay of the socialization and formal authority information transfer mechanisms to determine if we could replicate this finding. We used three distinct levels of *o* for this experiment.

All other factors were held constant and are listed for completeness in Table 4.1. For each combination of experiments, we ran 200 replications of the simulation. In total, we ran 1200 separate instances of the simulation.

Table 4.1 Virtual Experiment Variables and Constants

Variable	**Values**	**#**
Structure	ACME: $m = 10$, $g = 2$; ZENO: $m = 6$, $g = 6$	2
Socialization (o)	0, .05, .9	3
Constants		
Complexity (c)	50	1
Redundancy (r)	.3	1
Simulation Length (s)	100	1
Grace Period (l)	5	1
Turbulence (t)	.05	1
Perception Acc (p)	.9	1
Update Capacity (u)	3	1
Staff Agreement (a)	.5	1
	Total Combinations	6

5. Results

In this section, we examine the results of the virtual experiment defined in the previous section and summarized in Table 4.1.

As expected and can be seen in Figure 5.1, ZENO tends to underperform ACME over time when socialization is held constant. Both firms reach a peak performance level and then begin to degrade. This degradation, despite turnover, is in large part because turnover is only applied to team members, as opposed to all staff. New individuals enter the organization, but the managerial class, which outperforms these new hires, suppresses their ideas to the organization's detriment.

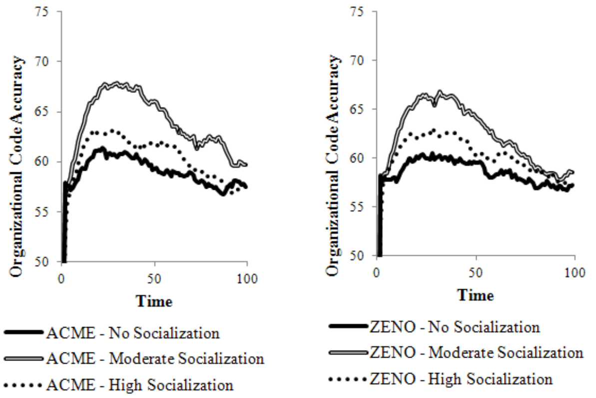


Figure 5.1 ACME and ZENO have similar organizational performance characteristics, although ZENO tends towards lower performance than ACME over time.

Socialization has a large and non-linear effect on performance, as can be seen in Figure 5.2. The chart shows the (averaged) peak performance score each firm achieved for all six conditions. Although explicit authority structure may have some small impact on peak performance, the implicit socialization probability has a large and non-linear impact.

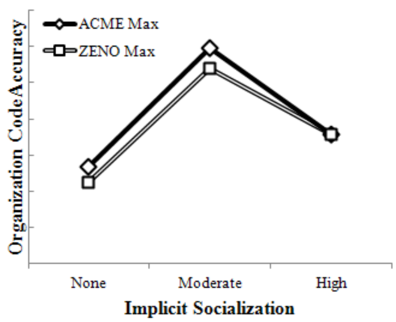


Figure 5.2 As suggested by Oh, Chung, and LaBianca (2004, p. 869) - an organization which supports cross-team socialization will perform better than one that either forbids it or mandates it

The impact on the CEO also suggests that a moderate amount of socialization across authority ties is useful. In Figure 5.3, we can see the averaged accuracy of the CEO's perceptions. Although the CEO in the highly socialized environment achieves their peak performance more rapidly than in the moderate case, their peak is lower. The graph, for both firms, also underlines the value of socialization. A CEO forced to rely only on the information relayed by their direct subordinates reaches their peak much later and that peak is much lower. The ACME CEO appears to retain relevance longer than their ZENO counterpart, possibly due to ZENO's less efficient group leader corps.

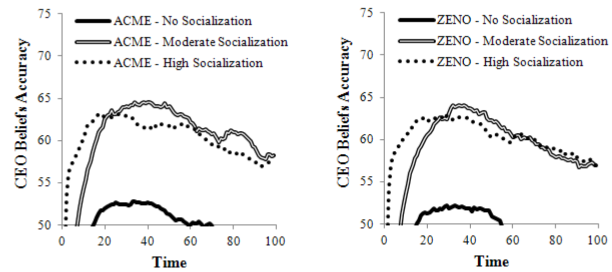


Figure 5.3 CEOs tend towards much better performance when they have more information than their direct authority ties alone can relate. The moderate socialization case peaks later, but higher, than the high socialization case.

The other metrics we tracked showed results closely correlated to the performance of the firm. Firms that are higher performing tend to need to replace fewer team members. Applicant review numbers followed closely the pattern found previously in Morgan and Carley (2011), where organizations that stressed socialization review many more candidates for open positions than organizations that did not.

6. Discussion

In this work, we integrated multiple models of interest related to predicting and understanding organizational performance. We presented two alternative visions for how organizations confront and adapt to change as summarized in the Mutual Learning (March, 1991) and Hierarchical Garbage Can (Carley, 1986a) models. We unified these two approaches to produce a new model that represents both explicit authority ties, as well as implicit relationships such as joint social activities or group co-membership. Using this new model, we replicated a result suggested by the business literature (Oh, Chung, and LaBianca, 2004) on how socialization can both help and harm an organization.

We also demonstrated that our model can suggest impacts of structural choices on organization outcomes. However, our organizational structures are noisy and highly variable because we took a stochastic approach to defining the authority structure. By contrast, GARCORG (Carley, 1986b) presented users with fully defined explicit structures based on naval operations. Our stochastic approach may also have resulted in noisy structures that were not sufficiently different (across the 200 averaged instances) when viewed through our average, maximum, and minimum metrics. It is also possible that those metrics are simply too coarse to identify prevalence towards hot-spots in either ACME or ZENO. We do not believe this work well characterizes the relative impact of structure versus socialization, but suggests that such a characterization may be possible in the future.

The Participation Model was used in the model as defined in Morgan and Carley (2011) to inform the hiring process, but the Participation Model also offers many insights that could affect managerial performance. One purpose of leadership is to force subordinates to confront the environment and perform their tasks despite of it. Morgan, Morgan, and Ritter (2010) present the work in an analogous, albeit combat-related, context. Thus, the variable p, rather than remaining constant for all staff, should relate to the quality and quantity of leadership.

In the current simulation, turnover applies only to under-performing team members. In practice, people at all levels of the firm leave those organizations for many reasons. Future iterations of this model will apply turnover to all staff members. Nevertheless, most organizations approach the hiring of top level executives differently from hiring at lower tiers of the organization - if only because no higher tier exists to make hiring choices.

This successful multi-model integration suggests that our larger approach towards multi-modeling and multi-level modeling may be of some use to the larger community.

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