OULUN YLIOPISTO

FACULTY OF TECHNOLOGY

MODELLING EXPLORATION AND EXPLOITATION IN ORGANIZATIONAL LEARNING

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INDUSTRIAL ENGINEERING AND MANAGEMENT

Bachelor's Thesis

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Tiivistelmä

Simulaatioita on hyödynnetty organisaatio oppimiseen liittyvässä tutkimuksessa 1960-luvulta saakka. Vaikka organisaatio- ja johtamistieteet olivat hyvin aikaisia simulaatiopohjaisen tutkimuksen ja teorian rakentamisen edelläkävijöitä ja samalla kun myös monet muut tieteenalat ovat alkaneet omaksumaan simulaatioiden hyödyntämisen tutkimuksessa eivät simulaatiot koskaan saavuttaneet oletettua suosiota organisaatio- ja johtamistieteissä lupaavasta alusta huolimatta.

Tämän kandidaatintyön tarkoituksena on luoda kokonaisvaltainen kuva simulaatio- ja mallintamiskäytännöistä organisaatio- ja johtamistieteissä, joka toimii pohjana työssä tarkasteltavalle organisaatio oppimisen keskeisimmän mallin tarkastelulle ja sen kehitykselle viimeisen kolmen vuosikymmenen aikana. Mallin tarkastelun avulla luodaan myös kattava kuva organisaatioiden oppimiseen liittyvien ajatusten ja käsitteiden kehittymisestä sekä mikä rooli mallinnuksella on ollut osana organisaatio oppimisen kehitystä.

Työn keskiössä on March (1991) esille nostama argumentti organisaatioiden resurssien kohdistamisesta olemassa olevan osaamisen ja teknologian hyödyntämisen (*exploitation*) ja uuteen teknologiaan ja osaamiseen liittyvän tutkimuksen (*exploration*) välillä. Työssä tarkastellaan organisaatioiden kykyä ja tarvetta tasapainotella edellä mainitun kahden resurssin välillä sekä niiden vaikutusta organisaatioiden osaamistasoon ja suorituskykyyn niin lyhyellä kuin pitkällä aikavälillä. Työssä luodaan laaja kokonaiskuva lyhyen- ja pitkän aikavälin hyödyn tavoittelun välisistä oletetuista ristiriidoista sekä tarjotaan mahdollisia ratkaisuja mallinnuksen ja empiirisen tutkimuksen pohjalta.

Osana työtä rakennan konseptuaalisen mallin tarkastellun March (1991) mallin ja työssä tarkasteltujen töiden pohjalta, jonka tarkoituksena on toimia pohjana toteutettavalle mallin rekonstruktiolle. Mallin rekonstruktion tehtävänä on toimia validointina alkuperäiselle mallille sekä tehdä mallista helpommin kommunikoitava, visualisoitava ja uudelleenpäivitettävä. Työ tarjoaa erinomaisen pohjan mallin jatkokehitykselle ja mallinnukseen liittyvälle jatkotutkimukselle organisaatio- ja johtamistieteissä.

Muita tietoja

ABSTRACT FOR THESIS

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Abstract

Simulations have been utilized in organizational learning research since the early 1960s. Despite organizational and management sciences being early adopters of the simulation-based research and theory construction and while other disciplines have begun to adopt simulations as part of their research the simulation-based research never reached its expected popularity in organizational- and management sciences despite its promising beginnings.

The purpose of this bachelor's thesis is to create a holistic view of simulation modelling in organizational and management sciences which will function as a basis for one of the most fundamental models in organizational knowledge research. In this work we will explore how the March (1991) simulation model and the article has evolved over the last three decades. By exploring the model this work will also create a comprehensive view about the development of organizational learning and the related concepts in the field as well as showcase the significance of simulation modelling as part of organizational learning development.

At the center of this thesis however is the argument represented by the March (1991) simulation model about the fundamental competition for scarce resources between organizational exploration and exploitation and their impact in organization's knowledge and performance rates. In this thesis we will create a comprehensive view of the supposed dilemma between exploration exploitation in organizational learning and offer suitable solutions for this problem based on simulation modelling and empirical research.

As a part of this thesis I will construct a conceptual model that will function as a basis for a future reconstruction of the original March (1991) simulation model. The purpose of the reconstruction is to validate the original model as well as make the model more communicable, visualizable and updateable. The work will serve as an excellent basis for future extensions in to the model and offers a strong basis for future research into modelling in organizational- and management sciences.

Additional Information

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1 INTRODUCTION

The focus of this thesis is March's (1991) work "Exploration and Exploitation in Organizational learning". The work has gained widespread notoriety and has thus become one of the most fundamental building blocks in modern organizational learning research and simulation based organizational research.

March (1991) proposes a simple computational agent-based model that laid the foundations for the popularized terms of exploration and exploitation in organizational learning. Due to the simple nature of the original mode it has functioned as an excellent building block for future research and as such many have proposed several different forms of extensions to his original model and expanded as well as questioned his original definitions of exploration and exploitation.

Firstly, this thesis will take a brief introductory view into the usage of modelling in organizational sciences through a literary review. We will explore the basic concepts of modelling and take a more comprehensive look into different methods of modelling in organizational sciences as well as the development of using simulation-based modelling as a research method in organizational sciences. The purpose is to lay the general foundations and understanding of modelling tools in organizational learning and explore the usability and gains of simulation-based models as a research method.

The purpose of this study is to look at the cultural impact and significance of March (1991) model and conduct a literary review exploring the extensions to original model and the significance of their research. This review will also examine the concepts of exploration and exploitation that have now become a fundamental part of organizational learning. The study will investigate how scholars view the concepts of exploration and exploitation and how these views have evolved over the decades in comparison to the model proposed by March (1991).

Lastly, the study will represent a conceptual model on the basis of the conducted research. The goal is to construct a representative conceptual model of exploration and exploitation that assists in the replication of the results reached by March (1991) as well as highlight the possible simplifications and assumptions made by the model. The ability to replicate the original results will function as means of validating the results reached by the original model. The conceptual model will function as a groundwork for future model-based simulation research done into the subject of exploration and exploitation dilemma that can be easily extended with the proposed future research questions or the simplifications noted in the conceptual model. There is also an importance of making a model that is easily visualized and communicable to an audience that may not be familiar with simulation modelling tools or the logic behind simulation modelling. Easily communicable results will increase the credibility of the reached results and make the modelling tools more accessible to a wider audience.

Thus, the research questions proposed by this thesis are as follows:

How can organizations use simulation modelling to outline organizational knowledge and performance?

What is the fundamental concept of exploration and exploitation and how has this concept evolved over time?

How organizations ought to choose and balance between exploration and exploitation when considering organizational knowledge and performance?

2 SIMULATION MODELLING IN ORGANIZATIONAL SCIENCES

2.1 Background

There is a long history in using simulation models in as a mean of conducting science dating all the way back to WWII (Harrison et al. 2007). In organizational sciences the use of modelling was pioneered by Cyert & March's (1963) behavioral theory of the firm but only started gaining more friction during the 1990s as a method of study (Burton 2003; Harrison et al. 2007). Despite already accepted as a legitimate means of doing science by disciplines such as psychology, economics, and natural sciences (Axelrod 1997) and gaining brief surge of popularity in the earlier decades, Harrison et al. (2007) note that the use of simulation modelling is still significantly underused in both management and sociology literature and that the use of simulations has not reached a wider audience outside of very few specialized simulation journals. It is theorized this could be due to misunderstandings in how models are used, in what kind of research they are useful and what are the appropriate steps for conducting simulation research. (Harrison et al. 2007)

For one to harness a basic view of what a computer simulation is we will start from the considerably basic definitions. Harrison et al. (2007) define a computer simulation as a "computational model of system behavior coupled with an experimental design" in which the execution of the design can also be called a "virtual experiment" to separate the simulations from a "traditional laboratory experiment".

The computational model consists of components or parameters and set processes that adjust changes in these parameters. The equations or functionalities set for the processes determine the altercations or value changes for the parameters after each passed time period ($t + 1$) given that the system itself is at time t. The model's initial conditions need to be specified separately. In a stochastic model a random chance might be introduced to the system changing the parameter values and model outcomes slightly and as such multiple iteration runs might be necessary. This is to represent things such as uncertainty, disturbance, or random noise in the system for example turnover in organization or adoption rates of certain beliefs. (Davis et al. 2007; Harrison et al. 2007)

Often the simulation process can be repeated with different variations. This can be done for a few reasons. Firstly, adjusting the parameter values or the initial conditions may be changed to test the behavior and outcomes of the system under different values. The possibility and flexibility of testing the system under different outcomes is often the reason why the simulation approach might be chosen. Secondly, testing different values in the parameters or initial conditions are crucial to test how sensitive the system is to changes, this called the "sensitivity analysis." Conducting this type of testing is important in order to test the robustness of the model. (Burton 2003; Harrison et al. 2007).

Computer simulations can be immensely powerful tools in conducting research especially when the availability of data might be lacking, unavailable or simply unobservable as the simulation models produce its own "virtual data" (Harrison et al. 2007). Additionally, Kreps (1990, pp. 6-7) gives a concise list of reasons for building formal models. In his view the advantages of a good formal model are "clarity, ease of comparability, logical power, and transparency." In short, the individual agents in the model can be tweaked, we can test our intuitions better and it provides a clearer way of communication to others as well as brings in new insight.

Lin & Carley (2003, pp. 30-31) also provide a brief list for benefits of using simulation in organizational context. Simulations allow wider ranges of exploration in ranges of stress, environment, and organizational design along with exploring the impact that these factors have on the performance of the organization. This makes it possible to address, get insight and build theories in what constitutes to performance in actual organizations without conducting actual human experiments and causing harm to individuals or conducting economic harm to an organization and thus can safely provide an outlook on both successful and failing firms without taking such a biased view on only successful firms (Burton 2003; Carley 2002). Lastly there has been proof of simulations corresponding well to the performance of real-world organizations making the results reached from those of simulations comparable to empirical evidence (Lin & Carley 2001).

It is still important to note that there are some basic limitations to simulations modelling. By making simulations more complex by adding more parameters or processes one can make simulations more realistic but at the same time doing so will come at the cost of deriving what truly constitutes to the changes in the model's behavior. As the model starts resembling more that of a real organization it will also gain the same incomprehensibility and indescribability that of a real organization. For this reason, a simpler model can often help understand the studied phenomena better which in turn can come at the cost of excluding essential elements that interact with the simplified model in a crucial manner. Deciding what elements are most essential is often at the hands of the person conducting the simulation and comes through experience and intuition which can inadvertently skew the models results. For this reason, a simple model is often used as a building block for the simulation where complexity is added to the model in a stepwise fashion so that the behavior of the model and its extensions can be properly understood. (Fioretti 2013; Harrison et al. 2007)

Other issues that may arise in building a simulation is in its grounding to empirical reality. As simulations are artificial and the data is generated virtually the model's correspondence to real-world behavior can always be brought to question. In order to build a more robust model, the model's parameters and processes can be drawn from empirical work where the only ungrounded parameters would be those of varying the parameters for sensitivity-analysis. Subsequently simulation model's results can also be compared to existing empirical work and literature to assess its functionality and correspondence to real-world behavior. (Harrison et al. 2007; Robinson 2008)

As simulation models are done computationally they are vulnerable to same set of flaws as any other computer programs. Faulty programming can cause programming errors (bugs) which can cause faulty results in the consequent testing. Relatedly, translating formal models into a specified computer code can often be overly complex and the separate set of people could translate the same formal model into a vastly different code that reaches different results. It can also be hard to difficult communicate the results of such model representing them in a sufficient enough detail so that others may gain understanding of what was done, giving them the possibility of evaluating the work and reach sufficient enough conclusions to build confidence in the model. (Balci 1998; Harrison et al. 2007)

2.2 Modelling methodologies in organizational science

2.2.1 System Dynamics

System dynamic's is a modelling tool developed in the 1950's by electrical engineer Jay W. Forrester (Forrester 1958). According to Forrester (1961, pp. 13) system dynamics is "the study of information-feedback characteristics of industrial activity to show how organizational structure, amplification (in policies), and time delays (in decisions and actions) interact to influence the success of the enterprise".

System dynamics is a continuous modelling system that can be best used in systems where the variables are numerous and related to one another and the individuals within the system are generally similar, as system dynamics focus on more holistic view of systems rather than individuals themselves (Harrison et al. 2007). This also means the models are often deterministic. As a continuous model the state changes within the system are also continuous rather than occurring at discrete points of time. In system dynamics real-world processes are represented as stocks, flows between the stocks and the processes that determine the values of these flows. It treats the system as a closed system with several continuous interacting feedback loops. Computationally this means that the model is essentially a set of coupled differential equations than can span up to several hundred different variables. (Borshchev & Filippov 2004; Dooley 2002)

System dynamics is best suitable for systems with complex timings and causality. It can be used to measure how differing initial conditions change the stability of the system. For this reason, it is often used to find initial conditions that can lead to major failures, catastrophes, as well as viscious and virtuous cycles. For example it system dynamics used by Repenning (2002) to find why minor interruptions can sometimes cause sudden catastrophes within organizational setting. (Davis et al. 2007).

2.2.2 Discrete Event

Discrete event modelling portrays (organizational) system as a set of discrete entities, resources and block-charts describing the flow of entities and resources through the system. Developed in the 1960s by Geoffrey Gordon an idea that devolved from his original GPSS system (Gordon 1961; Borshchev & Filippov 2004)

In this system the entities are often passive objects passing through block-chart that can for example represent people, parts, tasks. As they travel through the block-chart there can be a network of different queues, delayed processes, decisions. The discrete systems are often stochastic and thus involve an element of random chance, for example certain activities for individuals can be sampled from a random probability distribution. The changes in a discrete system occur defined discrete points of times instead of a continuous flow when compared to for example system dynamics (Morecroft & Robinson 2005). The general uses for discrete systems are often used at different services, manufacture, business processes, and supply-chain management (Borshchev & Filippov 2004).

2.2.3 NK fitness landscape

A mathematical model that was originally introduced by Kauffman and Levin (1987) and used for evolutionary biology and has now been adopted by some organizational scientists to explore organizational behavior and optimization of organizational systems.

The NK model can be used to model systems with several interacting components that can exist in several different states. In the model the N determines the number of components in the system and the K measures the degree of interaction between these components determining for the interdependence of the system. From the set parameters the NK-model produces a two-dimensional NK fitness landscape, with "peaks" and "valleys" where the agents that search this landscape (Kauffman & Levin 1989; Ganco & Hoetker 2009; Wright 1931). The peaks in the landscape represent the local optima that is defined as the "configuration of elements of the decision vector such that it is not possible to improve the decision's overall payoff by performing a given type of search" (Ganco & Hoetker 2009).

The NK model stresses finding exact search strategies while traversing on the fitness landscape to find an optimal point. For this reason, it is particularly useful for understanding speed and timings of what it would take for a system to adapt an optimal strategy or how timing affects to the performance of the optimal strategies. For example, Gavetti & Levinthal (2000) used the NK-model to find what impact experiential learning would have on the speed of adopting an optimal organizational policy. Where N represents the organizational policy elements and K the interactions between these elements. (Davis et al. 2007).

2.2.4 Agent-based model

Agent-based modelling has its roots in object-oriented programming popularized in the last 1980s made possible with the advancement of computer science. In object-oriented programming operations and data is grouped into modular units called objects, where each object has its own data and methods and the objects can be structured into a functional network. These objects in turn can represent actors in a real world that communicate with one another. (Li 2011)

Perhaps currently the popular modeling approach in management simulation. Agent-based models focus on modelling the behaviors of individual agents who make up a social network and can influence one another through their behavior (Harrison et al. 2007). This means that the agent-based models are decentralized, meaning a similar global system behavior that is defined in system dynamics or discrete event models does not exist. Instead modeler defines behavior at individual level which makes up the global behavior as a result of the agents being able to interact with each other in a dynamic environment as well as being able to learn from one another. In this way the behavior of the social system emerges from the behavior of the individuals. (Borshchev and Filippov 2004; Li 2011).

For this reason, agent-based models have been commonly used in social sciences as it can provide useful information that stems from individual level behavior and treat the organizations as an ongoing process that emerges from individual and group behavior. As agent-based models are not similarly constrained by rationality or “pure strategies” as for example game theory, they also offer a viable option of looking at organizations as dynamic, constantly changing systems. (Fioretti 2013)

2.2.5 Cellular automata

Cellular automata models exist on a $m \times m$ grid that where each square of the grid forms a cell. The model changes depending whether the cell is occupied by an actor or not and interacts with other nearby cells locally (Harrison et al. 2007). Cellular automata uses semi-intelligent agents that are spatially related to each other. and the influence that the agents have on each other is dependent on the distance between them. For this reason, it can be used to model macrolevel system patterns emerging from the microlevel interactions in an equivalent manner to agent-based model, for example processes of diffusion, segregation, and competition. The difference to agent-based modelling however is that the agents follow the same set of rules and are often deterministic. (Wolfram 2002; Davis et al. 2007)

Although not quite common in organizational sciences, cellular automata has been used by some scholars for modelling organizational behavior. Lori and Larsen (1996) used cellular automata to study dependency between competition and legitimation processes through density-dependence theory. The organizations were located on a spatially related two-dimensional grid with set rules for competition that affected their neighboring cells. They were able to observe how microlevel behaviors in competition and legitimation affected macrolevel system patterns such as population density, founding rates and failure rates over time. (Davis et al. 2007; Hannah & Freeman 1989).

3 LITERARY REVIEW

3.1 Nature of exploration and exploitation

The focal point of March's (1991) framework is the inherent tradeoff between "exploration of new possibilities and the exploitation of old certainties in organizational learning". The term exploration is defined by terms such as search, variation, risk taking, exploration, experimentation, play, flexibility, discovery, and innovation, whereas the term exploitation has been defined by refinement, choice, production, efficiency, selection, implementation and execution (March 1991). Over the years a general consensus has been reached among the scholars about the definition of exploration referring to learning and innovation though there is lack of similar agreement on whether exploitation refers exclusively to the use of past knowledge or also the pursue and acquisition of new knowledge through refining existing skills. (Gupta, Smith & Shalley 2006; He and Wong 2004)

According to March (1991), there is an inherent relationship and trade-off between the exploration and exploitation where organizations must make decisions between allocating scarce resources into exploiting already acquired knowledge and exploration of gaining new knowledge. Exploitation of existing technology is described as having more certain short-term returns while the gains from exploration are often long-term with no guaranteed results. Though there is a need for both exploration and exploitation as organizations that focus exclusively in exploration will never gain the returns from its knowledge and those that focus exclusively in exploitation will often suffer from obsolescence (March 1991; Levinthal and March 1993).

The empirical evidence seems to suggest that the balance between exploration and exploitation is necessary for the success of an organization (He and Wong 2004) there is an inherent tendency in organizations for path-dependent behavior favoring either exploration in due to myopic behavior and short-run survival in the case of exploitation. Organizations can also fall into "competence traps" by gaining cumulative experience at niche skills in certain parts of the organization and creating self-reinforcing behavior by further focusing on these areas thusly reinforcing explicitly exploitative or explorative behavior. (March 1991; March and Levinthal 1993)

3.2 Model of exploration and exploitation in organizational learning

As part of his claims March (1991) constructed a computational simulation model to study the different influences in organizational learning and performance. This model of "mutual learning" is based on the premise of existing organizational behavioral code with m set of beliefs with potential values of 1, 0 and -1, which are initially set at 0. These sets of organizational beliefs work as a storage for knowledge that both simultaneously learns from the members of the organization and that the members of that organization can learn from. (March 1991)

There are four distinct features to the model that are used as a basis for his simulation. Firstly, there exists an environment outside the organization called external reality that is independent of organization's members beliefs. The reality is modelled as having m-dimensions that can have the values of -1 or 1 with equal probability of 0.5. (March 1991)

At each time period there exists an n number of individuals in an organization. These individuals hold beliefs about each of the m-dimensions about the organization's external environment that are reflected in the organizational code. The individuals' beliefs can have values of -1, 0 or 1 that can change over time. These beliefs are compared against the values of the existing external reality. (March 1991)

Organization's members change their beliefs through the process of being introduced to the organizational code by either socialization or education into the organization's code of beliefs. During any period, individuals have a chance of modifying their beliefs to that of the code unless their belief on that particular dimension is 0, with probability of p_1 which is called the socialization rate. The probability of learning from the code is reflective of the effectiveness of socialization within the organization. (March 1991)

The organizational code adjusts to the beliefs of the individuals within the organization whose beliefs correspond to the external reality on more dimensions than the code itself with a probability of p_2. The code will adjust itself on dimensions where the majority belief of the superior group differs from the beliefs of the code with a probability of $1 - (1 - p_2)^k$, where k is the number of individuals in the superior group that hold this majority view. The code will also adjust itself to false beliefs, if those beliefs are held by the majority in the superior group. (March 1991)

Both individual beliefs and knowledge of the organizational code is measured at each period against how well they represent the external reality. At each period both the individuals and the code affect each other's beliefs. Individuals do not affect each other's beliefs directly but only through the organizational code. Neither the individuals or the organization experience the external reality. Over the time the beliefs of the individuals and the organizational code will converge and within a closed system reach an equilibrium where all individuals and the code share the same beliefs and thus in a closed system the beliefs become stagnant. (March 1991)

The results from the model illustrates the trade-off between exploration and exploitation through individual and organizational learning showing how individuals with slower socialization rates maintain more diverse set of beliefs through exploration allowing the organizational code to learn from the individuals. Comparable results are shown through heterogeneity of learning rates where mix of fast learners $p_1 = 0.9$ and slow learners $p_1 = 0.1$ are introduced to the organization where the code can learn from the slow learners and reach higher level of knowledge at every level compared to homogenous individual knowledge. The heterogenous mix of individuals performs better at all levels compared to strictly one set of learners reflecting the need for balance between exploration and exploitation. (March 1991)

Effects of an open system with turnover rate and environmental turbulence are also considered. With each period the there is a probability p_3 of a person leaving the organization and being replaced with an individual with randomly distributed beliefs. Similarly considering environmental turbulence in each period the external reality has a probability p_4 of changing from -1 to 1 or 1 to -1 conversely. The results show moderate improvements at moderate turnover rates for faster learners while the average knowledge rate of slower learners suffers at all increased rates as they do not have the time to adapt to the organizational code. (March 1991)

The model showcases how exploitation achieved by the fast learners that adopt quickly to the organizational code increase the organizations learning efficiency but at the same time converge prematurely with the organizational code leading to suboptimal knowledge equilibrium. While slower learners allow the organization to maintain more diverse set of beliefs and for the organization to explore wider variety of beliefs leading to higher equilibrium of knowledge in the long run (March 1991).

3.3 The Influence of March (1991)

The influence of March's (1991) work has had on organizational sciences and scholarly thinking is certainly undeniable with currently over 22,000 citations on Google Scholar and over 6,000 citations of Web of Science it has become one of the most foundational works in organizational learning.

In their article Wilden et al. (2018) conduct an empirical review into March's work and its impact on scholarly thinking and the scholarly work influenced by March (1991). Through bibliographic coupling and network analysis managed to identify five distinct diverse clusters of research influenced by March's (1991) work.

The first cluster has focus on organizational learning with two sub-groups that focus in co-evolutionary adaptation and learning strategy, performance, and change. Second cluster orients itself around learning and collaboration that includes sub-clusters of acquisition and international learning and second sub-cluster with the focus in alliances and inter-organizational collaborations. Third and the largest with 10,851 citations focuses on dynamic capabilities, absorptive capacity and knowledge management. Fourth cluster has emphasis on organizational exploration and exploitation, ambidexterity and firm performance. Fifth and the last cluster is based on technology and innovation and includes themes from open innovation and evolutionary economics. (Wilden et al. 2018)

In this thesis we will mainly focus on the model conducted by March and the extensions provided to his model as well as the impact of these models on organizational learning as well as the general argument of tradeoff between exploration and exploitation. We will also take a brief look into other areas of research or 'clusters' to the extent they relate to organizational learning or extending the capabilities of March's (1991) model for modelling organizational learning and the dilemma of exploration versus exploitation.

3.4 Is there a tradeoff between exploration and exploitation?

March (1991) emphasizes the importance of balance between exploration and exploitation for the long-term success of existing organization even though the nature of the two is seemingly inherently incompatible. Both compete for the scarce resources within the organization and show pattern-dependent behavior leading up to self-reinforcing behavior. Due to uncertain nature of exploration the outcome is often negative which in turn might lead to even further exploration in hopes of newer ideas creating a failure trap. For exploitation, short-term successes and refined skills can create positive feedback loops that in turn lead up to success traps (March & Levinthal 1993). Due to nature of exploration and exploitation they both require different organizational routines and mindsets from one another making the simultaneous pursuit nothing short of an impossibility (March 1996). By this logic, the nature of exploration and exploitation ought to be viewed as two ends of a continuum.

Notwithstanding the strong foundations laid out by March (1991) many have come to question the arguments leading up to his conclusions. There is an ongoing debate about the nature of exploration and exploitation and whether it should be considered an orthogonal activity as some resources such as information, knowledge and resources in their external environment such as public resources or strategic alliances, could be considered infinite (Gupta et al. 2006).

Even though there have been studies that show negative correlation between exploration and exploitation (e.g. Park et al. 2002), there seems to be an overwhelming amount of empirical evidence of the two activities being at least partially orthogonal activities and showing no correlation or possibly even positively correlate with each other instead of competing for scarce resources (He & Wong 2004; Gupta et al. 2006; Katila & Ahuja 2002). Theory suggests that the positive correlation could be caused by the opportunities created by exploration that grant organizations future possibilities in exploitation. Similarly, exploitation grants organizations income that could later be used in future exploration coined as “the paradoxical association between exploration and exploitation” (Lavie, Stettner & Tushman 2010).

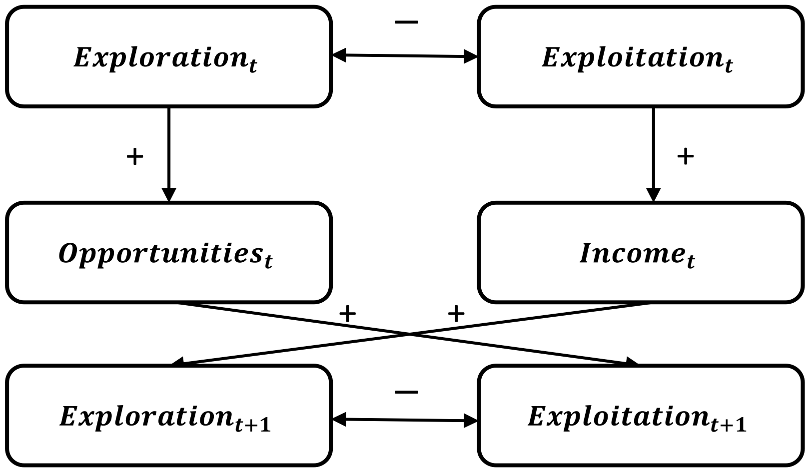

Figure 1. The Paradoxical Association Between Exploration and Exploitation (retell. Lavie et. al. 2010)

The empirical evidence from the largest 500 S&P corporations seems to suggest that the degree in which an organization should engage in explorative behavior depends on the technological dynamism (Uotila et al. 2009). Similarly, Gupta et al. (2006) concluded that the dependent variables when considering the dilemma of exploitation and exploration would be the scarcity of the resources needed to pursue both exploration and exploitation and whether it happens on a single domain as in a single person or a single organizational unit which makes them mutually exclusive. Having several loosely coupled units within an organization could make it possible for separate units to conduct exploration than those who are engaging in exploitation.

This would conclude that while a lot of the literature supports the idea of orthogonal view of exploration and exploitation as being positively correlative instead of competing resources a universal claim cannot be made that would support exploration and exploitation being either a continuum of competing resources or orthogonal. The correlation as the correlation between the two is highly dependent on things such as environmental uncertainty, competition and organization's resources. (Gupta et al. 2006; O'Reilly & Tushman 2013; Uotila et al. 2009).

However, it should be noted for performance implications that if exploration and exploitation are seen as competing resources on a continuum and thus being mutually exclusive the performance curve will follow an inverted U-shape seen in the figure 2. In a situation where they are viewed as being orthogonal the performance between the two will be complementary to each other as seen in the figure 3. These implications could also have an impact in any suggested models. (Gupta et al. 2006)

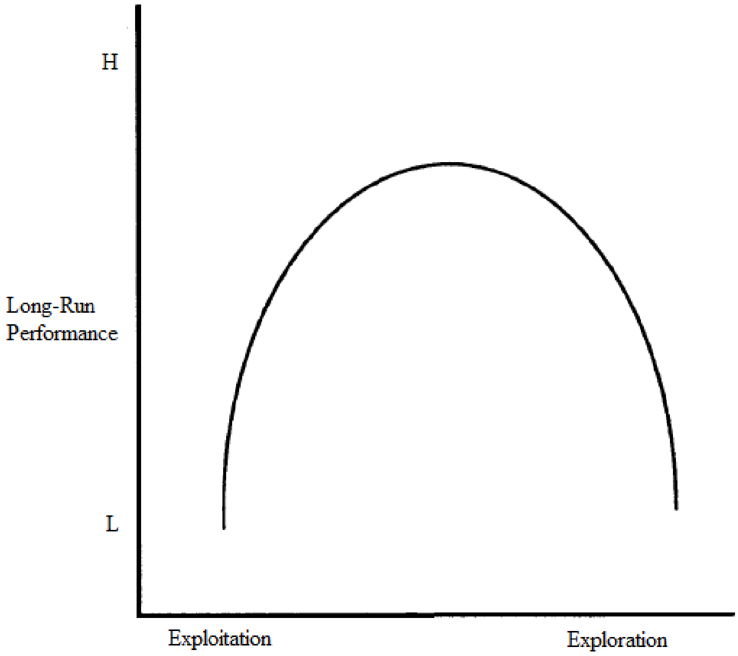

Figure 2. Exploration and Exploitation being on a competing continuum. (retell Gupta et al. 2006).

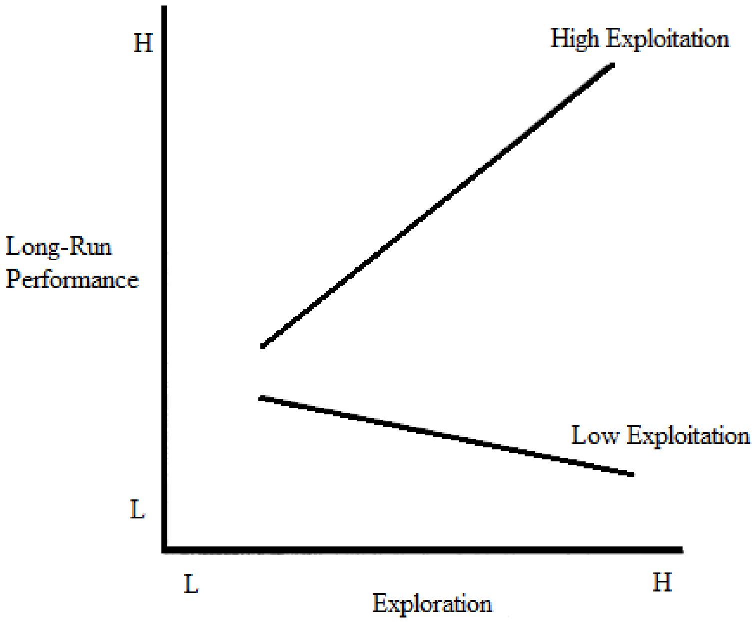

Figure 3. Exploration and exploitation as orthogonal resources. (retell Gupta et al. 2006).

3.5 Balancing exploration and exploitation

Despite the general consensus on the need for balancing out the levels of exploration and exploitation (Gupta et al. 2006; He & Wong 2004; Levinthal & March 1993; March 1991) the means by which organizations ought to do so differ. Currently there exists two main school of thought between ambidexterity (He & Wong 2004; Katila & Ahuja 2002; O'Reilly & Tushman 2013) and punctuated equilibrium (Levinthal & March 1993; Tushman & Romanelli 1985).

Currently less focused on in the organizational research, the punctuated-equilibrium, also sometimes called the sequential ambidexterity (e.g. Duncan 1976; Tushman & O'Reilly 2013) lends itself to the idea of "temporal cycling between long periods of exploitation and short bursts of exploration" (Gupta et al. 2006). Where organizations allocate resources sequentially to either exploration or exploitation for discrete periods of time with the idea of focusing on "maximally exploiting the available opportunities, rather than a more continuous evolutionary process of balancing exploitation of available opportunities at a given time with preparing the ground for future growth opportunities" (Burgelman 2002).

Organizational ambidexterity that has mostly arisen from March's (1991) work along with Duncan (1976), has gained significant traction and become its own independent area of research (e.g. Tushman & O'Reilly 2013). The theory was originally suggested by Duncan (1976) and largely popularized by Tushman & O'Reilly (1996), defined by them as "The ability to simultaneously pursue both incremental and discontinuous innovation and change results from hosting multiple contradictory structures, processes, and cultures within the same firm". More recently Tushman & O'Reilly (2013) have extended the definition of organizational ambidexterity as follows: "Organizational ambidexterity refers to the ability of an organization to both explore and exploit exploit — to compete in mature technologies and markets where efficiency, control, and incremental improvement are prized and to also compete in new technologies and markets where flexibility, autonomy, and experimentation are needed". More specifically this approach of balancing exploration and exploitation could be called simultaneous- or structural ambidexterity, where the ambidexterity appears between separate subunits within the organization performing exploration and exploitation simultaneously instead of during discrete time periods. (Gibson & Birkinshaw 2004; Tushman & O'Reilly 2013).

A third type of approach has also been theorized by Gibson and Birkinshaw (2004) proposing a way of contextual ambidexterity where the balance between exploration and exploitation is resolved on an individual level. Gibson and Birkinshaw (2004) argue that contextual ambidexterity could be achieved by "building a business unit context that encourages individuals to make their own judgments as to how best divide their time between the conflicting demands for alignment and adaptability". This would mean hosting an organizational context that would enable the individual freedom to pursue either exploration or exploitation as needed (Gibson & Birkinshaw 2004). Closest empirical comparison to Gibson & Birkinshaw's (2004) view of contextual ambidexterity would be Toyota's production system (TPS) as described by Adler, Goldoftas & Levine (1999) where workers are expected to perform monotonous routine tasks (exploitation) while striving to find ways to perform their current jobs more efficiently (exploration).

Although initially proposed as separate methods of dealing with the issue of exploration and exploitation (Tushman & O'Reilly 2013), it is also very likely that each of proposed methods could exist simultaneously. For example, Gupta et al. (2006) argues that certain loosely coupled systems could simultaneously be engaged in structural ambidexterity while on a sub-unit level go through switches from exploration to exploitation meaning they would also be engaged in punctuated equilibrium on an individual subsystem level. Kauppila (2010) also echoes these thoughts through a case-study showing how Finnish technology firm Vaisala used contextually ambidextrous organization while also having structurally separate organization units.

3.6 Extending the March's (1991) model

March's original model has worked as a significant groundwork for modelling practices in organizational learning. Due to its simplistic nature it gives useful insight into causal events at organizational learning but doing so there can also be a significant risk of missing out on several key elements that might still have an impact to the studied phenomenon (Harrison et al. 2007).

Next, we will investigate several other articles and scholarly work that use March's (1991) simulation model described earlier as a basis for their simulation modelling efforts but also look to build on this model with key elements that could provide new insightful information regarding organizational learning.

3.6.1 Interpersonal learning and tacit knowledge

In his original work March (1991) viewed mutual learning between individuals and the organizational code, though this learning happened strictly through this code. Miller et al. (2006) consider expanding on this view by introducing direct interpersonal learning between individuals. Giving the individuals a location in the space with the distinction between local and distant search complementing the argument by Levinthal and March (1993) of 'spatial myopia' which has been empirically supported by Katila and Ahuja (2002) where distribution of knowledge between individuals is more efficient with closer proximity. They also give the ability for the individuals to possess tacit knowledge that cannot be transferred through organizational code and lastly recognizing that organizations may vary in their attempts to codify their knowledge which means that updating the organizational code is often episodic and might not update on each time period.

The code follows March (1991) original work but adds four additional features to his original simulation model. Firstly, the n individuals are located in a grid with four neighbors the grid has no corners, meaning each individual has four neighbors one at each side. Secondly the individuals can now learn through local and distant search. In local search individual identifies the best performing neighbor and compares and changes to each belief of that neighbor with probability of p_3. In a case of equal performance one superior neighbor is chosen at random and if all neighbors are inferior the individual will engage in distant search by choosing four people from the population by random and choosing to learn from the best performer out of them. If the chosen individual has superior performance to that of the searcher they will adopt the individual's beliefs with probability of p_4. The order in which the individuals will perform their search is chosen at random. (Miller et al. 2006)

Considering tacit knowledge, a proportion q between $(0 \leq q \leq 1)$ of the m beliefs are tacit, that cannot be conveyed through the organizational code and must be learned from others. Learning from the code is episodic and every τ periods the organizational code is updated where all individuals learn from the code within the same period. During the time periods between updating of the organizational code the individuals will learn focus on learning from one another. (Miller et al. 2006)

Findings from the model suggest that rates of local- and distant learning in a closed system without turnover or turbulence provide best results at moderate rates of search $0.3 \leq p_3 \leq 0.7$. This could be explained as the level of local learning becomes higher, individuals will engage more in distant search which in turn will dissipate the population-wide diversity quicker leaving the level of knowledge at suboptimal equilibrium. (Miller et al. 2006)

If organizations are introduced with turnover higher levels of local learning will always be advantageous as it allows the conservation of tacit knowledge, while distant search has negligible effect. The largest impact in degradation of knowledge is on tacit knowledge as the organizational code makes the codifiable knowledge more resilient towards erosion as it works as a storage for knowledge, but a lot of the tacit knowledge can be lost when the individual leaves the organization. (Miller et al. 2006)

Miller et al. (2006) simulation model extends March's original (1991) model by bringing in several new dimensions of learning. The implications of this model support the premises and empirical evidence laid out by (Benner & Tushman 2003; Gibson and Birkinshaw 2004; Tushman & O'Reilly 2013) about structural ambidexterity, emphasizing the importance of having loosely coupled subunits to accommodate diversity and homogenization of beliefs and avoiding suboptimal knowledge equilibrium. There is also a recognition for future research considering the environmental dynamism regarding their model (Miller et al. 2006).

3.6.2 Internal variety and environmental dynamism

Kim & Rhee (2009) extend the model of both March (1991) and Miller et al. (2006) by considering future research questions given by Miller at al (2006). The simulation model uses aforementioned Miller et al. (2006) simulation model as their basis, additionally introducing the environmental variety with conceptions of amplitude and frequency that the external environmental realities shift. Secondly Kim & Rhee (2009) also consider the effects of internal variety between the individual-level knowledge within the organization in order to map the relationship between organizational adaptation to environmental change and internal variety within the organization.

The external reality is viewed as in the original mode having *m*-dimensions with values 1 or -1. Here amplitude represents the average proportions of the dimensions that the beliefs will shift on (e.g. 0.01, 0.1, 0.5) at a given period. Frequency represents the time interval (number of periods) between each environmental shift. Internal variety equals to differences in individual-level of knowledge in the organization. Rest of the simulation model adopts most of the features in Miller et al. (2006) simulation model with the exception of only having local search and if there are no neighbors with superior knowledge the individual will simply not learn. (Kim & Rhee 2009)

The results of the simulation seem to suggest that in order for organizations to adapt to highly turbulent environment there needs to be a low level of exploitation with higher levels of exploration meaning the rate of which the individuals learn from the organizational code needs to be preferably low (0.1), while the rate of local search should be very high (0.9) for optimal organizational knowledge. This combination of socialization shows best results at each level of amplitude (0.01 & 0.5) and frequency (1/30 & 1/1). It is theorized that this is caused due to lower level of learning from the code helps maintaining higher levels of internal variety that'll help the organization to adapt to turbulent environments through imperfect adaptation that can generate higher levels of organizational knowledge. (Kim & Rhee 2009)

From behavioral standpoint of view this would mean in particularly turbulent environments such as in technology industry, employees should be encouraged to explore and be protected from the organizational codes or norms as well as promoted to share this knowledge with other individuals (local search) regardless if the presented information is true or false (Kim & Rhee 2009). These findings seem to go against the presented idea of trying to find balanced moderate level of exploration and exploitation (He and Wong 2004) and favor the empirical findings of (Uotila et al. 2009) in that especially turbulent environments require higher level of engagement in exploration.

3.6.3 Isolation of subgroups and organizational learning

The simulation model represented by Fang, Lee & Schilling (2010) explores the learning outcomes between different group network structures under different conditions. The simulation model explores whether the semi-isolated sub-unit structure is beneficial for long-term organizational performance and learning and whether the functionality of this structure is dependent on the complexity of the tasks faced by the organization, environmental dynamism or personnel turnover.

The argument lends its ideas from the work of Wright (1932, 1964) about his work on evolution of populations. In his work Wright argues that species that exist in single large communities do not possess similar capabilities of adaptability in comparison to evolving populations that are divided into semi-isolated subgroups that maintains the genetic diversity between these populations. Similar arguments have been made and empirically tested in organizational sciences for the preservation diverse ideas and organizational knowledge through structural ambidexterity (e.g., Benner & Tushman 2003; Duncan 1976; O'Reilly & Tushman 1996).

Fang et al. (2010) simulation model again follows March's (1991) basic premises of external reality and individual beliefs, but instead the organization is seen as set of individuals interacting with each other and learning happens purely interpersonally between individuals through bidirectional comparison of performance. Individuals can determine someone's performance being superior and make decisions about updating their own beliefs through majority decision rule described by March (1991).

The compared organizational structures follow Watts' (1999) "connected caveman" model where the isolated sub-units can have random connections between them with likelihood β. In the example figure the original structure has $\beta = 0$, the semi-isolated structure figure 4(b) represents $\beta = 0.1$.

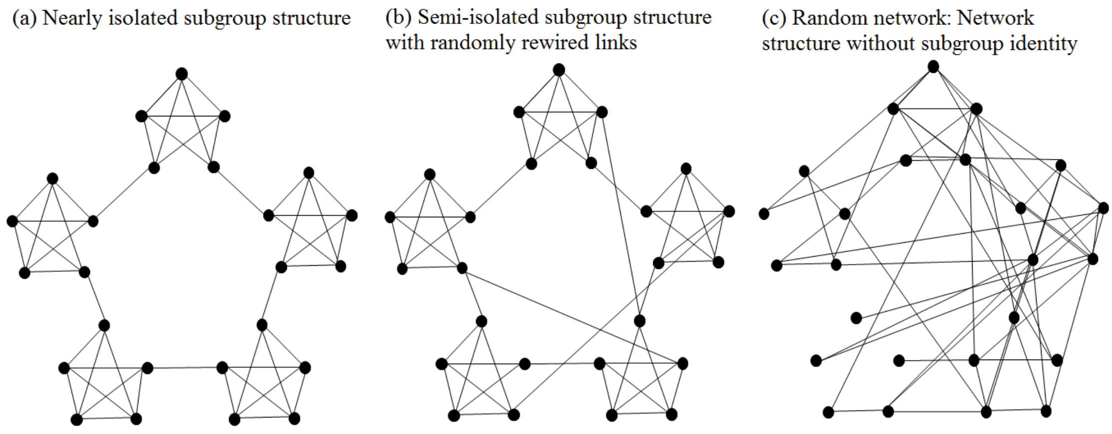

Figure 4. Connected Caveman Model (retell Watts 1999; Fang et al. 2010)

The model uses modified NK model to measure performance called the “generalized m/s payoff function” where s constitutes for interdependence and m for the dimensions of the problem. For example, if problem has five dimensions (m = 5) and s = 5 the individual needs to identify correctly in all five dimensions or else their payoff is zero. If in the same situation s = 1 and the person has four correct dimensions and one incorrect their payoff is four. In this model s = 5 and m = 100 corresponding to moderately low interdependence. (Fang et al. 2010)

The diversity of individuals is measured with “dissimilarity index”:

$$(1)\ Dissimilarity = \frac{2}{mn(n-1)} \sum_{i=1}^{\frac{n(n-1)}{2}} \sum_{j=1}^{m} \omega_{ij}$$

Where n is the number of individuals and m is dimension of the belief (Fang et al. 2010).

From their simulation models Fang et al. (2010) were able to discern that most optimal connectivity between sub-groups lied between $\beta \in [0.05, 0.1]$ resembling the semi-isolated subunit present in figure 4(b). At all values above $\beta \geq 0.1$ the long run performance showed decrease. This is assumed to be due to faster spread of ideas throughout the organization leading to faster homogenization in divergence of beliefs and lack of diversity.

Although performance was impacted negatively by larger subgroup sizes due to faster homogenization, the semi-isolated subunits remained the best the best performing organizational structure. Similar results were shown when introduced with different rates of turnover and environmental dynamism and organization sizes showing robustness of the structure in different environments (Fang et al. 2010).

The results of the simulation bring with few additional extensions to the March (1991) model and seem to compliment the ever-growing academic work on organizational ambidexterity (e.g. Duncan 1976; Katila & Gautam 2002; Lavie, Stettner & Tushman 2010; O'Reilly & Tushman 1996) confirming the theoretical and empirical basis of structural ambidexterity in organizations through a very robust simulation model. Another interesting takeaway could be the excellent performance of particularly small semi-isolated sub-units of seven people compared to other sub-unit sizes which could enhance the accuracy of the existing research literature on ambidextrous organizations (Fang et al. 2010).

3.6.4 Information technology and organizational learning

Kane and Alavi's (2007) present a computational model based on March's (1991) original work introducing information technology to his model that has become increasingly relevant in the current state of organizational learning. The model introduces IT-based learning mechanisms through e-mail, knowledge repositories and groupware that all serve a different function in organizational socialization.

Kane and Alavi (2007) use a case-organization studied by (Alavi et al. 2005) who are leaders in applying IT-based tools in organizational learning. The sample company called "Company Z" uses three types of IT for organizational learning. A disparate knowledge repository, a virtual team room where individual project teams can share and discuss specific knowledge with one another that also works as a knowledge storage and thirdly e-mail and instant messaging as a way of connecting employees and sharing knowledge forming electronic communities of practice where people with mutual interests and expertise can share knowledge as a way of introducing interpersonal learning and learning across the groups. Each period the individuals have set probability of choosing one of the methods of learning. The individuals were split into 10 separate teams of 10 with a number. (Kane & Alavi 2007)

Each team contributes to a knowledge repository collectively. Each time period the team synthesizes knowledge from the most knowledgeable individuals whose knowledge level of the external reality is above the group average and choose the majority belief for each dimension from this group which will form a single knowledge vector for the team's knowledge repository which is then compared to the external world and given a knowledge level. Individuals can also look-up information from other team's knowledge repositories that possess superior knowledge compared to theirs called the ϕ_{KRP}-group and adopt the beliefs of the knowledge vector with likelihood of p1 for each m dimensions. (Kane & Alavi 2007)

Team rooms are only accessed by the team members and if an individual chooses to learn from the team room they will only learn from individuals within the team with higher level of knowledge called the ϕ_{TR}-group and for each dimension adopt a majority value of this group with the likelihood p1. (Kane & Alavi 2007)

Electronic communities of practice (ECOP) are assembled at random from the entire population and form total of four separate groups in the organization. Individuals within the ECOP group form a subnetwork with whom they have similar interests with. The probability that the individuals share similar interests within ECOP groups and are willing to learn from one another has a set value of $p_i = 0.25$. From this subnetwork of people, the individual will only learn from those with higher levels of knowledge compared to theirs called the ϕ_{ECOP} -group. Individuals in this group also only share portion of their knowledge-dimensions and not the whole knowledge vector that the individual can compare themselves to called R_{ct}. They will adopt these beliefs with the likelihood of p1. Each individual can belong to only a one group at a time. Individuals can also learn from a random individual within the organization with a probability of $p_{ni} = 0.02$. (Kane & Alavi 2007)

The results from the simulation shows similar patterns to March's (1991) work where methods that encourage rapid short-term learning (exploitation) such as knowledge repositories and team rooms converge quicker with the organizational code yielding poorer long-term performance. Due to the sporadic nature of ECOP it encourages more exploratory behavior within the organization and sustains a higher knowledge variance within the population allowing the organizational code to learn longer from the individuals leading up to better long-term performance.

Due to the tendency for organizations to favor exploitation (Levinthal & March 1993; March 1991) combining exploitative IT-learning mechanisms with ECOP quickly eroded the variance introduced by ECOP leading to weaker performance, team rooms and knowledge repositories showed increased performance when combined with other mechanisms. Due to exploratory nature and introduction of variance by ECOP as a learning mechanism it also manages to offset exploitative behavior from the individual learning rates and contradictory to March (1991) showed highest level of performance with individual learning rates of $p_1 = 0.9$. Other IT-learning mechanisms showed little to no change at different individual learning rates. This also meant that organizational turnover as a means of introducing variety was not necessary and in fact produced weaker performance with all learning tools, though it's also important to note that the exploitative tools were also more resistant to turnover. (Kane & Alavi 2007).

Kane & Alavi's (2007) simulation further support March's (1991) claims of knowledge variance improving long-term performance but also provides important insight in choosing appropriate IT-tools for organizational learning. Depending on the organization's strategy, turnover and environment there's an important distinction to be made. As an exploratory tool ECOP supports more stable and exploitative strategies with faster learning while knowledge repositories and team rooms seem to do to the exact opposite due to their more exploitative nature. The study provides important distinctions when considering the compatibility of different IT-based learning methods as ECOP showed significantly improved results when used independently while other tools benefitted from one another. Kane & Alavi's (2007)

3.7 Synthesis

Since the emergence of March's (1991) article on exploration and exploitation many of the original claims and definitions have evolved significantly although some of the more fundamental beliefs have stayed the largely same.

March (1991) argued that exploration and exploitation are consuming fundamentally scarce resources for which organizations compete for and have a dependency in gravitating towards one or the other through path-dependency. Some academics (e.g. Gupta et al. 2006; Katila & Ahuja 2002) have refuted these points by pointing out that depending on the context some resources such as information, patents, strategic alliances could in fact be infinite and the nature of exploration and exploitation can in certain environments in fact be orthogonal instead existing on a competing continuum. Lavie et. al. (2010) also argued for the "paradoxical association between exploration and exploitation" which implies that instead of being path dependent and incompatible the knowledge gained from exploration could instead support further exploitation and the resources from exploitation could similarly support organizational exploration.

The ways in which organizations could balance their exploration and exploitation has also come under question. Originally (Levinthal & March 1993; March 1991; Tushman & Romanelli 1985) argued for the punctuated equilibrium approach where organizations take a sequential approach switching between short periods of exploration and longer periods exploitation. Since then a completely new field of research as arisen on ambidexterity (Wilden et al. 2018) considering the capabilities of organizations to perform exploration and exploitation simultaneously through either structural approach by splitting the organization into smaller sub-units (Tushman & O'Reilly 1996; Tushman & O'Reilly 2013) or contextual approach in which the organizational culture encourages the individuals to engage more freely in both exploration and exploitation as they see fit (Gibson & Birkinshaw 2004).

The empirical evidence (e.g., He et al. 2004; Katila & Ahuja 2002; Uotila 2009) as well as the simulations models (e.g., Fang et al. 2010; Miller et al. 2006) both seem to be in favor of the structural ambidextrous approach for organizational management showing significant improvements in performance in comparison to alternative methods even throughout various levels of environmental dynamism and organizational turnover, although it is very likely that many organizations engage in all of the aforementioned strategies at different time periods or even simultaneously (Gupta et al. 2006; Kauppila 2010; Tushman & O'Reilly 2013).

What remains unchanged however is the almost universal agreement about the benefits of internal variability for the organizational knowledge and performance as well as durability towards environmental dynamism. Originally proposed by March (1991) the same sentiment is echoed throughout academic literature. Whether variability is introduced or sustained through organizational turnover (March 1991), IT-assisted learning mechanisms (Kane & Alavi 2007) or maintaining a loosely connected sub-unit organizational structure (Fang et al. 2010) the results remain the same. Maintaining higher levels of internal variety of beliefs and knowledge among individuals produces better long-term organizational performance and knowledge when compared to purely explorative or exploitative strategies.

Even if the exact ideal ratio between exploration and exploitation is not completely agreed upon as it might also be dependent on the turbulence of the external environment (He et al. 2004; Kim & Rhee 2009; Uotila et al. 2009) both the simulation models and the empirical evidence are in support of March’s (1991) most fundamental claims about there needing to be a balance between organizational exploration and exploitation and that engaging in only one type of behavior cannot be sustainable in the long run.

4 CONSTRUCTING THE CONCEPTUAL MODEL

4.1 Definitions and requirements

The definition of a conceptual model according to Robinson (2008) is “the process of abstracting a model from a real or proposed system”. The purpose of building such model is to fulfill four basic requirements: validity, credibility, utility, and feasibility. In short, this means that the purpose is to build a conceptual model that will make sure the planned model fulfills its intended behavior, it is easy to understand and use, and that we have the time and resources required to build the intended model.

The first part of conceptual modelling framework is understanding the problem Robinson (2008). In our case the problem situation could be defined as the difficulty of communicating, visualizing, and building upon the current model of exploration and exploitation by March (1991). The model will also function as validation for the results reached March’s (1991) simulation model.

Secondly, we will want to look at the objectives of the model. These can be divided into few different objectives. What is the gain we want to achieve from using the model and the nature of our projects objectives as in the time-scale and resources available and lastly clarifying the nature of the model for example, how the model performs and what kind of general features it might have (Robinson 2008).

Important objective is the aim to replicate and validate the results reached by March (1991) in his work to closest possible extent. For our purposes, the general goal of the model is to represents March’s (1991) original model in such a way that it’s easily communicable and visualized through simple 2D animations, reusable, and extensible. Also increasing of the awareness and availability of modelling in organizational sciences and social sciences in general could be considered as another objective of this model. As the scope and time limits of this project are very narrow the aim is to use a very conservative model design. It would be important to make the model easy to use through simple interactive features for accessibility.

The next goal is to recognize the inputs and the outputs to the model. The goal of outputs is usually to either identify that the modelling objectives have been achieved and if the objectives aren't being achieved, why that would be the case. The goal of inputs is to serve as the data that can be changed for the modelling goals to be achieved, which means changing the rules or the quotative data in the model. (Robinson 2008)

Following March's (1991) model the wish is to follow the same model outputs and inputs as in the original. This means we want to be able to measure the average equilibrium of knowledge within the organization with a simple line chart that works with a time-series to determine the achievement of the objectives. The model will have significantly more inputs. Modifiable inputs in the model should be both the rate with which the individuals learn from the code and the code learns from the individuals. We should also be able to impact the rates of turnover and environmental turbulence as well as number of individuals, dimensions of reality, and the repeated simulations.

It is also necessary to determine the model's content in terms of scope and level of detail that the model contains. Determining the model scope requires splitting the simulation models into four type of components. entities, activities, queues, and resources (Pidd, 2004; Robinson 2008). Entities are often things such as "parts in a factory, customers in a service operation, contacts in a call center, and information in a business process." Activities are physical objects such as machines and computers. Queues are defined as different systems, buffers and waiting areas. Resources are staff and the equipment. Determining the level of detail requires making decisions about the amount of detail for each component in the model scope. This means making decisions about the levels of detail for each of the four categories. (Robinson 2008).

In our simplified model of March (1991) the components we will address in the model are the individuals within the organization as a resource, individual and code learning rates, turnover and environmental turbulence, and the external environment. The level of detail for the individuals is simply the quantity of the individuals as well as their beliefs about the reality. The individual, code, turnover and environmental turbulence will be addressed a probability ratio of change. The external reality will also be addressed value that the individuals and organizations beliefs are compared to.

Model assumptions and simplifications are part of determining the project scope. When making assumptions there might be uncertainties or beliefs about the modelled phenomena in the real world, while simplifications are conscious decisions of allowing more rapid development and use of the model (Robinson 2008).

The conceptual model will pose some assumptions. In the model will for example assume that the number of individuals will always remain static despite turnover rates, they will be instantly replaced by someone. Similarly, the model assumes that the frequency and the amplitude of both environmental turbulence and turnover rates remain the stagnant throughout the simulation and will not vary. Every individual will hold true, false or indifferent beliefs and the external environment will hold true or false beliefs without any possible gray-areas in-between.

When it comes to March (1991) several significant simplifications have been made to the model that will also be incorporated into this model. The simplifications can be reliably addressed by referring to other scholar's work in this matter. For example, Miller et al. (2006) shows that tacit knowledge, interpersonal learning, and location in space to the agents which also allows differentiating between local and distant search have significant impact on organizational learning. This has also been addressed by Levinthal & March (1993) as "spatial myopia". Fang et al. (2010) address the network structures in communication and their impact on learning as well as introducing interdependence in learning through modified NK-model. Kane & Alavi (2007) noted the impact between explorative and exploitative IT-based learning mechanics within and their impact on organizational learning.

These are the examples of simplifications based on the material of this thesis. Other possible simplification to the model not introduced here could include things such as organizational forgetting (Blaschke & Schoeneborn 2006) or the impact of organizational selection mechanisms such as promotion based on tenure versus performance and difference between promotion between recent and extended performance on organization's knowledge level (Rodan 2005).

Lastly, we will need to identify the data requirements for the proposed model. The data requirements can roughly be roughly be split into three distinct categories: "contextual data, data for model realization, and validation data" (Pidd 2003; Robinson 2008). Contextual data is often required to gain a thorough understanding of the problem and aid in the construction of the contextual model. Data for model realization can be gathered from the level of details required for each component. The validation data can potentially be gathered from previous data or empirical evidence (Robinson 2008).

In this example the required data and validation will come from the March (1991) from the ability to replicate his results. The data for model realization can also be built from the detail requirements constructed earlier. The empirical studies explored in this thesis can also function as a form of validation for the constructed model.

4.2 Signifigance of validation

Though there are some scholar's that argue against the importance of validation in organizational sciences (e.g. Van Maanen 1995) validation still has its purposes in right context. For example, Davis et al. (2007) argue for a contingent approach for validating simulation-based theories. In their view the importance of validation depends highly upon the basis of the constructed model and theory. If the model has been built-upon a strong grounding in empirical evidence the significance of validation diminishes, but if the theory and models are only based in nonempirical arguments such as analytics or other detached disciplines like physics validation becomes more important. Being able to replicate the results as there is always a risk of faulty code and programming errors in computer-based simulations (Davis et al. 2007). The purpose of this type of model testing is the verification of behavioral accuracy and returns the expected results (Balci 1998).

Whereas the original model of March (1991) did not have the empirical grounding one would expect, by now the results of the model have been confirmed by significant amount of empirical research (e.g. He et al. 2004; Katila & Ahuja 2002; Kim and Rhee 2009; Kauppila 2010; Uotila et al. 2009). Though this thesis will not be able to validate the results through empirical data, it seeks to contribute by providing a platform for future model that is able to replicate the results of March (1991) as there is always a risk of faulty code and programming errors in computer-based simulations (Davis et al. 2007). The purpose of this type of model testing is the verification of behavioral accuracy and returns the expected results (Balci 1998).

5 CONCLUSIONS

Historically simulation models have been severely underused and underdeveloped in the study of organizational sciences. The aim of this thesis has been to bring awareness and availability of simulation modelling by exploring the different approaches of simulation modelling in organizational sciences as well as introducing the reader to one of the most influential simulation models in organizational sciences. The work briefly explored few of the most popular examples of simulation modelling organizational sciences and their applicability in varied scenarios. Currently the most common of these methodologies in organizational sciences appears to be agent-based modelling due to its ability to assign individual-level behavior and construct the system as an emergent structure that manifests itself as the socialization between individuals.

Another focus of this work has been the study in development of ideas about the fundamental nature of exploration and exploitation in organizational learning and the development of March (1991) simulation model through both empirical research as well as extended simulation models based on the original work conducted by March (1991).

Research into the concepts of exploration and exploitation as proposed by March (1991) showed some distinctive fluctuation between the agreeance on the definitions of exploration and exploitation as well as significant development of the original ideas. The results seem to largely disprove the competitive nature for scarce resources of exploration and exploitation and instead show potentially cumulative from these organizational behaviors. The methods in which organizations should engage in the balance of exploration and exploitation have come under keen scrutiny and in support of ambidextrous approach instead of sequential engagement in exploration and exploitation. Both the empirical evidence and simulation models have seemed to have to be in a concordance regarding aforementioned results and also agree on the fundamental claims of improved performance under heterogenous exploration and exploitation although the exact degree in which organizations should engage exploration and exploitation seems to be highly dependent on the environmental turbulence.

Parameters from the simulation models studied in this work operate as a part in the construction of the conceptual model. The conceptual model will function as a basis for the future work in the development of ideas and the simulation model constructed by

March (1991). The conceptual model offers simple guidelines in the future work of replicating the March (1991) model with modern tools as well as highlights the possible assumptions and simplifications in his original work. The work conducted here should also offer wide variety of information and guidance towards choosing the right modelling approach based on the explored simulation modelling techniques and the constructed conceptual model.

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