Modelling Culture in Multi-agent Organizations

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Abstract. We introduce a novel way to model and visualize culture in multi-agent organizations exploring the multi-dimensionality of culture and cultural modelling from a complex systems and multi-agent systems standpoint. The need for performing such modelling and simulation is evident since in-vivo organizational experiments are costly, not easily generalizable, and may not be feasable in critical situations. The proposed model enables one to point to strategies for organizational transformation/evolution by i) developing a unique approach to culture modelling from a holistic and systems-theoretic perspective according to seven dimensions, and ii) simulating cultural interactions as a multi-agent system that achieves an equilibrium of beliefs. Incipient results with a simple model reveal the dynamics of emergent culture of an agent organization having distinct roles and influences that develop as new individuals are added to the system.

1 Introduction: Modelling Organizational Cultures

Cultures develop through complex interactions between parts of an organization, its actors, environment, technologies, etc, [2], (ch. 6). These interactions represent a key determinant of relationships and organization formation that diversifies organizations from each other in ways that make them culturally compatible, complementary, or conflicting. This can be seen when different cultures are present in a single institution, or when personal cultures are in conflict with those of the organization to which individuals belong. In such cases competing cultures influence decisions and actions of individuals and cause cognitive dissonance and stress over which behaviour is appropriate, [13], and hence which belief (and culture) is stronger.

As a concept, culture is difficult to classify and model due to inherent imprecision in defining and isolating its components, which can have many possible realizations, i.e., in individual and group beliefs, and even in long-held traditions. Culture is challenging to understand but plays a key role as a determinant of relationships among individuals in organizations and as a macro-level driver of individual actions (see [8], (ch. 8), for more on culture as it relates to organizations). Cultural modelling allows for studying the effect and influence of culture and predicting how the type of culture at hand will affect the ability of the organization to function to achieve its objectives. This modelling is particularly

relevant in policy-making, among other domains, as it gives stakeholders a way to visualize and discuss cultural effects in different organizational scenarios.

Contributions of this work are two-fold: i) it adds to the literature of culture as a complex system by presenting a new seven-dimensional model to describe and discuss culture, and ii) it models cultural interactions as a multi-agent system that achieves equilibrium in beliefs. Section 2 highlights some related work in the area of culture modelling. Section 3 presents a working definition of culture. Section 4 describes the notions behind a complex system and makes the case for culture as such a system. Section 5 discusses a new model for culture in seven dimensions. Section 6 describes the approach to measure culture with belief-based agents. Section 7 describes three experiments to show the emergence and evolution of culture. Section 8 concludes the paper.

2 Related Work

Literature pertaining to culture modelling is vast and interdisciplinary. However, in this work four key sub-areas are considered: i) agent-based interaction models, ii) norm-governed models, iii) mathematical models, and iv) multi-dimensional models that describe culture in organizations.

In terms of agent-based interaction models, the MASQ, [16], and MOISE+ (with Brahms), [14], approaches are similar to the one proposed in this work. MASQ addresses the culture problem with a framework based on four quadrants and two overlapping spectrums: the individual(I)-collective(C) and the internal(I)-external(E). The I-I quadrant refers to the individual, the I-C to a group, the E-I to the physical reality of an individual, and the E-C to the physical reality of a group. The authors define culture as strictly internal knowledge, patterns, and rules in the I-C quadrant. Their perspective is similar as it advocates culture as shared beliefs, but does not target the emergence and influence of culture. MOISE+/Brahms is another approach using agents to model organizations based on the structure, work processes (roles), and normative aspects. The aim is toward organization-aware simulation, and although culture is mentioned briefly as tradition, an emergent property of norms, it is not addressed specifically.

In terms of norm-governed models, PreSAGE, [5], presents a rule-based mechanism to develop agent systems based on peer-pressure through reputation, reinforcement learning, and voting strategies. This approach has a similar aim of understanding cultural influence, but does not discuss culture or use belief frameworks. Additionally, in [1], ad-hoc networks are used for resource sharing based on event calculus, rules, and graphs. It is similar to the current work in that it investigates the notions of permission and obligation, as well as institutional power among agents; however it does not target the modelling of emergent culture.

In terms of mathematical techniques, wavelet transforms have been used to model ethnic violence due to poorly structured boundaries and population densities (being well-mixed or well-separated), [7]. This approach highlights the

impact of physical factors such as boundaries on the emergence of social phenomena, but does not present a detailed model of culture.

Finally, in terms of multi-dimensional modelling of culture there are a number of approaches (see [2] for a handbook of culture models). These target various views on organizational dynamics using a wide-range of dimensions, such as those proposed by Payne, (ch. 10), Ashkanasy et al., (ch. 8), Dickson et al., (ch. 28), and Hofsteder, (ch. 25). In contrast, we target a way to understand "mechanisms in societies which permit ... stability in culture patterns across many generations," [8], and the development of a framework which can underline these mechanisms.

3 A Working Definition of Culture

In our quest for a working definition we considered two classic views, namely culture as a "set of shared attitudes, values, goals, and practices that characterizes [and emerges from] an institution, organization, or group," [9], and culture as a system, "an entity standing in a state of equilibrium within a specific environment," [18]. This combined perspective underscores a holistic view of culture as both a bottom-up/emergent property that achieves a steady state (stable behavioural pattern) and as a top-down influencer of behaviour. The bottom-up view results from individual behavioural interactions, shared beliefs, and learning-by-observation from actors in an organization. The top-down view of culture highlights its feedback effect on individuals within the system whereby established collective beliefs in the past affect personal behavioural interactions in the present.

Along this line we settled for defining culture as *the holistic interaction among n agents across seven distinct dimensions that cause stabilization of beliefs within these agents over time.* This definition is useful as it targets interaction at the level of individuals, captures the notion of shared beliefs over time, and highlights the need for a multi-dimensional perspective of culture (respectively in this work the physical, individual, functional, social, structural, normative, and information dimensions are considered). The focus on shared beliefs as a determinant of action is a central concept since beliefs provide an understanding of motivations for behaviour and can be traced to internal and/or external sources (e.g., as messages passed between individuals). In this way the influence at both the individual and collective levels can be understood through beliefs. This approach can be extended from a mono-cultural context to a multi-cultural one and shapes the fuzzy sociological notion of "culture" into a more concrete problem. Using multi-agent systems modelling and simulation it is possible to describe an individual agent in terms of its beliefs and actions, as well as the different interaction configurations that can take place among agents, enabling analysis of the system at both individual and collective scales.

4 Culture as a Complex System

Culture can be understood from the perspective of complex systems, since it exhibits a unique micro-level interaction of the individuals which results in emerging macro-level patterns situated in a dynamic environment. As a result work on culture requires a holistic method that encompasses system behaviours and structures at both levels of granularity. It is also important to highlight the openness factor of organizations, since individuals may be continually added or removed from the environment domain. This macro and microscopic focus, from an open-systems perspective, presents culture as "emerging" from interactions of individuals (bottom-up emergence) yet having reinforcing feedback influence (top-down adaptation), [15], on these same individuals. Perturbations occur when new elements from outside the system are encountered (e.g., new agents are added to the system). Over time, this can result in the emergence (and evolution) of the existing culture as newer, more dominating beliefs are accepted and a new steady-state "equilibrium" of culture is achieved and maintained.

In terms of complex systems three core properties are considered in this work: emergence, evolution, and equilibrium. Emergence is the notion that "the whole is more than the sum of parts ... that constitutive characteristics are not explainable from the characteristics of isolated parts ... [but] appear as 'new' or 'emergent'," [18], (ch. 3). Evolution is the accumulation and advancement of macro-level changes in a system over a period of time, across any significant property of the system, in any direction. Equilibrium is the balance, or "centeredness" within a system, [18]: a net effect that stems from all micro-level interactions within the system. It may be considered as "the system in an unchanging state," [3], which, at the macro-level, is the result of shared beliefs that are no longer challenged by individuals at the micro level.

These properties of emergence, evolution, and equilibrium as they relate to culture are important in the modelling process. They describe complex systems phenomena, i.e., organizing forces that promote growth, and disorganizing (chaotic) forces that promote decay. This delicate balance, from the open-systems perspective, is fundamental to understanding culture as a system—an organic, stabilized construct that both emerges as well as evolves. Unravelling this complex system of culture will require a better understanding of its component structures across levels, as complexity is understood via "the amount of information necessary to describe a system," [3].

5 Seven Dimensions for Cultural Modelling

The key components of culture are diverse and represent both physical and sociological factors that determine the kinds of culture that emerge in a system. Knowing both the components and their properties will provide useful parameters for changing and exploring culture from the bottom-up. This work advocates an approach to model culture in seven dimensions, each based on a primary

question: "Does component, or property, X affect the emergence or evolution of culture?" This builds on our previous five-dimensional modelling framework for joint emergency-response operations, [4], which considers the physical, human (individual), functional, structural, and normative dimensions. The seven-dimension approach further incorporates the social and information dimensions. These span different scales (macro and micro) and allow us to consider culture holistically.

The *Physical* dimension relates to components in the actual world, ranging from tools and technology used to common assets such as buildings, cars, and clothing. The *Individual* dimension represents actors in the culture. The *Functional* dimension associates a particular role to the individuals within the system and rests on the notion that the culture preserves itself through what actions are taken by individuals in accordance with their role. The *Structural* dimension characterizes the organizational layout and involves understanding how communication flows when fulfilling objectives. The *Normative* dimension characterizes policies and rules that govern the behaviour of individuals within the culture. This highlights not only what needs to be done by whom, but also when it needs to be done. This dimension is highly important, as it dictates how the system ultimately behaves and adapts.

The *Social* dimension is used to classify the type of interaction that takes place between actors, as the nature and speed of social communication are often essential to the whole system (e.g., internet-based cultures develop and evolve quickly). The social also refers to how individuals interrelate, including factors such as trust and reputation ("willingness to take risk", [10]), and information sharing (willingness to share sensitive information). Finally, the *Information* dimension captures the elements that the system consumes and produces, as well as who the producers and consumers of this information are at a given time. In addition, properties of information, such as classification and sensitivity levels, impact the culture of organizations that process this information.

The seven dimensions are further discussed in [11] and are useful in defining cultural parameters (or components), depending on the model domain. These parameters are mapped to a particular dimension and eventually used as a factor in an individual's internal belief system. For instance a "casual dress code" culture depends on physical parameters (such as location), individual parameters (such as degree of comfort with casual dress), functional parameters (such as having a back-office role with low visibility vs. high interaction with the public), structural parameters (such as degree of communication with superiors), social parameters (such as whether communication is always formal or implicit based on observation of neighbours), information parameters (such as whether the dress code was communicated), and normative parameters (such as the policy of dressing casually for a particular day-of-the-week). These elements together would describe a single culture system based on dress code.

6 Exploring Emergence and Evolution of Culture with Multi-agent Simulation

In order to test these notions of culture, we model a basic organization having roles, norms, and structure using multi-agent systems simulation. We use the notion of a *belief set equilibrium* to measure culture, which represents the balance and change in beliefs over all individuals in the system at a given time. When multiple agents interact similar shared beliefs are easily accepted without argumentation, while dissimilar beliefs may cause argumentation before a consensus is reached by the community. If accepted by the majority, these beliefs become part of the culture (i.e., social memory). A divisive belief may be strengthened if it is advocated by an influential agent, such as a new manager who has authority over particular agent(s). As more agents join the organization, the culture that has stabilized becomes more resilient to change. However, if a major destabilizing force occurs (e.g., a key agent in an organization is replaced), then a cultural shift may occur, eventually resulting in a new belief equilibrium.

A theoretical motivation for the approach is found in, [2]. Social actors engage in social processes called events, (ch. 3), which result in the notion of meaningfulness created by powerful organizational actors, such as managers, who are able to construct and maintain organizational rules. Anyone participating in an organization does so by interpreting events and influencing the meanings that others give to these events, (ch. 6). Rules develop and change through the actions of numerous actors as they establish, enact, enforce, misunderstand, resist, and/or break the rules, and it is precisely the configuration of these rules and actors involved that constitute a specific culture, (ch. 6).

In order to show emerging culture, we demonstrate how the belief set equilibrium of an organization is affected under three conditions: i) the effect of adding the most influential agents in the organization at the beginning of the experiment, ii) the effect of adding the most influential agents in the organization in the middle, and iii) the effect of adding the most influential agents at the end. These agents are described in Section 7, with an influencing factor dependent on role occupied, personality, and social connections within the organization.

6.1 Cultural Belief Set

In order to discuss a collective view of culture we introduce the concept of the cultural belief set (CBS). A CBS contains beliefs that exist in the organization's cultural landscape. These may be about particular attitudes, values, goals, or practices. We consider that each belief in the CBS can assume one of three values, based on deontic logic: prohibited, permitted, or obligated. As an example, a belief that "punctuality = prohibited" means that it is culturally unacceptable to be punctual; "punctuality = permitted" means that it is culturally neutral whether or not someone is punctual; and "punctuality = obliged" means that it is culturally required to be punctual.

Since the belief value in the CBS has been restricted to three possibilities, the current culture's value of a particular cultural belief, x, in the CBS can be

ascertained by determining which of the three possible values has the greatest consensus among the various individuals in the organization.

6.2 Influence Calculation

The influence of one agent over another agent is used as the mechanism for changing culture. It is based on the notion described previously that key individuals in the organization have a greater influence on the culture. Influence can be computed using factors from each of the seven dimensions. In this paper, the factors in Table 1 have been incorporated into the influence calculation and are part of the influence factor set (IFS) in Table 2. The IFS is defined as the set of all beliefs that an agent considers when computing influence of another agent versus itself.

The influence calculation, ι_1, of $agent_b$ on $agent_a$ is seen in Equation 1 below. This computes the difference between two agents based on p attributes and takes into account how strongly an agent is impacted by particular attributes of the IFS.

$$\iota_1 = \sum_{j=1}^{p} (IFS_a(j) - IFS_b(j)) * \alpha_a(j), \tag{1}$$

where p is the number of items in the influence factor set (IFS) involving $agent_a$'s beliefs about $agent_b$ (i.e., items 1 - 7 in Table 2); j is an index to a row in the IFS table and α is the corresponding impact factor; IFS_a and IFS_b are the influence factor sets for $agent_a$ and $agent_b$, respectively.

Equation 2 represents a similar calculation, but for internal influences (e.g., preferences) of $agent_a$ that do not involve $agent_b$ directly.

$$\iota_2 = \sum_{j=p+1}^{n} IFS_a(j) * \alpha_a(j), \tag{2}$$

where $p + 1$ is the first item of the IFS that does not involve $agent_b$; n is the total number of items in the influence factor set (i.e., items 8 - 13 in Table 2); j is an index to a row in the IFS table and α is the corresponding impact factor. The total influence calculation for $agent_a$ is $\iota_a = \iota_1 + \iota_2$.

6.3 Updating the Cultural Belief Set

In the simulation, agents share cultural beliefs with other agents whenever a cultural event takes place. These events occur whenever an agent tests a cultural belief in its CBS'. (CBS' is used to distinguish the agent's personal belief set from the organizational belief set CBS which represents the current culture.) These events take the form of a fact in the world, e.g., $agent_a culturalbelief = value$. The current agent, $agent_a$, is enacting a specific belief in its CBS'. This agent will receive direct feedback—praise or chastisement—from the other agents in the organization. This feedback is in the form of $agent_b culturalbelief =$

Table 1. Factors incorporated into the influence calculation and influence factor set (IFS)

Cultural Influence Factors		
Structural	1	How does agent A relate structurally (within the context of an organization) to agent B? {supervisor, subordinate, colleague}
Physical	2	How close is agent A's workstation from agent B's workstation? {proximity_Threshold} (agent A has a greater chance of being influenced by agents within its proximity threshold)
Functional	3	How similar is agent A's role to agent B's role? [0-1]
Individual	4	Do agent A and B share the same gender? {true, false} (agent A has a greater chance of being influenced by an agent with the same gender)
	5	Are agent A's and B's personalities congruent? [0-1] (agent A has a greater chance of being influenced by an agent with a congruent personality)
	6	How does agent A's experience in the organization compare with agent B's experience? (agent A has a greater chance of being influenced by an agent with more experience)
	7	How does agent A's leadership ability compare with agent B's leadership ability? (agent A has a greater chance of being influenced by an agent with more leadership ability)
Normative	8	Is the particular belief from the CBS formally or informally specified? (an agent has a greater chance of quickly shifting its cultural belief if it relates to a norm that is formally specified)
Social	9	Does agent A seek peer validation from agent B? [0-1] (this may be due to several factors)
	10	Does agent A trust agent B? [0-1]
	11	Through what medium does agent B principally communicate to agent A? {face-to-face > Web 2.0 > phone > email}
Information	12	Does agent A experience the cultural feedback first-hand or second-hand from agent B? (this speaks to the strength of the confidence interval)
	13	If directly, does agent A receive feedback via verbal or non-verbal cues? (this speaks to the strength of the confidence interval; besides verbal cues may be misinterpreted)

Table 2. Influence and impact factors used in the CBS (α values assigned in simulation).

Item No.	**Influence Factors**	**Impact Ratios (α)**
External Influences:		
1	Structural Relation	Structural Impact Ratio
2	Workstation Proximity	Distance Impact Ratio
3	Role Similarity	Role Impact Ratio
4	Gender	Gender Impact Ratio
5	Personality Similarity	Personality Impact Ratio
6	Experience Similarity	Experience Impact Ratio
7	Leadership Similarity	Leadership Impact Ratio
Internal Influences:		
8	Formally Specified	Formality Impact Ratio
9	Seek Validation	Validation Impact Ratio
10	Trust	Trust Impact Ratio
11	Communication Medium	Communication Impact Ratio
12	First-hand Feedback	First-Hand Impact Ratio
13	Verbal Feedback	Verbal Impact Ratio

value. If the value from $agent_b$ matches $agent_a$'s value, the behaviour or belief is being positively reinforced; otherwise, it is being negatively reinforced. An agent's cultural beliefs are reconsidered every time the agent experiences an event. The other agents also experience the event, but their feedback is received second-hand, or indirectly. Events that are experienced first-hand by the agent will have a greater impact on the value of a cultural belief than events that are experienced second-hand. This is accomplished via $IFS(12)$ in Table 2.

For each belief, x, in an agent's CBS', a confidence value is associated with each of the three possible values—i.e., prohibited, permitted, or obliged. In order for the value of x to change, the confidence related to one of the other possible values must become the new maximum. These confidence values are based on the beliefs expressed by other agents, following a cultural event, combined with the influence of other agents' based on previous calculations in Equations 1 and 2 (see Table 2 and 3). For instance, dressing casually may start as a prohibited belief for $agent_a$, but as more and more interactions take place with different belief values, eventually the permitted or obligated value may become the new maximum, meaning that $agent_a$'s belief value will change. Equation 3 shows the confidence calculation associated with the three possible values of belief x inside $agent_a$'s CBS'.

$$\Phi_{prohibited}(x) = \sum_{i=1}^{k} \frac{\beta(x, i, prohibited) * \iota_i}{k}, \tag{3}$$

$$\Phi_{permitted}(x) = \sum_{i=1}^{k} \frac{\beta(x, i, permitted) * \iota_i}{k}, \tag{4}$$

$$\Phi_{obligated}(x) = \sum_{i=1}^{k} \frac{\beta(x, i, obligated) * \iota_i}{k}, \tag{5}$$

where x is the belief under consideration in the CBS'; k is the number of agents in the system; ι_i is the influence of $agent_i$ on the current agent (in Equation 1 and 2); β is the function below which produces a 1 if $agent_i$'s value for belief x matches the value currently under consideration, i.e., μ, which is one of the three possible values of x: prohibited, permitted, obligated.

$$\beta(x, i, \mu) = \begin{cases} 1 \text{ if } CBS'_i(x) = \mu \\ 0 \text{ otherwise} \end{cases} \tag{6}$$

After each cultural event, the agents recompute confidence for all three possible values for each belief in their CBS'. As it relates to the CBS', if there is a tie between the confidence values for belief x and one of the tied values matches the agent's current belief value, then the agent's current belief value will be used. Otherwise, permitted will arbitrarily be used if it is part of the tie, and obliged if permitted is not in the tied set.

Ultimately, the belief value with the greatest confidence will be selected by the agent as cultural belief x. However, if an agent's confidence is below a certain threshold (unique to the agent), then the agent will feel free to "test" this cultural belief with counter-cultural behaviours, i.e., the agent may perform an action that is counter to the belief value in the CBS. Such "agents-of-change," [17], if combined with high influence, may eventually shift an institution's CBS into a new equilibrium.

Table 3. Initial values for each agent's CBS'.

Agent	**Overtime**	**Formal Attire**	**Punctuality**
$agent_1$	permitted	prohibited	obligated
$agent_2$	obligated	prohibited	obligated
$agent_3$	obligated	prohibited	permitted
$agent_4$	prohibited	obligated	permitted
$agent_5$	prohibited	obligated	obligated
$agent_6$	prohibited	obligated	permitted
$agent_7$	obligated	obligated	prohibited
$agent_8$	prohibited	obligated	permitted
$agent_9$	obligated	prohibited	obligated

7 Simulation Experiments

We present three experiments involving a model of a small, generic organization over a fixed time period, from initial inception of the organization (i.e., from three initial agents) to its achievement of a full population and a stable culture (i.e., all agents are added to the organization and no further culture testing is done by the agents). The objective is to show the emergence, evolution, and equilibrium of culture over time by studying the CBS. We use the Brahms multi-agent development environment, [6], to facilitate integration with previous work, [4].

The organization, an IT startup, Figure 1, consists of the following nine agents: an owner ($agent_1$), IT manager ($agent_2$), receptionist ($agent_3$), payroll manager ($agent_4$), and five generic workers generic worker agents reporting to the IT manager ($agents_{5-9}$). These agents are fully connected to each other in terms of communication, but with "subordinate-to" and "colleague-of" relationships based on role. This means that a worker agent that is influential can still communicate with the owner of the organization. This can represent informal networking, for example, of potentially influential agents who may not hold powerful formal positions within the organization. In this paper, the owner, IT manager, and payroll manager are given the highest influence values across all agents based on Equations 1 and 2. This organization can thus be seen as one that respects formal authority more than informal authority. In addition, the initial values for each agent's CBS' are shown in Table 3 (these belief values change and converge, as shown in the experiments below).

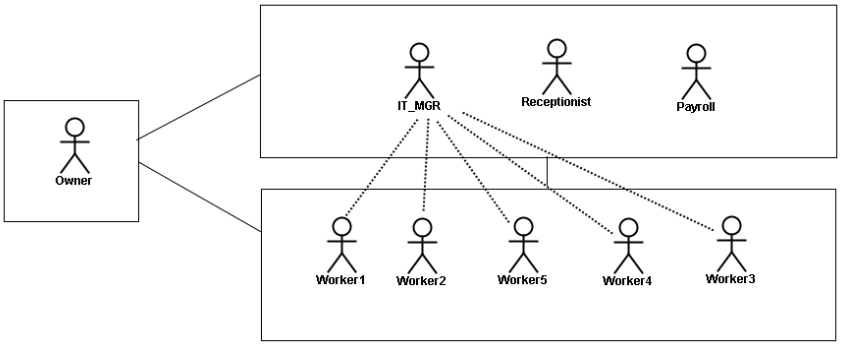

Fig. 1. A simple example of an organization consisting of nine agents. The most influential agents are the owner, IT manager, and payroll manager. Each agent is fully connected with all other agents. The dotted lines indicate supervisor-subordinate relationship between the IT Manager and worker agents.

The CBS in the following experiments is comprised of the following three beliefs that are heavily determined by the culture of the agent organization: i) working after hours (overtime), ii) appropriate business attire, and iii) punctuality. The agents' confidence in whether these are prohibited, permitted, or obligated at any time during the simulation shows the cultural pattern of the organization. As a result, three separate runs of the simulation are conducted, with different orderings for when the most influential agents (owner ($agent_1$), IT manager ($agent_2$), and payroll manager ($agent_4$)) are added to the organization. In the first experiment the simulation is run with the three most influential agents added to the system at the beginning of the simulation period. The second experiment adds these agents at the middle of the simulation period. The third simulation adds these agents near the end of the simulation period.

7.1 Visualizing the Cultural Belief Set

In presenting culture visually, radar plots are used to show i) the cultural belief values in the CBS that ultimately become the dominant culture (axis labels), ii) the number of agents present in the system when a cultural sampling is taken (edge numbers), and iii) the *shape* of the resulting cultural system (which will be a triangle, since the CBS used in the experiments contains three beliefs). When the triangle is an equilateral one, it means there is complete cultural consensus among the agents and the emerging culture has reached a state of equilibrium.

It bears highlighting that different orderings of agents result in different cultures emerging (the belief values in the axes are different across the experiment plots). Trends in the shapes, or orientation, of cultures over time show resilience, [12], and stability according to the variation of shape. Note for each experiment different cultures emerge (as shown on axes) depending on when interactions with the most influential agents take place.

7.2 Experiment 1: Adding Most Influential Agents at the Beginning

In this experiment, the organization begins with the three most influential agents: the owner and the two managers. These agents then have one simulated month to perform cultural interactions before a new agent is added (see Figure 2). During this time, two of the agents agree that employees must work after hours and be punctual, and all three agree that business attire is not that important . After the one month period, another agent is added to the organization. Once again, the agents take one simulated month to perform cultural interactions before the next agent is added.

As can be seen in Figure 2, once four agents are added to the organization, the cultural belief set stabilizes and other agents added to the system adopt the organization's culture. This is because the existing agents are sufficiently influential and eventually convince all existing agents within the organization to conform to their culture. So it can be said that the culture is resilient to change.

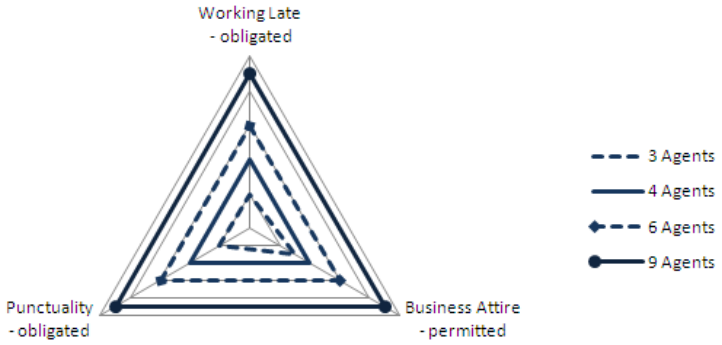

Fig. 2. Experiment 1: Adding most influential agents at the beginning. Cultural beliefs stabilize after the fourth agent is added.

7.3 Experiment 2: Adding Most Influential Agents in the Middle

In this experiment, the organization's three most influential agents are added to the organization after three other less-influential agents have performed cultural interactions for a month. The owner and two managers are added separately in successive months, before the remaining three agents are added in the same manner.

As can be seen in Figure 3, complete stabilization of the culture does not occur until six agents have been added to the organization. This suggests that the influence of the most powerful agents impacted the initial culture of the organization, which existed during the first month when the three initial agents were present. This likely occurred because none of the first three agents were sufficiently influential to cause other agents to change or adopt their beliefs.

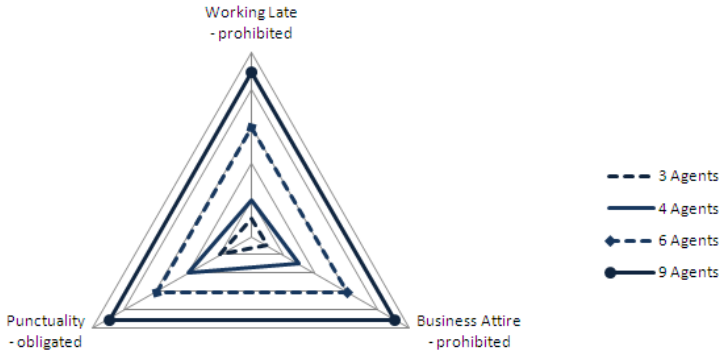

Fig. 3. Experiment 2: Adding most influential agents in the middle. Cultural beliefs stabilize after the sixth agent is added.

7.4 Experiment 3: Adding Most Influential Agents at the End

In this experiment, the organization's three most influential agents are added to the organization late in the simulation, in incremental time steps, following the initial three agents and the three other less influential agents.

As can be seen in Figure 4, complete stabilization of the culture occurs once six agents have been added to the organization. This suggests that even though the most influential agents are not added until the end, the first six agents are able to create enough "pull" together to compensate for the greater influence of these other three agents. Because these influential agents are added individually, neither one alone is able to overcome the cultural stability (or resilience) already existent within the organization.

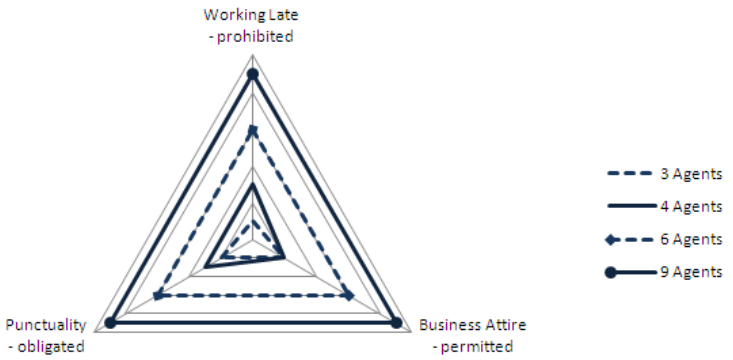

Fig. 4. Experiment 3: Adding most influential agents at the end. Cultural beliefs stabilize after the sixth agent is added.

8 Conclusion

This paper furthers our recent work, [11], on understanding cultural relationships, and their impact on the "collective programming of individuals," [8]. Culture is defined, and an early exploration of the emergence and evolution of culture in organizational contexts is shown. This is an early step towards future studies about the interplay and eventual integration of two or more different cultures in a shared system environment. The perspective is that culture is not only an intangible social construct, but also an emergent property, and the primary theme is that in order to understand, discuss, and measure culture it must be recognized as a complex, multi-dimensional, and multi-agent system.

The complex systems perspective is valuable as it enables considering culture holistically, from both the top-down (emergence) and bottom-up (influence and local rules). The multi-dimensional viewpoint adds to existing literature

on modelling of culture's component dimensions with the addition of a seven-dimensional approach. The multi-agent modelling and simulation of culture further advances the complex systems and seven-dimensional model perspective with the notion of achieving belief-based equilibrium of agents over time, according to relationships, communication, and influence idiosyncracies of each agent as individuals in an organizational system. This simulation has been developed for a small test organization of belief-based agents.

The three initial simulation experiments show how culture may emerge for different configurations of the same agent organization, depending on when highly-influential agents-of-change are added to the system. Future work will involve further testing of the simulation with organizations of different configurations, including different network structures, in order to better understand the resilience of culture, and what conditions are needed to enable an agent-of-change to have transforming influence on an organization. Also of interest is the integration of different culturally-oriented organizations (e.g., mergers).

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