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The role of agent types in detecting and responding to environmental change.

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INTRODUCTION

Historical and contemporary relationships between people and the changing environment in which they live can offer insights for anticipatory environmental modeling and management that promote social-ecological resilience, even under unfamiliar conditions of change. Changes in resource use patterns by humans (acting as agents) responding to their environments may significantly affect feedbacks in resource availability and quality. Such feedbacks are increasingly being examined since they have the potential to impact the cultures, lifestyles, and resource use patterns of human communities. The outcomes of adaptive responses (or lack thereof) are determined not only by inherent environmental conditions (Alessa et al 2009), but also by social responses arising from agents' perceptions about the need to adapt to environmental conditions by agents (i.e., anthropogenic influence). We propose that the latter component is critical and strongly dependent on the composition of the agents who comprise the community. For example, if resources (e.g., water) are perceived as scarce and there is concern for collective well being, a community may successfully implement a water management plan which includes the use of technology, incentives and/or enforced social norms (Wang et al 2005), thus changing feedbacks between human-hydrological systems resulting in more favorable outcomes. Similarly, unfavorable outcomes may result if there is lack of awareness of resource conditions (Alessa et al 2010) and an inadequate or inappropriate response. Consequently, understanding and projecting future scenarios of change relies on an understanding of the physical resources (e.g., hydrology) as well as social dynamics, such as the influence of values, perceptions, social networks and, as we propose here, the types of agents.

Societies are highly heterogeneous with respect to individual perceptions and responses to change; that is, there is plurality. Ultimately, cumulative behaviors determine responses to change such that anthropogenic feedbacks to biophysical systems supersede factors such as climate change and are manifested at finer temporal and spatial scales (Gardner et al 1996). One consequence of this is that human activities elicit changes at finer spatial scales more quickly than at broad scales (Alessa et al 2007). The types of activities and responses to change in which a community engages depends on the types of people who live there. With this in mind, it is thus surprising that our understanding of how agent types interact with respect to perception of change is so lacking. In this paper, we provide evidence that our understanding and modeling of the diverse responses by human networks to change may be better informed by understanding agent types within a network as well as the perception of change by these agents as a continuous feedback system. We provide, for the first time, data from an on-going collaborative study which reveals that community resilience at local scales may be significantly influenced by agent types and the way they perceive changes in their water supplies.

Why Understand Agents?

One measure of leadership is the caliber of people who choose to follow you. ~Dennis A. Peer

An autonomous agent (e.g., an individual) has a cognitive element which is subject to social influence and infrastructural (e.g., economic) constraints (e.g., Castelfranchi 1998, Castelfranchi 2000, Conte et al. 2000). The concept of “agents” and “roles” is not new and occurs in diverse fields of study ranging from artificial intelligence (e.g., Perry 1988) to sociology (e.g., Fales 1977) to psychology (Biddle 1979). A cognitive agent (i.e., a person) has three main features: cognition (perception), reason (preferences), and purpose (intentions) (Castelfranchi 2001). These features encompass the general concept that agents are intelligent actors who respond to social and environmental stimuli in multiple ways including hysteresis (e.g., not responding to a stimulus until it carries risk), learning (e.g., becoming more efficient) and values (e.g., the Prisoners’ Dilemma). Roles are carried out by agents based on both their formal and informal situation within a network or group (Biddle 1979). The dynamics of human responses to change are often studied at the scale of institutions and/or populations (Cash et al. 2006). In this paper, we articulate a phenomenon where different types of agents appear to have distinct roles in initiating, facilitating, and opposing collective organization in remote, resource dependent communities. Based on both participant observations and interviews in case-study communities, we categorize our agents into three broad categories: “initiators”, “supporters” and “opportunists”. In this study, we designate these agent types as alpha (α), beta (β) and gamma (γ). Their features (Table 1) may be summarized as formal or informal leadership or ‘expert’ roles (α), facilitating, mentor or ‘helper’ roles (β), and roles which optimize network resources (both human/social and material/economic capital) toward more individual rather than collective gains (γ). We propose that the ratios and distribution of these agent types within communities will affect the ability of a community to reorganize following a perturbation.

Table 1: Agent type descriptions with comparison to typologies derived from simulations.

Agent Type	Role	Comparison to Equiluz et al 2005	Comparison to Lopez-Perez 2008
α	Initiator of a response to change	Satisfied cooperators (leaders)	Principled agents
β	Supporter of a response to change	Unsatisfied cooperators (conformists)	Principled agents
γ	Opportunistic reaction with respect to a response to change (possibly a detractor to a response to change)	defectors taking advantage (exploiters)	Selfish agents

This typology has similarities to the role differentiation proposed by Equiluz et al. (2005) that emerge from computer simulations of a Prisoners’ Dilemma model. They identified leaders (or satisfied cooperators), conformists (or unsatisfied cooperators), and exploiters (or defectors that take advantage of others), where these three social roles emerge from the self-organizing dynamics of the system and that are based on the payoff to the individual and the extent of their cooperation with others (Equiluz et al. 2005). Lopez-Perez (2008) distinguishes between selfish agents, concerned only with their own material payoff, and principled agents, who are also concerned with social norms. This differentiation is also based on game simulations, in this case the Revolution game. While individuals can adopt these specific types of roles, they are also dynamic as the three agent types are key positions on a spectrum where an agent can adopt different roles simultaneously or change roles (Masolo et al 2004).

Various studies suggest that agents adopt specific roles within a network regardless of their institutional or social hierarchy (e.g., Granovetter 1985). For example, "leaders" in a network do not necessarily have to occupy leadership positions. The roles that agents play, the ratios of the different types of agents and their means of utilizing social capital are critical to our understanding of how communities respond to change. Methods to assess agent types are in their infancy but several studies have demonstrated their importance in predicting group and population behaviors (Johnsen 2003, Eguiluz et al 2005). Once agent types are revealed and individual attitudes and values surveyed, understanding collective social behavior requires taking into account the interactions among the individuals of the group and acknowledging that these interactions are mediated by a network of social relations (Granovetter 1973, 1978).

The social structure of the group and the embeddedness of the interactions in the social structure (Granovetter 1985) have been identified as important factors in explaining the evolution of cooperation (Macy and Skvoretz 1998). In the same way that the actions of individuals are affected by the social network, it has been documented that the network is not an exogenous structure but is created by individual choices (Lazer 2001). However, there are few specific models of social dynamics that explicitly incorporate the concept of coevolution of the individual agent and the behavior of the overall network (Lazer 2001). In fact, in the long-term research agenda posed by Macy (1991), a central point is that the structure of the network should not be considered as given, but should be seen as variable. Macy poses the question of how social structure might evolve in tandem with the collective action it enables. This question goes beyond models in which some network evolution is decoupled from the evolution of the actions of the individuals in the group. An understanding of the agent types, their associations, distributions and ratios is critical to understanding network dynamics (e.g., Eguilez et al 2005). This is necessary in order to scale up the processes of interactions of a few agents to interactions of many agents.

Perception of change in remote resource-dependent communities on Seward Peninsula, Alaska

A particularly important context in which to examine the role of agent types is with respect to freshwater resources on which communities rely for subsistence and proximal use of natural resources (e.g., fish). Areas such as the Seward Peninsula, Alaska offering manageable scales and well-defined watersheds provide outstanding opportunities to study the links between humans and their environments. In remote resource-dependent communities of Alaska, previous work has shown that age differences, specifically generational, are significant in the perception of change in hydrological resources (Alessa et al 2008a) and in the values held toward water (Alessa et al 2010), with elders being more cognizant of change than other generations and holding greater cultural value and less utilitarian value toward water. In addition, the perception of change in water resources varies with the presence of technology, in this case a municipal water supply, such that users of a natural water source are more cognizant of change than users of a municipal supply (Alessa et al. 2007).

We hypothesize that change in water resources is also perceived differently based on the type of agent and their collective knowledge base. In this case, we assume that knowledge is experience encumbered through long residence time in a community, chronological age and correspondingly historic resource use patterns (Alessa et al 2007, 2008a, 2010). Agents that occupy informal or formal leadership roles in the community (α) are more sensitive to external stimuli and more likely to perceive these changes as requiring a response (e.g., through altered behaviors). Communities in which these agents represent a specific proportion of the population are likely to be more responsive to change, that is, more resilient.

METHODS

This study was carried out as a part of a larger project (Alessa et al. 2008a) and used the same approach and data collection protocol to that previously described in Alessa et al (2007, 2008a, 2010) but extends that work by including data on agent types. The project involved a collaborative team of anthropologists, biologists, geographers, hydrologists and water engineers working in cooperation with five rural Inupiaq communities on the Seward Peninsula, Alaska. The project was initiated through the village Indian Reorganization Act (IRA) Council (i.e., Tribal Council) in each village which served as an important venue for permission to work in the village for discussing results, and for seeking feedback on results. The study was approved by the Institutional Review Board before commencing the study.

Exploratory visits to ten villages on the Seward Peninsula were carried out in 2004 and interviews of key informants produced between two and five interviews per village. We selected five villages for further study based on IRA Council interest in the study, the diversity of water issues reported in exploratory interviews, and the types of water sources (natural, municipal, mixed) available in the village. In 2005 and 2006, we returned to each of the five villages and asked a set of questions as part of a semi-structured interview about water use (Alessa et al 2007), knowledge of water sources (Alessa et al 2008a), values of water (Alessa et al 2010), and perception of change in water resources (Alessa et al 2007, 2008a), and the role of individuals with respect to decisions in the village affecting response to water and subsistence resources. A total of 134 useable semi-structured interviews were obtained representing 95% of the individuals whom we approached to request an interview. As has been documented in Alessa et al (2008a), the sample was divided into age groups classifying the population into three generations: 18-39 years, 40-59 years, and 60+ years labeled as the “modern-schooled”, “boarding-schooled”, and “ land-schooled” respectively in reference to the dominant manner and location of that cohort’s youth education in the village (Alessa et al. 2008a).

Interview questions included a series of questions about the respondent’s use of water in the village (natural water sources used, use of a municipal water source if present), their perception of the quality and quantity of those water sources, and their perception of change in those water sources over the period of time with which they had familiarity with the water source. Individuals were asked what their perception of change in the quality and availability (quantity) of community water sources was. Water sources referred typically included the municipal supply (present in two of the five villages) and the major river or creek used by the village. We developed indices of perceived change using a 3-point scale (Alessa et al 2008a), where perception of change in water quality (poorer quality, no change, or better quality) and perception of change in water availability (less availability, no change, or greater availability) were rated. Chi square analysis with SPSS was used to test the strength of association between variables.

Agent types

In this study we used a multi-modal approach to classify respondents by agent type. An attitudinal scale was included in the questionnaire comprising questions that measured an individual’s role in initiating or facilitating response to changes in the community with respect to water and other resources issues. The scale comprised five items denoting actions or behavior reflecting initiation of a response to water / resource concerns in the community, five items denoting support or involvement in existing responses to water / resource concerns in the community, and five items denoting actions or behavior that were motivated by self-interest vis-à-vis collective interest. As part of the semi-structured interview, during which the questionnaire was used, individuals were also asked to peer-identify individuals in the community fulfilling roles as initiators, facilitators or opportunistic agents. Thirdly, we interviewed representatives from tribal corporations, the regional safe water program, and regional government who regularly spend time in the community and asked them to identify individuals in each community fitting the roles of initiators, facilitators, and wildcard agents with respect to water / resource matters. This approach produced consistent results (i.e., model outputs as validated by field observations and community feedback). This 'triplicate reference' method uses observation, self- and peer-identification, and replication. Ideally, replication is conducted at least three times in order to establish a consistency index of self-identification and peer-reference. Continued participant observation may serve to provide greater detail for agents adopting specific roles in different contexts. Knowledge regarding the overall status of the community/network is also important when assessing agent types and their ratios. That is, the history and status quo of a community/network (e.g., responsive to change and successful in adapting) should be known in order to correlate a broader outcome to the numbers, types and ratios of agents which constitute them.

Community resilience

The relative vulnerability–resilience of each of the five communities to changing water resources at the local scale was measured using the Arctic Water Resources Vulnerability Index (AWRVI) assessment tool (Alessa et al 2008b). AWRVI is based on a socio-ecological systems view and comprises a set of biophysical and socioeconomic indicators that provide a normalized (0.0 – 1.0) index of vulnerability–resilience to change (Alessa et al 2008b). The AWRVI score for each village was compared to the agent distribution and ratio for the village.

RESULTS

The multi-modal classification of agent types resulted in 23% of respondents being categorized as α agents (n=29), 69% as β agents (n=88), and 8% as γ agents (n=10) in all five villages collectively. The age distribution for agent types in all five communities indicated that β agents included more young people (18-29 years) than α and γ agents while the majority of α agents (61 %) and γ agents (72 %) were in the 30-49 years age group. However, there was not a significant relationship between agent type and age group (Table 2). Both α and β agents tended to include more people with shorter residence times in a community than γ agents, while γ agents included people who predominantly had intermediate residence times in a community. A significant relationship did not exist between agent type and residence time (Table 2). Both α and β agents included similar numbers of male and female while γ agents were predominantly male.

There was no difference or significant relationship in perception of municipal water quality or municipal water availability either by sex (see Alessa et al 2008a) or by agent type (Table 2). There was also no difference or a significant relationship in perception of river water quality or river water availability by sex (see Alessa et al 2008a). However, a significant relationship existed by agent type for both perception of river water quality (Table 2) and perception of river water availability (Table 2). A greater proportion of alpha agents (67%) perceived river water quality to be lower compared to either beta agents (35%) or gamma agents (0%). A greater proportion of alpha agents (47%) perceived river water availability to be scarce than either beta agents (15%) or gamma agents (0%).

Results for the perception of change in water quality and quantity during a respondent's period of residence in the community indicated differences in perceptions among agent types. Moderately strong significant relationships existed by agent type for both perception of change in river water quality (Table 2) and perception of change in river water availability (Table 2). A greater proportion of alpha agents (38%) perceived change in river water quality compared to either beta agents (10%) or gamma agents (0%). Similarly, a larger proportion of alpha agents (43%) perceived change in river water availability than either beta agents (12%) or gamma agents (0%).

The proportion of α to β to γ agents within each of the five communities was significantly different (Table 2). This moderately strong relationship differentiates between those communities (1 and 3) with a higher proportion of α agents and a lower proportion of γ agents and those communities (2, 4, and 5) with a higher proportion of γ agents and a lower proportion of α agents (Table 3). The relative ratio of agents (α: β: γ) in these communities was 1:3:0 (communities 1 and 3) and 1:5:2 (communities 2, 4, and 5).

Table 2: Summary statistics for perception of freshwater with respect to agent type for Seward Peninsula, Alaska communities.

Measure	Variable tested for association	Significance	Chi square	Degrees of freedom
Age				
	Agent type	†ns		
Residence time				
	Agent type	†ns		
Perception of change in municipal water quality				
	Agent type	†ns		
Perception of change in municipal water availability (quantity)				
	Agent type	†ns		
Perception of river water quality				
	Agent type	$p = 0.05$	$\chi^2 = 16.88$	6, 127
Perception of river water availability (quantity)				
	Agent type	$p < 0.01$	$\chi^2 = 18.84$	6, 127
Perception of change in river water quality				
	Agent type	$p < 0.01$	$\chi^2 = 18.04$	6, 127
Perception of change in river water availability (quantity)				
	Agent type	$p < 0.01$	$\chi^2 = 21.15$	6, 127
Ratio of agent types (α to β to γ)				
	Community	$p< 0.005$	$\chi^2 = 20.49$	

†ns = not significant

Using AWRVI, two communities (communities 1 and 3) were identified whose vulnerability-resilience index scores were in the threshold range for vulnerability-resilience – the most resilient communities among the five communities of our study (Table 3). Two communities (communities 2 and 4) were rated in the moderately vulnerable range, and community 5 was rated as vulnerable (Table 3). This provides a relative measure of the susceptibility of the community to changes in water resources and the capacity of the community to respond to such changes.

DISCUSSION

Our data indicate that both α and γ agent types are individuals who have accrued significant life experience (with a mean age of 43 and 40 years respectively). Alpha agents are almost equally distributed between males and females and γ agents consist primarily of males between the ages of 30 to 49. While these data are intriguing we can only speculate that this may reflect a broad body of knowledge which shows gender differences in cooperative (α) and conflict-driven (γ) agents (e.g., Bird 1999, Betzig 2004). It is plausible that it is the relative proportions of α to γ agents which influence the resilience of a community. This may be due to γ agents acting as opportunists where the choice for individual benefit outweighs the collective rationality (e.g., Kollock and Smith 1996) resulting in a reduction of the total benefits and opportunities for a given community (Sherif 1966, Fudenberg and Tirole 1991, Kruger 1993).

Table 3: Ratios of agent types and AWRVI scores of vulnerability - resilience for each study community on Seward Peninsula, Alaska.

Community	**Agent ratio** (α: β: γ)	**AWRVI score** **(0.00 Vulnerable – 1.00 Resilient)**
1	1:3:0 (High alpha)	0.47 (threshold)
2	1:5:2 (High gamma)	0.27 (mod. vulnerable)
3	1:3:0 (High alpha)	0.49 (threshold)
4	1:5:2 (High gamma)	0.32 (mod. vulnerable)
5	1:5:2 (High gamma)	0.25 (vulnerable)

The finding that the ratios of agent types (with different perceptions of water resources) vary between communities (Table 3) was unexpected. We interpret these data to imply that agent ratios may lend the ability (or inability) to respond successfully to change. In other words, a group of α agents may act as highly accurate 'sensors' whereby change is perceived and other agents are organized to action. For communities who must compete for both subsistence and financial resources (i.e., infrastructure, facilities and programs), this may be a critical factor in determining how resilient or vulnerable they are, particularly under conditions of slow and fast environmental change. This could be because α agents can anticipate emergent problems accurately and respond to them successfully, in part because they are readily accepted by β agents and develop adaptation plans which are clearly collectively beneficial. This is supported by the AWRVI scores which show that more resilient communities have a distribution of agent types which consist of a greater proportion of α agents and a lower proportion of γ agents –

approximately 1:3:0 ratio of α, β, and γ agents (Table 3). It is further corroborated by anecdotal evidence from interviews showing that these communities have both high self-perceived and proxy (programmatic and physical infrastructure) resilience. Those communities which have lower resilience (Table 3) and lower self-perceived and proxy resilience have a significantly lower proportion of α agents and a higher proportion of γ agents – 1:5:2 ratio of α, β, and γ agents (Table 3). It appears that the ratio of agent types makes a difference but we are unable to determine a specific threshold in the agent ratio at which community responsive succeeds or fails, this is something that future research could examine – does it take just a few gamma agents to disrupt community adaptation?

The results for differences in perceptions of agent types suggest that α agents are more likely to perceive changes in the environment as requiring either a proactive or responsive action which benefits the community as a whole. Our data show that γ agents do not appear to detect changes in their environment with respect to water resources. However, we speculate they may be able to detect opportunities from which they derive personal benefit either by cooperating with or impeding the actions of the α and β agents as a collective unit. It is γ agents who may be referred to as "wildcards" in a community and it is the relative influence of both α and γ agent types on β agents which may determine the effectiveness of β agents as facilitators of response to change. Ultimately, we believe that different communities will have different capacities to self-organize into adaptive networks depending on the agent profiles present within them and the magnitude at which change in water quality and quantity is perceived.

The agent typology set out in this paper provides an empirical verification of the theoretical constructs of agent types proposed through simulation (e.g., Equiluz et al. 2005, Lopez-Perez et al. 2008). The results support our suggestion that community resilience at local scales is significantly influenced by agent types and the way they perceive changes in local water resources. Specifically, this supports the hypothesis that change in water resources is perceived differently based on the type of agent and their collective knowledge base. Communities in which initiators of change (α agents) represent a greater proportion of the population appear to be more resilient than communities in which they are a lesser proportion and in which there is a greater proportion of opportunists (γ agents). In both cases the relationship on response to change is a function of the relative influence of α and γ agent types on β agents, as supporters of any response to change.

A mathematical explanation for the influence of agent types on community response to change is provided in Altaweel et al (in press). This proposes network theory and Hebian learning (Hebb 1949) for elucidating how agents influence, and are influenced by, interactions. Hopfield (1982) describes how such interactions work mathematically using a neural network approach that Altaweel et al (in press) build on to explain how individuals use both local (agent level) and global (i.e. the social network) interactions in decision making leading to behavior. This follows in many ways the agent approaches as advanced by Holland (1996).

Other explanations for this alpha, beta, gamma agent ratio effect could result from historical /environmental precedent that influences community dynamics. For example, case-based decision theory (Gilboa and Schmeidler 1995) proposes that human decisions tend more to be influenced by individual experience that shape future behavior. So, if a pattern of certain behavior is evident in a community, this can replicate itself over a number of generations. In the case of Seward Peninsula we might consider historical reasons that influence the behaviors observed from community to community.

The data reported in this paper represent a single static profile of agent types in five communities and does not provide any evidence for the dynamic nature of agent composition in these social systems. We speculate that agent types are not static and that agents can switch in the roles they exhibit with respect to response to changing water resources in the same way that Masolo et al (2004) suggest that agents can change roles. This is an avenue that requires further examination and data for support, and a direction worthy of future research. Also the evidence provided is based on small, remote community dynamics and the question can be asked of whether the relationship between agent ratios and adaptation holds for larger, more complex communities? Future research could address the role of social scale in this relationship.

CONCLUSION

We propose that the ability of a community to successfully respond to change depends in large part on the composition of agent types in the community. In virtual environments agent types have emerged as important but there are few empirical demonstrations of this phenomenon. Here we provide evidence to support this hypothesis and clearly show that perceptions of change with respect to water resources vary by agent types. This single finding contributes to our understanding of critical factors that enhance to ability of communities to respond to environmental change.

An enormous amount of effort has been directed toward identifying factors which promote resilience at the community level (e.g., Adger 2000). However, many of us have experienced the best laid plans fail to come to fruition simply because of social group dynamics. We take this common anecdotal observation several steps further to state that the social roles that individuals have, specifically, as initiators, facilitators, or opportunists may be a powerful determinant of whether a community can successfully respond to challenges. The ability to discern more clearly these dynamics will likely yield unprecedented insight into how to better cultivate resilience.

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