Modelling Culture in Multi-agent Organizations

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Abstract. Culture is a key determinant of relationships and organization formation; however, its role, key properties, and mechanisms are not yet fully understood. This work explores culture and cultural modelling from a complex systems and multi-agency standpoint that takes into account the multi-dimensionality of culture. 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. This work contributes to agent modelling of organizations 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 of high functioning agents that achieve an equilibrium of beliefs. Experiments present an early model of an agent organization, having distinct roles and influences. As new individuals are added to the system emergent culture develops, with resilient properties.

1 Introduction: Modelling Organizational Cultures

"There must be mechanisms in societies which permit the maintenance of stability in culture patterns across many generations." — Hofsteder, 2001

Cultures develop through complex interactions between parts of an organization, its actors, environment, technologies, etc, [2], (ch. 6). These diversify organizations from each other in important and unique ways that can be seen as compatible, complementary, or even conflicting. This is seen when different cultures are present in a single institution, or when personal values or standards of behaviour are in conflict with those of the organization to which they belong. In such cases there are competing cultures influencing decisions and actions of individuals which cause cognitive dissonance and stress, [13], over which behaviour is appropriate, 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 the components of culture as it is a fuzzy concept with many possible realizations, i.e., in individual and group beliefs, in the physical reality of actions and environment, in the established conceptual ideas about it, and also 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 [9], (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 work will affect the ability of the organization to function and progress. This modelling is relevant in policy-making, among other domains, as it gives stakeholders a way to visualize and discuss cultural effects in different organizational scenarios.

This paper targets organizational culture modelling, and further presents our recent work, [12], on clarifying cultural relationships, and how "collective programming of individuals," [9], takes place. 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.

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, of high functioning agents, 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 high-functioning agents. Section 7 describes three experiments to show the emergence and evolution of culture. Section 8 concludes the paper.

2 Literature Overview

Literature pertaining to culture modelling is vast and interdisciplinary, however this work relates to four perspectives, i) those that use agent-based interaction models, ii) those that use norm-governed models, iii) those that use mathematical models, and iv) those that use a multi-dimensional approach to describe culture in organizations. In terms of agent-based interaction models, MASQ, [17], frames the culture problem with a framework based on quadrants determined from two overlapping dimensions, the individual-collective and the internal-external spectrums. The I-I quadrant refers to the individual, the I-C to a group, the E-I for the physical reality of an individual, and the E-C for the physical reality in a group. In terms of culture the authors define it as strictly internal knowledge, patterns, and rules in the I-C quadrant; this is a similar vision as it advocates culture as shared beliefs, but does not target the emergence and influence of culture. MOISE+/Brahms, [15], 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, [6], presents a rule-based mechanism to develop agent systems based on peer-pressure through reputation, reinforcement learning, and voting strategies. This approach is similar to the vision of understanding cultural influence, but does not discuss culture, or use belief frameworks. Also, in [1], ad-hoc networks are used for resource sharing based on event calculus, rules, and graphs. It is similar in studying permission, obligation, and institutional power of certain agents. Lastly, mathematical techniques of wavelet transform have been used, [8], to model ethnic violence due to poorly defined boundaries and being well-mixed or well-separated. This approach highlights the impact of physical factors and emergence, but does not present a detailed model of culture.

The multi-dimensional perspective of culture is not new, and in organizational sciences there are many models identified (see [2]). Payne, (ch. 10), presents a model of culture based on three dimensions. Ashkanasy et al., (ch. 8), promotes a model with ten dimensions. Dickson et al., (ch. 28), presents a nine dimensional model. Moreover, in [9], Hofstede, (ch. 25), promotes a five and six dimensional model for nations and governments, respectively. See [12], for more on these organizational science dimensions.

3 A Working Definition of Culture

Culture is a "set of shared attitudes, values, goals, and practices that [both] characterizes an institution, organization, or group", as well as emerges from and sets the behaviour of a group, [10]. Culture is also considered as a system, "an entity standing in a state of equilibrium within a specific environment," [19]. These perspectives underscore a holistic view of culture as both a bottom-up/emergent property that achieves a steady state (stable behavioural pattern) and is 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 as an influencer highlights its feedback effect on individuals within the system, as established collective beliefs in the past effect personal behavioural interactions of the present.

Along this line a working definition is 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 multidimensional perspective of culture (in this work the physical, individual, functional, social, structural, normative, and information dimensions are defined). 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, as messages passed between individuals. In this way the influence at both the individual and collective levels can be understood as beliefs. The definition can also be extended from a

mono-cultural context to a multi-cultural one and shapes the fuzzy sociological notion of "culture" into a more approachable problem. Using multi-agent systems modelling and simulation it is possible to describe the individual, and also the different interaction configurations that can take place, to analyze the system at both a small or large scale.

4 Culture as a Complex System

Culture can be understood from the perspective of complex systems, that is, having both a micro and macro scope with unique micro-level interaction, and emerging macro-level patterns; these are further situated in a dynamic environment. For organizations this micro-level is the level of individuals and the macro-level is the level of the whole organization as a unit. As a result work on culture requires a holistic method that encompasses system behaviours and structures at both levels of granularity. In addition to these two levels of detail it is 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, combined with the allowance of an open systems perspective, presents a culture as "emerging" from interactions of individuals (bottom-up emergence) yet having reinforcing feedback influence, [16], on these same individuals (adaptation to top-down forces). Additionally perturbations are considered as new elements are encountered from outside the system, resulting in further emergence and evolution over time whenever newer, more dominating, beliefs are accepted and a new steady state "equilibrium" of culture is achieved and maintained.

Emergence, evolution, and equilibrium are common complex systems concepts. 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'," [19], (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, [19]; 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 in the case of macro-level culture takes place when a shared belief is accepted and no longer challenged by individuals at the micro level, reducing variation in emergent culture.

Hence the 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 viewpoint, 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, [5], [4], which considers the physical, human (individual), functional, and normative dimensions. The seven dimension approach also incorporates a social and information dimension. These relate to the culture definition holistically, with the physical, individual, and functional dimensions referring primarily to elements at the micro-level; the structural, social, and information dimensions referring to elements equally relevant from both viewpoints; and the normative level relating more highly to the macro-level.

The *Physical* dimension relates to components in the actual world, ranging from tools and technology used to common assets such as buildings, cars, clothing, etc. The *Individual* dimension represents actors in the culture, whether they be simple ants, complex machines, smart sensors, or sophisticated cognitive actors like humans. 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 hierarchy and involves understanding the chain of command of supervisors, subordinates, and colleagues. The *Normative* dimension characterizes policies and rules that govern the behaviour of individuals within the culture. This highlights not only what ought to be done by whom, but also when it needs to be done. This dimension is highly important, as it dictates what the system looks like and how it 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", [11]), and information sharing (willingness to share sensitive information). The *Information* dimension represents elements that the system both consumes and produces as it performs its function. This level characterizes information and who the producers and consumers of information are at a given time. The properties of information available (like classification or sensitivity) influence the culture in organizations that depend on this information.

These dimensions are further discussed in, [12], and are useful in defining cultural parameters (or components), depending on the model domain. They are mapped to a particular dimension, and eventually used as a factor in an individual's internal belief system. For instance casual dress code culture depends on physical parameters such as location; individual parameters like the

degree of comfort with formal dress of a person; functional parameters like having a back-office role with low visibility/interaction with the public; structural parameters like degree of communication with superiors; social parameters like whether communication is always formal, or implicit based on observation of neighbours; information parameters like whether the dress code was communicated at all; and the normative parameters like the policy of being casual for a particular day-of-the-week. These elements together would describe a single culture system based on dress code. A more detailed example is seen in the following sections (see Table 1).

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 display culture, which represents the balance and change in beliefs over all individuals in the system at a given time. When multiple agents begin interacting, forces cause some beliefs to be accepted by the community and become part of the culture (i.e., social memory). Such a force may be a new manager, for example, who has authority over (a) 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 such as a manager in an organization is replaced), then a cultural shift may occur, eventually resulting in a new belief equilibrium. As such shared beliefs are maintained as a central concept.

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 and is 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. It is precisely the configuration of these rules and actors involved that constitute a specific culture.

In order to show emerging culture, we demonstrate how the belief set equilibrium of our basic organization is affected under three conditions: i) the effect of adding the most influential agents in the organization at the beginning of the time interval, 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 below, with an influencing factor dependent on role occupied, personality, and existing social connections within the organization.

6.1 Cultural Belief Set

A cultural belief set (CBS) contains beliefs that exist in the organization's cultural landscape. These may be about particular attitudes, values, goals, or practices. For this work, 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. If there is a tie and one of the tied values matches the previous value, then the previous value will be used. This can be likened to the effect of tradition. Otherwise, permitted will always be used if it is part of the tie, and obliged if permitted is not in the tied set.

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 its culture. This influence can be computed using factors from each of the seven dimensions. In this chapter, the factors in Table 1 have been incorporated into the influence calculation and are part of the influence factor set (IFS).

The influence calculation, ι_1, of agent b on agent a is seen in Equation 1 below.

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

where n is the number of items in the influence factor set (IFS) involving agent a's beliefs about agent b (items 1-7 in Table 1); j is an index to a row in the IFS table and the corresponding impact factor, α, for that row; IFS_a is the influence factor set for agent a; IFS_b is the influence factor set for agent b. Equation 2 represents a similar calculation, but for influences that do not involve agent b directly.

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

where n is the number of items in the influence factor set involving agent a's personal values (items 8 -13 in Table 1); j is an index to a row in the IFS table and the corresponding impact factor, α, for that row. Agent a's first-hand experiences are considered in items 8, 12, and 13 in Table 1, where the value

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)

in the IFS is adjusted depending on whether it is known to be true or false. Finally, the total influence calculation for agent a is $\iota_1 + \iota_2$.

Table 2. Influence and impact factors used in the CBS

	Influence Factors	**Impact Ratios**
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
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

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 $agent_b culturalbelief = value$. 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 everytime 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 1.

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 up 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'.

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

,

where the value of μ is one of the three possible values of x: prohibited, permitted, obligated; 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.

$$\beta(x, i, \mu) = \begin{cases} 1 \text{ if } CBS'_i(x) = \mu \\ 0 \text{ otherwise} \end{cases} \tag{4}$$

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 always 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 for 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 by performing counter-cultural behaviours, i.e., the agent may perform an action that is counter to the belief value in the CBS. These "agents-of-change" have high confidence and can shift an institution's cultural belief set, [18], leading to evolution, and eventually, as new confidence values for all agents climbs above their individual thresholds, the CBS will stabilize to a new equilibrium.

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 a single agent) to its achievement of a full population and a stable culture (i.e., all agents are added to the organization for the period and no more culture testing is done by agents). The objective is to show emergence through interaction in the CBS, emergent evolution, and emergent equilibrium. We use the Brahms multi-agent development environment, [7], that builds on the Beliefs-Desires-Intentions (BDI) paradigm, [14], for ease of implementing belief-based agents. Goals and intentions are not considered, although they may add to future work.

Table 3. Initial values for each agent's self-influence (α_i) and cultural beliefs are shown below.

Agent	α_i	**Overtime**	**Formal Attire**	**Punctuality**
$agent_1$	60	permitted	prohibited	obligated
$agent_2$	55	obligated	prohibited	obligated
$agent_3$	67	obligated	prohibited	permitted
$agent_4$	77	prohibited	obligated	permitted
$agent_5$	44	prohibited	obligated	obligated
$agent_6$	64	prohibited	obligated	permitted
$agent_7$	74	obligated	obligated	prohibited
$agent_8$	64	prohibited	obligated	permitted
$agent_9$	34	obligated	prohibited	obligated

The organization, an IT startup, consists of the following nine agents: an owner, receptionist, payroll manager, IT manager, and five generic workers. 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 be able to communicate with the owner of the organization, for instance, and can represent informal networking of potentially influential agents who may not hold powerful positions in an organization. In the model shown in Figure 1, Agent_1 is the Owner, Agent_2 is the IT manager, Agent_3 is the Receptionist, Agent_4 is the Payroll manager, and the remainder are generic worker agents under the IT manager. Agents 1, 2, and 4 are given the most influential property values from Table 2 and, thus, have the highest influence value across all agents based on Equations 1 and 2.

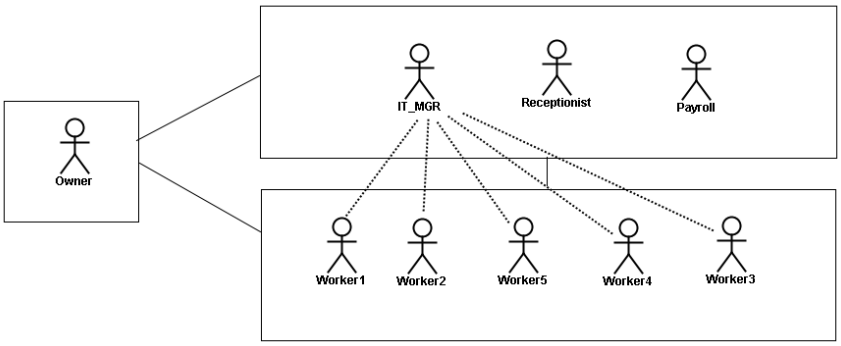

Fig. 1. A simple agent organization consisting of nine agents. The most influential agents are the Owner, IT manager, and Payroll manager. Each agent is fully connected with all other agents, as evidenced by the connection between rectangles. The dotted lines indicate supervisor-subordinate relationship between the IT Manager and worker agents.

Each agent begins with an initial set of beliefs pertaining to both the CBS and the influence factors and impact ratios which were described previously (see Table 3). 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 ordering 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. It is expected that the culture should evolve differently based on when these agents are added.

7.1 Visualizing the Cultural Belief Set

In presenting culture visually, radar plots are used to show a) the cultural belief values in the CBS that ultimately become the dominant culture (axis labels), b) the number of agents present in the system when a cultural sampling is taken (edge numbers), and c) 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; that is, 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 and stability according to the variation of shape. Changes in the size of the plot represent variation in culture maturity, but also indicate the number of agents in the organization. These plots capture the system in a unique way that can be extended to CBS's of different sizes. Points near the origin show number of agents holding a belief to be true at the end of a CBS calculation. Note for each different culture, three different cultures emerge (shown on axes) depending on what interactions 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. 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 (see Figure 2). 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.

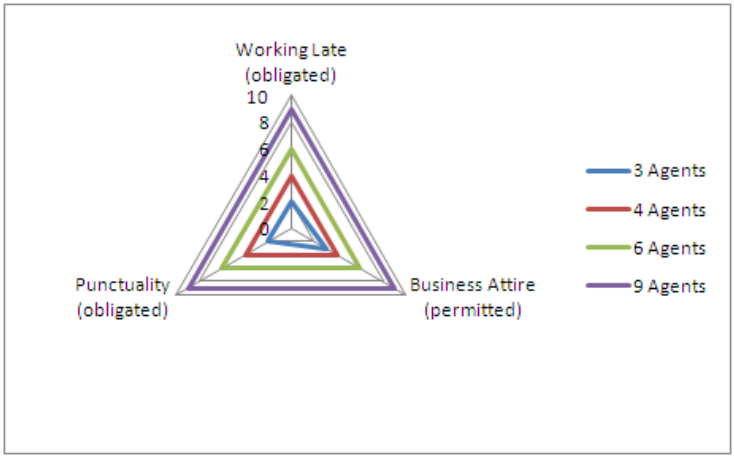

Fig. 2. Experiment 1: Adding Most Influential Agents at the Beginning. Cultural beliefs stabilize after the fourth agent is added.

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.

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 convince the other agents to adopt their cultural position.

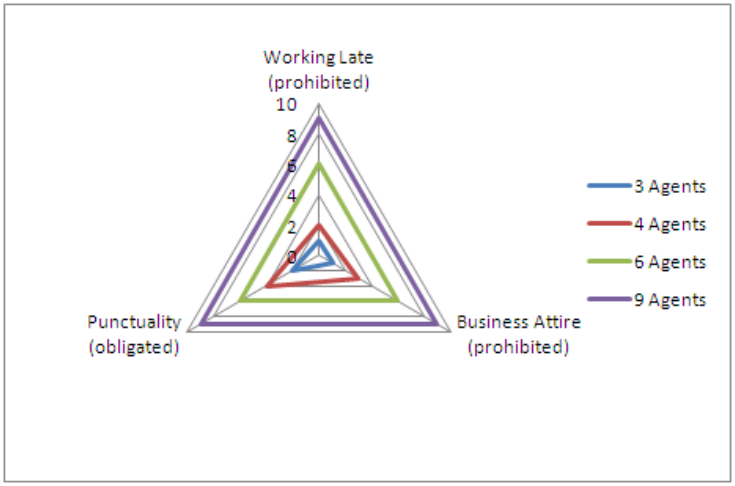

Fig. 3. Experiment 2: Adding Most Influential Agents in the Middle. Cultural beliefs stabilize after the sixth agent is added.

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.

8 Conclusion

In this paper, culture has been defined and presented as a complex, multi-dimensional, and multi-agent construct. The complex systems viewpoint is valuable as it allows for considering culture holistically, from both a top-down (emergence) and bottom-up (based on influence and local rules) perspective. 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 puts the complex systems and seven-dimensional model into 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

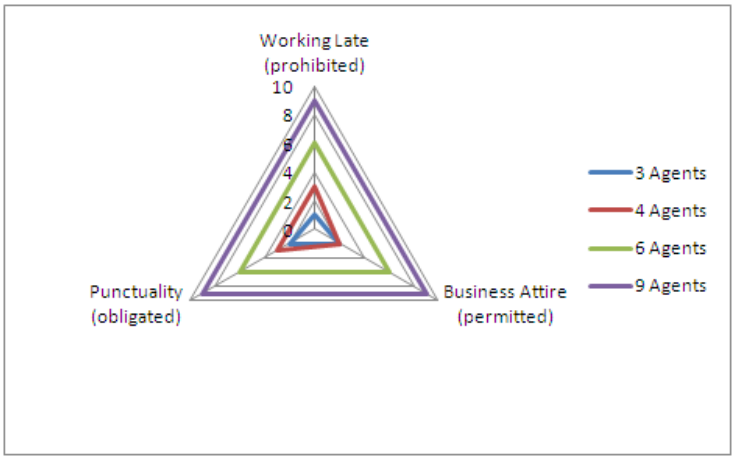

Fig. 4. Experiment 3: Adding Most Influential Agents at the End. Cultural beliefs stabilize after the sixth agent is added.

system. This simulation has been developed for a small test organization with high functioning BDI-based agents.

Three initial simulation experiments have been conducted, showing how culture emerges for different configurations of the same agent organization, depending on when agents of change having high influence levels are added to the system. The developed multi-agent simulation shows that culture can be modelled and visualized in a new way. Future work will involve further testing of the simulation with organizations of different configurations in order to better understand the resilience of culture, and what conditions are needed to allow for an agent of change to sweep through an organization. Furthermore, studying the integration of different culturally-oriented organizations is also of interest.

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