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Graduate School of Education and Psychology

PATTERNS OF CHANGE IN ORGANIZATION PERFORMANCE

A dissertation submitted in partial satisfaction

of the requirements for the degree of

Doctor of Education in Organization Change

by

Terrill Lee Frantz

October 2004

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Under the guidance of a Faculty Committee and approved by its members, has been submitted and accepted by the Graduate faculty in partial fulfillment of the requirements for the degree of

DOCTOR OF EDUCATION
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DEDICATION

This completed work is a permanent dedication:

* To my Mom and Dad, who continually and forever demonstrate the power of leading by example,

* To my wife, Darin, and six year-old daughter Nikita who have lovingly provided more to this effort than words will convey, and

* To my sister, Lynn (1955-2004) who was tragically denied the God-given right to live to see this work be completed.

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ABSTRACT

This study involved the examination of computer-simulated organization-performance data. The researcher found discernable patterns of performance improvement and decline in 100 simulated case histories. The ability for current patterns to identify the future change-direction of performance was also explored and evidence was found that certain specific patterns are more predictive that others. Discovery of an organization's change-pattern profile may serve as: (a) A technique to gain deeper insight into the underlying dynamics of an organization's behavior, and (b) an early warning technique usable by change-practitioners and managers. Change-patterns were constructed by using the symbols, + and -, representing the direction of the change, e.g. improvement or decline, in performance levels between two adjacent reporting periods. Change-patterns derived from between 2 and 6 time-periods were studied. In the abstract, the simulated organizations' performance task was a binomial categorization problem in which performance was defined as a measure of the organization's decision-making accuracy. Sample data were generated from a computational model of an adaptive and task-oriented organization embodied in an agent-based computer simulation. The simulation—specifically the ORGAHEAD model—was run 100 times, generating 100 performance values for 100 time-periods, for each case. This resulted in a total of 10,000 performance values being investigated in this study. A total of 48,500 unique change-patterns were analyzed. A Runs Test was applied to the performance change data and evidence was found that temporal performance data showed a sign of serial dependence. Implications for the findings of the study and areas for further research are identified.

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Chapter One: Introduction

The purpose of this study was to explore patterns of change in organization performance and to investigate whether past change patterns can identify the direction of the next performance change. The basis for the change patterns investigated is the directional change (the increase or decrease) of performance levels for up to six consecutive time periods. Having a pattern-based perspective on the future direction (improvement or decline) of an organization's performance, provides change practitioners additional insight that aids in evaluating intervention decisions.

Patterns are abundant in nature (Camazine, 2003). The shape of a spider web or snowflake, the colors of a butterfly wing, a zebra's stripes each contain an observable visual pattern, while temporal patterns occur in ocean waves and tides. There is a complex pattern to the weather and perhaps a yet-to-be-discovered pattern to earthquake frequency.

Concurrently, human beings seem to have a natural disposition to seeking out patterns. Recognition of a pattern can bring perceptual order to an increasingly complex world. Uncovering a hidden pattern may introduce a welcome sense of predictability of what the future might bring.

Recently social science researchers have joined physicists, mathematicians, biologists and others, in searching for patterns in their respective subject matter. Their research increasingly includes the application of complexity theory and its underlying techniques. Researchers recognize that some phenomena, when analyzed at certain levels,

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often exhibit a clear pattern that can sometimes be rationalized by a few simple rules of behavior (Wolfram, 2002).

This complexity-based perspective may be necessary to making large advances to existing knowledge in the sciences. Traditional organization-science research techniques and perspectives may have run their course. These tools may not be as effective in today's increasingly multicultural and complex organizations.

By applying contemporary techniques, researchers have been successful in discovering patterns embedded in social and organizational behavior. The Elliott Wave Principle of Human Social Behavior is being applied as a predictor of stock market prices. Its primary contention is that changes in social mood cause and therefore precede changes in the *character* of social events. In essence, patterns of the past precede and affect future behaviors. The Elliott Wave Principle finds that social moods are patterned in a wave shape (Prechter, 1999) that fluctuates between peaks and valleys. The technique of technical stock market analysis is based on patterns of past stock prices and market behavior. Although still controversial when applied to the stock market, the theory underlying the Elliott Wave Principle has been heralded as a predictor of everyday events since such events are ultimately based on the pattern of collective human emotion (Casti, 2002).

Predictive patterns are evident in some existing organization theory. The idea of the s-shaped Diffusion of Innovation Curve was first supported empirically by a study of hybrid seed corn in Iowa (Ryan & Gross, 1943). This curve, a widely recognized predictive pattern of group behavior which typifies the cumulative number of adopters of

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an innovation in a social system over time has been applied to the study and understanding of the different innovation adoption rates by individuals (Rogers, 1995).

Well-known organization researchers and theorists have observed patterns in organizations and have reported the phenomena in their publications. Nearly 25-years ago, Mintzberg (1978) recognized organization strategy as being "a pattern in a stream of decisions" (p. 934). Earlier in the classic book, *A Behavioral Theory of the Firm* mangers' attention to organizational goals was recognized as having a sequential pattern thus being counterproductive (Cyert & March, 1992).

A frequent measure of an organization's success, its performance, has not been subjected to rigorous scientific search for underlying patterns. In response to this oversight, this study addresses two unexplored questions: (a) is there a pattern to organizational performance, and (b) is there a recognizable underlying pattern that foretells future organization performance?

Some organization managers may be at ease with the notion that in order to move two steps forward, organizational progress may sometimes have to take one step backward. But, managers may question whether the steps backward are necessary, desirable, or excessive. Understanding both the patterns of performance and their predictive capabilities may help managers make wise policy and intervention decisions.

Purpose of Study

The purpose of this study is through use of computer simulation to explore current temporal patterns of organization performance and to investigate whether such patterns may be suggestive of future performance. This study provides evidence of underlying

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patterns in performance and explores the possibility of their predictive ability. Knowledge of patterns and their usefulness in foretelling future performance can provide valuable insight for change practitioners. This study also intends to serve as an example of utilizing contemporary research techniques, specifically computer simulation, which can provide organization researchers with significantly expanded research capabilities.

Research Questions

Through the analysis of computer-simulated organization performance data, the following research questions are asked in this study:

1. For the examined cases, what is the frequency distribution of organization-performance change patterns?
2. For the examined cases, to what extent does the current organization-performance change pattern identify the direction of the next change in performance?
3. For the examined cases, is the current direction of change in organization performance independent of the prior direction of change?

Background

Although organization performance has been studied in-depth for many years (e.g., Likert, 1958) it seems to continue to have an elusive notion. With little agreement (Cameron & Whetten, 1981; Ford & Schellenberg, 1982) on a single definition of performance, with wide inconsistency in defining the boundaries of performance, with conflicts in theories of causality (Lenz, 1981), and with arguments over the influence of the environment (Lawrence & Lorsch, 1986; Pennings, 1975), the call to better

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understanding and further study of organization performance seems clear. Nevertheless some researchers have suggested abandoning performance as a research topic (Cameron & Whetten, 1981; Goodman, 1979; Hannan & Freeman, 1977). However, its relevance cannot be overstated since, by definition, all organizations are seeking high performance and long-term performance success is rare (Wiggins, 1997; Wiggins & Ruefli, 2002). Evaluating the success of management's drive toward its own effectiveness (Barnard, 1968) is highly correlated to organization performance, making such measures *personal* for many of the measure's stakeholders.

Understanding and, subsequently, managing performance is hindered by the increasing complexity of the underlying organizational system. When viewed as an *open* system — a system that has an exchange with the environment as opposed to one that does not (Coveney, 1991) — an organization has many simultaneously interrelated moving parts and needs to perform within an environment that is in constant flux (Hanna, 1988; Lawrence & Lorsch, 1986). However, from a systems theory perspective, performance is a *closed* system with performance being, "not simply a dependent variable" (Child, 1974a, p. 176) — high performance often begets higher performance, which has been demonstrated in laboratory studies (Shea & Howell, 2000). Even the intangible, such as personal and organization aspiration levels can have an affect on performance outcome (Greve, 1998).

Perhaps somewhat counter-intuitive but also obvious is traditional organization theory's suggestions that poor performance promotes organizational change (adaptation), which then leads to improved performance. Empirical evidence fails to lead to such

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conclusion, although researchers have not yet proved a positive result always emanates from such a process. Post adaptation, organization performance often remains the same or frequently declines. (Donaldson, 1999)

How performance is perceived and success is judged stems from one's view of the organization (Ford & Schellenberg, 1982). Many studies of performance consider the trait approach to evaluate outcome by focusing on the characteristics of the organization's culture (Gordon & DiTomaso, 1992). Social Network Theory considers the relationships among organization members as the primary driver of performance (Burt, Gabbay, Holt, & Moran, 1994). Systems Theory considers the underlying system dynamics as the main driver of performance. This study is mainly influenced by the perspective of Systems Theory with a respectful appreciation of other perspectives.

Having dynamical characteristics suggests, and empirical evidence supports, that organizations are complex (Anderson, 1999) and surprising (Daft & Lewin, 1990) and that their behavior is nonlinear (Casti, 1994). Relative to linear phenomena, nonlinear dynamic systems are difficult to predict, and thus a challenge to manage. However, while patterns may be complex at one level of analysis often simple patterns become apparent when analyzed from a different perspective. Clarity concerning the level of analysis is essential to sound theoretical argument (Bidwell & Kasarda, 1976). Past studies of organization performance have disagreed on just what the *relevant* level of analysis should be (Cameron & Whetten,1981).

While the core perspective of this study is from the Systems Theory viewpoint, a more postmodern view of the organization is also embraced. Wheatley's (1999) view of

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organization from "37,000 feet" (p. 4), which is the vantage point of this study, considers the organization as a complex dynamic system with interdependent parts. Although not a specific set of theories, Complex Systems Theory presents itself as a perspective with three facets (Morel & Ramanujam, 1999): the characteristics of the system studied, the analytical tools used to perform the study, and the paradigms of chaos theory that characterize complex systems.

Exploring an organization from the perspective of a complex dynamic system is relevant not only to deeper understanding, but also has implications for the organization's own self-development practices. As Guastello (1995) points out, embracing such a paradigm is to invert Lewin's unfreeze-change-freeze paradigm of organization change. Instead, change is the steady state of affairs. Anything appearing frozen is just a temporary hiatus between turbulent changes.

As organizations are dynamic systems, *time* is a dimension essential to understanding behavioral phenomena. (Coveney, 1991). This fourth dimension seems somewhat neglected in most conventional organization research (Frantz, 2004) and when *time* is acknowledged, studies often treat it as a neutral and passive variable (Torbert, 2002), as a boundary condition (George & Jones, 2000), or as an action. Recently, however, George and Jones (2000) have argued that the time dimension should play a far more important role in organization theory, claiming that such an emphasis will result in better theory. As this study demonstrates, holding a time perspective is an essential element to understanding organization performance.

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The time-interval assumption made in organization studies is a critical consideration to the relevance of a theory (Zaheer, Albert, & Zaheer, 1999). For example, theories of trust in an organization are time-dependent, since there are different factors affecting personal trust from the short-term and long-term time scales (Blau, 1964; Zucker, 1986) (e.g. demographic-based and interaction-based, respectively). While mathematical time is continuous, in their analysis of a series of data over time, human beings manage and calculate time according to varying time intervals, which can lead to vastly different meanings and conclusions (Zaheer, Albert, & Zaheer, 1999).

Seen from the perspective of time, the evaluation of performance can appear to be mysterious. However, by suggesting that for each of the three time horizons for organizational planning—short-term, medium-term, and long-term—different evaluations should be made. Gibson, Ivancevich and Donnelly (1973) have devised a model that can make time seem less unwieldy. This study also seeks, by serving as an example, to reduce the reluctance of including a time dimension in organization research.

Significance

There are two primary implications of this study. First, this research has practical implications since it deepens the understanding of organization performance; thus leading to more effective change-intervention decisions. Second, and more strategic, this research helps to extend the bridge between the established conventional organization-scientists and the emerging community of computational (using mathematics) and complexity theorists.

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This study is significant for change practitioners, including managers, because it suggests that performance, when viewed through a pattern-seeking lens, may provide insight that is not evident using more traditional lenses. Recognizing organization performance patterns benefits these decision makers by providing a basis for aiding decisions such as the timing of new interventions and ending existing change programs.

Historic measurements are a time-lagged measure of activity and provide a view similar to that of looking into a rear-view mirror. By recognizing predictive patterns in advance of performance failures, decision makers can intervene with preemptive strategic changes before unwelcome levels of performance occur. Moreover, recognizing natural ebbs in organizations' performance levels can temper costly knee-jerk reactions to a temporary lapse in performance. As the adage goes, *if it ain't broke, don't fix it.* Similarly, recognizing performance improvement as a fleeting event can prevent leaders from embracing such a phenomenon as a permanent trend.

Although the performance level of an organization determines the likelihood of different types of organization change (Greve, 1998), it should be acknowledged that performance is not the only possible driver toward change. Commitment to a losing course of action (Staw, 1981), for example, can circumvent performance level change indicators. In addition to performance levels, the motivation, opportunity and capability to change can spearhead the drive to change (Miller & Chen, 1994). The researcher believes these factors can be better managed by incorporating knowledge of performance patterns into the decision-making.

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Two contemporary aspects of this study are its use of computer simulation and its approach to performance from a multidisciplinary perspective. The use of computer simulation to manufacture data is still a new methodology for organization research, but it is one that has been increasingly employed in recent studies. The multidisciplinary approach sanctions that the same phenomena when looked at through the various lenses of other disciplines (such as physics, mathematics and economics) and their tools (such as time-series analysis and computer simulations) may provide new insights that further understanding when applied in conjunction with conventional research techniques.

This study also forms a base for future research and for progress in the important area of organization performance and change management. It is the researcher's hope that this study leads other researchers beyond exploration of patterns to the development of models which are predictive in nature.

Following Chapters

There are four chapters following this first chapter. Chapter Two is a review of the current literature pertaining to organization performance, organization as a dynamic complex system, organizational rhythm, and organization performance levels over time. Chapter Three describes the research method, including the study design, procedures, methodology, limitations, and other specifics. Chapter Four presents the case data generated and findings from analysis of the data. Chapter Five presents the research conclusions and recommendations, including implications of the study and recommendations for future research as well as closing comments.

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Chapter Two: Literature Review

The purpose of this chapter is to ensure a common knowledge base exists across the readers of this study and to further underscore the scope and challenge to researching performance patterns. This is achieved by providing a review of the literature in several relevant supporting areas. By assembling the work of varied inter-discipline researchers, a perspective is provided which leads to recognizing the subtleties and complexity of performance pattern research.

There are two major sections in this literature review. Together they provide both broad-brush coverage on important and relevant topical areas and an in-depth review specifically on existing research in performance patterns. The sections are entitled, Towards a Unified Perspective, and A Retrospective of Organization Performance Over Time.

The first section is presented in three parts. It begins by covering traditional research on organization performance in general, then introduces the evolving thinking surrounding dynamic complex systems. The third part brings together a collection of research and thinking on the ebb-and-flow of an organization's life. This ebb-and-flow concept is being referred to in this document as "organizational cadence." Throughout this entire section, relevant terminology will be included and explained in order to prime the reader for later chapters.

The second section of this chapter, A Retrospective of Organization Performance Over Time is directly topical and poignant to this study. The section assembles relevant fragments of research from a variety of different researchers. Bringing this together into

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one place provides an invaluable single source of current knowledge specific to performance over time.

Towards a Unified Perspective

Research literature from three pertinent subject areas is provided here to construct a unified and grounded foundation leading to a baseline of knowledge for the readers of this study. This groundwork paves the way for more poignant discussions in the later chapters.

Espousing Organizational Performance

Organization performance is a subject prevalent in organization theory research. However, the notion of organization performance has many different forms thus leading to conflicts and contradictions in its definition. The lack of a single clear definition may be problematic when trying to measure and evaluate organization performance. Furthermore, the plethora of causal research seeking to discover the single characteristic responsible for high performance has little hope of attracting the interest of organizational leaders and operational change agents. Without agreement around a definition and consistent measurement, determining the drivers to performance becomes a mute activity. There may be little hope for organization performance research being adopted by managers and change agents without definitional clarity. As the following discussion depicts, research on organization performance is imprecise but understanding it remains essential.

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An enduring theme. Organization performance may very well be the most researched notion in the social sciences. It has long been of keen interest to traditional research in organization science. Perhaps its beginning can be found in the time of the Stone Age. Perhaps in the hunting and gathering societies, hunters organized around a collective need sought to improve their hunting and gathering performance to better feed their dependents. They invented tools and they organized to improve their performance. Perhaps one can categorize these early thinkers as action researchers.

Organizations exist to perform. Organizations are formed as a solution to the limitations of an individual's capacity to perform, thus superior performance is at an organizations core. The pursuit of superior performance has been identified as organizations' "prevalent" objective (Rumelt, Schendel & Teece, 1994).

Performance as an innate drive of an organization is so prominent, that the analysis of performance has been christened an "enduring theme" (March & Sutton, 1997, p. 698). Nearly every study of organization makes at least some reference to the phenomenon (Yuchtman & Seashore, 1967).

The stock market's vicious appetite for increasing financial performance clearly adds to the momentum of this enduring theme. Perhaps there is a cynical explanation. The attention to organization performance may be partially explained by the findings of Ouchi and McGuire's (1975) study. Their research suggested that managers' feel a need to provide superiors with legitimate evidence of their management skill and that performance measures can provide the evidence they seek. The focus on performance may merely be the popular response to the organizational condition of "many available

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solutions seeking a problem" as suggested by the study, "A Garbage Can Model of Organizational Choice" (Cohen, March & Olsen, 1972).

In the academic community, studies pertaining to organization performance abound. A recent electronic search of the Academy of Management (AOM) publications library resulted in finding the term "performance" in the title of 606 AOM articles. In the "default fields" (Title, abstract, keywords, etc.) search, "performance" was found in 1,426 articles. As the Academy first published in August 1954, this suggests that "performance" appears in the title of one of the Academy's several publications on the average of once per month.

Since it's first issue in 1923, the Harvard Business Review has "performance" in the title of 67 articles and the term can be found in the key search fields of 553 articles. (Note: These electronic searches for the word "performance" ultimately includes various types of performance beyond organizational, i.e., individual, financial, et cetera.)

At Amazon.com, there are 312 books listed in response to a search for "organization performance", and "over 32,000" listed for the word "performance."

There is some further ambiguity (March & Sutton, 1997) to the academic study of performance. The terms "performance" and "effectiveness" have been used interchangeably in and across organizational studies (p. 705).

Much of the academic research conducted directly on the topic of performance has focused on identifying the underlying drivers to superior or problematic performance, or the impact under special circumstances such as time constraints (Canady, 1968; Lin, 1994). Performance is studied as a characteristic of an organization or as a measure of an

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individual (Paull, 1980). In academic studies, performance is usually treated as a dependent variable instead of being regarded as an independent variable (Yuchtman & Seashore, 1967).

Even with so much attention to the study of underlying drivers, there seem to be no answers that lead to specific actions a manager should take in a specific situation. Reviews of interdisciplinary studies seeking to identify the determinants of performance found such research broadly inconclusive (Lenz, 1981). One such review has even found, "in a few instances", contradictory results across empirical and case studies. (Lenz, 1980).

Should such a history of confusion and in-conclusion warrant a deeper rethink? The confusion surrounding the study of performance has gone so far as to even prompt the wonderment of the usefulness of studying the concept. (Hannan, Freeman & Meyer, 1976)

Clearly, organization performance and the study of it are many different things to many different people. Regardless, studies will continue to involve performance, directly or indirectly, as it remains an enduring theme of interest to researchers, authors and managers alike.

The notion of performance. A single definition of organization performance eludes researchers and efforts to understand the notion are hindered by its abstractness. Measuring performance, without an agreeable definition, is debated endlessly as the outcome affects many varied stakeholders. However, just as Justice Potter Stewart's court

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opinion on obscenity for the U.S. Supreme Court *Jacobellis v. Ohio* (1964) case goes, "But I know it when I see it...", observers seem to know organization performance when they see it. The notion must exist, but researchers are unable to satisfactorily define it.

A study reviewing seventeen models of organizational performance suggested that effectiveness (a.k.a. performance) is an *abstract* idea rather than a *concrete* phenomenon. The author even poses the question asking if there is really such a thing as organization effectiveness at all (Steers, 1975).

There have been efforts to "demystify" (Hanna, 1988, p. xii) performance. However, disclaimers (p. xiv) accompany such efforts. An article in the Academy of Management points to the broad disagreement over the concept of performance among authors (Ford & Schellenberg, 1982). Regardless, even if such disagreement were to be resolved, as Scott (1977) suggests, there are continued contradictions in research. Scott questions the underlying assumption of a link and a correlation between the characteristics of an organization and its performance.

As an abstract construct, performance may be merely a collection of several variables that have been cognitively joined together into a single whole (Steers, 1975). Furthermore, such abstract collection of variables may have little to do with one another. An approach of measuring performance by separately measuring components was utilized in an organizational study, which found that there were "relatively few significant" relationships amongst some of the components studied (Friedlander & Pickle, 1968).

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Even if relevant variables were chosen and formulated into a single value of performance, such single measure may remain controversial. Keeley (1982) presented the multiple constituency problem which enhanced his earlier constituency (Keeley, 1978) theory at a more complex level. He suggested that the typical solution is to select an "arbitrary" formulation, which often suffices only for the dominant subgroup. This inevitably leads to disagreement over the interpretation of the performance measure, thus the assessment of the organization remains controversial (Hage, 1980). Arrow's Theorem (Arrow, 1963) implies that no such single measure can exist that suffices the self-interests of multiple stakeholders in the performance outcome.

Assigning a beneficial value to a specific performance measure is not broached in this study, but is certainly relevant, according to the constituency approach to organizational performance. The constituency approach (Connolly, Conlon & Deutsch, 1980) sees the organization as an open system (Katz & Kahn, 1966) made up of multiple and often conflicting coalitions (Cyert & March, 1963), which the organization needs to accommodate and balance, leading to organizations having multiple measures of performance.

However, from the single value function perspective (Salancik, 1984), it is suggested that even this complex collection of multiple constituent-focused performance measures can actually be massaged into one single objective that all constituents can embrace and ultimately measure an organization's performance.

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Evaluating and measuring performance. Consistent with the difficulty in finding agreement on the notion of performance, is the challenge of selecting ways to measure it. Steers' (1975) review of existing descriptive and prescriptive models of performance pointed to a "lack of consensus" (p. 549) in identifying a single practicable set of performance criteria. The level of analysis poses a challenge to consistency in the evaluation of performance. The same Steers' (1975) review found research did little to connect performance measures at the individual level to that at the organizational level (p. 555).

More recently, this disconnect is recognized and being addressed by the popular "Balanced Scorecard" (Kaplan & Norton, 1992, 1996), although the balanced scorecard is packaged as an operational management tool and not specific academic research, per se.

Early models largely considered only a single variable in measuring performance and many are still used, for example, *profit* remains a measure undeniable in relevance. Later, more sophisticated multivariate models were developed which promote the evaluation of performance in terms of the relationships between important variables (Steers, 1975). This more complex perspective makes theory building more difficult yet it continues to be questioned if any one of the variables by itself will have a strong enough effect on performance (Boswell, 1973).

Central to evaluating performance is the aspirations of the observer, who judges whether the outcome of a given measure is good or bad. The aspiration level is the smallest outcome that would be deemed a success, per the observer's assessment

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(Schneider, 1992). From a psychological perspective, this is the performance level where the observer is cognitively neutral (Kameda & Davis, 1990) and is the level which can be called the "border line" between success and failure as well as the point where doubt and conflict begin (Lopes, 1987).

There are several descriptive theories aiming to explain how an individual evaluator develops a particular aspiration level for an organization and thus biases the evaluation. Social comparison theory submits that aspiration levels are determined by likening performance levels of others in a reference group (same industry for example) to that of the organization (Cyert & March, 1992; Festinger, 1954). A perspective points to the performance aspiration levels being driven solely from within, considering the organization itself being the primary key determinate (Collins & Ruefli, 1992; Cyert & March, 1992).

In the case of self-evaluation aspiration levels – assigning success or failure to your own organization performance - often high-performers mentally removed themselves from their usual reference group, i.e., "we are different." This may not be the case when evaluating the performance of others where other high-performers remain associated with the usual reference group (Wood, 1989).

Other descriptive theories emphasize to a greater extent the dimension of time in their model. Looking at the past as history and evaluating past performance (absolute or relative) to set aspiration levels (Fiegenbaum & Thomas, 1990), these recognize the time-ordering of past outcomes for future aspirations.

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The Strategic Reference Theory (Bamberger & Fiegenbaum, 1996; Fiegenbaum, 1997; Fiegenbaum, Hart & Schendel, 1996) is a comprehensive explanation which encapsulates the perspectives of the prior theories as it says that aspiration levels are determined from a merged evaluation of internal capability, external conditions, and time.

Studies specific to the time aspect tend to analyze performance history over long time frames and seek to identify causality. The Wiggins and Ruefli (2002) study, "Sustained Competitive Advantage: Temporal Dynamic and the Incidence and Persistence of Superior Economic Performance", is one of the first to study long time organization performance – in this case the sample extends temporally over 25 years. Their research, however, avoids causality and instead inspects performance as a dependent variable outcome in relation to its systemic temporal dynamics and its affect on sustained strategic competitive advantage.

Influences on organization performance. If one can subscribe to the notion that a butterfly flapping its wings in Mexico can ultimately result in a hurricane in Japan, then they can safely agree that practically anything can have an effect an organization's performance … perhaps, including that very same imaginary butterfly. The plethora of literature searching for the Holy Grail of causalities and drivers of performance, since such inquest "defies a sure answer" (Child, 1974a, p. 175), so only a high-level summary of causality will be provided here.

Perspectives on the set of influences on performance can be categorized as holding a universalistic view, where relevant attributes are a fixed set, or holding a

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contingency view, where influential set changes depending on the circumstances (Child, 1974a). Empirical evidence supporting either view can be found in the same study. In a study of 800 senior managers in eighty British organizations, "tentative support" was found for both the universalistic and contingency views (Child, 1975).

From another standpoint, influences are classified as either one of two more lucid categories. The source of a performance influence is either an internal (to the organization) factor or an external factor, as in the organization's environment (Lenz, 1980). Internal factors include organizational culture (Gordon & DiTomaso, 1992), structure (Barnett, Greve & Park, 1994) and strategic orientation (Robinson & Pearce, 1985). External factors, for example, include influences such as governmental policy and industry competition.

Linking these two types of factors, is the more behavioral aspect – both individual and group – such as risk taking (Bourgeios, 1985), group affiliation (Khanna & Rivkin, 2001), locus of control (Anderson, 1976) and hiring decisions (Lubatkin & Chung, 1985). Hirsch (1975) found that the environment influenced organizational effectiveness (a.k.a. performance), although organizations do have direct impact on their environment and vice versa.

An interdisciplinary review found that there is little evidence of simple causal relationships to performance—further, that it would be misleading to conclude that performance is entirely determined by environmental circumstances (Lenz, 1981), thus performance could be considered controllable. (Child, 1974b).

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As though the notion of performance and identifying causality to infinite factors were not enough to keep academic debate fueled, performance levels cause a change in itself. This systemic self-feedback, from the systems perspective, elevates the level of this study of performance from merely complicated to highly complex social research.

The Organization as a Dynamic Complex System

"Organizations are complex systems" (Carley, 2000, p. 1). Recognizing this, a relationship between organization theory and complexity theory is just beginning to be formed by organization scientists. For example, see: Anderson (1999); Morel & Ramanujam (1999); Carley (2000); and, Dooley (2002).

However, it seems the general organization change community has yet to embrace the complexity science perspective. An electronic search of the entire Academy of Management journal catalogue, yielded only a single article referring to complexity theory in this context (Anderson, Corazzini-Gomez & McDaniel, 2002), and this article's coverage of complexity theory was limited to just three paragraphs.

In the past, organization theory involving the term "complexity" was limited to a generic use of the term. Such theory eluding to organization complexity were limited to meaning that an organization is "complicated" and that organization size was the traditional measure of an organization's complexity (Beard, 1978; Daft & Bradshaw, 1979).

However, the application of complexity theory to organization science does seem to be taking hold in the "hard science" research community. Journals such as

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Organization Science, *Administrative Science Quarterly*, *System Dynamics Review*, Computational & Mathematical Organization Theory, and *Nonlinear Dynamics, Psychology and Life Sciences*, among others, regularly publish research/studies on organization theory viewed from the complexity paradigm. The number of researchers studying organizations from the complexity perspective appears to be increasing and can be epitomized by the May-June 1999 issue of *Organization Science*, which was dedicated entirely to "Applications of Complexity Theory to Organization Science."

Because of the *freshness* of this topic to the organization change community, what could be considered simply a primer on complexity theory is provided here - this in lieu of the more atypical in-depth and expansive coverage in a literature review. Deep knowledge of the details of complex systems, complexity theory, non-linear dynamics, or chaos theory, is not necessary for the intended reader of this research. For this study, and specifically for this section, the aim is to simply *plant the seed* of this still-novel perspective into the minds of organization change practitioners.

Complexity theory is "not a theory, but a paradigm … an approach to [study] complex systems" (Carley, 2002, p. 2). What is essential, however, is embracing the core perspective of these different paradigms. Organizations are increasingly being studied through a lens different than that of the past. Traditionally, researchers have studied the trees of the forest. This complexity perspective instead studies organizations from the perspective of looking at the forest. This perspective looks at organization behavior at a level of analysis much higher than was done in the past by setting aside concern of causality and instead looks at performance as a entity upon itself.

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Fritjof Capra (1996) who happens to be a trained physicist that academically evolved to a systems theorist - introduces this perspective quite succinctly:

> The great shock of twentieth-century science has been that systems cannot be understood by analysis. The properties of the parts are not intrinsic properties but can be understood only within the context of the larger whole. Thus the relationship between the parts and the whole have been reversed. In the systems approach the properties of the parts can be understood only from the organization of the whole. Accordingly, systems thinking concentrates not on the basic building blocks, but on basic principles of organization. Systems thinking is "contextual," which is the opposite of analytical thinking. Analysis means taking something apart in order to understand it; systems thinking means putting it into the context of the larger whole. (p. 29-30)

General systems theory. General Systems theory has its early roots in cybernetics, but it took 20 years to arise from its beginnings. Cybernetics was first proposed by biologist in the 1940's (Bertalanffy, 1962, 1968; Haines, 2000a; Wolfram, 2002). Cyberneticists thought it possible to understand biological systems by forming analogies with electrical machines (Wolfram, 2002).

Ultimately, through further developmental thought, Cyberneticists accentuated the control of feedback loops in a system. They argue the presence of feedback loops in a system is the primary determinate of a system having a complex nature, i.e. behaving as, and thus being labeled a "complex system." Cybernetics hit roadblocks in the evolution of this thinking since the only method of analysis available at the time was traditional mathematics (Wolfram, 2002).

Von Bertalanffy (1968) implied that despite the obvious differences in living systems, there are characteristics common to any system as a concept onto itself. General

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Systems theory was born from such thinking as it was recognized that the approach could be applied to any such system in general, not specific only to biology. This approach overcomes the "fragmentation of knowledge and the isolation of the specialist" (Skyttner, 2001).

General Systems theory provides a generalized conceptual framework, which recognizes that, the set of components of a system are interconnected and perform for the overall objective of the whole. General systems theory helps in finding new solutions to problems created by the earlier solution of problems (Skyttner, 2001). These concepts and principles have been applied in an increasing number of disciplines, recently including sociology and organization theory. General systems theory is considered a "meta-theory", which is a theory that organizes ideas from several "local" theories into a single generic theory that may be applicable to other phenomena (Guastello, 1995, p. 5).

Jay Forrester (1958, 1968) progressed general systems theory into the development of system dynamics. He first applied system dynamics methodology to business processes, such as inventory management and purchasing. A growing interest in the system dynamics perspective has spawned the recent more mainstream movement of systems thinking and application of system dynamics modeling in a wide variety of organization-related applications (Anderson & Johnson, 1997; Gharajedaghi, 1999; Goodman, 1979; Haines, 2000b; Kim, 1999; Richardson, 1999; Sterman, 2000; Weinberg, 2001).

System dynamics is easily recognizable by the use of causal loop diagrams, which serve as an important tool for representing feedback loops in a system (Sterman, 2000).

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Frequently associated with Jay Forrester and the Massachusetts Institute of Technology (MIT), system dynamics use is thriving (Sterman, 2000) and has been called "one of the key management competencies for the 21st century" (Kim, 1999, p. 1).

Complex Systems Theory. Wolfram (2002) calls something complex if the observer's powers of perception have not yet managed to find any simple description of it. Recognizable or not, humans participate in and intervene in circumstances that are characteristic of complex systems - interventions occur without guarantee to the outcome of those actions (Axelrod & Cohen, 1999). Like General Systems Theory, Complex Systems Theory "cuts across the boundaries between conventional scientific disciplines." "It makes use of ideas, methods and examples from many disparate fields. Results should be widely applicable to a great variety of scientific and engineering problems, [as well as social ones]" (Wolfram, 2003).

The dawning of Complex Systems Theory (CST) has been attributed to French mathematician Henri Poincare at the beginning of the 1900's (Ott, 1993). Poincare was interested in the (still unsolved) mutual gravitational attraction of three celestial bodies and their resulting orbit. His prize-winning publication, "On the Problem of Three Bodies and the Equations of Equilibrium", is noted as being the first research to recognize characteristics of complexity (Exploratorium Museum of Science, Art, and the Human Perception, 2003). Poincare observed non-random, yet unpredictable behavior resulting from a simple, non-linear rule – Newton's Law of $F=mA$ (Moon, 1992). Repeating the simple rule results in complicated long-term behavior (Eisenberg, 2002).

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There are four important characteristics of complexity: Self-organization; Non-linearity; Order/Chaos Dynamic; and Emergent Properties (Kirshbaum, 2002). A system that contains several subsystems that are connected via feedback loops is considered a self-organized system (Guastello, 2001). These systems respond to feedback in an apparently automatic manner (Kirshbaum, 2002). These subsystems, humans in an organization for example, adapt as semi-autonomous units which evolve over time as they seek to reach their specific objective (Dooley, 1996).

An important property of a complex system is its nonlinearly (Dooley & Corman, n.d.). In an agent-based system, (an organization for example), while the various agents may follow a simple linear rule of behavior, the aggregate of the behaviors usually behave in a nonlinear manner.

Although systems may behave in a non-linear manner, after a period their behavior becomes stable and somewhat predictable and orderly when in an equilibrium state. They often oscillate stably or exhibit chaotic behavior within predictable boundaries (Gordon & Greenspan, 1988). Even after starting in a random state, a complex system will usually evolve toward order (Anderson, 1999). Although stable, the systems commonly oscillate a relative amount (Gordon & Greenspan, 1988).

A complex system has interacting elements characteristically exhibiting emergent properties (Morel & Ramanujam, 1999). Such properties are observable and are empirically verifiable patterns (Morel & Ramanujam, 1999) and seem to have a life and rules of their own (Goldstein, 1968). Global patterns or structure emerges from the local

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interaction of the elements (Mihata, 1997). Prediction of a complex system is not considered to be "hopeless" (Axelrod & Choen, 1999).

Organization system behavior. The phenomena of organization behavior can be described as a complex system. Is it a system? Lawrence and Lorsch (1986) found it useful to view an organization as an open system (one that is affected by its environment) in which the behaviors of the members are interrelated, yet also are independent of the organization.

Is it complex? Organization behavior is certainly "complex" if Wolfram's rule-of-thumb for recognizing a complex system is applied – a system is complex if there is yet to be a simple description for it (Wolfram, 2002). Doubtfully many can successfully argue that organizations are still not considered complex systems. However, researchers seem to be on a path to simple description, thus simplicity, although there remains much to do.

Organizations are among the most complex systems imaginable (Boulding, 1956; Daft & Weick, 1984) with characteristic behavior that is non-linear and hard to predict (Anderson, 1999). To recognize the reach of organizational complexity, it is level eight on Boulding's (1956) system complexity hierarchy scale, making organizations the second most complex construct.. The nine-level scale was developed as part of general systems theory starting with basic patterns of the universe such as the arrangement of atoms in a crystal, up to the transcendental. Organizations, as a social system, are rated several levels more complex than plants, animals, and the next step after humans.

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Expanding beyond the simple measures and univariate (discussed earlier in this chapter) – based on solely on an organization's either "horizontal or vertical" differentiation (Hall, 1977) – measures of an organizational complexity being quantified as the number of departments (Daft & Bradshaw, 1979) are more elaborate calculations.

Organization theorists more recently have measured organizational complexity with respect to the number of activities or subsystems within the organization, although strategies for measurement are debated in the scientific community (Crutchfield, Feldman & Shalizi, 1999). This can be measured in three dimensions: the number of levels in the organizational hierarchy; the number of job titles or departments in the organization; and, the number of geographical locations (Anderson, 1999).

An operational view of organizational complexity points to a definition as a measure of the amount of differentiation that exists within different elements constituting the organization (Dooley, 2002). By this definition a restaurant is low complexity because there are few job specialties, while a hospital, with significant numbers of specialization, would be a highly complex organization (Dooley, 2002).

Regardless, organizations have been considered complex because the underlying people making up the organizations are complex (Dooley, 2002) and their relationships follow suit. Beyond their individual differences, Schein (1980) suggests that each person is capable of wearing many different hats. This quickly eliminates *simplicity*.

Contrary to the manner in which organizations are generally studied, organization behavior, from the complex system perspective, is actually the result of a series and sequence of events occurring over time rather than just a few incidents (Dooley, 2002,) or

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interventions. Dooley's perspective is consistent with the emergence characteristic of complex systems, and suggests a perspective materially different than that of punctuated equilibrium theories (Romanelli & Tushman, 1994; Tushman, Newman & Romanelli, 1986) from the traditional organization change community. Dooley's view appears consistent with, but from a lower level of analysis relative to that of the traditional structural inertia theories (Hannan & Freeman, 1984; 1989) of organization as well as the research into sequential routines of organizations (Cohen & Bacdayan, 1994).

As organizations are complex systems operating in dynamic environments, where they must seek to evolve to a maximum state, there often is not a formula for a single peak or performance. Instead, they operate in a multi-peaked fitness landscape (Dooley, 2002) of optimal outcomes that are under near constant flux (McKelvey, 1999). These "rugged landscapes" (Kauffman, 1993) result in a situation where organizations looking to make it in multiple areas are advised to keep the number of simultaneous changes to "just a few" (McKelvey, 1999). Complexity of an organization (highly complex or simple) has been determined to be a factor in strategic success (McKelvey, 1999).

An "emerging" perspective of organizational study is the application of evolutionary thinking into "ecological models" of organizations (Morel & Ramanujam, 1999). These models are expansions of research that identified simple phases that an organization goes through in its lifetime, such as the five phases of development described by Greiner (1972, 1998), and Fletcher and Taplin's (2002) six-phase adaptation. The ecological models directly apply complex systems theory to organizations. They recognize the ideas of self-organization, non-linearity, order/chaos

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dynamics, and emergence as being characteristic of organizations and the system of their behavior. Although they suggest exercising caution in applying pieces of complex systems theory to actual practice (Morel & Ramanujam, 1999).

Organizations behave according to their processing of information from the environment (Daft & Weick, 1984) and organizations separate themselves from one another in the process of how they interpret the environment (Daft & Weick, 1984).

In the same manner as a complex system, organizations seem to stabilize (Wiggins & Ruefli, 2002) and become homeostatic thus maintaining system equilibrium as a result of members (the system components) adjusting their behaviors.

An Anthology of Organizational Cadence

Characterized earlier (p. 11) as the "ebb and flow" of organization life, an organization seems to behave with an unseen cadence. To aid in perceiving such rhythm, this section examines the organization from the complex systems perspective, as discussed in the prior section, as well as from the traditional theory perspective. A macro view of the organization is taken in this section.

Like poetry, an organization continually dances on its dynamic landscape. Depending how one observes this behavior, an organization's movement can look constant and alive, or look stolid and comatose.

Observing organization change from a high level of analysis can make the organizations look to be inert with only a periodic transformational change. The same

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organization from a micro view can look to be in constant movement and change (March, 1981; Weick, 1999).

Organizational life. The model of punctuated organization change has widely influenced modern organization change thinking (Sastry, 1997) and has spawned extensive writings on transformational change. According to the model, the organization spends the vast majority of its lifetime lingering in the state of convergence – characterized by change being restricted to small incremental adjustments.

Being inert portrays this state of the routine, yet still a relentlessly shifting and adaptive organization, but entombed in routine. However, for organizations embracing a strategy of continuous change (Brown & Eisenhardt, 1997), convergence periods are actually the routine. The study of organizational routine is arduous because of the nature of studying complex patterns in social action, which can circumstantially vary (Pentland & Rueter, 1994). Emanating from a theory of ordinary action, while organizational processes may be stable, the resulting actions are not steady (March, 1981). The performative model of organizational routines, makes the case that such routine behavior is actually the source of continuous change (Feldman, 2000).

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Structural Inertia Theory. Although organizations may appear inert, or be lingering between the events of punctuated change, change continues clandestinely in the form of routine learning and adaptation, albeit at different paces across organizations, as if by an underlying behavioral script (Gioia & Poole, 1984; March, 1981). In an empirical study of the U.S. Automobile Industry (Dobrev, Kim & Carroll, 2002), the authors write:

> In our view ... organizations are inert not because they do not change but because the change they embark on is constrained within an experimented course of actions that have not proved detrimental in the past (p. 6).

A Retrospective of Organization Performance Levels over Time

Performance measures have some non-behavioral characteristics of relevance to this research and to a fuller understanding of the variations in organization performance. These are discussed in this section with an aim towards developing a sense of the thinkable and hidden macro-level attractors affecting levels of organization performance.

Regression Toward the Market Mean

Regression towards the mean, is in statistical terms what might be considered a "bias" (Vogt, 1999) and may be heeded as a strange attractor to organization performance from the perspective of complexity theorists. Organization change theorist, Henrich Greve (1999) hypothesizes that while it may be difficult to identify the specific performance level, expected performance will regress toward the mean performance of

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other organizations in the same market and towards the historical average performance level of itself.

Managers' decisions are one cause of this phenomenon. In order to preserve the status quo managers make risk-level decisions relative to their perceived level of current success, based on perceptions and aspirations relative to competitors (March, 1988). Greve (1999) furthers that when deciding to intervene with a change, decision-makers may use performance context to predict the consequences of such change, thus further affecting performance level tendencies.

Another factor believed to lead to regressing of organization performance to the mean is the occurrence of institutionalized diffusion (DiMaggio & Powell, 1983). Members of one organization are known to move from organization to another organization in the same industry. This isomorphous behavior homogenizes organizations and their subsequent performance as the movers bring with them techniques and practices from the original organization and spreading them to the new organization.

In an empirical study of the dynamism of organization performance (performance as measured by Return on Assets (ROA), it was found that firms have a tendency for convergence towards the mean. Of note, the higher performing firms regressed toward the mean at a slower pace than the lower performers (Mueller, 1990).

Performance Limits

Organization performance levels often have unforeseen systemic limits. From virtual experiments (computer simulations), Carley (1992) theorizes that in a stable

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environment, organization performance reaches a limit, if not shifted by a strategic or environmental change. She attributes this to organizational learning having a natural maximum level.

From an organizational culture perspective, Sorensen's research (2002) on the relationship between an organization's culture and performance points out that in a non-volatile environment, a strong culture will have less variability (be more dependable) performance than a weak culture. Organizations with a strong culture excel at incremental improvements, while weak cultures are more likely to make large improvements to performance.

Noisy Performance Levels

Performance levels are not straight lines, up, down or sideways. There appears to be a great deal of variability and fluctuation to the trajectory of performance, particularly in the short term. While perhaps holding a negative connotation, the term used to refer to this variability in performance levels is "noise" (Sterman, 2000). According to detailed studies on organization learning (Carley, 1992) and adaptation (Carley, 2002, 2001), there is evidence that performance productivity levels of organizations do have this characteristic of noisy trajectories.

The difficulty of identifying these small, transient and short-lived effects of the "natural variations" (Coleman, Arunakumar, Foldvary & Feltham, 2001) shows itself in the limited number of academic references to the phenomena. Without the benefit of prior organizational studies specific to productivity noise, evidence of its presence is limited to

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visual observation in the graphical results published in a few unspecific, but somewhat related studies.

It has been demonstrated in virtual experiments that organization performance levels clearly change over time. At times these variations can be significant (Carley, 2000), which lead to varying judgments by observers about the perceived success of an organization. This judgment can vary widely and be dependent on when the judgment is made. If the performance is temporally in a trough, then judgment is often negative, vice versa.

While in many of the references in this section the study was based on a computer simulation, it should be recognized that the variations could be the result of computer science calculation error caused by rounding differences. The impact of computer rounding difference, in a complex system modeled on a computer, can have dramatic effect over time ultimately leading to polar outcomes in the long-term (Gleick, 1987).

This concern can be mitigated by empirical evidence. Snell and Loyd empirically studied the correctness (performance) of school teachers' judgment accuracy of their students' progress (1991). The teachers' daily performance scores over a 30-day period clearly showed noisy non-linear trajectory with variations in correctness increasing, decreasing between measuring periods. However, often there was no variation of performance in neighboring measurement periods. In the longer-term there was an upward trend.

It should be noted in the teacher study, at the conclusion of the research, the performance trajectory had not yet reached a steady state (the longer trend remains up

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instead of flat-lining.) and that even with manual calculations, rounding adjustments may result in the underlying variability. However, the error of one time period will not affect the results of the next time period, as the teachers do not make computer hardware rounding errors as mentioned above.

Although over a much shorter time span, another group decision performance study (Chidambaram & Bostrom, 1993), also showed a similar variability in the short-term performance levels.

Evidence of this variability from time unit to time unit is consistent with dynamic systems theory. Depending on the questions being asked, the noise may be essential enough to affect the outcome—purposely inserting noise into systems dynamics based business models is recognized as an important characteristic that should be included in models; "The rain of random noise falling on our systems does play an important role in dynamics,…" (Sterman, 2000).

A study by Lenz (1980) concluded in the short run that environmental factors account for a greater portion of the performance variation than does strategy. This suggests that organization strategy is more prominent in the longer-term measurements of performance   In a proposed contingency theory, Denison (1984) points out that strong cultures lead to consistency in the short term of performance. Yet in the longer term a strong culture makes it difficult for the same organization to adapt to environmental changes and thus improve its performance. This proposal was supported by a survey-based study of managers in 11 insurance companies (Gordon & DiTomaso, 1992).

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Summary

This chapter ensures a sufficient knowledge base exists across all consumers of this research. The discussion provides both broad-brush coverage on important and relevant topical areas and an in-depth review specifically on research in performance patterns.

Performance is a much-studied notion in organization research, yet fully understanding it remains elusive. Recent advances in complexity theory are introducing a fresh lens in which to research performance. Complexity perspectives coupled with a systems view provide valuable new insight into performance and increase the methods available to study it. This study embraces this new thinking and uses advanced techniques to provide even greater insight into the traditional notion of organization performance.

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Chapter Three: Research Method

The purpose of this study was—through the use of computer simulation—to explore patterns of change in organization performance and to investigate whether past change patterns can identify the direction of the next performance change. The basis for the change patterns investigated is the directional change (the increase or decrease) of performance levels for up to six consecutive time periods. Having a pattern-based perspective on the future direction (improvement or decline) of an organization's performance, provides change practitioners additional insight that aids in evaluating intervention decisions.

This chapter will describe the research design and methods for this study. The first section, Data Generation and Collection Procedures, explains how the source data sets were obtained. The next section, Data Analysis Techniques and Methodology, describes how the source data was investigated and includes definitions of operational variables. Several short sections follow: (a) Limitations of Method, (b) Human Subjects Exception, and (c) Data Retention. At the end of this chapter, the essential elements of the research methodology are summarized.

Through the analysis of computer-simulated organization-performance data, with performance regarded as the accuracy of an organization's decisions, the following research questions were asked:

1. For the examined cases, what is the frequency distribution of organization-performance change patterns?

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2. For the examined cases, to what extent does the current organization-performance change pattern identify the direction of the next change in performance?
3. For the examined cases, is the current direction of change in organization performance independent of the prior direction of change?

Design Overview

In its design, this study adopted both traditional and contemporary approaches. The design is grounded in the traditional method of longitudinal research, the examination of patterns of change in organization performance over time. It is also traditional in that it is an exploratory study, -- what Kumar called a "feasibility" or "pilot" study, as opposed to an experiment (1996, p.9). It does not seek to establish causality, but rather to better understand the dynamics of organization performance. However, its methodology is also contemporary, since it used a computer simulation of organizations rather than actual human-based organizations to generate its source data. Nevertheless, even with its contemporary approach, the study can be characterized using traditional terminology: (a) A *case study*, in that it is a specific instance of an organization is examined; (b) *blind,* in that the study subjects do not perceive they are being investigated; (c) *nonexperimental,* since no cause and effect relationship is explored or anticipated; and (d) *retrospective*, in that only historical data are investigated. In a general sense, this study may also be portrayed as a retrospective-prospective study since it involves both the past and the future.

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Research Instrument

Because of the high costs and impracticality of obtaining the large amount of source data the study required, and in order to study the data in a controlled environment, the researcher chose to use ORGAHEAD, a computerized model of organization performance (Carley & Svoboda, 1996). ORGAHEAD, which has been established as being valid for this study (see Appendix A), encapsulates relevant aspects of organization behavior, which for this study result in valid organization performance data.

Research Protocol

This experiment was conducted in two discreet steps: First, the computer simulation software was executed 100 times, generating the entire set of sample data used; second, the sample data was imported into an Excel® spreadsheet and analyzed. The researcher performed both these steps.

Case Design

Each case of organization performance can be thought of as analogous to a military organization faced with various kinds of incoming aircraft. The aircraft is either a *friend* or an *enemy*. The organization must decide either to *defend* itself or to *allow* the aircraft to enter its airspace. Whether the decision is *correct* or *incorrect* is the basis for ultimately determining the organization's performance score.

While computer simulation allows for the generation of an unlimited number of cases of organization performance, the researcher restricted his study to 100 cases. Too many cases can make management of the source data unwieldy. For each of the 100

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cases, performance data from 100 time periods were collected, that number again being chosen for practical reasons. Finally, for each of the 100 time periods per case, 100 organizational decisions were collected from the simulation.

Thus the case design provided for 1,000,000 decisions derived from the 10,000 performance scores spread across the 100 cases. In this way the study deliberately oversampled (Vogt, 1999) rather than running the risk of not having enough data for satisfactory findings. (As these large numbers demonstrate, compared to live empirical research, computer simulations can generate massive amounts of data at relatively insignificant costs. Moreover, by making such large amounts of data available, computer-based research can allow for greater depth in the exploration of organizational phenomena .)

The Bernoulli Theorem, which suggests that by creating larger numbers of trials of the event under investigation, one gets closer to the phenomenon's empirical probability, thus it provides theoretical support for oversampling. For example, if one were to toss a coin 1000 times, it will probably approach the expected 50/50 split between heads and tails more closely than if the coin were tossed 100 times (Vogt, 1999).

As a result of this case design, data consisting of 10,000 data points were made available to this study. These data points represent organization performance history and were used as the sample data.

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Description of the Organization

The "virtual" subject of this study, a single military organization (Carley, 2000), is faced with a series of incoming aircraft approaching the country it is responsible for defending. The organization tasked with deciding whether to *defend* or to *allow* an unidentified approaching aircraft to enter the country's airspace. This organizational task is described in detail later, but it serves as a representation of many routine decisions actual organization, military or non-military, may face day-to-day, e.g., deciding to commit to a supplier's offer.

The characteristics of the organization embodied in the simulation include limiting the organization's personnel to a maximum of 45. The actual number can vary, with personnel added to or removed from the organization during the simulation, as long as the total number never exceeds 45. After every 200 decisions, the organization assesses its own performance and evaluates whether to make personnel changes, such as adding new personnel, or removing some. The evaluation also includes considering reporting structure changes. Any changes decided upon are implemented immediately.

There are three levels to the organization's reporting structure. The top-level person makes the decisions for the organization based on personal learning, first-hand information about the aircraft, and advice from the direct reports. Communications within the organization are one-way upward.

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Description of the Performance Task

As designated for this study, the accuracy of a decision has been considered a measure of performance in organization research (Canady, 1968; Carley & Ren, n.d.). That is, for each time period and for each specific case, the military organization is obliged to make a decision: to defend against incoming aircraft or to allow it to proceed. This decision is a classification task, in that the organization must identify an incoming aircraft as one of two distinct types: a friend or an enemy. The organization uses its individuals' knowledge and judgment— its *organizational knowledge*— to classify the object as one of the two possibilities.

Depending on how the incoming aircraft or object is classified, the decision is either correct or incorrect. The organization strives to make *correct* decisions. The organization's history of correct and incorrect decisions is the basis for evaluating the organization's performance. It is this measure of the organization that was observed and analyzed in this study.

Each data point in the series of performance data reflects the accuracy of a single decision made by the organization. When only two possibilities exist, i.e., correct or incorrect, and values are mutually exclusive outcomes; this is categorized as a Bernoulli trial (Vogt, 1999). This distinction is important for the Runs Test described later.

Data Generation and Collection

To generate data, this study utilized the ORGAHEAD computer simulation software, which contains a computational model of an organization. ORGAHEAD is a

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stochastic model of adaptive learning behavior in an organization. The behavior of the model is dynamic and adaptive. The virtual organization performs in a task environment and embodies organization change activities, such as hiring, firing, and reorganizations.

The ORGAHEAD simulations were executed in a manner similar to prior experiments conducted by other researchers and were modeled after a study on organizational adaptation in volatile environments (Carley, 2000). Data was collected from ORGAHEAD at the most minute level available. Each of the organization-level decisions was recorded.

The ORGAHEAD simulation was executed on a desktop personal computer running the Microsoft Windows® operating system. The ORGAHEAD software was not modified beyond the controlling and affecting of characteristics via its standard configuration file. The data generation and collection step took approximately 1 minute per case to run on a laptop computer with a 100 MHz central processing unit.

Description of Computer Simulation

The ORGAHEAD software model, which was developed and is maintained by the Center for Computational Analysis of Social and Organizational Systems (CASOS) at Carnegie Mellon University (CMU) has been used as a theory-building research tool in prior theory-building studies on organizational learning and adaptation (Carley, 2001, 2000; Carley & Svoboda, 1996).

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ORGAHEAD falls into a genre of models called intellective models. These models are not designed to recreate precise behavior entirely, but instead are intended to represent specific dynamics of a phenomenon (Pew & Mavor, 1998).

ORGAHEAD models organization behaviors and produces organization performance activity based on Monte Carlo (a non-deterministic process using random-number-generation algorithms) techniques and organizational adaptation characteristics. ORGAHEAD's performance measures are based on the accuracy of carrying out a task (making a decision) and are affected by the task itself, the actions of each of the organization members, the strategic changes to the organization's membership and structure, and the members' experience.

There are several input parameters for ORGAHEAD that may serve as the independent variables for this research. Beyond basic output control options, the parameters of the virtual organization are flexible according to the user and allow for such characteristics such as maximum organization size, hiring and firing policies, and even risk-taking attributes. These input parameters remained identical for each run of the simulation for this research.

The dynamic aspect of ORGAHEAD that brings the simulation closer to reality is that the model implements an adaptation model. This is implemented in two ways. First, the members of the organization receive feedback on their decisions, and that feedback is "remembered" (and forgotten) leading to a change as in judgment— hopefully an improvement—over time. Second, as a response to its projection of future needs, the model allows for changes to the organizational structure. These changes consist of adding

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or removing members of the organization, or of changing the organizational structure, namely the reporting lines.

ORGAHEAD is designed to "reflect the basic realities of organizational life" (Carley, 2000, p. 248). The simulation builds a multilevel organization with associated reporting lines among the management and workforce. As applied in this study, the organization is a military organization with officers and enlisted personnel. The organization has a decision task to perform, with a "correct" decision associated with each task presented in the simulation.

The organization's top officer makes the final decision on behalf of the organization. As in the real world, the decisions are made using past personal experience, i.e., personal learning, direct knowledge of facts, and recommendations from others at a lower level in the organization. Recommendations passed from person to person are made in the same manner as those of how the top officer makes the final decision – via personal experience, factual information, and recommendations from others.

Communication between the members of the organization is via a direct reporting line; however, reporting lines may bypass certain levels of the organization. For example, a subordinate may report to and communicate directly with the top officer. However, a person may not report to (thus not communicate with) a person at the same or lower level of the organization.

As in an actual organization, each person rarely sees all of detail necessary to making a decision. If a person does have access to facts, he or she will often see only

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some of the underlying facts needed for the recommendation, or, in the case of the top officer, for the final decision.

Since the ORGAHEAD organization is dynamic, the personnel reporting lines can be changed, added, and removed. Personnel of any level may be hired or fired throughout the simulation period. Each virtual organization has a strategy for such changes. For example, those who have a stable change strategy do not make any changes to staff levels or reporting during the course of the simulation. A procedural strategy involves hiring when the performance is good and firing when performance drops.

ORGAHEAD, a computational model developed on the basis of the PCANS model of structure in organizations (Krackhardt & Carley, n.d.) architecture is characterized by personnel, resources and tasks, and relationships linking them. Agent-based simulations, such as ORGAHEAD, are effective tools for Social Theory testing (Verhagen & Smit, 1997), and in particular for decision-making research (Verhagen, n.d.).

Respective of copyright, the source code for ORGAHEAD is not available to the public, although the executable program is made freely available for research purposes. The software is used in this research with the expressed permission of its author. (See Appendix B for permission details.)

Exploration Methodology

To facilitate exploration of the data, all the source decision-based data (the actual disposition, i.e., *friend* or *enemy*, and decisions made, i.e., *defend* or *allow*) was imported

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into an excel spreadsheet and combined into a performance-score history, i.e., 100 performance scores, for each of the 100 cases.

The Excel spreadsheet calculated several basic descriptive statistics for the performance history data, including arithmetic mean, minimum and maximum performance scores, and range. Seeking computational simplicity in this study, the researcher has limited the analysis to these basic statistics and to ways in which they can be directly applied to the three research questions. The spreadsheets are simple in complexity and have been made available to other researchers (see the Data Retention and Availability section later in this Chapter).

Definition of Terms

Several study-specific constructs in the form of criterion variables are introduced and discussed in this section.

Performance score. The performance score is a frequency count of the number of correct decisions in a given time/ reporting period. For example a performance score of 75 means that 75 of the 100 decisions in that particular set were found to be correct. The performance score, which can range from 0 to 100 for any period, is essentially a percentage value of correctness for the period. There are 100 performance scores calculated for each of the 100 organizations, for a total of 10,000 performance scores.

Performance history. This is the term used for the entire set of performance scores (n=100) of a single case. The temporally-ordered performance history is used to determine the difference-sign values.

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Directional-change value. From a consecutive series of ordered performance scores, i.e., the performance history, differences are calculated between the performance measures of two adjacent periods. These differences are labeled as either a "+" or a "-" for a positive or negative difference, respectively. The difference-sign value ignores the magnitude of change.

Change-pattern. These are directional-change values that are aligned into a time-period ordered set (change-pattern history) to be analyzed in this study.

Change-pattern frequency. Change-pattern frequency is the number of times a specific change-pattern is found within a—usually longer—directional-change sequence.

Change-pattern prediction. This is change-pattern, accompanied by a calculated percentage value, representing a level of predictability, i.e., a change-patterns ability to predict the direction of the next performance change (improvement or decline).

Change-pattern run. Often called a streak in sports statistics; a run is an uninterrupted series of the same-value (improvement or decline) of directional-change variables in a change-pattern. For example, the directional-change patterns +---- and -+++- contain two and three *runs*, respectively.

Data Analysis

The statistical tables—presented in Chapter Four and used as the basis for the findings—were designed specifically to answer the three research questions. All of the data contained in the tables comes directly from the excel spreadsheet.

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The first research question, *for the examined cases, what is the frequency distribution of organization-performance change patterns* is supported by a series of tables which contain histograms of frequency of occurrences for performance change-patterns. Each possible change-pattern, consisting of a set of directional-change variables, i.e. + and - symbols, is looked for and counted in the performance-history data.

The second research question, *for the examined cases, to what extent does the current organization-performance change pattern identify the direction of the next change in performance* like the first research question is supported by a series of tables which reflect histograms of the frequency of occurrences for performance sign-differences. However, Research Question 2 contains an additional directional-change variable representing the change in performance in the next time period.

The third research question, *for the examined cases, is the current direction of change in organization performance independent of the prior direction of change* involved a Runs Test being applied against the performance-change history for the 100 sample cases.

The pattern-frequency charts were constructed to show the number of times a given pattern was found in the data. To accomplish this, first the raw performance data was reduced to a simpler form to make it more manageable. This nonlinear wave of decision-accuracy performance data was first converted into a series of + and -'s by using a discretizing wave equation (Budnik, 2003). This process of introducing discrete approximations of the data, which derives from digital physics, provides a practical approach to a complicated problem. For example, the procedure allows computers (which

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are discrete machines) to work with ocean waves (the heights of which are continuous measures) by rounding the measurements to a precision that is manageable by both computers and by humans.

The exploratory data analysis technique was used to identify wave patterns in the data. The primary objective from a data analysis perspective was to identify strong coupling relationships (Perng, 2000) between wave patterns. For example, if the data forms a W pattern, then 80% of the time, the next performance level will exceed the measure at the top of the W (Tukey, 1977).

Notes on the Runs Test

The Runs Test ascertains non-randomness in a sequential series of binomial data consisting only of only two possible values— i.e. a succession of Bernoulli trials. This test checks whether the data making up the series is independent from one data point to the next, e.g., if the values in a sequence are random of one another. Runs Tests have been used in other experiments involving computer simulations (Chen & Kelton, in press) as well as applied to sports statistics (Albright, 1993; Reifman, 2003).

The Runes Test evaluates the number of sequential runs in a series in order to estimate independence. A single sequential run occurs when the data has an unbroken sequence of the same value, in this case either a + or a -. This statistical technique uses the number of runs in a sequence of sample data to test for randomness in the order of the data. This technique is based on the order in which the data occur; it is not based on the frequency of the data. The Runs Test looks solely for independence. Relative to other

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more-complex techniques, the Runs Test is not considered to be a powerful (Knuth, 1998) test; thus when more definitive results are desired, it is often accompanied by other tests.

As applied in this study, the Runs Test provides evidence of the dependence of a value in one time period and its dependence on the value of the time period immediately preceding it. Using a more sophisticated statistical technique may provide more reliable results, but in keeping with the goal of simplicity for this research, the Runs Test is considered appropriate.

Limitations of Method

Although the design of the study is based on sound methods, it has some intrinsic limitations. This is a *virtual* experiment—the source of data is computer generated from a computer simulation. Regardless of the established validity of the ORGAHEAD simulation, any model (computerized or not) is a simplified representation of reality. There are undoubtedly aspects of reality that have not yet been incorporated into any model, perhaps there are even aspects to reality that researchers have not yet recognized.

Applying the findings from research based on computer simulations requires a cautionary stance, since there are inherent differences between a simulation and any real-world organization or, more specifically between ORGAHEAD and an actual military organization, e.g., the speed in which decisions must be made is not part of the ORGAHEAD model.

The challenge faced by organization scientists is comparable to that of economists. In a speech entitled "Monetary Policy Under Uncertainty" which was given

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during an equity stock market debate about the true direction of the current economy (improvement or stagnation), Federal Reserve Chairman Alan Greenspan (2003) acknowledged the limitations of using computational models:

> Uncertainty is not just an important feature of the monetary policy landscape; it is the defining characteristic of that landscape. (para. 1) ... Despite the extensive efforts to capture and quantify these key macroeconomic relationships, our knowledge about many of the important linkages is far from complete and in all likelihood will always remain so. Every model, no matter how detailed or how well designed conceptually and empirically, is a vastly simplified representation of the world that we experience with all its intricacies on a day-to-day basis. Consequently, even with large advances in computational capabilities and greater comprehension of economic linkages, our knowledge base is barely able to keep pace with the ever-increasing complexity of our global economy. (para. 3)

To process fully, the information from such an enormous volume of data can involve the use of highly sophisticated statistical techniques. These complicated procedures have been purposely excluded from this study so that practitioners, as opposed to researchers only, may make use of the findings. For example, results from the distribution theory of Runs, which assigns a probability distribution to the length and number of runs in a sequence of Bernoulli trials (success or failure), should be pursued

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(Mood, 1940; O'Brien & Dyck, 1985). It seems highly probable that the information provided by such a statistical tool would have great value for any organization change agent or manager.

The results of the distribution of Runs Tests would be strengthened by using a Mertingale approach (Li, 1980), which investigates the occurrence of patterns across repeated experiments. Another useful statistical technique is the Longest Run Test, which is part of the Distribution Theory of Runs used since 1940 and developed much earlier (Mood, 1940; Whitworth, 1886). This method is often employed in analyzing sports: for example, batter hitting streaks in baseball (Albright, 1993). DNA research also uses the approach (Som, Sahoo, & Chakrabarti, 2003).

Human Subject Exemption

This research is not subject to Pepperdine University IRB (Institutional Review Board) review because the design of the study does not involve the use or collection of any data from individual human participants. The verification of non-use of human subjects was confirmed by the chairperson of this dissertation committee prior to undertaking the research (see Appendix C).

Data Retention and Availability

The entire set of data generated for and referred to, as well as the analysis spreadsheets in this study are made available for a minimum of five years after the publication of this document. A computer disk containing the data may be obtained by contacting the researcher.

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Summary

The methods and underlying detailed design of this study have been carefully selected to ensure the findings from this study are valid and make a creditable contribution to the understanding of organization performance. This study has both traditional and contemporary approaches influencing the design. Most notable of these approaches is the use of a computer simulation, which generates all of the organization-performance data. Although computer-simulation data has inherent limitations, the application of the findings of this study has relevance to both practitioners and researchers as discussed in Chapter Five.

The 100 cases of performance histories are investigated for patterns in the difference-sign sequences between adjoining time periods. The performance data was imported into Excel spreadsheets and analyzed according to the requirements grounded in the three research questions. The findings from this process are presented in Chapter Four.

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Chapter Four: Sample Data and Findings

The purpose of this study was to explore patterns of change in organization performance and to investigate whether past change patterns can identify the direction of the next performance change. The basis for the change patterns investigated was the directional change—the increase or decrease—of performance levels for up to six consecutive time periods created by computer simulation. Having a pattern-based perspective on the future direction—improvement or decline—of an organization's performance provides change practitioners additional insight that aids in evaluating intervention decisions.

This chapter profiles the sample data used for the investigation and presents the findings from the analysis conducted by the researcher. The findings are presented in three separate sections, each pertaining to one of the three research questions. A summary section that recaps the findings is provided at the end of this chapter. Appendix D provides the supporting detailed data discussed in this chapter.

This study took an exploratory approach to researching organization performance. Instead of investigating the often-studied causality aspects of organization performance, this study researched performance from the top-down perspective. Organization performance was viewed as an entity upon itself as opposed to being the result of a collection of causes. In particular, the frequency of specific patterns of performance—increases and decreases between adjoining time periods—was investigated and the reliability of these patterns to provide specific guidance on the change in performance in the subsequent time period was explored.

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Through the analysis of computer-simulated organization-performance data, with performance regarded as the accuracy of an organization's decisions, the following research questions were asked:

1. For the examined cases, what is the frequency distribution of organization-performance change patterns?
2. For the examined cases, to what extent does the current organization-performance change pattern identify the direction of the next change in performance?
3. For the examined cases, is the current direction of change in organization performance independent of the prior direction of change?

A computer simulation generated the sample data for this study. The simulation was executed multiple times, resulting in 100 independent cases of source data each consisting of historic organization-performance data.

In each execution of the simulation, a virtual military organization was tasked with correctly identifying an incoming aircraft approaching the military's defensible airspace. In order that the organization would make an appropriate decision, i.e., to *allow* or to *defend,* the organization was first tasked with identifying the aircraft as either a *friend* or an *enemy*. In each simulation—with one execution representing one subject case—the organization was presented with 10,000 incoming aircraft approaching one-by-one; thus, the organization was faced with 10,000 separate decisions in chronological order. The accuracy of these decisions—i.e., *correct* or *incorrect*—was tallied and summarized into organization-performance scores. This data roll-up process resulted in a

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set of 100 performance scores for each case, with each performance score representing 100 decisions.

This study investigated the patterns within these 100 performance-score histories. Specifically, the difference-sign of performance scores between two adjoining time periods was investigated. The difference-sign values, either + or -, represented an increase or decrease, respectively, of the performance score from one period to the next.

Sample Data Overview

This section profiles the sample data generated in this study by running the computer simulation and makes important points related to several variables pertaining to the discussion of the research questions' findings. The sample data profile consists of presenting basic descriptive statistics pertaining to the unprocessed simulation output data and the resulting performance scores used in the exploration. The discussion that follows is important to understanding the findings and provides background pertaining to both the directional-change and the change-pattern variables.

The sample data were generated by executing a computer simulation 100 times—once for each subject case. Executing the simulation generated more data variables than were pertinent to this study, which is specific only to organization performance. The data generated by the simulation amounted to approximately 100 megabytes of computer file space, equaling approximately 50,000 printed pages. This data contained all of the output generated by the simulation and included variables not of direct interest to this study, e.g., workforce hiring and firing data and reporting structure changes. Only the data pertinent to determining the performance scores were extracted for further processing.

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The extraction of the study-relevant data from the original output files resulted in a single dataset containing variables for 1,000,000 decisions. Each decision consisted of two variables, representing (a) An approaching aircraft disposition, i.e., *friend* or *enemy*; and (b) the corresponding decision made by the organization, i.e., *allow* or *defend*. The single decision data-set held all data for the study—for the 100 cases—which equates into 10,000 individual performance-scores.

The organization in each case, or simulation run, was presented with an evenly distributed number of *friend* and *enemy* aircraft whose purpose was to be responded to by a setting in the simulation software configuration. Thus, the organization would decide the incoming aircraft was *friend* 50% of the time and *enemy* 50% of the time, the precise order of the friendly and hostile aircraft being determined randomly.

The performance-score variable was the number of correct decisions in a single performance-reporting period. For example, a performance score of 75 meant that 75 of the 100 incoming-aircraft decisions during that reporting period were determined to be correct. The maximum performance score for any period (maximum 100 and minimum 0) was essentially a percentage value of correctness for the period. There were 100 performance scores calculated for each of the 100 organizations—a total of 10,000 performance scores. The performance-scores were conjoined temporally to form a performance history for a given case.

The analysis of the decision data has shown that—for the 100 cases studied—collectively, 72.5% of the incoming aircraft were correctly identified. The lowest

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performance-score across all cases was 37, and the highest performance-score was 95, giving a statistical range of 58.

From a consecutive series of ordered performance scores, i.e., the performance history, differences were calculated between the performance measures of 2 adjacent time periods. These differences were labeled as either + or - for a positive or negative difference, respectively, and were referred to as *direction-change* variables.

A change-pattern variable is a set of directional-change values, ordered chronologically, for a single case. Change patterns representing from 2 to 6 consecutive time periods were considered. For example, a series of six performance-scores (75, 72, 81, 84, 80, and 85) represents five values of change: -3, +9, +3, -4, and +5. Since only direction is of relevance to this study, the magnitude of the change values becomes -, +, +, -, +, which evaluates to the 6-period pattern: -++-+.

The total number of these unique change patterns possible in the performance-history data for a single case is 62, which is determined by the number of possible values for each position in the pattern, i.e., 2, and the length of the sequence. Thus, lengths 1, 2, 3, 4, and 5 have 2, 4, 8, 16, and 32 possibilities, respectively, for a total of 64. There are 64 unique patterns of lengths 1 to 5 possible when each item has only a binomial value, i.e., a + or -. It is important to point out that patterns of length 2 are embedded in patterns of length 5 several times. For example, ++ is contained in the pattern +++-+ twice.

A pattern also has at least one run contained within it. A *run*, often called a *streak* in sports statistics, is an uninterrupted sequence of same-values. A pattern has a maximum number of runs within itself, based on the length of the pattern.

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Research Question One

Research question one, "For the examined cases, what is the frequency distribution of organization-performance change patterns," required inspecting the performance directional-change data and counting the observations for each of the 64 possible change-patterns, with the result that a total of 31,310 change patterns were observed.

All of the change-pattern tallies were recorded in tables (Tables D1-D5), according to the time-period length for the change pattern. These tables were sorted according to the observed frequency—from most frequent to the least frequent. To facilitate further analysis and discussion, the change patterns were then ranked into quartiles.

These tables (Tables D1-D5) were inspected by the researcher and summarized into a table (Table 1) provided below and discussed here. While a separate analysis was conducted for each of the five change patterns lengths—representing from 2 to 6 consecutive time–periods—the discussion based on the summary table is from a holistic perspective.

Table 1 summarizes the most notable aspects of the five observed frequency tables (Tables D1-D5). Each column pertains to data found in the table corresponding to the number of time-periods in which the change-pattern belongs, i.e., based on the length of the change-pattern.

Three observations of significance are presented in the summary table and discussed below. While there are many other lenses through which to look at this data

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and many less significant observations to be made, the most relevant observations are provided here. First, the most frequent change-pattern in each of the change-pattern groups was an *alternating pattern* starting with an improvement (+). Alternating patterns are change-patterns which have alternating direction-change values from one value to the next, e.g., +-+-+ and -+-+-. Thus these patterns alternate between improvement and decline in performance from one time-period to the next.

Table 1

Summary Analysis of Observed Frequency of Change Patterns

	Summary Analysis of Observed Frequency of Change Patterns (i.e., Summary of Tables D1-D5)				
Number of Time Periods	2	3	4	5	6
Total Possible Change-Patterns	9,900	9,800	9,700	9,600	9,500
Most Frequent Change-Pattern	+	+-	+-+	+-+-	+-+-+
Least Frequent Change-Pattern	-	--	---	----	-----
Alternating Patterns	n/a	64.0%	39.1%	24.0%	14.5%
Trend Patterns	n/a	36.0%	11.0%	2.8%	0.6%
% Hybrid Patterns	n/a	n/a	49.9%	73.2%	84.9%

Note. + Signifies an improvement in performance, - signifies a decline in performance. Alternating Patterns *alternate* direction-change values from + to -, i.e., +-+-+ and -+-+-, etc. Trend Patterns have the same direction-change value throughout. The pattern, i.e., -----, and +++++, etc. n/a - Not Applicable.

Second, the least frequent change-pattern in each of the change-pattern groups was a *trend pattern* of performance decline (-). Trend patterns are change-patterns which

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have the same direction-change values throughout the entire pattern, e.g., ++++ and ---. Thus, these patterns consistently reveal either improving performance or declining performance from one time period to the next for the length of the change-pattern.

Third, alternating change-pattern pairs occurred much more often than trend change-pattern pairs. (Each alternating pattern in a pattern group has a counterpart, or paired change-pattern which alternates as well, but its values are opposite those of the corresponding time period: The +-+'s counterpart is -+-; and the -+-+-'s counterpart is +-+-+. The same holds for trend change-patterns. In each change-pattern group, there is a pair of trend change-patterns, e.g., ---- and ++++.) The table (Table 1) highlights the difference in observations between the alternating pairs and trend pairs for each change-pattern group.

As expected, the percentage of hybrid change-patterns (those patterns not in an alternating pair or trend pair, thus, all other patterns) increased since as change-pattern length increases, the number of patterns possible increases exponentially.

Findings

Two important findings can be derived from examination of the observed frequency of change-patterns analysis: (a) Alternating change patterns are predominate in the sample data; and (b) trend change patterns occur very infrequently in this sample.

These findings are consequential to this study because they render a strikingly clear and simple profile of the change patterns found in the sample data. This

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demonstrates that the data does have a distinguishing property that can be easily found and described without the use of sophisticated techniques.

As demonstrated and discussed in this section, in response to this study's research question one, "For the examined cases, what is the frequency distribution of organization-performance change patterns," a frequency distribution of organization-performance change patterns has been successfully developed and has been found to provide evidence of a discernable change-pattern profile in the sample data as a result of this investigative process.

Research Question Two

Research question two, "For the examined cases, to what extent does the current organization-performance change pattern identify the direction of the next change in performance," required inspecting the performance directional-change data, counting the observations for each of the 64 possible change-patterns, and recording the direction of the next change—with the result that a total of 31,310 change patterns were observed.

All of the change-pattern and next-change tallies were recorded in tables (Tables D6-D10) according to the time-period length for the change pattern. These tables were sorted and ranked into quartiles—from most able to the least able—, according to the change-pattern's ability to identify the direction of the next change.

The calculation which determined the ability of a change-pattern to identify the direction of the next change is a relative measure (relative to other change patterns for the same length time- period) that requires the following steps: (a) Calculating whether the percentage difference between the change patterns' next directional-change represents an

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improvement (+) or a decline (-); (b) ranking change patterns in order of this value, from highest percentage (a value of 1) to the lowest percentage; and (c) averaging this ranking with the ranking for the same change pattern according to the observed frequency (see Tables D1-D5).

This calculation is based on the idea that a change pattern is more able to identify the direction of the next change if, historically, it more often is followed by one of the same directional-change values than the other. A change-pattern *always* followed by a performance increase is more predictive than a change-pattern that only *sometimes* is followed by an increase.

For example, suppose a three-period change pattern of ++ has been observed in the data a total of 10 times. If the next-change value is an improvement (+) in 8 out of those 10 occurrences, then the decline value (-) must have occurred 2 times. The statistics are captured numerically in a percent-difference value, thus this example would have a percent difference value of 60%; determined by (8-2) / (8+2).

Given the percent-difference values for two change-patterns, the change-pattern with the largest percent-difference value is more predictive than the change-pattern with the smaller percent-difference value. Thus, for example, comparing the above example—a percent-difference of 60%—with another change-pattern which has been observed 10 times and has next-change values of 5 improvement values (+) and 5 decline values (-), thus a percent-difference of 0% is much less predictive than the 60% change-pattern.

However, the percent-difference value solely determining the ability to predict, can be misleading because the number of observations for the change-pattern is not taken

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into account. Consider a change-pattern that has occurred 2 times with the next-change value being + both times—this results in a percent-difference value of 100%—suggests a strong ability to predict the next-change value. However, a change-pattern with 100 improvements and 1 decline would yield a 99% percent difference. To correct this phenomenon, the observed-frequency value—specifically its relative rank—must be included in the determination of the change-pattern's ability to identify the direction of the next change.

The tables (Tables D6-D10) were inspected by the researcher and summarized into the table (Table 2) provided below. While a separate analysis was conducted for each of the five change patterns lengths—representing from two to six consecutive time-periods—, the discussion based on the summary table is from a holistic perspective.

Table 2

Summary Analysis of Change Patterns' Ability to Identify Direction of Next Change

	Summary Analysis of Change Patterns' Ability to Identify Direction of Next Change (Summary of Tables D6-D10)				
Number of Time Periods	2	3	4	5	6
Most Useful Pattern for Prediction	-	+-	-+-	-+--	+-+--
Next direction-change	+	+	+	+	+
Least Useful Pattern for Prediction	+	-+	--+	---+	----+
Next direction-change	-	-	-	+	+

Note. + Signifies an improvement in performance. - Signifies a decline in performance.

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Table 2 summarizes the most notable aspects of the five observed frequency tables (Tables D6-D10). Each column pertains to data found in the table corresponding to the number of time-periods in which the change-pattern belongs, i.e., based on the length of the change-pattern.

Three observations of significance are presented in the table and discussed below. While there are many other lenses in which to look at this data and many less significant observations made, the most relevant observations are provided here.

Findings

Two significant findings arise from analysis of the Table 2 summary: (a) The most useful change-patterns in each time-period group consistently identify an improvement (+) as the direction of the next change; (b) a change-pattern with a decline trend and an improvement as the most recent change is consistently the least useful change-pattern for predictive purposes.

These findings, while specific to the sample data, are of consequence to this study since they demonstrate that it is possible to use current organization-performance change patterns to identify the direction of the next change in performance. The procedure to bring these hidden patterns to the surface, as performed in this study, is simple to carry out and has been shown here to provide information not immediately apparent using traditional analysis techniques. The findings in this analysis show that research question two has been addressed: Change patterns can be used to identify the direction of next change in organization performance.

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Research Question Three

Research question three, "For the examined cases, is the current direction of change in organization performance independent of the prior direction of change," involves conducting a Runs test against the change-pattern histories of each of the 100 cases. The Runs test is a statistical technique that uses the number of runs in a sequence of sample data to test for serial dependence in the order of the data. This technique is based on the order in which the data occur; it is not based on the frequency of values in the data. While its evidence is not conclusive, the Runs test does provide insight into the characteristics of the data being examined.

A separate Runs test was applied against the performance-score history data for each of the 100 cases studied. In 80% of the tests, the null-hypothesis— that there is *not* a dependency between one value and the next—was rejected. Thus, the data of the cases analyzed *do* suggest serial dependence.

Findings

An important finding that can be synthesized from the Runs Test results is that the performance scores from one value to the next may *not* be independent of one another. This finding implies that the performance score of a future period in some way is affected by the directional-change value of the current period.

While this phenomena was found in 80% of the 100 cases, it would be improper to make definitive statements immediately or to broadly apply conclusions from this finding. Two facts are of concern: (a) In 20% of the cases, the serial independence of the

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data cannot be ruled out; (b) the Runs test is a very low-powered statistical tool. Both concerns serve as caveats to applying the findings to consequential situations. Nevertheless, the evidence is strong enough to encourage future studies focusing on this particular phenomenon.

Summary

This chapter presented findings based on the data generated by a computer simulation for the study. Running the simulation for 100 cases resulted in the equivalent of over 50,000 pages of output. From this output, 100 patterns of organization performance were distilled and analyzed.

The data was analyzed in three separate processes, in order to address the three research questions. A frequency analysis, a strength of outcome analysis, and a Runs Test were conducted to answer each of the three research questions, respectively. Further in-depth analysis and grounding of these findings, as well as conclusions and recommendations, are provided in the next chapter.

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Chapter Five: Conclusions and Recommendations

The purpose of this study was through use of computer simulation to explore current temporal patterns of organization performance and to investigate whether such patterns may be suggestive of future performance. The basis for the change patterns investigated was the directional change—the increase or decrease—of performance levels for up to 6 consecutive time periods created by computer simulation. Having a pattern-based perspective on the future direction—improvement or decline—of an organization's performance provides change practitioners additional insight that aids in evaluating intervention decisions.

This chapter discusses the conclusions reached and recommendations made based on the research and its findings. Recommendations for future study and closing remarks are provided at the end of this chapter.

This study took an exploratory approach to researching organization performance. Instead of investigating the often-studied causality aspects of organization performance, the study researched performance from the top-down perspective. Organization performance was viewed as an entity unto itself in this study, as opposed to being a result from a collection of causes. The frequency of specific patterns of performance increases and decreases between adjoining time periods was investigated. The reliability of these patterns in providing specific guidance on the change in performance in the subsequent time period was also explored.

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Through the analysis of computer-simulated organization-performance data, with performance regarded as the accuracy of an organization's decisions, the following research questions were asked:

1. For the examined cases, what is the frequency distribution of organization-performance change patterns?
2. For the examined cases, to what extent does the current organization-performance change pattern identify the direction of the next change in performance?
3. For the examined cases, is the current direction of change in organization performance independent of the prior direction of change?

A computer simulation generated the sample data for this study. The ORGAHEAD computer simulation was executed multiple times resulting in 100 independent cases of source data each consisting of an historical view of an organization's performance.

In each execution of the simulation, a virtual military organization was tasked with correctly identifying an incoming aircraft approaching the military's defensible airspace. After identifying the aircraft as being either a *friend*, or an *enemy*, the organization would make a decision to *allow* the aircraft to proceed or to *defend* against it. In each simulation—one execution representing one subject case—the organization was presented with 10,000 incoming aircraft approaching one-by-one; thus, the organization was faced with 10,000 separate decisions to allow entry or not, in chronological order. The accuracy of these decisions—whether they were *correct* or

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incorrect—was tallied and summarized into organization-performance scores. This data process resulted in a set of 100 performance scores for each case, with each score representing 100 decisions.

The study investigated the patterns within these 100 performance-score histories. Specifically, the difference-sign of performance scores between two adjoining time periods was examined. The difference-sign values, either + or -, represented an increase or a decrease of the performance score from one period to the next.

Conclusions

Based on the findings of this exploratory study, and the attending research questions, three significant conclusions can be reached and supported: (a) Change-patterns can be found in an organization's performance history; (b) such patterns have a discernable association with the future performance; and (c) future performance is not independent of past performance.

First Conclusion

Relating to the first conclusion, this study provides evidence that change patterns do exist and can be observed in organization-performance history. As described in the findings section of Chapter Four, two sample data-specific findings can be synthesized from analysis of the pattern-frequency distributions: (a) Alternating change-patterns are predominate in the sample data; and (b) trend change-patterns occur very infrequently in this sample.

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These findings are consequential to this study since they render a strikingly clear and simple profile of the change patterns found in the sample data. This demonstrates that the data has a distinguishing property that can be easily found and described without the use of sophisticated analytical techniques. Both fluctuations and alternating improvement and digression in performance appears to be the norm for these sample cases.

This finding is consistent with evidence from empirical research conducted by Morel and Ramanujam (1999), who found that such patterns could be observed in organizations. This finding also provides more evidence that patterns do exist in organization performance, although they may not be as visible as other patterns in nature. The patterns found here are not as readily apparent as the patterns of color on butterflies or of stripes on a zebra's coat.

It was found that alternating change-patterns (alternating performance improvement, then decline, or visa versa) from one period to the next were prominent. In each of the groups investigated, these alternating change-patterns were more frequently observed than all other change-patterns. This phenomenon is consistent with the way negative feedback loops behave in a closed system: Organizations adjust their aspirations from period to period based on feedback (the most recent performance score), which often causes variability in effort, resulting in the variability of performance. The alternating pattern also demonstrates that performance-aspiration levels within organizations become self-realized (Wood, 1989).

The computer simulation's design encapsulates the organizational learning and adaptation phenomena: Learning and adaptation manifest the organization's conscious

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change, since the organization seeks to improve its performance by an adaptation—that is, change—based on what it has learned. The virtual organization is evaluating itself for hiring/firing or reorganization every two performance-score reporting periods. The resulting flip-flops in performance could be a direct result of this cyclical mode, implying that cycles in organizations are manifestations of the reorganization efforts. This is consistent with what Carley (1999) pointed out in an earlier study.

Flip-flopping performance—as with an organization's innate drive toward improvement—is consistent with the organization being a goal-seeking social construct. The bias towards improvement can be interpreted this way: The flip-flopping performance demonstrates that organizational adjustments tend to over-shoot performance expectations. That is, in the course of continually adjusting, organizations over-compensate for poor performance; thereby causing cycles of exaggerated improvement and decline.

Second Conclusion

Relating to the second conclusion, the three important findings that can be synthesized from the observations of patterns and subsequent difference-sign values as described in Chapter Four consisting of the following: (a) Flip-flop patterns show the most predictive power; (b) prediction-accuracy positively correlates with the pattern length; and (c) the success rate of the pattern increases as the pattern length increases.

The predictive power of patterns evident in this data is striking and adds credence to Axelrod and Cohen's (1999) assertion that prediction of a complex system is feasible.

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A rhythmic sequence of up then down appears to be the prevailing pattern in this data. The phenomena could be explained by the organization accommodating and overshooting adjustments, thus producing the stable and orderly (Anderson, 1999) characteristic that complex systems, such as the motion of planets exhibit. This data demonstrates the oscillation that Gordon and Greenspan (1988) observed in complex systems even while they are in a steady state.

The data supports the notion that an organization is a complex system. The nonlinearly of the data is consistent with the characterization of complex systems provided by Dooley and Corman (n.d.). The predominate frequency with which the fluctuating improvement-then-decline, or decline-then-improvement, series appear, demonstrates the nonlinearly characteristic of organization performance.

Third Conclusion

Implicit in the third conclusion, the finding that the performance scores from one value to the next may *not* be independent of one another is the notion that the performance score of the next-future period may in some way *depend* on the performance score of the most-recent period.

While this phenomenon was found in the majority of the cases, it would be improper to immediately draw and broadly apply definitive conclusions from the finding. In particular, there are two areas of concern: (a) In 20% of the cases, the serial independence of the data could be ruled out; and (b) the statistical power of the Runs Test is very low relative to other statistical tests. Nevertheless, the evidence obtained seems

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amply strong enough to warrant further studies being conducted around the possible serial dependency within organization performance.

Implications of the Study

The conclusions reached in this study have implications for practitioners and researchers alike. For practitioners, the study demonstrates that clear patterns exist in organizations' performance-histories; and that these patterns may be used to predict the direction of change in future performance. For researchers, the study reveals the usefulness of contemporary computer-modeling methods and of the application of interdisciplinary perspectives to a traditional research topic.

Implications for Practitioners

The conclusions from this study have several actionable implications for the broad group of organization-change practitioners, including organization managers. This study provides insight into the hidden phenomena of patterns in organization performance. For practitioners, two implications that can be derived are immediately relevant: (a) Practitioners should use knowledge of the existence of performance patterns while *designing* change programs and interventions; and (b) they should utilize knowledge of these patterns in the change and organization management *decision-making* process.

When designing change programs practitioners should recognize that performance patterns do exist and that they may provide useful clues in foretelling future near-term performance. For the practitioner who possesses the knowledge, this may mean resisting

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intervening during a downturn or an upturn and not making strategic changes. On the other hand, it may also mean implementing a change program to smooth out the volatility in performance. Further, it can mean designing programs so as to leverage the downturn, thereby enhancing future performance. If properly anticipated, a down-turn can allow practitioners to turn that event into a stronger than normal upturn.

Implications for Researchers

This study has two implications for organization researchers: (a) Computer simulation should be utilized as an organization-research tool; and (b) Complexity Theory should be the vantage point taken for future research.

Using computer simulation and implementing simulation-based exploratory study as a method means that experiments can be rerun risk free and at low cost. Because that are capable of controlling the environment in which the research is conducted, simulations can be used to determine the baseline case for empirical studies.

This study demonstrates the use of taking a complexity theory perspective in the uncovering of unseen phenomena in organizations. Examining organization performance from a higher, more systemic-level, rather than from the more usual causality perspective was shown to be a valuable application of Complexity Theory to organization research.

Recommendations for Future Research

Although this study is but one step forward in expanding academic understanding of organizations, it opens the door to many new questions. The success of the study, specifically the approach taken and the findings, leads to the recommendation of two

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specific areas for future research: (a) Exploring how change-pattern profiles might vary over the life-time of an organization, and (b) investigating the possibility of developing a set of change-pattern profile archetypes that could be practically applied.

The first area involves investigating how pattern profiles might change over the lifetime of an organization. Recognizing that organizations pass through stages in their growth life-cycle—from conception to shutdown—performance levels often change during these periods. Future researchers might well address the question of whether the profile of an organization's performance-patterns change over time; if so, determine the manner in which they change and the root cause of the transition.

The design of this experiment deliberately includes capturing data from the period of an initial start-up phase for each case in the simulation. Since the virtual organizations being simulated are new and without history, the determination of the choices made—thus its performance—may appear to have occurred randomly during this initial training period.

The impact of restricting the study to the training period data can only be speculated upon. Casual observations suggest that the performance for these virtual organizations nearly always improves between the first and second period, which can somewhat skew overall results, even if only slightly. The number of periods under study (n=100) keeps this initial period bias minimal. However, the impact of a greater number of initial performance scores requires greater scrutiny. Overall, the observed impact is that the performance levels of organizations will often be below the historical mean during the early training period, which is not surprising, given a train-as-you-go scenario.

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A second area for further research is to investigate the applicability of developing a set of change-pattern profile archetypes. Just as business organizations can be grouped by the industry in which they operate, which allows for generalizations to be made about the behavioral characteristics of individual organizations, perhaps the change-profile archetypes can group organizations into behavioral groups. These characteristics may determine other aspects of organization behavior such as causality. Categorizing organizations according to similar performance patterns and then studying them from this perspective is an exciting prospect and one that could lead to new and fruitful ways of thinking about their structures. Hypothetically, for example, organizations we now consider to be as different as IBM and Ben & Jerry's might in fact turn out to be very similar when viewed from the perspective of their performance patterns.

Closing Remarks

This study is a demonstration of the viability of applying pattern analysis to performance data. The results from applying simple techniques to an organization's performance history can provide additional insight into the direction of performance change. While more research is necessary to make this methodology fully operational, this study represents a step forward in applying the concept.

Looking at performance as an entity unto itself and understanding change-patterns of performance rather than using traditional methods may give practitioners an edge when they are seeking to understand today's increasingly complex organizations. In addition, using computer simulation to aid the exploration allows for deep insight at low cost into organizational performance. While the temptation to utilize empirical data from

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an actual organization is understandable, the sheer volume of such data makes it both extremely expensive and impractical to obtain. Thus in practical terms, pattern-searching analysis would seem to require the aid of computer simulation.

While this study represents only a beginning, the researchers looks forward to more sophisticated time-series analysis techniques being used in future studies to provide much more information about organization-performance change-patterns. Exploring patterns in other measures of organization performance—beyond the simplistic binomial-decision considered in this study—may require additional cost and complexity, but may prove increasingly beneficial to practitioners.

Although some might argue that more probing analysis and more complicated mathematical techniques are warranted in order to move the study of performance forward in the long run, requiring these might actually prove to be detrimental to progress. If the knowledge gleaned is to be acted upon in the real world, the results of any research in the field should be easy to understand. By keeping this study's design within the bounds of simple methods, the researcher believes he has increased the likelihood of change practitioners embracing its findings. Ultimately, implementation of what the data reveals was the goal of the research.

This project approaches the study of organization performance from a top-down, as opposed to the more common bottom-up perspective. It explores organization performance as an entity onto itself rather than as a result with underlying causes. This study has utilized computer simulation to study virtual instead of actual organizations as

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the source for data. While, the results specific to this study may not be directly relevant to an actual organization and a specific intervention, per se, the study makes a significant indirect contribution to the study of organizations.

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Appendix A: Simulation Validation

The validity of the instruments used in research is a critical contributor to the confidence in the findings. {roviding information about the instrument is an "essential" component (Creswell, 1994, p. 120) of research design - even "vital" (Shaughnessey, Zechmeister & Zechmeister, 2000, p. 141). Data collection instruments can include surveys, secondary sources, and personal observation among others.

For this study, there are two data collection instruments involved. The first is a computer simulation, which generates the performance data being subject to analysis. The second instrument is the data analysis software that summarizes this plethora of data. The computer simulation instrument is discussed in this appendix, while the data analysis software is implemented using standard spreadsheet software, i.e., Excel.

The data generation instrument used in this study is named, ORGAHEAD (Carley & Svoboda, 1996; Carley & Lee, 1998). ORGAHEAD was initially developed as part of a National Science Foundation project awarded to Carnegie Mellon University. Over the past several years, ORGAHEAD has been enhanced with additional features. The software remains supported by Carnegie Mellon today and is available for researchers' use.

Computer simulations in general and those similar to ORGAHEAD have recently been used in studies of organization performance. A closely related predecessor of ORGAHEAD, DYCORP (Lin & Carley, 1995) was used to further research in the understanding the tradeoff between accuracy and errors in decision-making performance

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(Lin, 1998) and has even been used as an instrument in doctoral dissertations (Lin, 1994). A 1997 study (Gibson, Fichman & Plaut) consisted of a simulation, based on a computational model of decision-making performance, in which the results were compared and successfully corroborated with empirical evidence.

Computer modeling of organizations and the subsequent running of the corresponding computer simulation has been used to understand and to aid in predicting organization performance (Christensen, Jin, Kunz and Levitt, 1999) - similarly to this study. Before presenting discussion specific to ORGAHEAD, a more general discussion about validation of computer simulation models is presented to develop a context for ORGAHEAD validation specifics.

The use of simulations in the social sciences really is not new (Inbar & Stoll, 1972; Greenblat & Duke, 1975), but the plummeting cost of technology is clearing the way for an increase usage. "The logic underlying the methodology of [modern] simulations is not very different from the logic underlying [traditional] statistical modeling" (Gilbert, 1993). Gilbert points out the main difference between the two is that simulation itself needs to be "run" while the statistical model requires the use of a statistical analysis software.

Social behavior-based computer simulations have many uses. Such software can be utilized for training and educational purposes (Walters, 1999) and for social science research (Gilbert & Troitzsch, 1999).

Validation specific to computational models and computer simulation in the social sciences and is a complex issue (Carley, 1996) and has been debated for many years

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(Cyert & March, 1963). The process of validation is in its infancy (Andreoni & Miller, 1995). Validation is not a certainty, it is a matter of degree (Law & Kelton, 1991; Kleindorfer, O'Neill & Ganeshan, 1998). Some call it a matter of "social conversation" instead of "objective confrontation" (Barlas & Carpenter, 1990). Validation has been called the most elusive of all methodical problems dealing with computer simulation as an instrument of organization research (Naylor & Finger, 1967, p. B-92).

There are calls for systemic ways of validating computational models (Thomsen, Levitt, Kunz, Nass & Fridsma, 2003) and simulations as some researchers have taken the position that without validation, study results are meaningless (Naylor & Finger, 1967). Unfortunately, others have claimed that verification and validation of numerical models of natural systems [such as social systems] is "impossible" (Oreskes, Shrader-Frechette & Belitz, 1994) Regardless, validation is important to simulation methodology (Barlas, 1998) and it should be made explicit that any model (thus simulation) is actually a simplification of reality (Coyle & Exelby, 2000, p. 28).

There are several types of validation pertaining to computational models (Knepell & Arangno, 1993). Mthe type relevant to this study is the comparability between the organization performance results generated by the simulation and organization performance data from a real organization (Hunter & Naylor, 1979, p. 423), e.g. external validity - or "operational validity" (Carley, 1996, p. 2).

To researchers not trained in modeling techniques, computer simulations may appear "bewildering" (Carley, 1996, p. 1), making simulations difficult to understand, thus the subsequent research and findings can be discounted. Some have pointed out that

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validation should not be held up as a prerequisite for (running and) presenting simulations and results (p. 6).

One simplistic approach to validation is to conduct a revised version of the Turing test. The "social Turing test" (Carley & Newell, 1994) method, like the traditional Turing test, is a method that evaluates whether an observer can blindly distinguish between the results of two separate data sources representing the same population. The Turing test is commonly applied in artificial intelligence research (Lugar 2002, p. 10). Although, it should be pointed out that social systems can show counterintuitive behaviors (Forrester, 1971) just as in artificial intelligence..

In 1996 a technique called "docking" (Axtell, Axelrod, Epstein & Cohen) was first suggested as a simulation technique later suggested as an exercise that contributes to the purpose of validation (Moss & Davidsson, 2001) Docking is a process in which two separate models are compared and made to give equivalent results. Reaching this level of equivalence gives both models a greater sense of validity. Specifically, ORGAHEAD has been involved in at least three docking studies (Louie, 2002; Louie & Carley, 2003; Louie, Carley, Levitt & Kunz, 2002; Takadama, Suematsu, Sugimoto, Nawa & Shimohara, 2003)

ORGAHEAD was developed to study the influence of organization structure on its performance. ORGAHEAD implements a simulated annealing technique to mimic an organization's search for the best structure. The model allows for adaptation by firing, hiring, re-tasking (access to information) and reassigning (changing the report structure) members. Using ORGAHEAD in a academic study, researchers found that organization

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performance depends more on individual learning than on organizational structure. This illustrates that ORGAHEAD has proved useful to basic organization research in the past.

ORGAHEAD has been used in studies of organization adaptability and architecture related to performance (Carley & Ren, 2001.). Related to ORGAHEAD's theoretical foundation, several simulations have been developed spawning from the ACTS theory (Carley, 1993; Carley, 2000; Carley & Prietula, 1994; Lin, 1994; Verhagen, 1998).

On the basis that the ORGAHEAD model has been part of several docking experiments and is widely used in the research community, this researcher considers ORGAHEAD a reasonably valid model relative to its purpose and the objectives of this study.

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Appendix B: Permission to Use Simulation

From - Sat May 24 07:26:02 2003
X-UIDL: 74f6ae7597246ff4b77b2ef52b7abc37
X-Mozilla-Status: 0013
X-Mozilla-Status2: 00000000
X-Apparently-To: terrill@org-sim.com via web14612.mail.yahoo.com; 23 May 2003 16:25:56 -0700 (PDT)
Return-Path: <kathleen.carley@cmu.edu>
Received: from ANALOG.ECE.CMU.EDU (EHLO analog.ece.cmu.edu) (128.2.133.58)
by mta2-vm3.mail.yahoo.com with SMTP; 23 May 2003 16:25:56 -0700 (PDT)
Received: from cmu.edu (12-226-124-216.client.attbi.com [12.226.124.216])
by analog.ece.cmu.edu (8.11.0/8.8.8) with ESMTP id h4NNPrG06335;
Fri, 23 May 2003 19:25:53 -0400 (EDT)
Message-ID: <3ECE1995.8090607@cmu.edu>
Date: Fri, 23 May 2003 08:52:37 -0400
From: Kathleen Carley <kathleen.carley@cmu.edu>
Organization: Carnegie Mellon University
User-Agent: Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.0.2) Gecko/20030208 Netscape/7.02
X-Accept-Language: en-us, en
MIME-Version: 1.0
To: "Terrill L. Frantz" <terrill@org-sim.com>
Subject: Re: ORGAHEAD for Dissertation Research?
References: <3ECDED92.8070508@org-sim.com>
Content-Type: multipart/alternative;
boundary="------------040905080500080601090708"

--------------040905080500080601090708
Content-Type: text/plain; charset=us-ascii; format=flowed
Content-Transfer-Encoding: 7bit

Terril
we will send you an executable of the current system and its interface
you should site these papers

Kathleen M. Carley & David M. Svoboda, 1996, "Modeling Organizational Adaptation as a Simulated Annealing Process." Sociological Methods and Research, 25(1): 138-168.

Kathleen M. Carley & Ju-Sung Lee,1998, "Dynamic Organizations: Organizational Adaptation in a Changing Environment." Ch. 15 (pp. 269-297) in Joel Baum (Ed.) Advances in Strategic Management, Vol. 15, Disciplinary Roots of Strategic Management Research. Greenwhich, CN: JAI Press. Pp. 269-297.

and in acknowledgements note that OrgAhead was provided by the Carnegie Mellon center for Computational Analysis of Social and Organizational Systems, CASOS.

Terrill L. Frantz wrote:

> Dr. Carley,
>
> I would like to utilize ORGAHEAD software as a research model for my
> dissertation for an Ed.D. in Organization Change at Pepperdine
> University. I am in the process of designing the research.
>
> My specific interest for the dissertation is to study the trajectory
> of the performance landscape - essentially furthering your work as
> described in "Organizational Adaptation in Volatile Environments",
> among your other related articles. I'm searching for temporal
> patterns in the oscillating performance levels across different
> organization samples in the hopes of finding something that can later
> be researched empirically.
>
> I have already taken the liberty to download ORGAHEAD v2.1.3 from
> Ju-Sung's page to test its execution and to play with it a bit.

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>
> Beyond the obvious references and credits, is there anything I need to
> address, or specifically do to gain your authorization to utilize
> ORGAHEAD in this manner?
>
> BTW ... A couple of months back I contacted you in regard to attending
> the Summer institute - I'm all signed up and look forward to meeting
> you in June.
>
> Regards,
> Terrill.
>
>
>
>
>
> --
> Terrill L. Frantz
> Managing Director
> Organization Simulations Asia Ltd.
> Hong Kong
> www.org-sim.com <http://www.org-sim.com>

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Appendix C: Non-Human Subjects Exemption

03/18/2004 15:32 FAX 13105685755 PEP GSEP 001

VERIFICIATION: RESEARCH DOES NOT INVOLVE HUMAN SUBJECTS
PEPPERDINE GRADUATE SCHOOL OF EDUCATION & PSYCHOLOGY

Name: Terrill L. Frantz

Proposed Dissertation Title:

TEMPORAL PATTERNS IN ORGANIZATION PERFORMANCE LEVELS

Per Institutional Review Board (IRB) guidelines, all proposed research in which a student is the principal or co-principal investigator and that involves either direct or indirect contact with human subjects must submit an application to the Graduate and Professional Schools IRB (GPS-IRB).

If your research does not involve the participation of human subjects and you are not using/collecting any data that has been obtained from individual participants, your research is not subject to IRB review and approval.

VERIFICATION OF NON-USE OF HUMAN SUBJECTS

I verify that this proposed research does not involve use of human subjects, either directly or indirectly.

Student's Signature: [signature] Date: 11 Mar 2004

Approved by: Robert M Canady — Committee Chairperson's Signature Date: March 16, 2004

NOTE: THIS FORM MUST BE SIGNED AND SUBMITTED TO THE EDUCATION DIVISION'S IRB PRIOR TO BEGINNING ANY DATA COLLECTION OR ANALYSIS.

RECEIVED BY EDUCATION DIVISION IRB SUB-COMMITTEE:

Signature: Kay Davis Date: 3-17-04

TOTAL P.01

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Appendix D: Data Analysis Supporting Detail

Table 1.

Observed Frequency of Two-Period Change Patterns

Change Pattern	Observed Frequency *n*	%	Rank
+	5,384	54.4	1
-	4,516	45.6	2
Total	9,900	100.0	

Note: Change Pattern represents the change in performance between two reporting periods. + signifies an improvement, while - signifies a decline

Table 2.

Observed Frequency of Three-Period Change Patterns

Change Pattern	Observed Frequency *n*	%	Quartile
+-	3,153	32.2	I
-+	3,115	31.8	II
++	2,176	22.2	III
--	1,356	13.8	IV
Total	9,800	100.0	

Note: Change Pattern represents the change in performance between two reporting periods. + signifies an improvement, while - signifies a decline

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Table 3.

Observed Frequency of Four-Period Change Patterns

	Observed Frequency		
Change Pattern	*n*	%	Quartile
+-+	2,086	21.5	I
-+-	1,704	17.6	I
++-	1,416	14.6	II
-++	1,381	14.2	II
+--	1,033	10.6	III
--+	1,022	10.5	III
+++	735	7.6	IV
---	323	3.3	IV
Total	9,700	100.0	

Note: Change Pattern represents the change in performance between two reporting periods. + signifies an improvement, while - signifies a decline

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Table 4

Observed Frequency of Five-Period Change Patterns

	Observed Frequency		
Change Pattern	*n*	%	Quartile
+-+-	1,172	12.2	I
-+-+	1,135	11.8	I
++-+	920	9.6	I
+-++	898	9.4	I
-++-	869	9.1	II
+--+	760	7.9	II
-+--	550	5.7	II
--+-	528	5.5	II
+++-	514	5.4	III
-+++	497	5.2	III
++--	481	5.0	III
--++	480	5.0	III
+---	267	2.8	IV
---+	262	2.7	IV
++++	211	2.2	IV
----	56	0.6	IV
Total	9,600	100.0	

Note: Change Pattern represents the change in performance between two reporting periods. + signifies an improvement, while - signifies a decline

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Table 5

Observed Frequency of Six-Period Change Patterns

Change Pattern	Observed Frequency *n*	%	Quartile
+-+-+	764	8.0	I
-+-+-	617	6.5	I
+-++-	589	6.2	I
-++-+	578	6.1	I
++-+-	536	5.6	I
-+-++	511	5.4	I
-+--+	414	4.4	I
+--+-	413	4.3	I
+-+--	393	4.1	II
++-++	375	3.9	II
--+-+	367	3.9	II
++--+	345	3.6	II
-+++-	340	3.6	II
+--++	336	3.5	II
+++-+	321	3.4	II
+-+++	297	3.1	II
-++--	282	3.0	III
--++-	280	2.9	III
+---+	214	2.3	III
--+++	197	2.1	III
+++--	187	2.0	III
--+--	157	1.7	III
++++-	156	1.6	III
-++++	151	1.6	III
---++	144	1.5	IV
++---	134	1.4	IV
-+---	132	1.4	IV
---+-	115	1.2	IV
+++++	51	0.5	IV
+----	49	0.5	IV
----+	48	0.5	IV
-----	7	0.1	IV
Total	9,500	100.0	

Note: Change Pattern represents the change in performance between two reporting periods. + signifies an improvement, while - signifies a decline

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Table 6

Ability of Two-Period Change Pattern to Identify Direction of Next Change

	Next Performance Change				Observed Frequency of Change Pattern	Relative Ability to Identify Direction of Next Change	
	Observed Frequency		Difference				
Change Pattern	Improvement (+)	Decline (-)	%	Rank	Rank	Rank Mean	Relative Ability (Rank)
-	3,115	1,356	39.3	1	2	1.5	1
+	2,176	3,153	18.3	2	1	1.5	2

Note: Change Pattern represents the change in performance between two reporting periods.

+ signifies an improvement, while - signifies a decline.

Table 7

Ability of Three-Period Change Pattern to Identify Direction of Next Change

	Next Performance Change				Observed Frequency of Change Pattern	Relative Ability to Identify Direction of Next Change	
	Observed Frequency		Difference				
Change Pattern	Improvement (+)	Decline (-)	%	Rank	Rank	Rank Mean	Relative Ability (Quartile)
+-	2,086	1,033	33.8	2	1	1.5	I
--	1,022	323	52.0	1	4	2.5	II
++	735	1,416	31.7	3	3	3.0	III
-+	1,381	1,704	10.5	4	2	3.0	IV

Note: Change Pattern represents the change in performance between two reporting periods.

+ signifies an improvement, while - signifies a decline.

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Table 8

Ability of Four-Period Change Pattern to Identify Direction of Next Change

	Next Performance Change				Observed Frequency of Change Pattern	Relative Ability to Identify Direction of Next Change	
	Observed Frequency		Difference				
Change Pattern	Improvement (+)	Decline (-)	%	Rank	Rank	Rank Mean	Relative Ability (Quartile)
-+-	1,135	550	34.7	4	2	3.0	I
+--	760	267	48.0	2	5	3.5	I
++-	920	481	31.3	5	3	4.0	II
+-+	898	1,172	13.2	7	1	4.0	II
---	262	56	64.8	1	8	4.5	III
+++	211	514	41.8	3	7	5.0	III
-++	497	869	27.2	6	4	5.0	IV
--+	480	528	4.8	8	6	7.0	IV

Note: Change Pattern represents the change in performance between two reporting periods.

+ signifies an improvement, while - signifies a decline.

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Table 9

Ability of Five-Period Change Pattern to Identify Direction of Next Change

	Next Performance Change				Observed Frequency of Change Pattern	Relative Ability to Identify Direction of Next Change	
	Observed Frequency		Difference				
Change Pattern	Improvement (+)	Decline (-)	%	Rank	Rank	Rank Mean	Relative Ability (Quartile)
-+--	414	132	51.6	3	7	5.0	I
+-+-	764	393	32.1	10	1	5.5	I
-++-	578	282	34.4	8	5	6.5	I
+-++	297	589	33.0	9	4	6.5	I
--+-	367	157	40.1	6	8	7.0	II
+---	214	49	62.7	2	13	7.5	II
++-+	375	536	17.7	12	3	7.5	II
++--	345	134	44.1	5	11	8.0	II
----	48	7	74.5	1	16	8.5	III
-+++	151	340	38.5	7	10	8.5	III
-+-+	511	617	9.4	16	2	9.0	III
++++	51	156	50.7	4	15	9.5	III
+++-	321	187	26.4	11	9	10.0	IV
+--+	336	413	10.3	15	6	10.5	IV
--++	197	280	17.4	13	12	12.5	IV
---+	144	115	11.2	14	14	14.0	IV

Note: Change Pattern represents the change in performance between two reporting periods.

\+ signifies an improvement, while - signifies a decline.

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Table 10

Ability of Six-Period Change Pattern to Identify Direction of Next Change

	Next Performance Change				Observed Frequency of Change Pattern	Relative Ability to Identify Direction of Next Change	
	Observed Frequency		Difference				
Change Pattern	Improvement (+)	Decline (-)	%	Rank	Rank	Rank Mean	Relative Ability (Quartile)
+-+--	300	91	53.5	6	9	7.5	I
++-+-	364	169	36.6	15	5	10.0	I
+-++-	391	194	33.7	18	3	10.5	I
+--+-	281	130	36.7	14	8	11.0	I
-+-+-	387	218	27.9	21	2	11.5	I
-+-++	169	332	32.5	20	6	13.0	I
++-++	122	251	34.6	17	10	13.5	I
+-+-+	331	428	12.8	26	1	13.5	I
-++--	197	85	39.7	11	17	14.0	II
+-+++	89	204	39.2	12	16	14.0	II
-++-+	226	346	21.0	24	4	14.0	II
++---	111	20	69.5	3	26	14.5	II
+++--	138	47	49.2	8	21	14.5	II
+----	42	6	75.0	1	30	15.5	II
-+---	103	28	57.3	5	27	16.0	II
--+--	114	41	47.1	10	22	16.0	II
+++++	10	40	60.0	4	29	16.5	III
-++++	38	110	48.6	9	24	16.5	III
--+++	61	134	37.4	13	20	16.5	III
-----	6	1	71.4	2	32	17.0	III
--++-	187	88	36.0	16	18	17.0	III
-+--+	179	231	12.7	27	7	17.0	III
---+-	86	27	52.2	7	28	17.5	III
-+++-	210	128	24.3	23	13	18.0	III
+--++	144	190	13.8	25	14	19.5	IV
++++-	101	51	32.9	19	23	21.0	IV
++--+	157	181	7.1	31	12	21.5	IV
--+-+	179	186	1.9	32	11	21.5	IV
+++-+	141	177	11.3	29	15	22.0	IV
---++	53	90	25.9	22	25	23.5	IV
+---+	118	93	11.8	28	19	23.5	IV
----+	26	22	8.3	30	31	30.5	IV

Note: Change Pattern represents the change in performance between two reporting periods.

+ signifies an improvement, while - signifies a decline.

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