The Micro-Dynamics of Network Leverage:

Implications for Change Agents External to an Organization

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Abstract

Much of the impact of a policy depends on how it is implemented, especially as mediated by organizations such as schools or hospitals. Furthermore, implementation depends on each organization's capacity to absorb innovations. Here we extend the concept of absorptive capacity to include the intra-organizational network *dynamics* that occur during the implementation of an innovation. In particular, we hypothesize the potential for intra-organizational polarization that is especially likely to occur when an organization is highly salient to its members. Using agent-based models we find that when organizational members are salient to one another, external change agents who attempt to direct organizations by introducing strongly oriented venues (e.g., professional development emphasizing specific teaching practices) may unintentionally contribute to polarization in the organizational network, inhibiting full implementation of the immediate innovation as well as reducing organizational capacity to implement future innovations. Thus the external change agent should consider the short term interaction with the intra-organizational network dynamics as part of the organization's longer term absorptive capacity.

INTRODUCTION: INTRA-ORGANIZATIONAL NETWORKS AND ABSORPTIVE CAPACITY

Most public policies are implemented by organizations which develop expertise and allocate internal resources to deliver services or programs (Cohen & Barnes, 1993; DeCarolis & Deeds, 1999; Cohen & Hill, 2001; Kilduff & Tsai, 2003; Werner, 2004; Kilduff et al., 2006; Scott, 2008; Weiss, Bloom and Brock, 2014). For example, educational policies are implemented by schools which reassign or replace instructional staff or choose new curricular materials as teachers ultimately deliver instruction to students (Bidwell & Kasarda, 1985; DeCarolis & Deeds, 1999; Weiss, Bloom and Brock, 2014). Similarly, health policies are implemented by hospitals, insurers, and professional associations (Barley, 1990; Poon et al., 2004; Watt et al., 2005); welfare-to-work programs are implemented by states and program offices (Weiss, Bloom and Brock, 20914), and immigration policy is implemented through law enforcement agencies (Ridgley, 2008).

An organization's specific ability to implement a policy or innovation can be described in of its absorptive capacity, defined as "an ability to recognize the value of new information, it, and apply it to commercial ends." (page 128, Cohen and Levinthal, 1990). Absorptive capacity typically includes elements of the organization's communication with the external environment (such as mediated by leadership), its ability to engage with external partners (Farrell & Cobrun, 2017), existing expertise that relates to an innovation, and the character and distribution of within the organization . But here we emphasize that each of these elements can be enacted and enhanced through intra-organizational networks. That is, formal leaders can more effectively guide the organization to new behaviors when they are well-established in the informal network (Moolenaar, Daly, and Sleegers, 2010; Moolenar and Sleegers, 2015; Hopkins et al., 2013). Similarly, expertise can be effectively cultivated and distributed when conveyed through informal networks. In fact, an organization's culture can be characterized partly in terms of its capacity to distribute relevant resources through networks (Frank et al., 2015). In this study we emphasize that the networks through which absorptive capacity is manifest are themselves dynamic. Networks not only convey information and norms, but networks themselves are modified by diffusion of

information and implementation processes (Frank and Fahrbach, 1999; Xu & Frank, 2016). In this sense, an organization's capacity is partly a function of the resilience of its network to sustain information flows before, during, and after the diffusion of new information or practices within the organization. Thus we attend to the intra-organizational network dynamics that affect members' responses to an externally generated policy shock. By network dynamics we mean how the micro network processes through which actors influence one another and select with whom to interact diffuse information and generate network structures. For example, network dynamics might the tendency for actors to interact with others like themselves (homophily). This in turn can cliques which compartmentalize information in an organization, ultimately limiting diffusion.

Examples of Micro-Network Dynamics of Absorptive Capacity

In an example of the network dynamics of absorptive capacity, Frank et al. (2013) found that the pressures and institutions associated with No Child Left behind (NCLB) contributed to polarization in instructional practices among teachers within schools. This occurred as teachers were initially affiliated with cohesive subgroups, or cliques, within schools that featured different orientations and receptivity to NCLB related practices. Under the pressure of NCLB, subgroups with an initial predisposition towards NCLB related practices became increasingly aligned with those practices as their members interacted with similar others who provided expertise and generated norms oriented towards NCLB. In contrast, other subgroups migrated away from NCLB associated practices as they lacked expertise associated with, and orientation to, NCLB practices. Thus schools became more polarized as teachers inhabited networks that were salient to their professional identities; ironically, the national policy intended to standardize opportunity around a particular image of reading contributed to the unintended consequence of uneven instruction. Such unevenness can ultimately create organizational challenges of coordination and collaboration beyond the focus of an intervention associated with NCLB (Woodward, 1965; Bidwell, 1965; Thompson, 1967). This can broadly contribute to inequitable opportunities for students within schools (Frank et al, forthcoming), as well as between schools which experienced differing levels of dysfunction (Frank et al., 2015).

As a second example of how the network dynamics of an organization affect absorptive capacity, consider the movement to evidence based practice in medicine. There are considerable institutional norms that push for evidence based practice, from the insurance and pharmaceutical industries as well as the federal government and elements of the medical profession (Guyatt, Cook and Haynes, 2004; Labrecque & Cauchon, 2013). But some physicians may resist evidence-based practice as it may not account for patient preferences and values and it may challenge physician autonomy(Labrecque & Cauchon, 2013). Correspondingly, implementation of evidenced based practices has the potential to polarize physicians within hospitals. This can occur if physicians are organized into cliques or subgroups (such as by specialty or by cohort) which have differing initial beliefs about the value of evidence based practice (Broom, Adams & Tovey, 2009). For example, haematology oncologists are less reliant on RCTs and more reliant on case studies than medical oncologists (page 196). As physicians then are influenced by members of their subgroups, initial differences between subgroups can become accentuated, resulting in polarization. Not surprisingly, implementation guides for evidence based practice emphasize whole hospital integration and diffusion (Oman, 2010) because failure to account for the complete set of intra-organizational dynamics could accentuate existing differences among subgroups of health care workers.

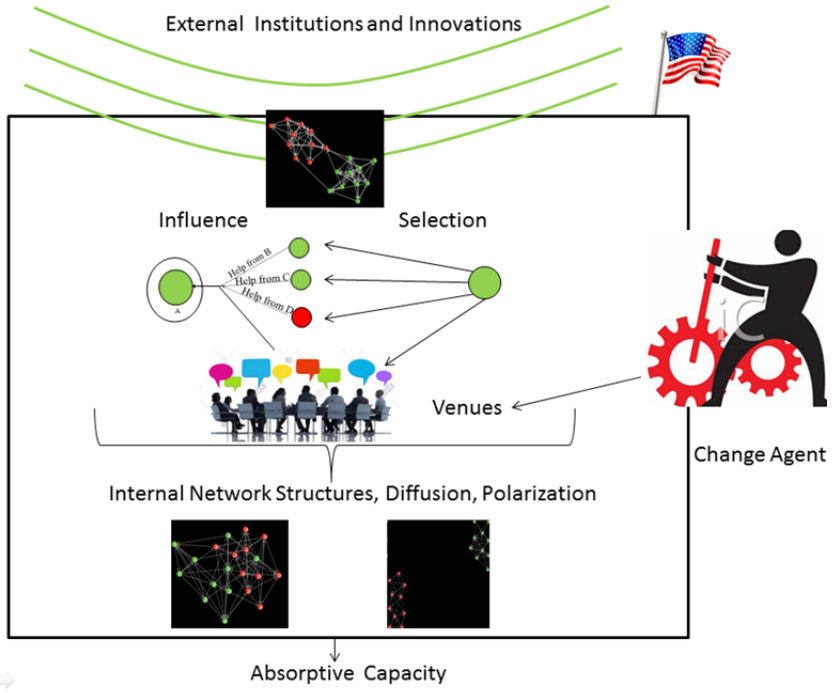


Figure 1. The Reconfiguration of Network Structures during Diffusion through the Network dynamics of Selection and Influence

The Micro-Network Dynamics of Absorptive Capacity

Figure 1 shows how the network dynamics generated through influence and selection generate internal network structures that contribute to an organization's capacity to absorb external innovations. At the top of the FigureFigure externally generated institutions penetrate the organizational boundary. This can be as leadership becomes aware of an innovation, or as institutions broadly penetrate the terms and schema through which members of the organization perceive their work (Meyer and Rowan, 1977).

But in Figure 1 the innovation/institution does not encounter the members of the as a single actor. Instead the members of the organization may already reside in discernable subgroups (represented by the red and green dots in the black square at the top) reflecting patterns interaction and predisposition to the innovation. Then, during diffusion members of the choose others with whom to interact (selection, represented by the lines connecting the dots on the right side of the Figure), in part based on their orientation to the innovation. Also during diffusion, members of the organization are influenced by those with whom they interact as they access

information and are exposed to norms. This is represented by the ripple around the green actor A which indicates an increase in the level of adoption of the innovation in response to the other green nodes to which A is exposed.

The cumulative processes of influence and selection can accentuate or reduce initial differences among between the positive (green) and negative (red) subgroups. In the context of NCLB in education, we conceive of the members of the positive subgroup as emphasizing basic skills in their teaching, while the members of the negative subgroup would emphasize whole language over basic skills. In that context, positive information would support basic skills instruction and negative information would support whole language.

The network structures resulting from the internal network dynamics then relate to an organization's absorptive capacity; polarization (as at the bottom right of the Figure) can inhibit the ultimate absorptive capacity as one subgroup's adoption of the innovation is offset by the other's resistance. On the other hand, an integrated organizational network as on the left can contribute to systemic coherence, allowing information to diffuse throughout the system and therefore contribute to overall adoption of the innovation.

Our simulations will show that subgroups are especially likely to form when the members of the organization notice one another and are important to one another – when the organization's members are salient to one another. When the members of the organization are salient to one another, actors will respond to the norms of those with whom they interact within the organization and will seek interactions with others with whom they have an affinity. This can accentuate differences between subgroups. In contrast, when the members of the organization are not salient to one another action will be based on information. In particular, actors will engage in beliefs or behaviors based on information to which they have been exposed and will seek interactions with others who potentially possess new information. This can create bridges between subgroups.

Network Leverage of Change Agents

In our conceptualization agents external to an organization cannot change organizational outputs by changing their own behaviors. Furthermore, we assume external agents cannot influence behavior through extensive direct interactions with members of the organization, which would effectively bring the external agent inside the organizational boundary (Williamson, 1981). Given that external agents cannot change the system by directing influencing actors or becoming part of the social network, we represent the external change agent seeking to direct an organization by introducing a venue.

In the venue, participating actors are exposed to information or advocacy for particular behaviors, and participants have a higher probability of interacting with one another than would otherwise be the case. These venues may push the organization toward intended behavior or polarize the organization depending on the internal network dynamics of the organization.

Generally in the context of education venues include settings and routines and practices that provide "instructional guidance" (Hopkins & Spillane, 2015; Hopkins & Woulfin, 2015). In particular, national policymakers might seek to introduce professional development programs into schools and districts (Desimone etal., Garrett et al.,). The providers of these programs do not enter the schools as full agents of the schools, seeking to establish network ties and change their own behaviors (Rowan & Miller, 2007). Instead the sponsors seek to change behaviors by providing information or representing national norms (see Hopkins and Spillane 2015 for a specific application in education). Furthermore, they do so by providing opportunities for subsets of teachers to convene, become exposed to one another, and perhaps create new network ties (Spillane et al., 2012). In this example, venues would supportive of NCLB orienting teachers towards basic skills instruction might be considered positive, while those emphasizing a mixture of whole language and basic skills would be considered relatively neutral.

In this study, our ultimate goal is to inform the action of change agents by revealing how the effects of the venues they create depend on the intra-organizational micro-dynamics of the organization they seek to change. Anticipating one of our key results, a forceful change agent can

exacerbate pre-existing intra-organizational rift lines. This can polarize the organization, ultimately inhibiting the implementation of the change agent's intended policy.

In the next section, we describe the general scenario we consider and then develop hypotheses based on conventional thinking about the impacts of external change agents on organizational outcomes. We then develop a second hypothesis based on the internal network dynamics of the organization. Recognizing non-linear intra-organizational network dynamics, conventional techniques for exploring equilibria are not adequate. Therefore, we draw on agent based models to investigate how these dynamics affect an organization's absorption capacity. We then experiment with our system in terms of the actions of external change agents seeking to direct the organization to particular behaviors.

THEORETICAL FRAMEWORK: EXTERNAL LEVERAGE THROUGH VENUES

General Scenario

We consider a set of actors in an organization; each actor engages in certain behaviors, such that the behaviors contribute to the organization outputs. The actors start with different behaviors but have common functions determining how they are influenced by network partners and how they choose network partners. Given this baseline we will show that polarization occurs when the organization is only moderately salient in the sense of actors being influenced by other members and exhibiting a preference for like-minded others.

Next, we consider agents external to the organization who seek to change organizational outputs by creating venues. For example, a change agent might seek to increase general endorsement of the teaching practices consistent with a particular educational policy.

Critically, members of the organization must choose to participate in the venue (attend to the event or visit the website) based on the attributes of the venue. In this sense the venues create spaces which increase the probability that any two actors participating in the venue will interact

1981). As such participants in the same venues have increased probability of sharing information capacity to impose a norm on one another.

Our research question then concerns what happens when an external change agent introduces a venue containing information supporting a policy goal into the network dynamics of an organization? For what internal dynamics is the change agent able to direct the whole organization in the desired direction, and under what conditions do the micro network dynamics generate unintended consequences that overwhelm the change agent's goal?

Hypotheses based on Conventional Beliefs of External Change Agents

Before we investigate how the internal network dynamics of on organization affect its systemic response to exogenous shocks, we consider conventional thinking about how to use exogenous shocks to shape an organization. To begin, there is high face validity for attempts to change organizations by introducing shocks which have valences in the desired direction. For example, if one wants to teachers to teach in a different way one introduces professional development (the exogenous shock) that trains teachers in the desired practices (Garet et al., 2001; Desimone et al., 2002; Weiss, Bloom and Brock, 2014). The same holds for any form of professional development. This approach to systemic change can be summarized in a baseline hypothesis:

H_1: Change agents can direct an organization to a desired policy goal by introducing a venue endorsing a goal or conveying information supporting that goal.

Note, the hypothesis is specified independent of the internal dynamics of the social system. Thus we have the corollary that the effect of an exogenous shock will be more dependent on the strength or valence of that shock than on the internal network dynamics of the system.

Our theoretical development suggests a second hypothesis inhering in intra-organizational network dynamics. Absorptive capacity rightly attends to the capacity of the organization's internal structures to diffuse information and practices. But an organization's capacity to absorb an

innovation also depends on the internal dynamics manifest during absorption; during implementation, networks, status, and the distribution of information are likely to change in ways that can support or impede an organization's capacity to absorb an external innovation. For teachers with specific expertise in whole language instruction may gain status if their school adopts whole language pedagogy. If some resent that elevation because of personality conflicts or the general differentiation of status, then the school may polarize during implementation (Glidewell et al., 1983; DePaulo et al., 1983). Such dynamic polarization would limit the implementation beyond what one might infer given the static characteristics of the school at the time of implementation. our second hypothesis is:

H_2: The capacity of the change agent to direct the organization to a desired goal depends on intra-organizational network dynamics.

The key is that the intra-organizational network dynamics can affect how shocks are distributed throughout a system, ultimately affecting the systemic response to the shock (Frank & Fahrbach, 1999; Xu and Frank, 2016). In particular, some shocks can accentuate polarization which ultimately impedes the organization's capacity to diffuse the innovation. In the next Section we turn to formal models of intra-organizational network dynamics so that we may explore how these dynamics affect systemic responses to exogenous shocks.

THE MICRO-NETWORK DYNAMICS

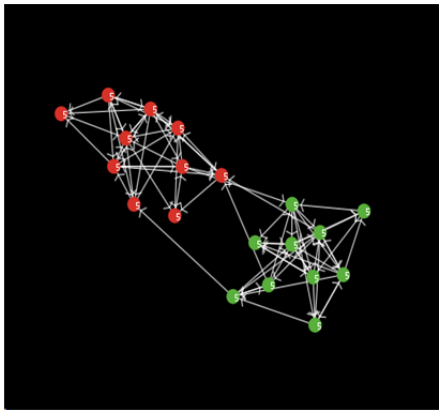
In this section we illustrate the basic models we use for the agent-based simulations to study organizational response as it emerges from individual behavior (Wilensky & Rand, 2015). In particular, we consider how actors in the organization deliberately seek information, choose their behavior (influence process) and with whom they interact (selection process). We conceptualize they make these choices based on the salience of the others in the organization. Here we define organizational salience in terms of how much the members of the organization notice one another

and consider other members important. We then initiate our simulations with two subgroups with different behaviors (representing baseline differentiation within most organizations – an we check in the results and technical appendix A). Finally, we experiment to learn which types of strategies (such as created by change agents) exert the most leverage on the organization given the intra-organizational network dynamics.

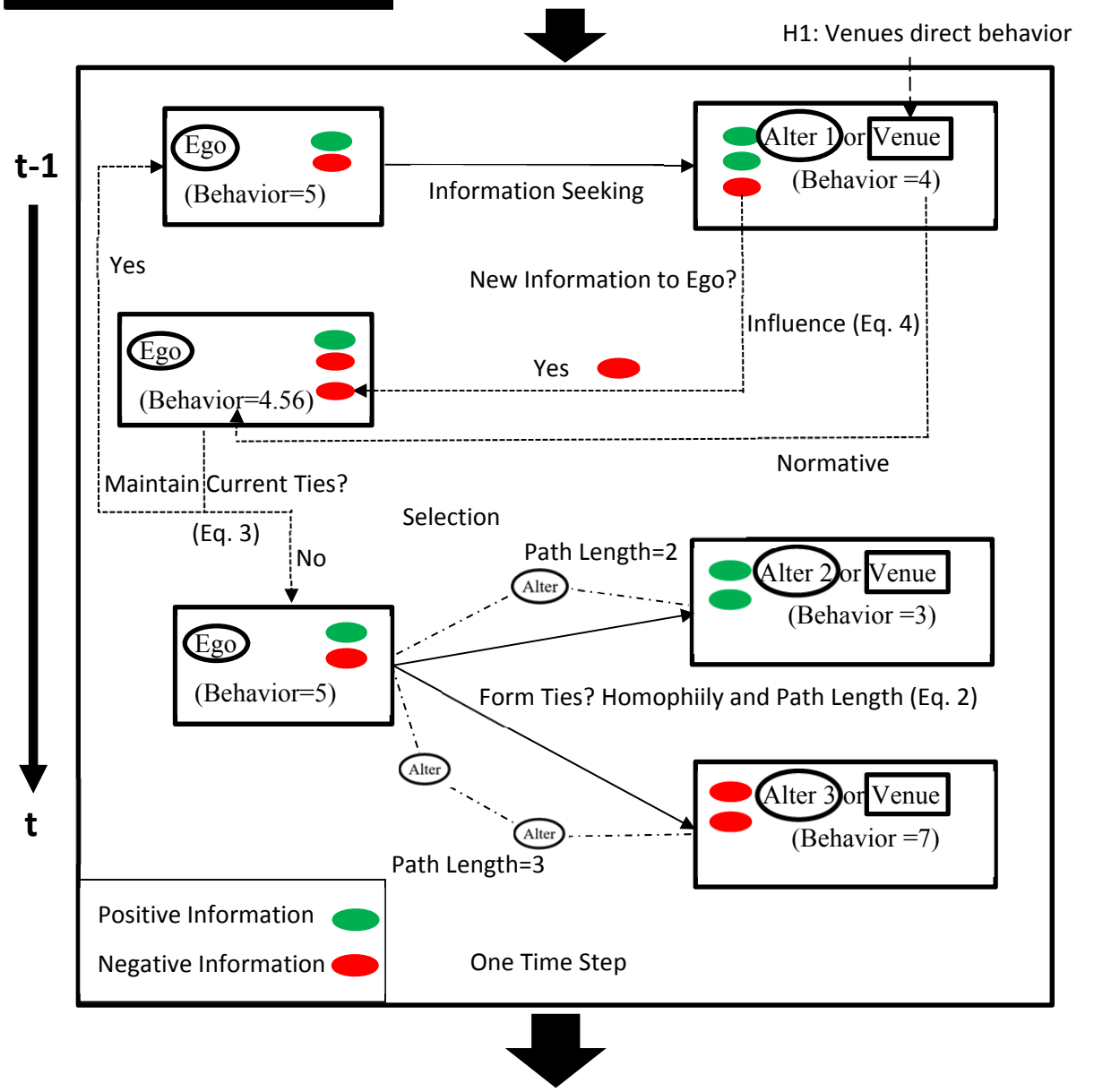
Overview of Agent-Based Processes

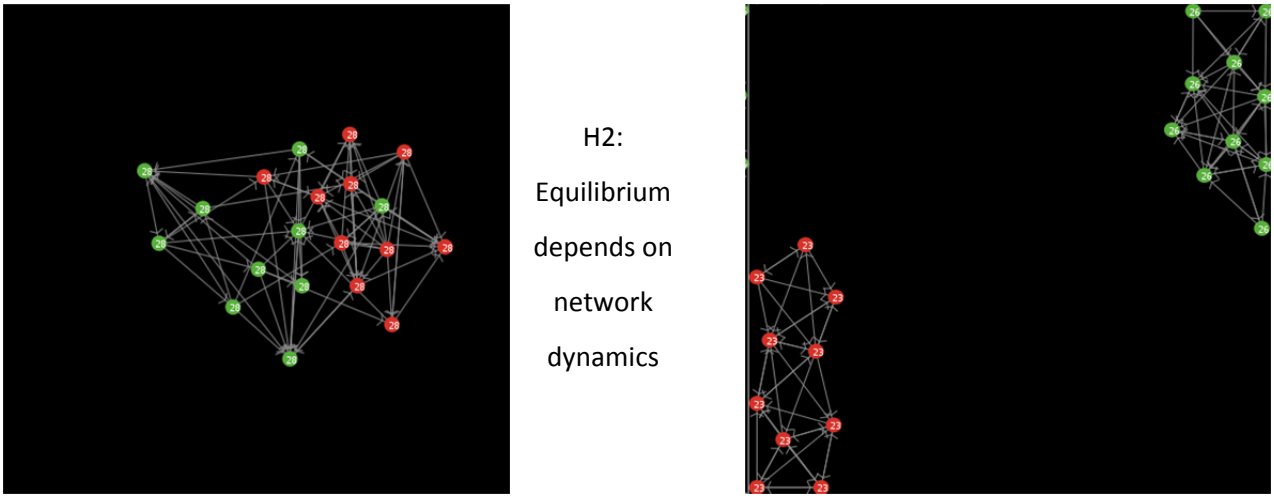
Each round of simulation begins with an assignment of actors to initial conditions consisting of their tie network, their behaviors, and possession of information. For example, at the top of Figure 2, there are 10 actors assigned to each of two subgroups (10 red nodes and 10 green nodes). Network ties are more concentrated within subgroups (density=.4) than between (density=.02). In addition, the subgroups are differentiated by their behaviors for example, the extent to which they support basic skills instruction or evidence-based practices.

Once the initial conditions have been established, in a single time step actors seek information, are potentially influenced, and then make decisions about dissolving ties and selecting new ones. Describing this process for a single ego, at time t-1 ego (top left of Figure 2) seeks information from alter 1 (top right) with whom ego already has a tie. If alter 1 provides information the path marked by the red ovals is followed back to ego. In this particular case ego updates the initial behavior of 5 to a new behavior of 4.56 based on receiving one piece of (red) information that does not support the behavior and an exposure to an alter with a behavior of 4. The information and normative effects are balanced according to equation 4 (that we present below, with rate of influence k=.5 and organizational salience α =.5). Note ego is only influenced by an alter when ego receives new information from the alter. Note also that actors respond to the information and norms of those from whom they receive new information, even if they subsequently sever the tie in a given time step.



Initial Condition: (1) two subgroups with dense networks within and sparse networks between; (2) one subgroup with higher level of mean behavior (positive green subgroup) and the other with lower level of mean behavior (negative red subgroup); (3) Each actor possess 5 random pieces of information.





Example equilibria for systems. Organizational salience is low (α=0.4) on the left and high (α=0.9) on the right.

Fig. 2. Network Dynamics driven by information seeking, influence and selection that shape systemic responses to innovations

After the influence process has been evaluated, the actor engages the selection process. First, a given ego considers whether to maintain existing ties, favoring the preservation of ties with alters who have provided novel information (as described in equation 3 below). If the ego severs a tie the ego may then initiate a new tie. The selection of new ties is based on the balance between new information available from those with whom ego has long network paths versus homophily with others who hold similar behaviors (as expressed in equation [2] below). A single time step occurs after all actors have cycled through the processes of information seeking, influence and selection.

Overall, Figure 2 shows how the processes of information seeking, influence, and selection generate the fundamental network dynamics through which actors change their behaviors and modify their networks. In the end, these dynamics can produce final equilibria such as at the bottom of Figure 2. In particular, the final equilibrium may consist of a near random network as on the left, or a polarized network as on the right. In the polarized network the ties occur exclusively within subgroups and behaviors diverge between the two subgroups.

Formal Models of Micro-Network Dynamics

Information Seeking Process. At any given time step, each actor posses information that is either consistent (positive) or inconsistent (negative) with the intended policy. For example, information about the benefits of phonics would be positive for supporting basic skills instruction and information about the benefits of whole language would be negative for basic skills instruction. In each time step, each actor is considered as an ego who seeks information from those in their networks (alters), who will randomly provide one piece of information in their possession to the ego. If the information is new to the ego, then ego will add this piece of information to its own information list; if the information is redundant, then it will not go into ego's information list.

*Influence Process***.** In each time step, actors choose their behavior according to their previous behavior, new information they receive, as well as the behaviors of their network members. Specifically, we choose a variation of Friedkin and Johnsen's (1990) influence model:

$$y_{it} = (1-\alpha) y_{it-1} I_{it-1} + \alpha \frac{\sum w_{ijt-1} y_{jt-1}}{\sum w_{ijt-1}} \qquad (1)$$

Where y_{it} represents the behavior of actor i at time t, and y_{it-1} represents actor i's behavior at time t-1. Behavior y is a continuous variable, with higher values representing higher level of implementation. For example, in a given educational reform with multiple elements, a teacher with behavior 12 implements 12 elements per week.

The term I_{it-1} is proportional to the total information to which an actor is exposed that supports a behavior. For each piece of positive information we assume a 5% increase in behavior, and for each piece of negative information we assume 5% decrease in behavior. In particular, $I_{it-1} = 1 + .05 \sum_z \text{information}_{iz}$ where information_{iz} is a binary variable (1 if positive information, -1 if negative information) representing the z^{th} piece of information to which actor *i* is exposed. For example, if an actor receives 2 pieces of positive information and 1 piece of negative information in time t-1, the overall effect of information I_{it-1} is calculated as 1+(0.05*2-0.05)=1.05.

The term $\frac{\sum w_{ijt-1} y_{jt-1}}{\sum w_{ijt-1}}$ represents the mean behavior of actor i's network members at time t-1, where w_{ijt-1}=1 if actor j is a member of the network of i at time t-1, 0 otherwise. Consider actor A has network ties with B and C who engage in behaviors of 5 and 9 respectively. Correspondingly, actor A is exposed to mean behavior of 7 through her network.

Given this model, α represents the salience of the organization on the actor's changes in behaviors, with $0 \leq \alpha \leq 1$. For a high value of organizational salience, egos respond strongly to the behaviors of their network members. This is above and beyond the information the ego obtained as a result of interacting with organization members – large organizational salience generates a normative effect of others in the organization. This normative effect can be due to ego's identification with others in the organization (Frank, 2009), because of a shared sense of fate (Portes and Sensenbrenner, 1993) or a sense of shared mission in the organization (Williamson, 1981).

When organizational salience (α) is low, ego's behavior is primarily a function of ego's prior behavior (y_{it-1}) modified by new information (I) to which ego is exposed. Importantly, this information can be conveyed by members of the organization (see below) but in this capacity other members of the organization carry no more weight than any other in ego's network – the organization member is simply a vector for conveying the information independent of the organizational context. For example, when there is considerable turnover among school faculty, teachers loose allegiance to the school (Ingersoll, 2001; Bryk and Schneider, 2002). As a result they act more atomistically, responding to individual incentives conveyed through information provided by individuals within or outside the school.

Selection Process

*Maintaining Old Ties***.** After actors have been assigned initial network ties, at each time step they decide whether they want to maintain each network tie. Assuming actors are motivated to seek

new information, we specify that when actors access redundant information from a network member, there is higher probability that the actor will re-evaluate and dissolve the network tie. This decision process is a function of how many consecutive times an actor is exposed to redundant information from the network member:

$$P_{ijt} = \lambda^{x}, \quad (3)$$

where P_{ijt} is the probability that actor *i* will maintain the network tie with *j* at time *t*, λ is a constant between 0 and 1, and *x* is an integer between 0 and +∞, which indicates how many consecutive times actor *i* is exposed to redundant information from *i*. If actor *i* accesses new information from *j*, *x* is set to 0 and the probability that *i* will maintain a network tie with *j* at time *t* is 1. The first time actor *i* is exposed to redundant information from *j*, *x* will be 1 and the probability to maintain the tie at time *t* becomes λ. If actor *i* continues to be exposed to information from *j*, *x* will increase by 1 each time until the tie is discontinued or actor *j* provides new information to actor *i*, in which case the probability is reset to 1. For example, assume λ =0.8, the first time ego receives a piece of redundant information from alter the probability to maintain the tie becomes 0.8. Then if ego receives a piece of redundant information from alter *j* again, the probability to maintain the tie becomes 0.8^2=0.64. We then compare this probability with a number randomly drawn from U(0,1). For example, if the random number is smaller than 0.64, ego maintains the tie. Note that even if the connection is discontinued, it may be resumed if organizational salience (α) is high and actor *i* and *j* already share similar behaviors.

Identifying New Ties. At each time step, actors decide with whom to establish network ties, assuming an actor's out-degree (number of others one nominates as a tie) is constant. In this case, we assume actors prefer to interact with others of similar behavior when they have a strong identification or affiliation with others in the organization. When they do not, they seek merely to interact with others who can instrumentally shorten their path lengths to potentially new information (Frank and Fahrbach, 1999).

The utility for actor *i* to choose *j* is:

$$U_{ijt}(mp_{ijt-1}, y_{it-1}, y_{jt-1}) = (1-\alpha)(mp_{ijt-1}) - \alpha \mid y_{it-1} - y_{jt-1} \mid . \quad (2)$$

The salience of the organization as represented by α is associated with the standard homophily term in a network model $|y_{it-1} - y_{jt-1}|$. When organizational salience is high actors the more similar the behavior of two actors the more likely they are to interact. Combining with the influence process above when organizational salience is high actors eventually form subgroups with homogeneous practices within the subgroup and heterogeneous practices between subgroups.

The counter balance to organizational salience in (2) the selection model is the term (mp_{ijt-1} -1) which represents the reduction in path lengths that occurs as a result of an ego's choice of interacting with *j*.. For example, if the network distance between actor *i* and actor *j* is 3 (mp_{ij}=3), and network distance between actor i and actor k is 5 (mp_{ik}=5), then actor i will gain more utility by connecting to k instead of j, because k is more likely to have new information for *i* (Granovetter, 1973). The more actors seek new information the more they will engage in interactions with others who are at greater network distance. This creates bridges that span across subgroups, and, in the extreme, breaks down subgroup boundaries.

*The relative rate of influence (*k*).* Note that in the influence and selection processes, we use the same parameter α to represent the salience of the organization. However, the relative rates at which influence and selection occur can vary. For example, the rate of influence would be high relative to that of selection if actors rapidly adopt the behaviors of those in their network but are slow to change network ties based on homophily. Therefore we express the rate of influence relative to that of selection as *k* ($0 \le k \le 1$), and incorporate *k* into the influence process in (1):

$$y_{it} = (1 - k\alpha) y_{it-1} I_{it-1} + k\alpha \frac{\sum w_{ijt-1} y_{jt-1}}{\sum w_{ijt-1}} \quad . \qquad (4)^1$$

Generally, when $k \rightarrow 0$ actors retain only their previous behaviors – influence occurs slowly relative to selection; as *k* increases the process of influence occurs faster relative to selection, and

[1] Alternatively, we can substitute α*k* with γ, a term that is different from α, representing that influence and selection are two separable processes as in Frank and Fahrbach (1999). However, here we recognize that these two processes are driven by the same underlying motivation –organizational salience (α) (Frank, Kim & Belman, 2010; Xu & Frank, 2016), so we link the two processes through the same parameter α.

when $k \rightarrow 1$ influence occurs at the same rate as selection.[2] Note that by setting $0<k<1$ we assume the rate of network change (selection) is always faster than the rate of behavioral change (influence), consistent with literature showing that behavior is more stable than networks (Engels et al., 1997; Mercken et al., 2010) – but we will explore alternative assumptions in section 4.2. Thus our models allow us to express the system in terms of the interplay of between influence and selection using two parameters: salience of the organization (α) and the rate of influence relative to the rate of selection (k). See technical appendix B for how we empirically anchored the ranges for α and k.

SIMULATION METHODS

We initiate our simulations with two subgroups with different behaviors, and we experiment to learn which types of implementation strategies via venues exert the most structural leverage on the system. We also examine how effects of these strategies interact with the salience of the organization and the rate of influence relative to selection.

Our primary focus is on efforts of agents external to the organization to change the behavior of organization members or the organization as whole. Interpreting the change agent in our models, the external agent does not exert leverage on the organization by changing its own behavior or network. Nor can an external change agent rely on direct interactions with organizational members. Instead, the external agent exerts leverage by creating venues or events that express a particular orientation or behavior to which members of the organization can be attracted and exposed. The choice for the external change agent then concerns how strongly to express a position in the venue the agent creates. A strong position encourages behavior consistent with a particular policy (e.g., basic skills for NCLB), but may create unintended consequences in terms of network dynamics and ultimately the adoption rate in an organization. It is in this sense that the network dynamics affect the organization's adaptive capacity. Therefore, the change agent must choose the venue with an

[2] If selection does not occur the network does not change, and the system converges to the same endpoint for $0<k<1$ (Frank and Fahrbach, 1999).

eye toward the attendant network consequences as well as the direct intended consequences for behavior.

We express the position of the change agent in terms of the valence of the venues the agent introduces into the system. We describe two types of venues, one containing information and orientation strongly supporting behaviors consistent with a policy which we call positive venues (the effects of negative venues can be understood by symmetric arguments concerning information that supports an alternative policy and behaviors), and the other containing a near-neutral orientation and an almost equal balance of positive and negative information supporting a policy.

Consider the change agent who seeks to encourage emphasis on whole language instruction in an elementary school. The change agent could choose to introduce professional development that exclusively emphasizes whole language instruction. This would represent a positive valenced venue in our framework. Alternatively, the change agent could introduce professional development that featured positive aspects of whole language but also included some positive aspects of basic skills. This would represent a near-neutral venue in our framework. Our analysis will then provide insight into the implications of the change agent's choice for the school's overall level of adoption given the internal network dynamics of the school.

Simulation Process

We perform agent based simulations in Netlogo 5.2.0 (Wilensky, 1999). Specifically, at each time step: (1) actors seek information from their network connections as described in the information seeking process; (2) if actors receive new information from their network connections, actors adjust their behaviors as described in the influence process; (3) actors decide whether to maintain current ties as a function of the information they received; (4) if actors decide to dissolve a current tie, they will form new ties as described in the selection process.

Experiment Conditions

Baseline Condition

In the baseline condition we initialize each network with subgroups as in Figure 2. In particular, the behaviors within subgroups follow a normal distribution with standard deviation 1; for the positive subgroup the mean behavior is 12, and for the negative subgroup the mean behavior is 8. While the actual numerical values are not explicitly empirical in the simulations, the difference between the two subgroups might represent the differences in the frequency with which the members of each subgroup, as teachers, implement elements of a given educational reform (with the green subgroup implementing 12 elements per week and the red subgroup implementing 8 elements per week). For actors in the positive subgroup, each actor is initialized with 3 random pieces of positive information and 2 random pieces of negative information. Each actor in the negative subgroup is initialized with 2 random pieces of positive information and 3 random pieces of negative information. In this way information is aligned with the behavior of the actor. The unique pieces of information are randomly drawn from a total of 15 pieces of negative information and 15 pieces of positive information.

Effects of Venues Created by External Change Agents

We initiate each round of simulation with 30 time steps given the baseline dynamics established by equations [2] through [4]. We then introduce shocks as venues with a particular set of information as well as orientation. Aligning with our assumptions about external change agents, these venues do not have capacity to change their behaviors or network ties. But, like any alter, a venue can influence an actor through the venue's orientation/behavior or by sharing information.

Actors in the organization can select venues to be part of their networks based on the selection process as in equation [2], and they can be influenced by venues based on the influence process as in equation [4]. The orientation/behavior contained in the positive valenced venue is 13, one within-group standard deviation higher than the initial mean behavior of the positive subgroup. The positive valenced venue also contains 3 pieces of positive information that are new to the

organization (and no negative information), representing the external information introduced by change agents to support a policy goal.

The baseline behavior of the near-neutral venue is fixed at the mean behavior of all the actors in the system at time-step 30. Like the positive venue, the near neutral venue contains 3 pieces of positive information that are new to the system. But the near neutral venue also contains 10 pieces of positive information and 10 pieces of negative information already in the system. In this sense the near neutral venue functions in part by recognizing the value of the information already in the system and seeking to redistribute that information.

For each experiment we stop a round of time steps when every actor obtains all pieces of information in the system, or after 600 time steps.[3] We set the baseline probability to maintain ties (λ) to be 0.8, and we vary the uncertainty salience of the organization (α) from 0.3 to 1 by intervals of 0.05, and chose the relative rate of influence (*k)* to be 0.1 or 0.5.[4] In each configuration we simulated 200 rounds, with a total of 200*15*2=6000 rounds.

Key Outcome Measures

Our first outcome measure is the probability of full information diffusion (Rogers, 2010). It is calculated as the percentage of the total rounds in which all actors obtain all pieces of information in the organization. This represents the extent to which actors have acquired all the information to evaluate the incentives of the policy. Our second measure is is the mean behavior of the actors at the end of each simulation round. This represents the extent to which actors have adopted behaviors consistent with a policy.

[3] We stop at 600 time steps because in a baseline experiment where we start from random networks, in most simulation rounds actors obtain all pieces of information in the system within 500 time steps.

[4] As a robustness test we also simulate the scenario where k=1. Results are consistent with the main findings, except that when organizational salience is very high ($\alpha >= .95$) even a neutral venue cannot create full information diffusion, as actors form globally polarizing yet locally homogenous subgroups before the introduction of the venue.

RESULTS

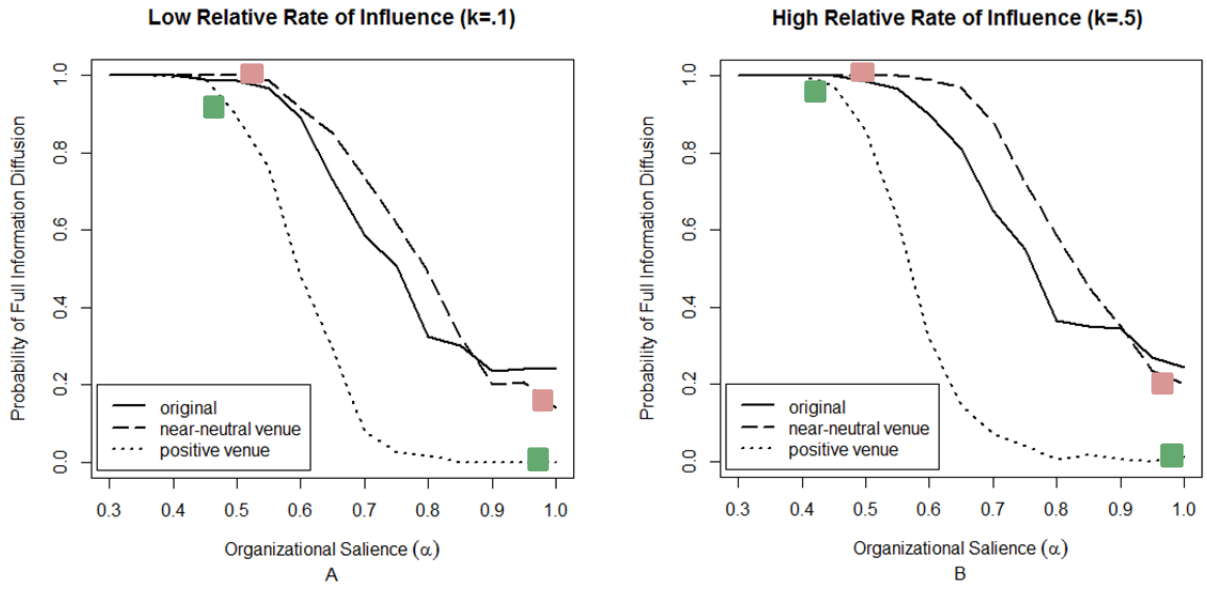
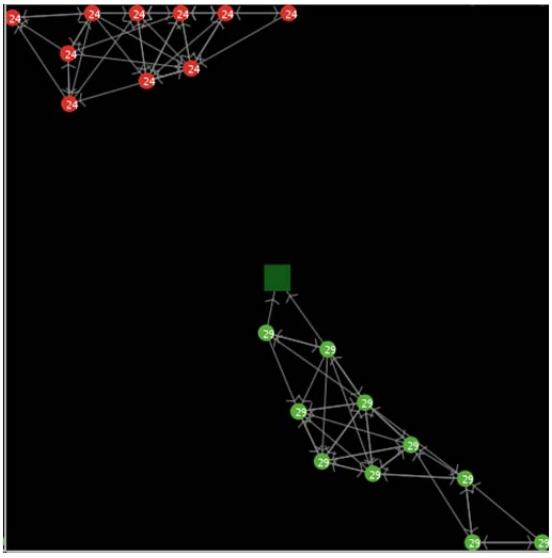
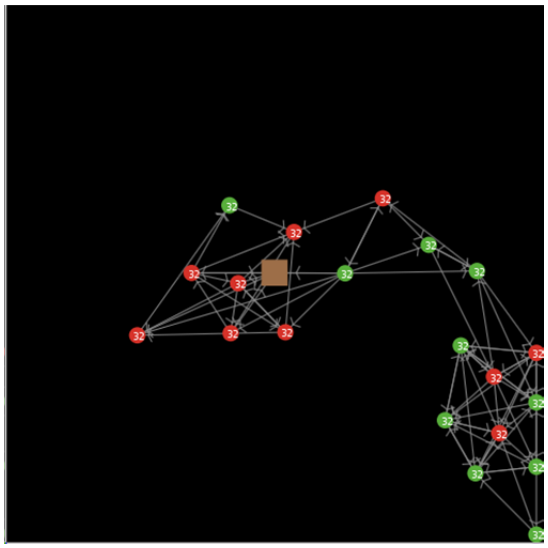


Figure 3. Simulations initiated with two subgroups for different relative rates of interpersonal influence (k). Probability of full information diffusion decreases with organizational salience (α), with more dramatic decrease when a positive venue is introduced.



A (α=0.9, Positive Venue)



B (α=0.9, Near-Neutral Venue)

Figure 4. Example equilibria for simulations initiated with two subgroups when a venue is introduced and organizational salience is high (α=0.9) and rate of influence is high (k=0.5). Numbers indicate the unique pieces of information each actor possess.

Diffusion of Information

In Figure 3 the solid lines represent conditions in which no external venues are introduced establishing a baseline against which to compare scenarios in which venues are introduced into the system. The baseline condition shows that the probability of full information diffusion (all actors obtain all unique pieces of information in the system) decreases as organization salience (α) increases. Examples of equilibria exhibiting the network structures as well as the information actors possess for organizational salience as moderate (α=.4) and high (α=.9) are shown in bottoms of Figures 2. For low values of organizational salience (α) actors establish an integrated network of interaction with others of similar *or* different behaviors, thus allowing the diffusion of information across the system. On the other hand, for high values of organizational salience the network becomes polarized as actors are influenced by subgroup norms and increasingly favor interactions with subgroup members. Ultimately this inhibits the diffusion of information between factions. These trends apply regardless of the relative rate of influence (k), although when influence is stronger as on the right, the tendency for polarization is mitigated for .8≤ organizational salience ≤ .9 and therefore more information is diffused.

Turning to the effects of venues, as organizational salience (α) increases, the dotted lines show a significantly sharper decrease (relative to baseline solid lines) in the probability of full information diffusion when a positive venue is introduced (for organizational salience > .45), with the probability decreasing to near zero when organizational salience > .8. This is because the positive venue attracts actors of similar behaviors (the green dots), accentuating their predispositions, and distancing them from those of the initially opposite behavior. On the other hand, the system is more able to diffuse full information when a near-neutral venue is introduced

(the dashed lines in Figure 3).[5] This is because the near-neutral venue attracts actors of either orientation (green and red dots) providing opportunities for them to continue to exchange information and influence one another.

Figure 4 shows examples of equilibria when a venue is introduced and when organizational salience is high (α= .9) and influence is high (k=.5). Figure 4A includes a positive venue which becomes integrated into the subgroup with similar orientation, and this is associated with polarization. Figure 4B shows a more integrated system as a result of a more neutral venue attracting actors of different behaviors.

Change in Behavior

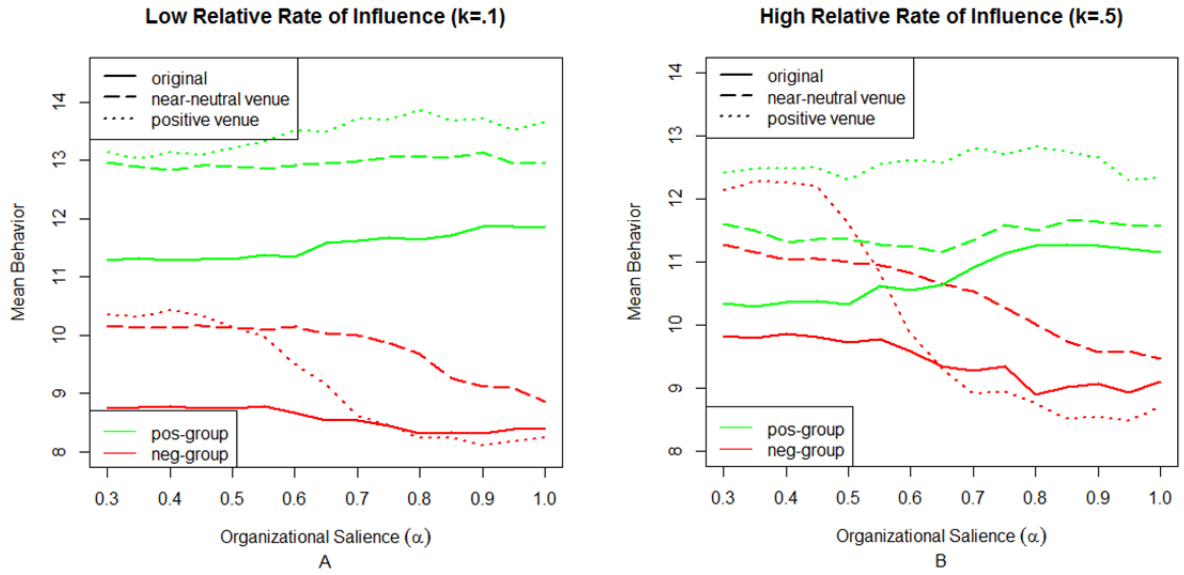


Figure 5. Simulations initiated with two subgroups for different relative rates of interpersonal influence (k).

Figure 3 shows that the trends for diffusion are not dramatically altered when the relative rate of influence is moderate (k=.5). But Figure 5 shows a more complex interaction between the relative rate of influence and the distribution of behavior between subgroups. In the baseline condition (represented by the solid lines) the subgroups (green for the positive subgroup, red for

[5] For organizational salience > .9 the equilibria for the near-neutral event are comparable to those for the baseline because the near-neutral event cannot compensate for the effects of homophily for extremely high organizational salience.

the negative subgroup) maintain separation across values of organizational salience (α) when influence is low (k=.1). But when the relative rate of influence is high (k=.5) the subgroups are more similar to each other for moderate levels of organizational salience. This is because members of different subgroups are able to influence one another and maintain similarity for low to moderate organizational salience (α<.5). It is only for high organizational salience (α>.5) that actors are drawn to interactions within their subgroups to generate polarizing behavior.

The effects of the venues on behavior are shown with the dashed and dotted lines in Figure 5. When influence is low, the pattern of separation between the subgroups for a near-neutral venue is similar to that for baseline (except all behaviors are moderately elevated because of the 3 pieces of positive information embedded in the near-neutral venue). The dotted lines show stronger separation and at higher values of organizational salience (α) as members of the positive subgroup are attracted to the positive venue, and as a result become more extreme in their behaviors. This also creates a social distance between the positive and negative subgroups, and as a result there is little counterbalance to the normative pressures within the negative subgroup, making it more extreme.

When influence is stronger, as on the right, the subgroups maintain integration for low organizational salience (α < .5) in baseline and for positive or near-neutral venues. Thus influence can compensate for the tendency for homophily to drive subgroups apart provided salience is low to moderate. But the mitigating effects of influence on polarization is diminished for high organizational salience (α > .5) in which case polarization occurs regardless of the presence or strength of valence of a venue (although the separation between the subgroups is smaller across conditions for high influence than for low).

Across our results the effect of the venue depends on the salience of the organization. When organizational salience is low (α < .5) an external change agent introducing a positive venue can shift the mean behavior of the organization without inducing polarization. On the other hand, when organizational salience is high (α > .5) a positive venue contributes to polarization, ultimately inhibiting the diffusion of information and constraining the overall change in behavior (increases in

the behavior of one subgroup are offset by decreases in the behavior of the other). Finally, the relative rate of influence (k) amplifies the distinction between high and low organizational salience.

Specification Checks

The Emergence of Subgroups

Our analyses assume the existence of informal subgroups within the organization. There is considerable theoretical and empirical support for the presence of such subgroups (Frank, 1995; Frank and Zhao 2005; Weber, 1946; Simon, 1962). Nonetheless, we explored the emergence of the subgroups from the fundamental network dynamics as given by equations [2] through [4] in appendix A. Results show that subgroups emerge from random networks under most conditions except the extreme condition when organizational salience is low ($\alpha = .3$).

Shocking Subgroups instead of Creating Venues

We have considered the external agent as creating venues because they are unable to directly influence the behaviors of members of the organization. Alternatively, we can consider scenarios in which external agents are able to distribute direct shocks either to all members of a subgroup or to subgroup leaders (those with high intra-subgroup in-degree). The results of these alternative scenarios are reported in technical appendix C including, examples of final equilibria. Results showed that the direction of the effects of shocking subgroups or leaders are consistent with the effects of creating venues, but the magnitude of the effects of shocking subgroup leaders are weaker.

DISCUSSION

Our context applies to the action of the agent who seeks to change the behavior of an organization. This might apply to a national policymaker who seeks to influence schooling by changing the instructional practices of teachers (DeCarolis & Deeds, 1999; Porter et al., 2011; Weiss, Bloom and Brock, 2014) or to medical professional associations who support evidence-based practice. We make what we believe to be an authentic definition of an agent who is

truly external to the organization, and therefore must exert leverage by creating venues (e.g., professional development) that will contain information supporting the intended change. It is then incumbent upon the members of the organization to participate in the venue, absorb information and distribute it throughout the organization. Given this context, we use agent-based models to investigate potential equilibria in terms of the distribution of information and attendant behaviors within the organization.

We start by assuming that there already exist at least modest divisions within the organization such as by formal departments or informal cliques. Given the existence of these divisions, our dynamic analysis shows there is a tendency for polarization in the system when actors are able to influence one another or select others based on similarity of behavior. Thus it is the tendency toward polarization that the change agent encounters in trying to influence organizational behavior. In this sense our baseline finding adds a dynamic element to the literature on absorptive capacity which typically focuses on the ability of an organization's static structures to facilitate communication and coordination.

But our findings are more specific than just that internal network dynamics matter. In particular, when social salience is high the change agent can more effectively influence the organization by creating a near-neutral venue which will mitigate against the polarization of the organizational members. For example, if the employees of a school have a strong affiliation with the school then external change agents might paradoxically exert the most leverage by creating professional development that exhibits an even-handed, or near-neutral orientation to a particular set of teaching practices. In contrast, when social salience is low, change agents can more directly influence organizational members by creating a venue which strongly endorses the orientation of the agent. This might obtain when the members of a school have weak affiliation with the school, such as when turnover rates are high (Ingersoll, 2001). The dependence of the optimal action of the change agent on the level of social salience confirms our second hypothesis, that the effect of the change agent depends on the internal network dynamics of the organization. Change agents can

direct an organization to a particular behavior by creating venues supporting that behavior when organizational salience is low.

Our second key result is that the process of implementation itself can change the intra-organizational dynamics. In particular, a change agent who introduces a venue with a strong endorsement may accentuate existing cleavages in the system. In the extreme, this can create polarization or factions, limiting the organization's capacity for coordination and to diffuse future innovations. Because changes in network structure have implications for the diffusion of any innovation, and because polarization may endure and be difficult to overcome, the effects of change agents may go extensively beyond their immediate actions.

Methodologically, although we recognize the formal organization as defining the broad conditions of diffusion, the action of the individual actors are derived from network dynamics of the individuals within organizations. Moreover, we emphasize our parsimonious formalization of the internal network dynamics of organizations (Chang & Harrington, 2006). The parsimony allows us to describe the essential internal dynamics in terms of two parameters, organizational salience (α) and the rate of influence relative to that of selection (k). While no doubt other factors affect influence (level of expertise, trust, etc.) and selection (proximity), our models allow the theoretical exploration of two key elements of internal dynamics that affect consequences of the actions of agents external to the system.

Guidance for External Change Agents

Our general advice is that the change agent should select action based on the internal network dynamics of the members of the organization as driven by the salience of the organization and the rate of influence relative to that of selection. This suggests careful measurement of the intra-organizational dynamics *before* introducing a change into the organization (Damschroder et

al., 2009). [6]Organizational culture is typically measured with instruments representing collective responsibility, trust, or other aspects of social capital flows between organizational actors (Bryk & Scheneider, 2002; Frank, 2009). Indirect measures of organizational salience may also be obtained from administrative data regarding organizational turnover, absenteeism, etc. If behavioral changes occur slowly even in the presence of low organizational salience one might infer that actors are not able to exert strong influences on one another. In this case external agents can exert leverage by introducing a venue strongly endorsing specific behaviors. If organization salience is high and the system is prone to polarization external change agents can exert maximal leverage by creating near neutral venues.

But transition to polarization is sharper the stronger the influence process. This would suggest that when influence runs rapidly external change agents must be especially sensitive to initial indications of separation that could rapidly lead to polarization. The relative rate of influence may be indirectly inferred by carefully monitoring the spread of behavior during diffusion. In this aspect, we can learn from qualitative work that attends explicitly to processes of influence and selection during implementation (Coburn and Russell, 2008; Penuel et al, 2009). More generally, external change agents must continue to monitor internal dynamics for polarization and diffusion after introducing a shock into the system.

Guidance for Internal organizational agents

Our simulations show that polarization is not the fault of leadership, nor is it happenstance. It is likely an inevitable result of network dynamics under commonly observed network dynamics. The challenge for the organizational leader then is to intervene to prevent polarization while leveraging the network dynamics for maximal impact. For example, intra-organizational leaders can deliberately create cross-group ties and increase rates of influence *k* so that members from

[6] This can extend to measuring social networks prior to intervention and then using the data to inform interventions (Valente 2012, 2017).

different subgroups can interact and learn from each other. In schools that have a strong mission or ethos one must deliberately cultivate relationships that cut across potential factions or cliques (Bryk and Schneider, 2002; Lightfoot, 2008)

Here, the organization's exposure to externally generated uncertainty creates a challenge for agents internal to the organization. The greater the external uncertainty, the more members of the organization may become important and relevant to one another to provide localized information and support in times of organizational stress (Portes and Sensenbrenner, 1993). That is, the greater the uncertainty of external conditions, the greater the salience of organizational members to one another. But the greater the organizational salience, the greater the potential for polarization. For example, when schools encountered uncertainty about the Common Core in terms of its association with standardized tests or in terms of their state's interpretation, teachers may have turned to close colleagues to make sense of the Common Core and for protection should they encounter a negative evaluation. But just as they turn to their colleagues, they increase the probability of polarization, as some may respond more favorably to elements of the Common Core than others. Thus the organization must balance cultivating salience against the potential for internal polarization.

Guidance for Empirical Models

Key to our analysis is the relative rates of influence and selection. While these have been estimated in a few circumstances (e.g,. Liu 2015; Liu and Srivastava, 2015; Matsueda and Anderson, 1998; Snijders, Van de Bunt, & Steglich, 2010), they have rarely been estimated with respect to the implementation of policy within organizations. The relative rate of influence and selection may be estimated from two time points of data including measures of relevant behaviors and sociometric questions (frank and Xu, forthcoming; Snijders et al., 2006). Knowing these relative rates and the circumstances that alter them would inform the development of models such as in [2] and [4] not only in terms of the relative sizes of the existing parameters but factors that

moderate the processes. For example, when organizational turnover is high actors may lose commitment to the others in the organization as a collective. This could either be interpreted as reducing the size of organizational salience (α) or moderating the effect of organizational salience in selection and influence.

Limitations

Our models are not fully realistic in their complexity. We make this choice to isolate a parsimonious set of leverage points, so we can understand the network dynamics that affect an organization's capacity to implement an innovation. But our agent-based models focus on meso-level phenomenon instead of fully predicting the range/complexities of organizational responses in any particular situation. In particular, we do not incorporate stakeholders such as unions in our model because for the most part unions do not directly engage the adoption or implementation of professional practices (such as pedagogy).[7]

We also primarily attended to informal mechanisms in the network dynamics driven by influence and selection. But of course some behavior and some interactions are regulated or mandated (Hopkins and Spillane 2015). Correspondingly, change agents could in theory create venues that imposed similar regulatory constraints. But cases in which a change agent has the capacity to regulate behavior are beyond the scope of this paper, as they deal more broadly with power and institutional relationships.

CONCLUSION

The intent of any policy is to change experiences of end users. Much of that experience is shaped by action within organizational boundaries. But organizations are not monolithic. In particular, organizations typically feature formal divisions or subgroups in which informal interactions are concentrated. These subgroups define the lines of potential polarization when

[7] Unions could play an indirect role in the implementation process by protecting teachers who decline markedly in their performance as a result of attempting to implement an innovation (e.g., because the innovation is ineffective).

external shocks are introduced into the organization. Ignoring this potential can generate serious unintended consequences that can undermine the immediate intent of action as well as the organization's capacity to learn, coordinate, and adapt to future innovations. Thus we urge change agents to attend to the network dynamics internal to the organizations that affect an organization's capacity to implement innovations.

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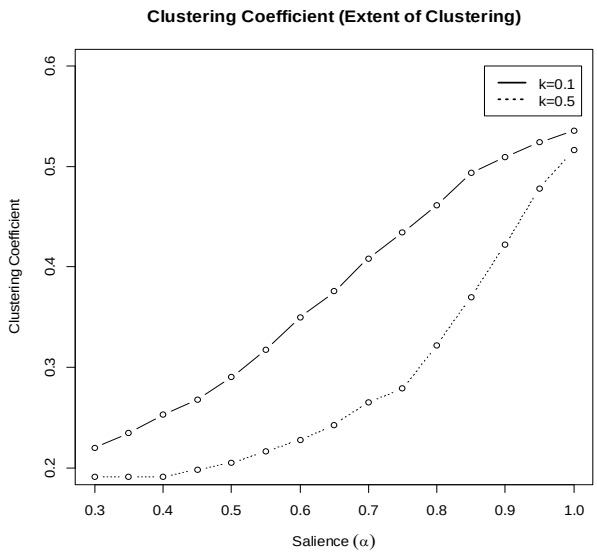
On-Line Technical Appendix A

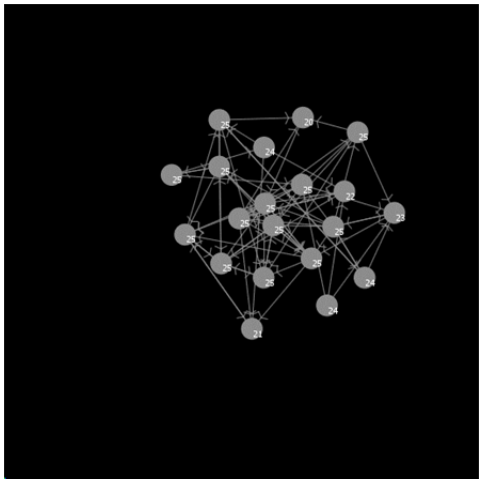
The Emergence of Subgroups from Random Networks

We explore the emergence of the subgroups from the fundamental network dynamics as given by equations [2] through [4]. Our results in Figure 1a show that subgroups emerge (as defined by clustering coefficient >.4) from random networks with an increase in organizational salience. For example, subgroups emerged in 80% of the rounds when α=.9. This result is consistent with Macy et al. (2003).

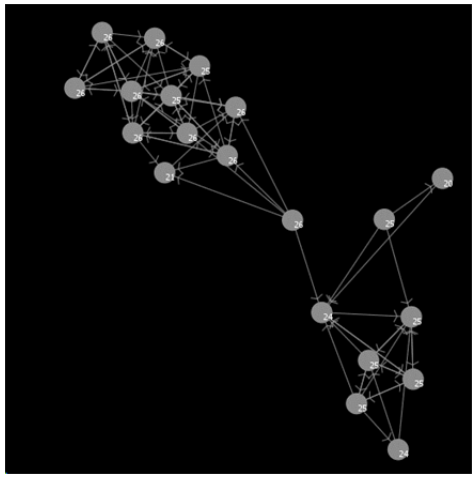
We also note that when the rate of influence relative to selection is high (k=.5), the emergence of subgroups is first delayed but then more dramatic. This is consistent with Xu and Frank (2016). The only condition under which subgroups do not consistently emerge is when organizational salience is low. Subgroups never emerged in the rounds when α= .3, as actors constantly strive to connect with distant others. This is consistent with Buskens & Van de Rijt (2008).



(A) Initiated from random networks



(B) α=0.4, k=0.5



(C) α=0.9, k=0.5

Fig. A1. The emergence of subgroups from random networks. We initialize the simulations with a random network with 20 actors. Density of the network is 0.2, actors' initial behaviors follow a normal distribution with a mean of 10 and a standard deviation of 2, and each actor begins with 2 pieces of positive and negative information drawn from a total of 30 pieces of unique information. A round is terminated after 50 time steps. Results showed that the subgroups emerged with increase in organizational salience (α), when the rate of influence relative to selection (k) is higher, the emergence of subgroups is first delayed but then more dramatic. (A) Clustering coefficient vs salience for different level relative rate of influence, *k*. Each

data point represents 200 rounds. (B) Example equilibrium showing a tightly connected network when organizational salience is low (α=0.4); (C) Example equilibrium showing subgroups when organizational salience is high (α=0.9).

On-Line Technical Appendix B

Anchoring the Magnitude of Organizational Salience and Relative Rates of Influence in Empirical Data

We provide some guidance for the magnitude of organizational salience (α) and rates of influence (*k*) from empirical studies. Conditional on other covariates, Frank et al. (2004) and Penuel et al. (2012) found modest to strong rates of influence among teachers (with the coefficient for the network exposure term roughly one third to two thirds as large as that for an actor's own prior behaviors), either in changing teaching practice or adopting innovations; Using data from Liu and Srivastava (2015) organizational salience (α) was high but relative rate of influence (*k*) was low among senators regarding the political orientation of their voting behavior. Generally, organizational salience and relative rate of influence have been found to be lower among professionals in stable working environments, but higher among adolescents or during periods of intense socialization such as in military or religious settings (Frank et al., 2008; Stouffer et al., 1949; Gellner, 2015; Durkheim & Swain, 2008).

On-Line Appendix C

Equilibria Resulting from Applying Shocks to the Most Central Actors within Subgroups

In the main text we considered the external agent as creating venues because they are unable to directly influence the behaviors of members of the organization. In this appendix we consider scenarios in which external agents are able to distribute direct shocks either to all members of a subgroup or to subgroup leaders (those with high intra-subgroup in-degree). As shown in Figure C1, the effects of shocking subgroup leaders are consistent with the effects of creating venues, but the magnitude of the effects of shocking subgroup leaders are weaker. This is because the leader, unlike the venue, is influenced by others and can change network ties. Therefore, leaders can become integrated into the organization, weakening their leverage on the system relative to venues which stand stable outside the organization.

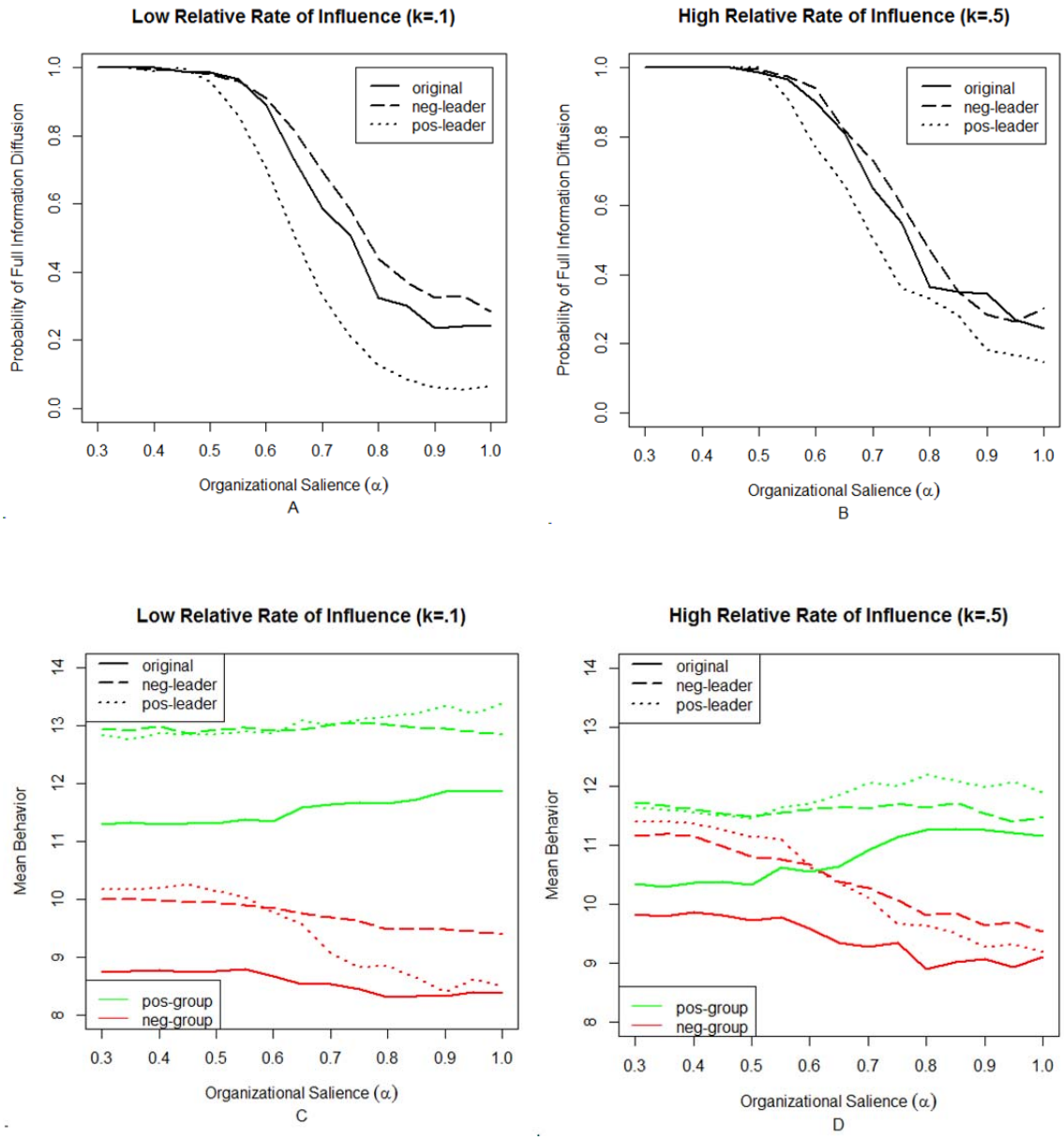
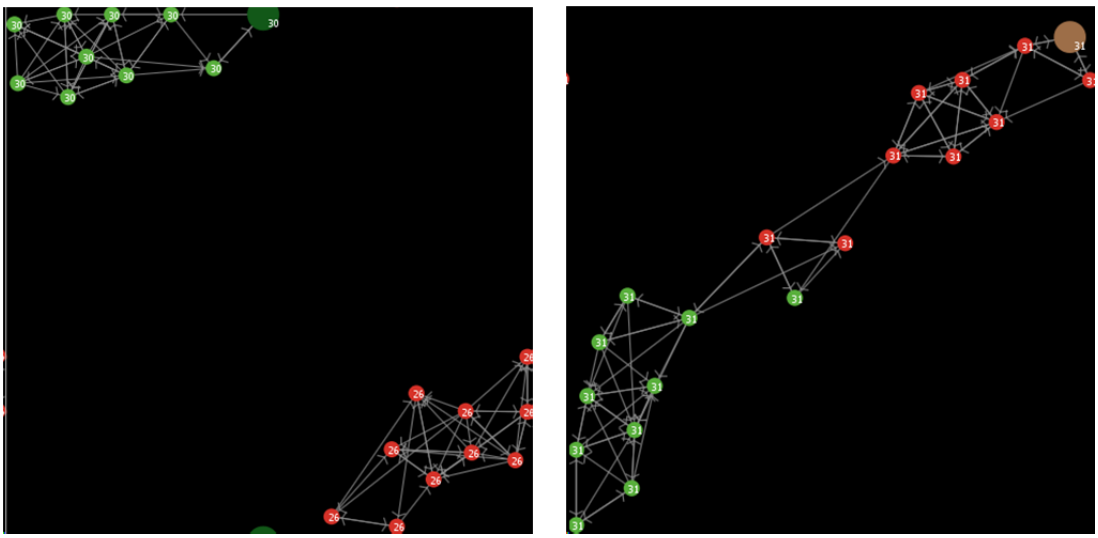


Fig. C1. Shocking subgroup leaders instead of creating venues. We initialize each round with two subgroups as in the main experiment. At time 30, we create two experimental conditions to shock the subgroups instead of creating venues: (1) we shock the actor with the highest in-degree in the positive subgroup with 3 pieces of positive information that are new to the system; (2) we shock the actor with the highest in-degree in the negative subgroup with 3 pieces of positive information that are new to the system. Results are generally consistent with the main results, the effects of shocking the positive subgroup leader have the same direction as creating the positive venue, and the effects of shocking the negative subgroup leader are

similar to those for creating the near-neutral venue. In both cases the magnitude of the effects of shocking subgroup leaders are weaker. (A) Probability of full information diffusion vs organizational salience (α) when rate of influence is low (k=0.1). (B) Probability of full information diffusion vs organizational salience (α) when rate of influence is high (k=0.5). (C) Mean behavior of each subgroup vs salience when rate of influence is low (k=0.1); (D) Mean behavior of each subgroup vs salience when rate of influence is high (k=0.5). Each data point represents 200 rounds of simulation.



(A) Shock to positive subgroup leader

(B) Shock to negative subgroup leader

Fig. C2. Example equilibria for systems when the subgroup leader is shocked. Organizational salience and rate of influence are high (α=0.9, k=0.5) in both cases: (A) factions inhibit information diffusion when positive subgroup leader is shocked; (B) weak between-subgroup ties allow information diffusion when negative subgroup leader is shocked. Green indicates the positive subgroup and red indicates the negative subgroup, darker green and brown node indicates the subgroup leader from positive and negative subgroup that were shocked with three pieces of positive information new to the system.