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Environmental determination or organizational design: An exploration of organizational decision making under environmental uncertainty

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Abstract

The relationship between the environment and organizational designs has been a main focus for the past several decades, often with different and even opposing views. Through a computer simulation model, this study attempts to provide a coherent framework by exploring how environmental uncertainty affects organizational decision making performance in an open systems setting where organizations can have different design conditions such as simple versus complex structures and operational versus experiential decision procedures. Results from this study suggest that, while distinctive effects indeed exist, there are important linkages between the environmental condition and the organizational design in affecting organizational performance.

Keywords: Environmental uncertainty; Organizational design; Computer simulation; Theoretical integration

1. Introduction

Organization theorists have frequently noticed the potential impact of environmental uncertainty on organizations and population ecologists have even asserted that the environment ultimately determines an organization's survival [29,30]. On the other hand, there are beliefs that organizations can design themselves to counter the impact of environmental uncertainty [25,35,63], though there have been inconsistencies regarding what specific structural or procedural designs should be adopted [4,59].

This study attempts to explore the relationships of these different perspectives. Specifically, we examine organizational decision making in an open systems setting where different environmental and organizational factors can play out. Such a focus is based on the belief that organizational management is fundamentally about decision making [67,68]. The importance of decision making is further amplified by the fact that orga-

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nizations often have to make choices under environments that are dynamic and uncertain with some of the problems bearing severe consequences that can threaten organizations' very existence [37,58,60].

This study relies on a computer simulation model using an agent-based artificial intelligence technique [5,76]. In the following sections, we first conduct a literature review on environmental and organizational factors that may affect organizational decision making from different perspectives. We then describe a computer simulation model based on factors discussed in the review. After the analyses of the result, we provide some discussions on the contribution, implication, and limitations of the study.

2. Research background

2.1. Environmental uncertainty

Organizations are open systems and have to interact with the environment [1,67,73]. To survive, organizations must make sound judgment of their surroundings and avoid costly errors. While there are multiple characteristics of the environment, one fundamental dimension that can affect how organizations respond has always been the degree of uncertainty [1,23]. An environment of low uncertainty exhibits stable conditions such as less variable customer demands, fewer radical technological innovations, and less rivalries among competitors, which puts less pressure on organizations' information processing capability [1]. On the other hand, an environment of high uncertainty features diverse and unstable condition such as variable customer demands, radical technological innovations, and fierce rivalries among competitors, and is thus more unpredictable [3,24]. High environmental uncertainty thus places more pressure on the organization to respond effectively [23].

Researchers in organization studies have indeed overwhelmingly acknowledged the importance of environmental uncertainty [6,23,64]. Scholars in the field of population ecology, in particular, have even argued that environmental forces can ultimately determine an organization's survival [29,30]. Given this perspective and the importance of uncertainty to organizational performance, we may derive the following proposition.

Proposition 1. *A higher degree of environmental uncertainty will lead to lower organizational decision making performance.*

2.2. Organizational design

While there is the grave concern of the impact of environmental uncertainty on organizational decision making, research in organization science has also been exploring how organizations can actively design themselves to fend off such external threats. Two key elements in organizing stand out, which are believed to affect the organization's ability to make decisions: organizational structure [25,35,51,54] and decision making procedure [16,45,52].

2.2.1. Organizational structure

Organizations use structures to coordinate members' activities and transform external resources into products or services [18,54]. Organizational structure is also about the vertical and horizontal differentiation within an organization for the coordination of divided work [28,62]. The importance of organizational structure cannot be overemphasized. This is evident in the classic research like the Aston group's study [62] and contingency theory [40]. Organizational structure can be simple or complex, reflected in part through different levels of differentiation. A complex organization will tend to have a structure that is high in vertical and horizontal differentiation as compared with a simple organization [28,62].

The organization literature is filled with prescriptions for how organizations should devise structures to deal with environmental uncertainty, ranging from a functional or centralized structure to a decentralized or product-line structure [20,28,54]. For this study, we focus on organizations that have centralized or hierarchical structures [47]. This is not only because hierarchical structures are the most common and natural ones in the world but also because there is a long research history on such structures in organization studies [51,69]. This paper focuses on two forms of organizational structures. One is a simple hierarchy characterized with less vertical and horizontal differentiation (e.g., a small firm with less product lines) and the other is a complex hierarchy with more vertical and horizontal differentiation [28]. By focusing on the variation in only vertical and horizontal differentiation, this paper tries to eliminate potential alternative explanations resulting from other sources of structural influence [75].

Organization science has long struggled to find the right structures for organizations. For the issue of organizational decision making under environmental uncertainty, two views have surfaced. The first view favors a more complex structure, as it believes with such a structure, small misjudgments at the low level may be countered by other sources and diminished along the way to the top, thus reducing the chance of mistakes. Indeed, organizational scientists have frequently argued for a buffer to shield the external threat [73] or building multilevel hierarchies to counter environmental uncertainty [63,69]. From this side of the argument, there could be the following proposition.

Proposition 2a. *The organization with a complex structure will tend to have higher decision making performance.*

However, there is also the other side of the argument. If a small misjudgment can be transmitted along the chain, how can one guarantee that it will not be amplified and that chain reactions will not result in an erroneous outcome [34,53]? Perhaps the more complex the structure is, the more layers the organization's structure has, and the more entangled the relationships will become; thus it may be more prone to unexpected errors. In that case, should organizations build simple structures instead? With this argument, there could also be the opposing proposition.

Proposition 2b. *The organization with a simple structure will tend to have higher decision making performance.*

2.2.2. Decision making procedure

Organizations use decision making procedures to assert control and reduce uncertainties [19]. Decision making is the heart of organizational operation. What procedure to use and how the procedures are used often can make a difference [2,17,57]. One type of decision procedure emphasizes following institutionalized and sometimes even rigid rules [16]. For this type of decision making procedure, individual members' past experience is not of concern. Each member is required to memorize a set of routine procedures and strictly follow the rule book, which is usually the programmed organizational knowledge and is sometimes regarded by the organization as standard operating procedures [41]. The important expectation from this procedure is for organizational members to be ''objective and unbiased'' in processing received information. This type of decision making procedure, which this study calls the operational procedure, can be found in many military organizations and companies involving high risks such as nuclear power plants. This can also be considered as rule following by organizations, with the institutionalized procedure representing their learning (or imitation) results [16,61].

Another type of decision making procedure takes a more traditional individual learning approach. It emphasizes individual members' past experience and discretionary learning capabilities [9,71]. For this type of decision making procedure, each member's received information goes through the member's subjective brain for him/her to make the judgment that best fits his/her past experience. This type of decision making procedure is based more on each individual's interpretations of the past than on the objectivity of the present [41]. This type of decision making procedure, which this study calls the experiential procedure, can be found in various manufacturing and service companies in the world. It has also been gaining increasing attention in recent years in studies of organizations [27].

While both decision procedures provide rules for making judgment given a set of information, there is no consensus regarding which should be adopted under environmental uncertainty. Of the two, the experiential procedure has frequently been favored because researchers and practitioners believe it can allow organizations to tackle external threats actively and have a better chance to adapt to the changing environment [39,77]. But as some scholars have noticed, there may also be a risk for individuals to over-learn the cues from the external environment [26,48]. One condition for a small external variation to become an erroneous outcome may exactly be the active transmission of such variation in the organization due to oversensitivity to feedback, whether big or small [55]. While the operational procedure may be more rigid to the change of the environment, it may actually gain the advantage of being insensitive to individual experience and allow the organizations to be less affected by individual members' local rationality, thus reducing the chance of organizational level mistakes. As a result, this institutionalized approach may enable organizations to minimize the chance of having undesired outcomes [61]. With these two sides of the arguments, we could have the following two propositions.

Proposition 3a. *The organization with the experiential procedure will tend to have higher decision making performance.*

Proposition 3b. *The organization with the operational procedure will tend to have higher decision making performance.*

Nevertheless, little is known with regard to whether each of the two procedures can actually be more effective than no procedure at all (random guessing) though the common perception is to favor having a decision procedure, regardless of what the procedure may be.

2.2.3. Time resource

Another aspect that is often overlooked in traditional organization theory is the availability of time resources for organizational decision making [27]. Because organizations function in a dynamic environment, the amount of time resources can affect whether environmental uncertainty may or may not result in poor decision making performance. In fact, time pressure can present a different type of uncertainty for the organization. When time resources are few and normal communication is stressful, organizations will experience greater constraint on their decision making processes, which will ultimately affect the organization's ability to combat the occurrence of mistakes [22]. This is especially true of today's world in which organizations have to respond to the environment in a timely manner in order to stay competitive [23]. However, the actual linkage between the level of time pressure and organizational performance remains to be explored. Given the importance of time resources, the following proposition would be expected.

Proposition 4. *A higher level of time pressure will lead to lower decision making performance for organizations.*

3. A computer model of organizations in dynamic environments

Organizations are dynamic and open systems [73]. To study the multi-level problem and address the important research question with regard to organizational decision making, we must understand the internal dynamic processes and sort out various complex relationships in organizations given different environmental conditions [36,65]. To achieve these objectives, we use computer simulation, in particular the agent-based modeling technique. Agent-based models allow the modeling of not only cognitively intelligent individual members (nodes) and their adaptive interpersonal relationships, but also organizational-level outcomes in a dynamic and controlled setting [5,76]. The decision to use this methodology is based not only on the necessity given the nature of this study but also on the fact that computer modeling, as an extension of human cognition [70] and a third symbol language besides natural language and mathematics [56], has its unique advantages over qualitative case studies, quantitative data analyses, and mathematical modeling [5,31,72].

3.1. Overview of the model

The simulation model has three levels: individual, organization, and environment. These levels are linked in a distributed decision making setting in which an organization faces multi-component task problems that are too complex for any one individual. Viewing organizations as interpretative systems [21], how members of an organization interpret the meaning of the task-related information taken from the external environment depends on his/her past experience. In the real world, what consequences a piece of information may carry may not be known before hand. Learning from experience makes it possible. Similarly in the computational model, we allow training to occur so that the simulated members in the artificial organization are given feedback regarding their past actions, enabling them to interpret the nature of the information they receive, some of which may be critical. Of course, this interpretation process may not always lead to accurate judgment of the external environment due to members' bounded rationality and structural constraints.

Members of the organization at any given time can take one action, including asking for information, reading information, making decisions, passing up decisions, and waiting. What action to take depends on one's position in the organizational structure (for example, a bottom-level member may not need to ask for information), the decision making procedure one uses (for example, if the organization adopts an operational procedure, each member will then follow this particular procedure), and the number of time units left (for example, if the top-level member has not received any recommendations from the lower levels and the time will expire in the next period, he/she will then make a random decision). This process goes on from the bottom-level analysts to the top-level manager, who can make an organization decision or request more information from his or her subordinates if time permits. After the problem is "over", the top management's final decision is recorded as the organizational decision and feedback is provided to the whole organization. Each individual member's recommendation can be kept in a file and memory updated if requested. A new problem then occurs.

Because the organization does not have prior knowledge of the true nature of all the problems nor their distributions in the task environment, and the organization makes the decision through coordination of members who have only partial information, the organization can make misjudgments even if all incoming information is correct. Some other studies have also explored the uncertainty caused by the sub-optimal conditions inside the organization such as member malfunctioning or information unavailability [11,12].

In the following sections, a brief description will be given for the main components of the computer simulation model used in this study. Due to the page limitation, not all details can be included here. Additional technical information can be obtained upon request or from some similar studies using agent-based modeling methods [44,45,50,76] (Fig. 1).

3.2. Modeling of individual agents

In the simulation model, the building blocks are "agents", which represent individual members of the organization. Each agent can carry out some basic functions such as reading information from other sources, processing information according to a specific procedure and memory, passing out information, and updating memory from feedback [12]. Our assumption is that an individual agent is capable of learning from past expe-

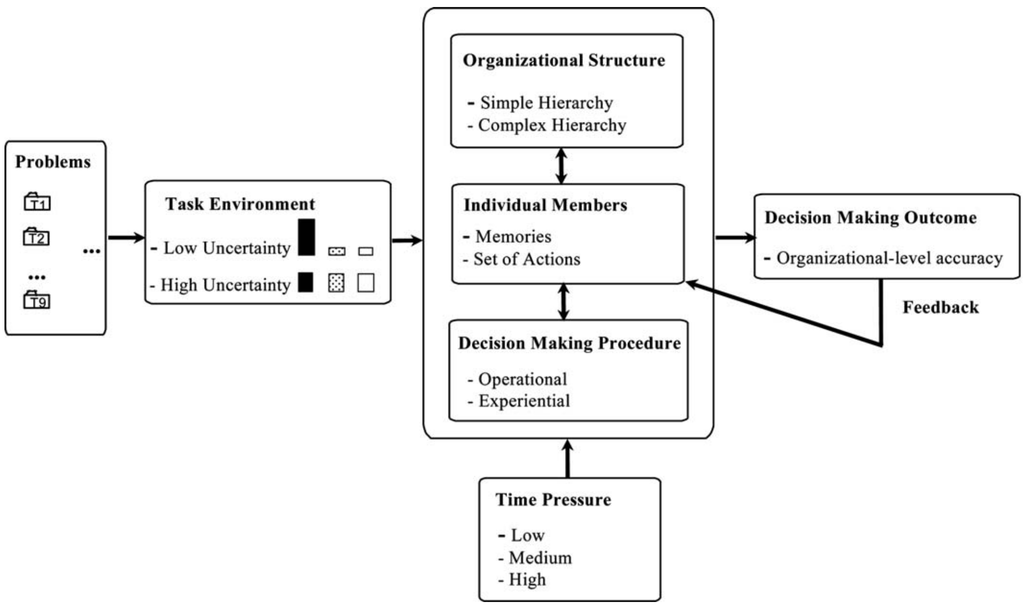

Fig. 1. An overview of the model design.

rience. Such trial-and-error learning, according to organizational behaviorists [39], is based on the idea that "behavior that is associated with success will be repeated and behavior that is associated with failure will not be repeated".

Although such individuals are highly abstract, we believe they embody the decision making essence of a "boundedly-rational" human being [68]. Each individual follows the satisfying approach using the most convenient and familiar solutions, which can be obtained through existing organizational procedures or heuristic short-cuts based on prior experience. We also assume that all individuals will eventually receive feedback about how the organization as a whole has performed (in the real world, such feedback can often be obtained through audit reports, shareholder reactions, and even the media), although such feedback may sometimes be misleading for specific individuals at the lower levels of the organization due to the distributed decision making setting and bounded rationality [11,39]. Our model, therefore, also considers cases where learning is not always beneficial, like in many real world situations.

3.3. Modeling of task problems

The simulation is based on a model originally developed for aircraft threat identification, where the organization faces a sequence of radar-detection problems as documented in other studies and reflected in real world cases [32,44]. Each problem is defined as a single aircraft moving through the airspace. Each aircraft has nine indicators: speed, direction, range, altitude, angle, corridor status, identification, size, and radar emission type. Each indicator can take on a certain range of values and may be interpreted by the analyst in charge of the respective radar equipment as fitting into one of the three threat categories: low (friendly), medium (neutral), or high (hostile). For example, for radar emission type, if the value is 0 (civilian), then it is interpreted as having a low or friendly nature; if the value is 2 (military), then it is interpreted as having a high or hostile nature. However, each individual indicator may not reflect the true state of the aircraft as a whole, which is defined in the task environment and is not truly known to the organization.

This task resembles real world settings that involve distributed decision making. A few examples include military radar operation, civilian air-traffic control, and manufacturing planning. For example, in a manufacturing planning setting, as will be referred to throughout this paper, the task can be considered as consisting of a series of production proposals that require the organization to decide whether to produce, hold, or reject the production of certain products based on information from nine indicators such as financial status of the company, human resources, technology, customer preference, etc. Because of bounded rationality, each member (or a sub-unit) of the organization naturally can only process a limited number of pieces of information while any one or two indicators may not provide a complete picture of the situation. Thus, an organization's decision requires coordination among various people who work with different indicators.

3.4. Modeling of environment

Most studies on environmental uncertainty stay at the conceptual level or rely on subjective perceptions by the respondents [6,7,64,74]. This study is different. It takes the advantage of computational modeling and builds different task environments where the true nature of each problem is predefined with an independent formula. With this mechanism, we can have a baseline against which an organization's decision outcomes can be compared. In this paper, we follow the work by Aldrich [1] and rely on the dispersion and concentration of task problems as indicators of environmental uncertainty, although we understood this is still just a limited aspect of the environment and there can be other forms of uncertainty [11,12]. Through the different distribution patterns of the task problems, we can have two type of environment with one of lower uncertainty and the other of higher uncertainty. While there are many possibilities for modeling environments of different uncertainties, we have simply chosen a function that has some degree of interdependence of indicators. The formula is as follows:

$$\text{Aggregated indicator} = T1 * T2 * T3 * 2 + T4 * T5 * 2 + T6 * T7 * T9 * 2 + T8 + T9 \quad (1)$$

In the formula, each Ti refers to one specific indicator that can take an integer value ranging from 1 to 3, with a number 3 representing a more positive indication towards the decision "3" (produce), and a number 1 representing a more positive indication towards the decision "1" (reject). By varying all possible values of nine indicators, the computer model can create a task environment that has a total of 19,683 (3^9) different combinations of problems. In other worlds, the simulation model can create an artificial population of possible problems, each having a true decision (produce, hold, or reject), though not initially known to the organization prior to the decision making process. When an organization make a decision for one of the problems from the environment, its performance can then be measured by comparing the organization's decision with the predefined true nature of the problem in the environment.

The distribution characteristic of the environment can be further predefined to make the environment either of low uncertainty or high uncertainty by setting the cut-off values for aggregated indicator for all problems. For the low uncertainty environment, the true decision "1" (reject) is defined when aggregated indicator is no more than 20; "2" (hold) is defined when aggregated indicator is between 21 and 22; and "3" (produce) is defined when aggregated indicator is greater than or equal to 23. Under this categorization, there are 1131 problems whose true decisions should be "1" (reject), 3321 problems whose true decisions should be "2" (hold), and 14,631 problems whose true decision should be "3" (produce). Given this manipulation, organizations under this environment will face most problems of the same nature.

For the high uncertainty task environment the cut-off values for aggregated indicator are predefined differently. When aggregated indicator is less than or equal to 33, the true decision should be "1" (reject); when aggregated indicator is between 34 and 49, the true decision should be "2" (hold); and when aggregated indicator is greater than or equal to 50, the true decision should be "3" (produce). Under this manipulation, the environment will be composed of 6488 problems whose true decisions should be "1" (reject), 6648 problems whose true decisions should be "2" (hold), and 6547 problems whose true decision should be "3" (produce). This environment can pose greater uncertainty to organizations because problems of different natures can occur with equally likely probability thus creating higher risk of judgment errors.

3.5. Modeling of organizational structure

Based on the work by other organization theorists [28,62], this paper models two forms of organizational structure, as depicted in Fig. 2.

3.5.1. Simple hierarchy

In this structure, there are nine analysts and one top-level manager, with no middle levels. Each analyst examines only one piece of information from the external task environment and makes a recommendation. Each piece of information accessed by an analyst is different from the others accessed by other analysts.

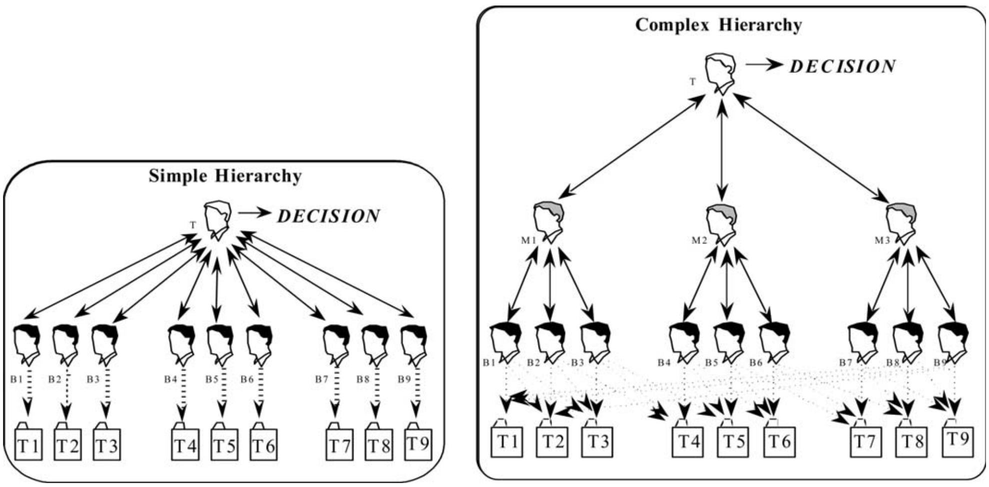

Fig. 2. An illustration of simple and complex structures.

All analysts report to the top-level manager. The manager examines these recommendations and makes the organizational decision. There is only one level of management and only one manager.

3.5.2. Complex hierarchy

In this structure, there are nine analysts, three middle-level managers, and one top-level manager. Each analyst examines three pieces of information from the external task environment and makes a recommendation to his or her immediate middle-level manager. Because each problem comprises nine individual characteristics, the information an analyst has access to is thus partially shared by other analysts. Each middle-level manager examines the recommendations from his or her subordinates and makes a recommendation to the top-level manager. The top-level manager examines the middle-level managers' recommendations and makes the organizational decision. There are two levels of management.

3.6. Modeling of decision making procedure

Based on the previous literature review, this paper models two stylized decision procedures, as are depicted in Fig. 3.

3.6.1. Operational procedure

When organizational members use this decision making procedure, they have stored standard operating instructions for their judgment. This procedure forces members to weigh each piece of information equally and make an unbiased judgment. For example, if a base-level analyst uses the operational procedure to process three characteristics of a problem represented as "1" (reject), "2" (hold), and "3" (produce), he/she will evaluate each piece of information with the same weight and then come up with a middle decision "2" (hold) as his/her judgment of the current problem, regardless of what other organization members may decide or what previous experience may be.

3.6.2. Experiential procedure

When organizational members use this decision making procedure, they will accumulate historical information of past problems through learning from feedback. Based on this past experience, personal judgment is made. For example, if a base-level analyst uses the experiential procedure to process three characteristics of a problem represented as "1" (reject), "2" (hold), and "3" (produce), he/she will use the three pieces of information as an index and search through his/her memory to find the correct decisions made for a similar pattern of information in the past. If most of the time in the past, the three pieces of information resulted in a true decision as a whole (determined by all nine pieces of information in Eq. (1)) to produce, he/she will then report a "3" (produce) as his/her judgment for the current problem. After the problem is over, the member can then learn from the feedback regarding the true nature of the problem and use this feedback to update his/her

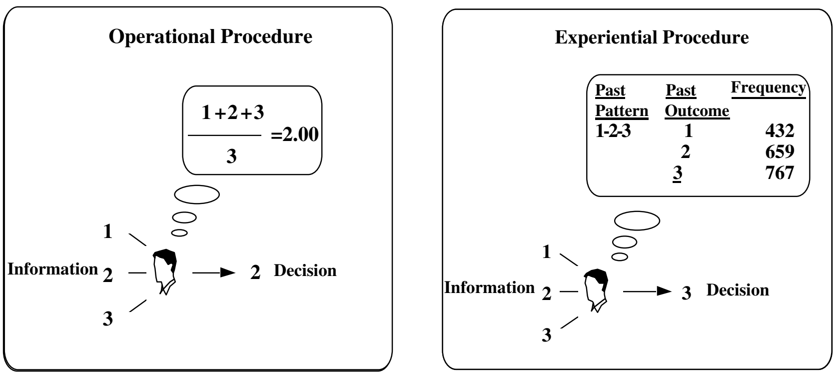

Fig. 3. An illustration of two decision making procedures.

memory. In the simulation model, this is simply done by adding 1 to the frequency of same outcomes given the similar set of patterns (Fig. 3).

3.7. Modeling of time pressure

This paper also considers three levels of time pressure: low, medium, and high. Time pressure is modeled according to how much time organizations need to make decisions and how much time is actually allocated. For each problem, the organization is given a time requirement reflected in the number of time units assigned. A low time pressure puts little or no time constraint on the organization. The number of time units allowed for organizations to make decisions ranges from 41 to 60. The organizational decision making process is supposed to be least affected by time.

A high time pressure requires an organization to respond quickly and so constrains the organization's decision making process. In this case, the number of time units allowed for organizations to make decisions ranges from 1 to 20. The organizational decision making process has much higher chance of being shortened, which may force organizations to take actions based on random guessing.

A medium time pressure constrains organization's decision making processes but allows at least one round of a complete decision process by the organization. In this case, the number of time units allowed for organizations to make decisions ranges from 21 to 40.

Each member of an organization can take one of the five actions at any time: asking for information (1 time unit), reading information (the number of time units equals the number of pieces of information), making a decision (the number of time units depends on both the number of pieces of information and the decision rule), passing up a decision (1 time unit), and waiting (1 time unit). While each action takes certain amount of time, there is also interdependence with the decision rule and the organizational structure, and so the total time that may need for one organization configuration may be different from another. For example, a more complex structure in general takes more time, and experiential decisions in general take more time. Furthermore, certain actions cannot be taken without pre-required actions and one member's action may depend on the action of another member. For example, in order to make a decision a manager must have first read the information, which depends on whether his or her subordinates have passed up their decisions. These can also potentially affect the timing of the decision process. Some of the relationships among different actions are listed in Table 1.

The estimate of time units for each action has been based on studies by Carley and Prietula [13] and Carley et al. [15] involving human subjects. In their decision making experiments, each subject's keyboard actions were recorded and then the time spent on each action calculated. Each subject processed 120 problems in about 40 min, which is about 20 s for each problem. For every problem, a subject read three pieces of information in about 6 s, made an experiential decision in about 12 s, and passed the decision to his or her superiors in about 1–2 s. For our study, we consider 2 s one time unit because if we let x be the number of seconds in each time unit, we have $3x + 6x + x = 20$, or $x = 2$. We use Carley and Prietula's [13] estimates because the nature of our task is very similar to theirs. We hope this will serve as an empirically based starting point for understanding the effect of time pressure.

Table 1
A summary of basic member actions in decision making processes

Action	Pre-required action	Time units needed	Note
A1: Ask for information		1	• Bottom-level members do not need to ask for information as they have no subordinates and have direct access to information
A2: Read information	A1	I	
A3: Make a decision	A2	2I	• For experiential rule
		I	• For operational rule (or take-the-middle-value rule)
A4: Pass up a decision	A3	1	
A5: Wait		1	• Once a member chooses to wait, he or she must wait through the whole time unit

Note: I is the number of pieces of information.

3.8. Measures of decision making performance

From this model, we can measure how organizations perform under different environmental uncertainties with different structures and decision procedures. We look at decision making performance in terms of how decisions match the true nature of the problems, which is represented as the percentage of correct decisions made given the total number of problems encountered under the examined conditions.

3.9. Simulation experiments

To examine organizational performance under various environmental conditions and with different designs, we vary task environments: low uncertainty or high uncertainty (2); organizational structures: simple hierarchy or complex hierarchy (2); and decision making procedures: experiential or operational (2). Thus, there are eight sub-experiments. During each sub-experiment all 19,683 problems are presented to the organization, with each problem assigned a time unit ranging from 1 to 60, which can later be categorized into three levels of time pressure: high, medium, or low (3). Feedback is provided to the organization after each problem. For the organization using the experiential procedure, each member's memory can be updated after each problem-solving process. For all problems, decision outcomes are recorded after comparing with the true natures of the problems in the task environment.

4. Results

The systematically generated results from the computer simulation model have provided some useful answers to the issue of organizational decision making under environmental uncertainty. Given that the research issue we are addressing is a multi-level one with nonlinear interactions, which often requires non-conventional analyses [33], we present the complete results in a cross-sectional and multi-dimensional fashion (Table 2). This allows us to look at the patterns of how organizational structure, decision making procedure, and time pressure may interact to impact decision making outcomes under both low and high uncertainty environments.

4.1. The effect of environmental uncertainty

A conventional method to test Proposition 1 would be to look at the overall effect of environmental uncertainty on organizational performance (Table 3). The result shows that the organizational level performance for

Table 2
Complete simulation experimental outcomes

Organizational structure	Decision procedure	Time pressure	Low uncertainty environment		High uncertainty environment	
			Decision making performance	# of cases, standard deviation	Decision making performance	# of cases, standard deviation
Simple	Experiential	High	.344	6561, .475	.378	6561, .485
		Medium	.614	6561, .487	.343	6561, .475
		Low	.911	6561, .285	.372	6561, .483
Complex	Experiential	High	.321	6561, .467	.323	6561, .468
		Medium	.633	6561, .482	.552	6561, .497
		Low	.917	6561, .276	.718	6561, .450
Simple	Operational	High	.367	6561, .482	.321	6561, .467
		Medium	.378	6561, .485	.685	6561, .464
		Low	.412	6561, .492	.716	6561, .451
Complex	Operational	High	.334	6561, .472	.323	6561, .468
		Medium	.487	6561, .500	.606	6561, .489
		Low	.490	6561, .500	.633	6561, .482

Table 3
The effect of environmental uncertainty on decision making performance

Low uncertainty environment Performance (*N*, std)	High uncertainty environment Performance (*N*, std)
.52 (78 732, .45)	.50 (78 732, .47)

Note: *N* is the number of problems encountered in this category; std is the standard deviation.

making accurate decisions under the high uncertainty environment (mean = .50; $n = 78{,}732$, std = .47) on average is significantly ($p < .01$) lower than that under the low uncertainty environment (mean = .52; $n = 78{,}732$; std = .45). This seems to support Proposition 1 that increased environmental uncertainty does degrade decision making performance. The result clearly shows the importance of the environment to the organization.

4.2. The effect of organizational structure

When we explore the role of organization design, however, we can see some different patterns. With regard to the effect of organizational structure (Table 4), the average organizational performance for a simple organization (mean = .49, $n = 78{,}732$, std = .46) is shown to be significantly lower ($p < .01$) than that for a complex organization (mean = .53, $n = 78{,}732$, std = .46) across both high and low uncertainty environments. However, further analyses that take into consideration of the decision making procedure (Table 2) reveal that a complex structure can help decision making performance but only under a low uncertainty environment with an operational procedure or under a high uncertainty environment with an experiential procedure. A simple structure, on the other hand, helps organizations under a high uncertainty environment with an operational procedure. This suggests that whether a specific structure is more beneficial to organization's decision making also depends on what type environment the organization is in and what procedures the organization uses. If the organization intends to operate in a low risk market, it may be most effective to have a complex structure coupled with an operational procedure. With these analyses, we can say that both Propositions 2a and 2b are only partially supported under specific conditions.

4.3. The effect of decision making procedure

With regard to the effect of decision making procedures (Table 5), the results show first that at the organizational level, an experiential procedure (mean = .68, $n = 78{,}732$, std = .49) tends to lead to higher ($p < .01$) organizational decision making performance than an operational procedure (mean = .48, $n = 78{,}732$, std = .48) when averaging across both low and high uncertainty environments. However, a further analysis shows that this case is only true when organizations are under a low uncertainty environment. An operational procedure can also have its advantage but only for organizations under a high uncertainty environment (mean = .55, $n = 39{,}366$, std = .47). The results further reveal that both experiential and operational decision procedures are significantly better ($p < .01$) than no procedure (random guessing with performance at .33, or one of three possible outcomes for each problem given the ternary choice task).

It is also worth noting, after considering more interactions with other factors (Table 2), that when an organization adopts an experiential procedure with a simple structure in a high uncertainty environment, the orga-

Table 4
The effect of organizational structure on decision making performance

Organizational structure	Low uncertainty environment Performance (*N*, std)	High uncertainty environment Performance (*N*, std)
Simple	.50 (39 366, .45)	.47 (39 366, .47)
Complex	.53 (39 366, .45)	.53 (39 366, .48)

Note: *N* is the number of problems encountered in this category; std is the standard deviation.

Table 5
The effect of decision making procedure on decision making performance

Decision making procedure	Low uncertainty environment Performance (N, std)	High uncertainty environment Performance (N, std)
Experiential	.62 (39 366, .41)	.45 (39 366, .48)
Operational	.41 (39 366, .49)	.55 (39 366, .47)

Note: N is the number of problems encountered in this category; std is the standard deviation.

Table 6
The effect of time pressure on decision making performance

Time pressure	Low uncertainty environment Performance (N, std)	High uncertainty environment Performance (N, std)
High	.34 (26 244, .47)	.34 (26 244, .47)
Medium	.53 (26 244, .49)	.55 (26 244, .48)
Low	.68 (26 244, .39)	.61 (26 244, .47)

Note: N is the number of problems encountered in this category; std is the standard deviation.

nization's performance gets close to that of guessing. The results suggest that organizations do benefit from having decision making procedures but how each procedure may be advantageous may depend on what environment the organization is in and what structure it has. Specifically, the results call for caution against the use of the experiential rule in decision making when the environment becomes unpredictable. With these results, both Proposition 3a and 3b again can only be considered partially supported under specific conditions.

4.4. The effect of time pressure

When averaging across other factors, there is a significant decrease of performance ($p < .01$) at the organizational level as the level of time pressure increases (Table 6). Further analyses from Table 2 show that there are further interacting relationships. For example, for organizations under a high uncertainty environment with a simple structure and with an experiential procedure, the effect of time pressure is not that obvious as their performance has stayed close to that of guessing. Proposition 4 is thus also partially supported.

The above results also show that there are nonlinear behaviors which are difficult to be captured by mathematical equations. The reversed relationships for organizations under low versus high uncertainty environments as time pressure changes (Table 6) suggest that under a low uncertainty environment, organizations may be more susceptible to the change of time pressure than under a high uncertainty environment. In other words, when organizations face a high uncertainty environment, a moderate level of time pressure may not degrade performance as much.

5. Discussion

Through theorizing aided by computer simulation, this study has taken an exploratory step to integrate different views in organization science by exploring how organizations can achieve better decision making performance under environmental uncertainty through purposeful designs. By modeling organizations as composed of intelligent members who function in their designed roles but are constrained by bounded rationality, this paper shows that while environmental uncertainty impacts organizational decision making, organizations can design structures and procedures to effectively fend off such impact under specific situations (Table 7). This study thus shows that there are linkages between the environmental condition and organizational design in affecting organizational decision making and that it is possible to integrate opposing views from the organizations literature. We believe findings from this study can shed light on the field of organizational decision making and provide useful directions for both theoretical development and managerial practices in organizations.

Table 7
A summary of main results

Propositions	Testing results
Proposition 1: Higher environmental uncertainty leads to lower decision making performance	Supported
Proposition 2a: Complex structure leads to higher decision making performance	Supported under a low uncertainty environment with an operational procedure and under a high uncertainty environment with an experiential procedure
Proposition 2b: Simple structure leads to higher decision making performance	Supported under a high uncertainty environment with an operational procedure
Proposition 3a: Experiential procedure leads to higher decision making performance	Supported under a low uncertainty environment or under a high uncertainty environment with a complex structure
Proposition 3b: Operational procedure leads to higher decision making performance	Supported under a high uncertainty environment with a simple structure
Proposition 4: Higher time pressure leads to lower decision making performance	Supported except under a high uncertainty environment with a simple structure and an experiential procedure

Our study has demonstrated the impact of environment on decision making in organizations. More importantly, it has shown how organizations may take a proactive role in designing effective structures and procedures to avert the threat of environmental uncertainty. Our study, however, cautions managers to first understand the nature of the environment before designing structures and decision procedures. No specific structure or procedure will guarantee the success of decision making in all conditions. It is more important for organizations to choose the right design in the right situation.

This study has again noted the importance of decision making procedures. An experiential procedure may not be effective in increasing organizational performance simply with its learning emphasis, because over-learning and over-reliance on past experience may not prepare organizations for less likely events. An operational procedure, on the other hand, is less sensitive to changes in the nature of the environment, as it relies less on individual experiences and more on unbiased institutional rules. This, however, may also inhibit it from gaining outstanding competitiveness when the environment is more mature and predictable.

Our study has pointed out that organizations can benefit from having the right structure. A complex structure has been shown to help organizations produce more accurate judgments of the environments at the organizational level but only with an experiential decision procedure. A simple structure consistently performs better in a high uncertainty environment but only with an operational procedure. Its performance, however, can also drop to very low if the situation changes. A complex structure, on the hand, has a higher base point even under the most adverse conditions. This suggests that if the organization's main concern is to have a low risk outcome, for example in the case of a nuclear power plant, it would probably be appropriate to have a complex structure, which can effectively buffer the occurrence of a grave number of errors at the organizational level.

Our study also has implications for organizational change management. It suggests to organizations that there may not be a universal or stable strategy that can best suit the organizations. They have to adjust their designs constantly to face the challenge of changing environmental conditions. In addition, this study has attempted to move beyond the limits of traditional contingency theory by providing more concrete and precise insights into change management [66].

This study has demonstrated that computer modeling can be a natural and effective method for studying dynamic organizations with interrelated conditions [14,31,38,76]. Scholars like Axelrod have also emphasized the usefulness of computer modeling, in particular the agent-based modeling technique, in dealing with adaptive behaviors of multiple interacting agents. In fact, Axelrod even claimed that ''simulation is necessary because the interactions of adaptive agents typically lead to nonlinear effects that are not amenable to the deductive tools of formal mathematics''. He further argues that ''the simulation of an agent-based model is often the only viable way to study populations of agents who are adaptive rather than fully rational'' [5, p. 4].

Scholars in that area have also done some work on testing agent-based models. In Carley and her associates' work of comparing artificial and human organizations, simulation results were consistently in line with the human experiment results in hierarchy and team organization settings, even though the simulations took much less time for a much wider range of issues [10,15]. Lin and Carley's [46] study has also examined the performance between simulated organizations and 69 real world organization in crisis situations and found high correlation between the two samples. Our model is built upon Lin and Carley's [44] model and was tested in their comparison studies. It has been proven to be both empirically valid and methodologically reliable.

This study has its boundary conditions and limitations. For example, the paper takes a strong structural equivalence view in that it regards individuals in structurally equivalent roles as having similar capabilities and functions [8,49]. While we wish we could have developed a model that captures all individual as well as structural differences, we also understand that it will be impossible to do so at this stage without the contamination of the more important behavioral effect that this study is focusing on. Future research should expand to more individual-level dimensions of the organization.

Also, this study only focused on a limited number of stylized features in each aspect of environmental uncertainty, organizational structure, and decision procedure and so the generalization of the results will have its constraints. While this may be necessary at this stage, we will need to further improve the model to encompass broader aspects related to organizational decision making. This study has only examined decision making in a distributed setting. We believe that with the changing nature of types of decision making, new relationships between environmental uncertainty and performance may emerge. That should also be worth exploring in future studies. It will also be beneficial to use information from more case studies of real world organizations to provide further empirical support and insight, which can in turn empower the theoretical strength of the computer model [42,43].

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