

# A CASE FOR CHAOS THEORY IN NURSING

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## ABSTRACT

This paper addresses the question of why nurses should understand chaos theory. A critique of the literature is used to demonstrate how chaos theory has been utilised in a number of disciplines, including nursing. Possible applications of chaos theory in nursing are proposed in order to demonstrate where it might assist nurses, in particular researchers, educators and policy makers. The appropriateness of the application of chaos theory as a framework for knowledge generation is also discussed.

## INTRODUCTION

Chaos theory has been developed from the disciplines of mathematics, computer science and meteorology and stems from earlier work by a number of mathematicians. During the last two decades it has been identified as one of the new sciences (Gleick 1987). Chaos theory is a science of the global nature of systems which enables simple mathematical equations to model complex systems. Small differences in input can have dynamic responses in output. This phenomenon has become known as sensitive dependence on initial conditions (Gleick 1987 p.8).

Nursing practice involves complex dynamic systems and it can be argued that it would be amenable to analysis using the methods of chaos theory. However, few nursing articles use chaos theory as a framework for understanding the nursing context. This paper will argue that nurses would benefit from understanding chaos theory and through its application gain a greater understanding of their practice. A number of questions are addressed: What is chaos theory? How has chaos theory been applied within the nursing literature and is this an appropriate use of the theory? How can it assist nursing? Is it an appropriate theoretical construct for nursing knowledge generation?

### Why should nurses understand chaos theory?

The question of why any researcher needs to understand chaos theory is one of importance. It can be argued that in order to gain new insights into phenomena of interest, underlying frameworks of analysis have to be understood. This is not unique to nursing. The newer sciences, such as quantum mechanics and chaos theory have been, and will increasingly be, used as such a framework. Chaos theory is argued by a number of nurse researchers to offer a new paradigm science perspective and to provide new ways to examine the world (Copnell 1998; Pediani 1996; Barker 1996; Coppa 1993; Phillips 1991). The theory must be understood before it can be applied to any nursing context. Without this understanding theory will be adopted without due regard to the

applicability of the concepts and therefore informed discussion, evaluation or critique becomes impossible.

New applications for chaos theory are being proposed and these will directly influence the knowledge base and practice of nurses. Chaos theory has already been used as a framework for research in areas such as physiology, demographics, economics and business planning, theology and leadership theory. Some of these have a direct effect on nursing.

### What is chaos theory?

Chaos theory explains how complex systems behave. Gleick (1987) believes that chaos is not simple anarchy but that complex systems follow some very simple rules. Small changes can result in large differences, which are not proportional to the magnitude of the change. This creates a nonlinear relationship. For example, a small change in wind turbulence can lead to large changes in weather in another area. These changes are not random but can be predicted using computers and simple mathematics.

### The nursing literature on chaos theory

On searching the computerised library databases for chaos theory in nursing, 49 articles were highlighted. A number of these had to be excluded on the grounds that they were not nursing related. Excluded were articles in the areas of homoeopathy, chiropody and rehabilitation counselling. A PhD thesis in nursing was also excluded on the grounds of availability. The earliest article found was published in 1991 and since then there has been a progressive increase each year. A selection of articles, from the 'Journal of Theoretic and Applied Chaos in Nursing', were included in this review. This particular journal is, as the name suggests, a very specialised journal devoted to chaos theory and its application to nursing. The first issue of this journal appeared in 1994. Murray (1997), supports the view that there is little nursing literature on chaos theory and has stated that there is minimal nursing-related material which deals with chaos, complexity or nonlinear dynamics. This could be used as supporting evidence for the notion that there is therefore no need for nurses to study chaos theory, but this is a short-sighted view. More articles are appearing each year and at this stage the possibilities chaos theory offers nursing have not been fully explored.

Since 1991 nurses who have made a contribution to the nursing literature on chaos theory include Murray (1997, 1992), Phillips (1992, 1991) and Vicenzi (1994) and Vicenzi et al (1997). In 1991, Phillips discussed the possibilities chaos theory offered to nursing research and particularly qualitative research. This discussion was based on the opinion that an understanding of naturalistic inquiry and nonlinear statistical models will enable nurse researchers to gain insights into the instability and

unpredictability of systems. This article provoked a rebuff from Puskar et al (1992) who reminded Phillips that chaos theory was a mathematical concept, and that they believed the greatest contribution that chaos theory could make to nursing research was in quantitative designs. Their reasoning would appear sound as statistical models provide quantitative data that enable researchers to model complex chaotic systems using simple mathematical equations. Phillips (1992) further explored chaos theory in his response to this rebuff and stated that they had failed to appreciate the beauty of nature's chaos, and had not understood linear thinking.

An article by Murray (1992) discusses the need for a critical care curriculum to include chaos theory. Murray (1992) has drawn upon the literature that uses chaos theory as a way to understand complex systems. He highlights the use of the theory by Goldberger et al (1990) to explain physiological systems but also asks the question: How might chaos theory be useful for nursing within critical care? He subsequently identified areas such as epidemiology, physiology and risk assessment. While at present he is unsure of chaos theory's usefulness due to a lack of available research evidence, he stated that nurses at least should have chaos theory as part of their knowledge base in order to critique the literature. Hence, he believes that chaos theory should be included in the critical care curriculum.

Analysis of the more recent nursing literature suggests that chaos theory has moved from being a possibility for nursing, to a theoretical approach that has been applied to nursing practice. The theory has been applied in three discrete ways by various disciplines, including nursing. For the purposes of this analysis three categories have been adopted; the mathematical constructs, the properties that chaotic systems exhibit (the tenets of the theory) and the notion of chaos.

### Different nursing views on chaos theory

#### *THE MATHEMATICS OF CHAOS*

Complex chaotic systems can be computer-modelled using a number of mathematical equations. What was seemingly random behaviour can be demonstrated to have exhibited order. The mathematics of chaos can be illustrated in the areas of business and physiology. Legge (1990) has used the mathematics of chaos to formulate a business plan. Buchanan (1998) reports that a number of scientists are investigating the correlation of the beat of a diseased heart with the mathematics of chaos theory. He also reported that the respiratory system, and in particular Cheyne-Stokes breathing, was another area of interest.

There are a few nursing articles in which the mathematics of chaos has been used as a tool for analysis. One such example is that of Pollock (1997) who analysed

the patient census of an intensive care unit over a four-year period. Two forms of statistical analysis were used. The results of analysis, which relied upon nonlinear dynamics (Lyapunov exponent and fractal structure), were compared with traditional time series analysis. The researcher found that there was a chaotic pattern in the nonlinear analysis whereas the traditional analysis failed to establish a pattern of census. Other examples can be found in the specialty chaos journal previously mentioned.

#### *THE TENETS OF CHAOS*

The tenets of the theory are the principles or properties that chaotic systems exhibit. Principles such as the nature of a nonlinear system, the self-similarity and iteration demonstrated with fractals and the butterfly effect are all examples of these properties. These tenets can be illustrated within the leadership and management literature. As an example Wheatley (1992) has used the imagery of fractals and drawn a parallel to an organisation where a strong value system is evident, and where values are role modelled by leadership and repeated at all levels within the organisation.

Similarly, in the nursing literature Bellin et al (1997) have used the tenets of chaos theory and applied them to ecological health nursing. Interestingly, this article has appeared in 'Complexity and Chaos in Nursing Journal' where apparently a strict interpretation of chaos theory is not required, as this article uses what are described as the tenets of chaos theory but are actually a loose interpretation of these. For example, collaborating is likened to a dynamic relationship with an unpredictable pattern (this is presumed to be a property of a chaotic nonlinear system).

Goertz Koerner (1996) has identified some of the properties of complex systems (self-organisation, self-generation and self-renewable) to illustrate how in a post-modern world nursing can use some of the new sciences as a research methodology. Chaos theory, quantum physics and ecofeminism are some of the new sciences which she sees as being particularly helpful. She states that new discoveries in the social, religious and psychological areas are converging with the new sciences and providing new definitions of reality and being. In her article, self-organisation is equated with a sharing of the vision and for nursing as 'caring in the human health experience' (p.6). Self-generation is seen as the process used by organisations to 'manage information in life-giving ways' (p.7). While neither definition articulates with the notion of self-similarity and iteration found with fractals, the aim of her article was to broaden the worldview of nurses. This may have been achieved, but the principles of chaos theory have not been adequately represented.

The nature of a nonlinear system has also been misinterpreted in the literature. Gleick (1987 p.23) states

that a nonlinear relationship is not strictly proportional and that linear relationships can be captured with a straight line on a graph. In a nonlinear system the end point is not known because of the cascading effect of the intervention, whereas in a lineal system the end result is known.

In the argument presented by Haberecht and Prior (1997) spiritual chaos during a period of bereavement was traced using chaos theory. They believe this to be a nonlinear system because the period in the middle (the grief period) was chaotic. In this case the situation could be interpreted differently. If grief is the starting point and harmony or peace and acceptance the end point, then this concept of grief is a linear process, even if during the transition a period of chaos (or perhaps unpredictable behaviour) occurs. Haberecht and Prior (1987), present a broad interpretation of the nature of a nonlinear system.

#### *THE NOTION OF CHAOS*

Within the literature there are also instances of chaos theory being used to explain chaotic behaviour without a clear link to the principles of chaos theory. The notion of chaos has been linked with theory to provide theoretical substance. The notion of chaos (as opposed to chaos theory) can be illustrated by Peters (1987) who has written a very successful text about thriving on chaos. In his book chaos is viewed as the changes that are occurring at an unprecedented rate and the paradoxes that this change presents. This is not chaos theory per se, but an interpretation of change occurring at a chaotic pace.

This particular interpretation is repeated in the nursing literature. Dombeck (1996) has used chaos theory to help describe situations found during psychotherapy. The notion of spiritual disequilibrium has been seen as a demonstration of complex systems behaviour and discussed in a number of nursing situations. This article, while using chaos theory as a theoretical underpinning, has in fact failed to refer to the literature in the area of chaos and must be questioned for the accuracy of the theoretical underpinning.

Vicenzi et al (1997) have used chaos theory, and in particular, the notion of a complex nonlinear system, as a way for nurses to understand their practice. This has been illustrated by the view that an adverse event such as a nosocomial infection can be difficult to predict. The authors argue that nurses working in a changing world need to understand how to work within complexity and chaos. Strategies such as abandoning false notions of control and acceptance of the uncertainty of the future are proposed as means by which nurses can apply chaos theory to their practice. This understanding of a complex nonlinear system would appear to equate with understanding of the nature of change, and more accurately reflects the notion of chaos as opposed to chaos theory.

## **A critique of the way that chaos theory has been used in nursing**

Chaos theory has been used to describe complex dynamic systems found in nature (Gleick 1987). The idea that chaos theory is directly applicable to every system is not established and needs to be questioned (Vicenzi 1994). This cautionary comment might be particularly relevant to nursing, which is concerned with the holistic nature of the person, health and illness, the environment and social factors. For example, it may not be appropriate for chaos theory to be used to analyse health care systems, or clinical systems of care. On the other hand, the environment, particularly where an ecological system (a natural system) is involved, is an area of interest for nursing theory development. Where the environment of the person is being studied then chaos theory would be an appropriate framework for analysis. Bellin et al (1997 p.15) used chaos theory as a frame to integrate individuals, families and communities into an aperiodic and holistic paradigm. Analysis demonstrates that this is an appropriate framework but it could be argued that they have not applied it correctly. It has been used to analyse the human dimensions of ecological health nursing as opposed to the ecological concepts.

The mathematics of chaos has been used with some satisfactory results and this has been demonstrated by the work of Pollock (1997). The correct application of the statistical methods will require both computer and strong quantitative data analysis skills, and nurses will need suitable academic preparation in these areas.

The tenets of chaos theory have to date been subject to a number of interpretations, some of which are questionable. Examples of misrepresentation are often centred around how a nonlinear system is defined. At this stage it is recommended that caution should prevail as not enough is known about chaos theory, and that chaos theory should only be applied in cases where a nonlinear system is operating.

The literature has also been used to demonstrate that what has been called chaos theory is in fact chaos. This is not acceptable and should be avoided. If nursing is to mature as a discipline with a definable knowledge base, there is no place for the incorporation of anything new for the novelty or gimmick value alone. This will only detract from the substantial gains which nurses have made in knowledge generation and validation. Hence nurses need to understand new theories in order for synthesis to occur.

Another issue identified in the literature search is the rapidly evolving nature of chaos theory and the ever-changing understanding of the nature of a chaotic system. Newer and quicker computers are being developed and the progress that this will generate in the future is hard to imagine. What is written today may be derided tomorrow,

but what will be important is that nurses keep abreast with new developments in order to stimulate debate and critique. Chaos theory should only be used to describe complex, natural nonlinear systems until such time as research demonstrates that it can be applied to other systems.

## **How chaos theory could be applied in nursing**

Chaos theory has been developed from an understanding of natural systems. Nursing knowledge is composed of many systems, such as physiological systems, health care systems and human systems. Some of these are natural systems and it is because of this relationship to natural systems that chaos theory has many applications in nursing. Chaos theory has the potential to help nurse researchers using quantitative designs to analyse data in situations where a nonlinear system is operating. Chaos theory explains how seemingly random events have a pattern of association. The behaviour of a chaotic system can be predicted using nonlinear dynamics. This could be in the study of demographics, particularly where prediction of population growth is concerned, or in epidemiology where the prediction of disease patterns is difficult. For example, difficulties in prediction arise when a steady demographic rate is interrupted or sent into chaos following drought or during some other disaster created by nature or man.

Another area where an understanding of chaotic systems may be of help is in the area of nursing informatics. The rationale for this belief is based on the ability of the computer to model systems. The computer enables complex chaotic systems to be modelled using simple mathematical equations. Nursing informatics uses computer systems to collect, manage and analyse data in order to help nurses support the practice of nursing and the computer models this data. Although the chaotic system is nonlinear and the systems modelled in informatics or linear systems, in the future the computer may be able to deal with this application.

Nursing knowledge, particularly nursing theory, may also be further developed using chaos theory. Chaos theory consists of a number of tenets that explain the behaviour of chaotic systems which occur in nature. These tenets include the notion of a sensitive dependence upon initial conditions and the well-known butterfly effect. The area in which the tenets of chaos theory may be applied is nursing theory. The nurse theorist Martha Rogers (1990 p.7) has developed a nursing theory entitled 'The Science of Unitary Human Beings'. Her theory contains a number of key concepts which she has defined and a number of these definitions use the same terminology as in chaos theory. Examples include 'multidimensional' which is 'a nonlinear domain without spatial or temporal attribute,' and 'unitary human beings' as 'an irreducible, invisible,

multidimensional energy field identified by pattern ... which cannot be predicted from knowledge of the parts'. A nonlinear domain and the notion of identification of pattern would appear to resemble some of the tenets of chaos theory. Apart from the obvious face value similarity, a suggestion that chaos theory may be a way to 'ground' or research some of Rogers' ideas bear consideration. (Vicenzi 1994 p.39) also notes that, although Rogerian science and chaos theory differ in their underlying assumptions, both direct nurses towards longitudinal research designs which focus on change over time. Meleis (1997 p.326) states that Rogers' theory is difficult to operationalise due to the complex nature of her concepts and the level of abstraction. She also notes (p.327) that her theory 'is more congruent with chaos theories'. The notion forwarded by Meleis of a number of chaos theories differs from many writers in the field of chaos and is an interesting possibility.

An area of nursing where the tenets of chaos theory could also be of assistance is in the area of nursing management. One direct application is for those nurses who are setting plans for the allocation of resources in states of emergency or contingency planning. Chaos theory is helpful here as it states that 'the behaviour of a chaotic system is deterministic and bounded' (Legge 1990). Hence, the likely resource requirements are determinable. Another possible application of chaos theory in nursing could be for those working within a complex nonlinear system, for example in accident and emergency or intensive care units. It is in these environments that applications may exist where patterns of attendance, particular presenting illnesses or injuries seem to come in seemingly random ways.

### **The future: Nurses who use chaos theory in their practice will need to understand chaos theory**

The question of who should know about chaos theory can be asked. It has been suggested that nurse managers and policy makers must be aware of chaos theory, as well as nurses working in informatics. Clinical areas in which chaos theory has application include intensive care and accident and emergency departments. Nurse researchers and educators may not directly apply chaos theory in their work but have a professional responsibility to be aware of alternate modes of thinking. Similarly, all nurses, as consumers of research should be aware of chaos theory. If other applications emerge in the future then the nurse involved will be required to study chaos theory.

## **CONCLUSION**

This selection of the literature has examined a number of articles that have referred to chaos theory in a nursing context and has illustrated diversity in the interpretation

and application of chaos theory. As in other disciplines, there is also some evidence to suggest that chaos theory has been misapplied due to a fallacious understanding of chaos theory. Chaos theory is also being used as an explanation of reality, particularly a social reality, without consideration as to whether this is an appropriate application.

It has been argued that there are a number of applications in nursing for chaos theory. The tenets of chaos theory have been suggested as being sympathetic with Rogers' theory of nursing and it has been suggested that the mathematics of chaos theory could be used as a form of analysis in order to ground Rogers' theory. These are promising developments.

Chaos theory is an important new science which is increasingly being cited in the nursing literature as a framework for research, education and practice. There are a number of possible practice areas in nursing where chaos theory might be very helpful, these include accident and emergency departments and intensive care. This is an exciting development but caution must be observed. Nursing must ensure that new theoretical ideas are analysed, and synthesis of the material must proceed in an appropriate manner. New theory should not be adopted without a full understanding of the material. With these provisos it would seem appropriate to include chaos theory as a topic in the curriculum of nursing graduate programs. This would ensure that nurses had some knowledge of chaos theory and would therefore be in a better position to critique the literature.

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