CHAPTER TWO

The relationship between science, psychology and cognition

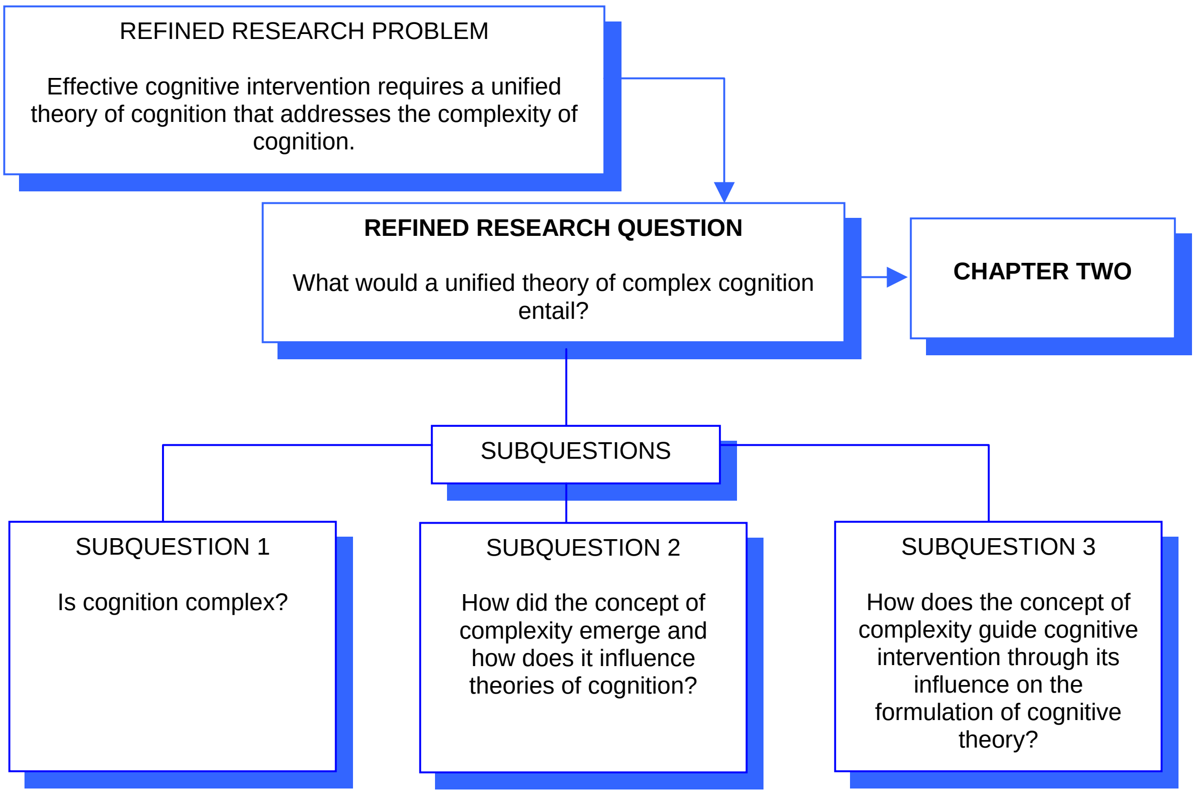
Over the last century, psychology has become much less of an art and much more of a science. Philosophical speculation is out; data collection is in.

Ben Goertzel, *The structure of intelligence*

Scientists rarely consider the limitations and biases of the mind to be important. They see the human mind as a collection of problem-solving abilities which can be applied to any complex problem. Aided by fast computers, they believe that its logic will prevail given enough time.

John D. Barrow. *Impossibility: The limits of science and the science of limits*

META-NARRATIVE 2.1



2.1 INTRODUCTION

The two central arguments which provide the direction for this study dealing with children's thinking in formal contexts, are that cognition is a complex phenomenon and that this complexity is not addressed in most cognitive interventions that are used to teach children thinking skills. Both arguments are reasonable statements with which many people would probably agree. But what does it really mean to say that cognition is complex, and are we agreeing on the same thing when we say that cognition is complex?

The Oxford Complete Wordfinder (Reader's Digest, 1993) defines something that is *complex* as something that consists of related parts. When something is complex, it is also thought to be complicated. The Oxford (Readers Digest, 1993) further defines *complicated* as something that is intricate, difficult or confused. What we currently know about cognition (Wittrock, 1991; Goertzel, 1993; Coltheart, 2001) indeed suggests that it consists of related parts, such as attention, perception, memory, thought, motivation, comprehension and metacognition, and therefore is complex. Barrow (1999, p. 86) says that 'the largest supercomputers that we have constructed so far pale into insignificance compared with the *complexity* [own emphasis], flexibility and compactness of the human brain.' The wealth of literature on various 'components' of cognition confirms the fact that the phenomenon of cognition is intricate and can be difficult to understand, while the abundance of loosely defined, ambiguous terms associated with cognition attests to the current theoretical confusion that exists in the field (Vosniadou, 1996).

Lorenz (1993) remarks that words are not living creatures in the sense that they can breathe, walk or experience feeling. Yet, like humans, they can lead unique lives. Although words may be born into a language with one meaning, they often grow up to acquire new meanings (Lorenz, 1993). So it is with *complexity* – in recent philosophical and scientific literature one finds that the construct has acquired some additional qualities which readers unfamiliar with complexity theory, may not be aware of. These additional meanings make it likely that theorists from various disciplines who agree that cognition is complex, are probably not agreeing on the same thing. Cilliers (1998, p. 2) remarks that "a complex system is not constituted merely by the sum of its components, but also by the intricate *relationships* [author's emphasis] between these components." It means that complexity does not refer only to the number of constituent parts of a system, but also to the *nature of the interaction* between those parts. Therefore, studying cognition as a complex construct should not only interest us in terms of the number of componential structures and processes that we can isolate, it necessitates an understanding of the nature of the interactions between the components of cognition.

I believe that current cognitive research reflects significant misconceptions regarding the nature of cognition. The most important misconception in the context of the present study concerns the lack of agreement among theorists and researchers on an appropriate metaphor that could reflect what the construct of cognition could possibly entail. While many theorists and researchers agree that there are non-cognitive factors (e.g. language, social interaction, emotion, power relationships, and so on) which influence thinking, such agreement is often only a superficial recognition of the *role* of non-cognitive factors in thinking. Attention to non-cognitive factors is more frequently found in theories addressing themselves to the social realm of human experience and less in theories that are biased toward the physical or psychological realms of human experience. Non-cognitive factors are rarely recognised as integral features of cognition, features without which cognition as we know it would not be possible. Perhaps that is why literature on the biological, social, emotional and political dimensions of cognition exists largely in isolation from one another. For example, despite much research on *language* and *cognition*, central issues related to both fields remain vague and controversial (Bowerman & Levinson, 2001). Indeed, it appears that it is only within the context of intra- and interpersonal problem-solving (counselling and therapy contexts) that a true integration of cognition, emotion, personal and social relationships is actively pursued.

Apart from its traditional denotations, the construct of complexity has recently acquired some additional technical connotations in mathematics and the physical sciences. Complexity is now also associated with terms that complexity and chaos theorists use to explain the behaviour of certain systems, such as self-organisation (Cillliers, 1998), chaos and sensitivity to initial conditions (Lorenz, 1993). These terms will be discussed in more detail in Chapter Three.

The theories that physicists employ to explain reality are constantly evolving towards a more complex and sophisticated picture of the world. Physics, especially the “new physics” (Zukav, 1980) as represented by quantum mechanics and relativity theory, has been termed the study of consciousness[13] (Goertzel, 1993) and has been regarded by some to be inextricably connected to the discipline of psychology (Zukav, 1980) because both disciplines study consciousness. This brings one to the point where, in order to appreciate what it means to

[13] The Oxford Complete Wordfinder defines consciousness as *the totality of a person’s thoughts and feelings* (Reader’s Digest, 1993) while Cairns-Smith (2000) says that feelings should be central in a definition of consciousness.

say that cognition is a complex construct, one needs to understand the historical development of the construct of complexity as it is reflected in the physical sciences.

META-NARRATIVE 2.2

The meaning of complexity has changed quite dramatically in response to developments in the physical sciences over the last hundred years. Taking cognisance of these changes and accommodating them in psychological theory is an important step towards an understanding of why cognition is not only a psychological phenomenon, but also a social and cultural phenomenon. Understanding the relationship between psychology and physics will assist us in understanding some of the reasons for the theoretical confusion that exists in the field of cognitive psychology. It will also serve to put the current upsurge towards postmodernism into proper perspective and, perhaps most importantly, it will help us to understand why we have reached a point in the study of cognition that requires a fundamental re-examination of the way we perceive it, and the way we teach it. Such a re-examination will certainly require paying closer attention to the emotional, social and cultural aspects of cognition and hopefully show too, why it would be important to promote a metaphor of cognition that makes room for complexity in cognitive intervention.

Because physics is acknowledged as an important catalyst for psychological theory development (Perna & Masterpasqua, 1997; Strube, 2000), it may be helpful to consider how developments in the physical sciences have shaped the destiny of psychology as a science in order to judge how it may have affected the study of human cognition. To do this, I will first consider the emergence of psychology as a discipline, and then demonstrate how its development has been profoundly influenced by three distinct periods in the development of modern science.

The first period in the development of modern science covers the *classical physics* of the 17th to the 19th century. The second period, that of *modern physics,* began in the early 20th century with Einstein's relativity theory and quantum mechanical theory and stretches all the way to the present. Contemporaneous with modern physics is a third period, the *postmodern (post-structuralist)* period, currently less well-acknowledged, and characterised by chaos theory and complexity theory, which began in the early 1970s and continues into the present. In each case I will show how the scientific worldviews attached to the period shaped the nature of psychology as a science.

Bearing in mind that the ultimate goal of this chapter is to establish how physical science has shaped psychology and the study of human cognition, I will attempt to show how each period has given rise to specific conceptions about cognition. I will conclude by providing a summary of the most crucial ways in which physical science has directed 120 years of human psychology in general and in respect of human cognition in particular.

2.2 PSYCHOLOGY AS A SCIENCE

2.2.1 Definitions of psychology

Plug, Meyer, Louw and Gouws (1988) define psychology as a science which investigates human behaviour by means of observation, experiments and measurements. Plug *et al.* acknowledge that various schools of psychology (such as developmental psychology, social psychology, experimental psychology, mathematical psychology and so on) may define psychology differently, but ultimately it is generally associated with the study of all forms of observable and non-observable human behaviour. Recently, Fröhlich (2000) has described psychology as a science which concerns itself with human experience (*Erleben)*, behaviour (*Verhalten)*, and actions (*Handeln)*. In addition, Long (2000) states that psychology involves the logical investigation of people's thoughts and behaviours.

Wertsch (1985) says that psychology is supposed to say something about what it means to be human, but also adds that psychology has not succeeded in this endeavour because psychologists have isolated and studied phenomena in such a way that it has prevented them from communicating with one another. In this regard, Wertsch (1985) says that psychologists have lost sight of the fact that "their ultimate goal is to contribute to some integrated, holistic picture of human nature" (p. 1). Psychology is defined by The Oxford Complete Wordfinder (Reader's Digest, 1993) as "the scientific study of the human mind and its functions, especially those affecting behavior in a given context." The Oxford (Reader's Digest, 1993) further defines the human mind as "the seat of consciousness, thought, volition and feeling or attention, concentration, the intellect, remembrance, memory."

Psychological studies are concerned with the scientific study of the mind as it finds expression in our awareness, thoughts and feelings and include processes of attention, concentration, and memory which are crucial to the intellectual functions of thinking and learning, and therefore, cognition.

2.2.2 *A definition of cognition*

Fröhlich (2000) describes cognition as all those functions and processes that are associated with memory (*Gedächtnis)* and information processing (*Informationsverarbeitung).* Fröhlich (2000) further describes cognitive psychology (*Kognitionspsychologie)* as a general term that includes the study of perception (*Wahrnehmung)*, thinking (*Denken)*, intelligence (*Intelligenz)*, and memory.

The term cognition is defined in the Oxford Complete Wordfinder (Reader's Digest, 1993) as 'knowing, perceiving or conceiving as an act or faculty distinct from emotion and volition.' The Oxford (Reader's Digest, 1993) further defines *thought* as "the process or power of thinking, the faculty of reason" and furnishes such synonyms as intellect, intelligence, reasoning, rationality.

But what exactly does it mean to say that psychology, and by implication the study of cognition, is a science? More importantly, what do we regard as "good" science and does current research in psychology reflect good science?

2.2.3 *The birth of psychology*

The event often quoted as signifying the birth of psychology as a science, is the establishment of Wilhelm Wundt's school of experimental psychology in 1880. It is routinely recognised as the point at which psychology largely disengaged itself from philosophy. However, few scholars seem to realise how complex questions from diverse scientific disciplines combined to make this event happen. Goertzel (1994) explains that the break between psychology and philosophy had a great deal to do with arguments about the nature of psychology and philosophy at the time. The arguments specifically centred around the way logic (an area of philosophy) and psychology addressed the issue of human cognition.

2.2.4 *Philosophical conceptions of cognition*

Indeed, the main question which has occupied philosophers from antiquity to the modern time, is whether human knowledge can ever be a true representation of the world as it is. The transition from *myth* to *logos*, i.e the earliest beginnings of philosophy, was initiated by the Greeks in c. 600 B.C. (Delius, Gatzemaier, Sertcan & Wünscher, 2000). Even then, there were differences among philosophers as to the nature of knowledge. Among the Presocratics there was Xenophanes (the founder of epistemological scepticism), whose basic epistemological principle was that thinking and being are the same, and therefore, anything that is impossible to imagine, cannot exist. One of Xenophanes' contemporaries, Parmenides, opposed Xenophanes by saying that thought and empirical experience should be kept apart because perception is only deception and mere opinion. This was also the position of the Sophists (Socrates being the most notable figure), who believed that no secure foundation for knowledge was achievable since perception and judgments are relative (Delius *et al.* 2000).

2.2.5 Psychology and logic

John Stuart Mill (1843, in Goertzel, 1994) believed that logic was a branch of psychology and thus believed that all knowledge was psychological (Delius *et al.,* 2000). Logic deals with the laws of thought. Thought takes place in the mind, which falls under the discipline of psychology, which defines itself as the scientific study of the mind and all its processes. Therefore, laws of thought that are formulated necessarily deal with a phenomenon that is inherently psychological by nature. Delius *et al.* (2000) say that Mill's position had great support in the 19th century, although it later came under attack.

Indeed, logicians such as Gottlob Frege insisted that logic is concerned with truth and that truth must be given a non-psychological definition (Goertzel, 1994). The object of scientific pursuit was truth, and at the time, truth meant the discovery of the laws of nature. Frege reasoned that psychology studied subjective experience, which (as postmodernist constructivists today would agree) makes an objective truth impossible. Goertzel (1994) explains that it was a major conceptual battle for Frege to free mathematical logic from psychologism. The battle can be considered by and large to have been successful because few modern-day logicians give psychology a second thought, just as most psychologists are able to study cognition without special knowledge of logic.

For a considerable time, psychology and logism existed in parallel universes, each addressing human thought along discrete lines. The early experimental psychologists purposefully avoided logic in their attempts to explain thought, while the logicians were intent on explaining thought along mathematical lines that were completely dissociated from everyday human thought. All of that would change with the arrival of the computer. Goertzel (1994) says that the advent of artificial intelligence (AI) in the sixties and seventies brought logism back with a vengeance. The goal was to produce a thinking machine that would obey the laws of logic, but logicians discovered to their dismay that mathematical logic had to be modified and augmented to bring it closer to human reasoning if it were to have any practical relevance. And so the logicians looked to psychology to obtain (what they hoped would be) a more complete picture of the nature of cognitive processes in order to build a science of reasoning (Goertzel, 1994).

As we shall see in later sections, the battle for independence between logism and psychology was part of a larger struggle that reflected deeper questions about human nature that were beginning to take shape in the latter half of the nineteenth century.

Saying that the birth of psychology *as a science* occurred in 1880 means that psychological thought existed before then, only it was not recognised as a science. Indeed, it was not only philosophy that accommodated psychological thought at the time. The physical sciences played a significant role, so much so that it might even be said that physics evolved to the point where human nature became the object of study, and psychology became a special branch of physics where the focus of inquiry shifted to the relationship between the physical body and consciousness (Zukav, 1980). Tracing developments in the physical sciences will enable one to see how significant its influence was on an emergent psychology.

2.3 THE CLASSICAL PERIOD

2.3.1 The nineteenth century Zeitgeist

In order to expound the notion of psychology as a branch of physics, let us examine various events in the period between the sixteenth and nineteenth century that conspired to provide the impetus for the emergence of psychology as a science.

Cole and Scribner (in their foreword to the Vygotsky publication of 1978) mention three events that took place almost simultaneously in 1860 which they believe led to the establishment of psychology as a science. All three events revolved around the publication of various authors. The first was Darwin's well-known *Origin of the Species.* Lesser known, was Gustav Fechner's *Die Psychophysik*, and the third was I.M. Sechenov's publication entitled *Reflexes of the Brain.*

As Cole and Scribner (in Vygotsky, 1978) say:

> These books by Darwin, Fechner, and Sechenov can be viewed as the essential constituents of psychological thought at the end of the nineteenth century. Darwin linked animals and humans in a single conceptual system regulated by natural laws; Fechner provided an example of what a natural law describing the relationship between physical events and human mental functioning might look like; Sechenov, extrapolating from muscle twitches in frogs, proposed a physiological theory of how

> such mental processes worked within the normally functioning individual. None of these authors considered themselves (or were considered by their contemporaries) to be psychologists. But they provided the central questions with which the young science of psychology became concerned in the second half of the century. (p. 3)

In order to understand how three publications, all by non-psychologists, namely a biologist (Darwin), a mathematician (Fechner) and a physician (Sechenov), could revolutionise the study of human behaviour (and profoundly influence the study of human cognition), it is important to understand the *Zeitgeist* of the late nineteenth century. At that time, Einstein's theory of relativity and quantum mechanics had not yet been discovered, and the reigning scientific paradigm was Newtonian physics, or classical physics.

With his discoveries of the law of gravity and the laws of motion, Newton and his contemporaries were convinced that they had unravelled, completely and finally, the mechanics of how nature worked.

Barrow (1999) explains that

> Newton's discoveries had been so impressive for nearly two hundred years that they had the hallmark of being the last word. No refinements of his laws had been suggested. His law of gravitation had successfully explained every astronomical observation (with the tiny exception of a wobble in the orbit of the planet Mercury round the Sun). In fact, during his own lifetime the success of his mechanics had led to speculations that his approach might provide the panacea for the investigation of all questions. The impressive completeness of Newton's *Principia* (1687) and the deductive power of his mathematics led to a bandwagon effect with thinkers of all shades aping the Newtonian method. There were books on Newtonian models of government and social etiquette, and Newtonian methods for children and 'ladies'. Nothing was imagined to be beyond the scope of the Newtonian approach. (p. 40)

As it turned out, neither was psychology. The publications of Darwin, Fechner and Sechenov opened up the possibility that man was an extension of the natural world and that it was quite possible, even desirable, to study human behaviour by the same scientific method that had proven extremely successful for Newton. Understandably, scientists from all disciplines were very receptive to Newton's theory in the nineteenth century, especially since Newton's ideas were being reinforced through the positivist philosophy of Auguste Comte (1798 – 1857) who encouraged scientists to study only that which was observable and reducible to laws.

Comte regarded the search for the source or the cause of natural phenomena as immature and to be avoided at all costs. It meant that, instead of searching for the cause of gravity, scientists should content themselves with the laws of gravitation. Comte viewed the evolution of human thinking as a process which must pass through three stages, namely the theological, metaphysical and positive stage (Barrow, 1999; Delius *et al.,* 2000). Comte viewed the first two stages as immature because of the emphasis on supernatural or abstract forces as the source of natural phenomena. The positive stage was more desirable since the mind had then given up its desire to explain the unexplainable (Barrow, 1999). The positivism of Comte therefore required a rejection of metaphysics and saw the source of knowledge in sensory experience, with observation being the only reliable method by which to obtain knowledge (Delius *et al.,* 2000).

The apparent perfection of the Newtonian paradigm and the success with which it explained natural phenomena made it a natural step of progression, that experimental psychology would adopt its scientific method of observation and experimentation as the method of choice.

2.3.2 Physics envy in psychology

Ever since its birth as a science toward the close of the 19th century, the young discipline of psychology has been characterised by a kind of *physics envy* (Masterpasqua & Perna, 1997) in the sense that it has remained responsive to developments in physics to this day.

Barrow (1999) suggests that "[scientists] see the human mind as a collection of problem-solving abilities which can be applied to any complex problem. Aided by fast computers, they believe that its logic will prevail given enough time (p. 90)." As Masterpasqua and Perna (1997) remark, this is because psychologists "self-consciously proceeded as though human affairs were as pre-determined, linear and predictable as Newton's and Laplace's universe (p. 4)." The relationship between psychology and physics was already recognised much earlier by Zukav (1980) who believed that René Descartes' vision of the world as a machine and Newton's formulation of the laws which govern that machine, made it deceptively easy to view nature and everything in it as linear, deterministic and predictable. In that sense, it is relatively simple to see how Newtonian physics contributed to the emergence of a definition of complexity that emphasised the structural nature of phenomena and downplayed the dynamic interactional nature of the components. Of course, cognition suffered the same fate as psychologists studied cognition mostly as a structural phenomenon which could be discovered fully by analysis of its components.

The perceived completeness of scientific knowledge in the physical sciences at the end of the nineteenth century was such that many thought there was not much left to know or discover. It was widely thought that it would only be a matter of time before Newtonian physics would explain the laws governing all natural phenomena. The fact that human consciousness was considered to be one of the last challenges which had not yet been adequately addressed and explained and which some influential scientists like Emil Du Bois-Reymond believed would never be explained (Barrow, 1999), probably increased the challenge to those scientists who called themselves psychologists, to discover how the laws of nature give rise to human behaviour and consciousness.

The intoxication of psychology with the scientific method implies that the central questions that have concerned psychologists for more than a century have mostly been generated outside the discipline of psychology, by the physical sciences. This is an important statement, because it suggests that the research questions which interest psychology as a discipline, are often not generated by psychologists from within the discipline, but by physical scientists from outside it.

For example, as early as the seventeenth century, it was *technological* creations moved by hydraulic power that gave rise to René Descartes' view of the world as a machine (Zukav, 1980) and also to his hydraulic model of the brain (Groves and Rebec, 1992). The discovery of *electricity* led to the discovery of electrical impulses in the brain (Groves and Rebec, 1992). Newton's law of *gravity* and laws of *motion* convinced psychologists that there must also exist universal laws that determine human behaviour, hence the stimulus-response theory of behaviourists like Pavlov and Skinner, and the psychoanalytic determinism of Freud (Masterpasqua & Perna, 1997). Even Jean Piaget's adaptive theory of cognitive development was inspired by Darwin's theory of evolution (Luis & Jansen, 2001).

In respect of behaviourist theory, Grace (2001) relates how its operationist[14] methodology was imported from a 1930 publication of the Nobel prize winning physicist, Percy Williams Bridgman, called *The logic of modern physics.* In fact, O'Donohue and Kitchener (1996) say that the behaviourists were initially quite adamant that psychology should be regarded as an empirical, natural science, and were convinced that psychology could learn nothing from philosophy.

In recent times, subdisciplines of cognitive psychology which research topics related to *artificial intelligence* and *computer science,* have continued to spawn theories of human cognition based on linear and deterministic laws that are supposed to govern human information processing (Strube, 2000).

[14] Operationism is described as a positivist approach to psychology in which operational definitions of concepts or constructs are believed to be necessary for meaningful research (Grace, 2001).

2.3.3 *Cognitive psychology and the study of cognition*

Cognitive psychology is the field in psychology which has been the most strongly influenced by the deterministic methodology of Newtonian physics. The cognitivist (information-processing) paradigm has been the dominant paradigm in cognitive psychology and is represented by three distinctive components, namely experimental psychology (information processing), computer modelling (neural networks), and cognitive neuropsychology (Coltheart, 2001).

The cognitivist paradigm views cognition as “processes of computation that solve problems about the world and the relation of the cognitive agent with its environment” (Gurney, 1999). In this definition, there is nothing to suggest that cognition is anything other than problem-solving through computation. No mention is made of the social, cultural or emotional aspects of cognition. Although mention is made of the “agent” and its “environment”, Strube (2000) assures us that the context of cognition remains a secondary consideration in the cognitivist paradigm. Coltheart (2001) states that cognitive psychology is a science dedicated to studying the nature of the mental processes responsible for people’s ability to perform basic cognitive activities such as understanding, producing language, recognising people, storing information in memory and acting intelligently upon the physical world.

Bowers (1999) mentions that much of the criticism surrounding a cognitivist focus on cognition is associated with the fact that social, cultural and other dimensions of cognition are ignored in favour of exclusive emphasis on cognitive processes in the mind. This, Groome (1999) says, is because humans are viewed as “limited-capacity processors” (p. 8) whose thought processes are compared to the workings of a telephone exchange, and so the notion of cognition as a phenomenon that is seated exclusively in the mind of the individual is an enduring theme of research in the field of cognitive psychology.

Strube (2000) confirms that modern cognitive psychology, as one of the fastest growing subfields of scientific psychology, has strictly adhered to the experimental methodology of the natural sciences, which entails experimentation and statistical techniques for data analysis. The adherence to the Newtonian worldview has specifically led cognitive psychology to reduce cognition as a phenomenon to isolated variables which could be observed and controlled.

Potter (2000) neatly captures this point when he says:

> Cognitivists are so used to pre-defining the world – in stimulus materials, in vignettes, in fixed-choice questionnaires – that they never have to address the flexibility and theoretically contested nature of everyday life where the world is not given in a single particular way, in particular fixed categories, but is reaccomplished and transformed. The mess is relatively invisible from within the standard cognitivist framework because its familiar methods break up the occasioned and action-oriented nature of participants' practices as well as predefining input and output. There are hardly any methodological cracks through which participants' constructions and orientations can seep out (p 35).

Such a focus, argues Strube (2000), makes research in cognitive psychology effect-driven rather than theory-driven. Experimental psychologists who study cognition are notoriously well-known for refraining from theorising about their experimental results, allowing themselves rather to be guided by observable results and nothing else.

Strube (2000) suggests that one of the main reasons for effect-driven cognitive psychology, is the prominence of physics in the 20th century. As a result, Strube (2000) finds himself in partial agreement with Groves and Rebec (1992), who took the critique of the relationship between psychology and physics a step further by pointing out that the physical sciences have succeeded in providing theories and technologies that continue to serve as psychological models for human functioning simply because the belief persists that the same deterministic laws which govern nature, must also govern human consciousness:

> Working from a less-than-complete knowledge base, investigators of brain function have been forced to think in terms of something they did know in order to make sense of what they did not. In most cases, this meant comparing the brain with the latest mechanical contrivance or engineering marvel. Any new technological achievement that came along – the telephone, the camera, the radio, the hologram, the computer – had its day as a model of how the brain works (p. 5).

Yet, such comparisons rest on the false assumption that technological devices are as complex in their workings as the human brain, when the truth is that they are merely complicated. The difference, Cilliers (1998) points out, is that systems which can be analysed completely and accurately, even though they may consist of a very large number of components and perform very sophisticated tasks, are complicated, not complex. They can be given an exact description. In contrast, Cilliers (1998) describes a complex system as one which defies exact description because of the intricate, non-linear relationships and feedback loops that exist in the system. Complex systems are almost always living systems. It is not possible to learn the behaviour of a complex system by studying the discrete components which it consists of. The very act of breaking up a complex system into its parts “destroys that which it seeks to understand” (Cilliers, 1998, p. 2).

2.3.4 Complicated versus complex

I argue therefore that the Newtonian scientific paradigm, and especially the application it has found in cognitive psychology, has encouraged psychologists to view cognition as a *complicated* structure, rather than a *complex* system. The classical physics paradigm has seduced psychologists into believing that the brain, the mind and cognition render themselves accessible to exact description, and that the study of cognition can be reduced to the study of a collection of physical and cognitive components with precise laws that govern them.

Even though Barrow (1999) acknowledges that nothing we have discovered in nature, from elementary particle physics to outer space, remotely compares to the complexity of what lies inside our heads, mankind’s inclination to explain cognition in terms of scientific theories and technological devices has had a definitive impact on our current understanding of human cognition. This, Cilliers (1998) says, is because the technologisation of science is changing the relationship between science and philosophy in a radical way, and he warns that

> …a clear description of what is happening is not easy, but the heart of the matter is that our technologies have become more powerful than our theories. We are capable of doing things that we do not understand. We can perform gene-splicing without fully understanding how genes interact….We can create new sub-atomic particles without knowing precisely whether they actually exist outside of the laboratory. We can store, and retrieve, endless bits of information without knowing what they mean. Central to all these developments are the phenomenal capacities of the electronic computer….The power of technology has opened up new possibilities for science (p. 1).

One of the strongest possibilities that the computer has opened up, is the one which allows the classical physics paradigm to be perpetuated in the study of cognition. Powerful computer programmes allow scientists to create ever more complicated models of how the brain might work, and the more powerful computers become, the more scientists are deluded into thinking that it can capture the complexity of human cognition accurately. Cilliers (1998) points out that the rise of powerful technology is not an unconditional blessing because “we have to deal with what we do not understand, and that demands new ways of thinking” (p 2).

In the next section, I will consider how computer technology, as an extension of the principles of classical physics, is shaping our thinking about human cognition.

2.3.5 Cognition and technology

In the early twentieth century, long before the arrival of the micro-chip, the potential for technology to dictate the course of human development was recognised unwittingly by Vygotsky (1930/1978) when he suggested that “man’s alteration of nature alters man’s own nature” (p. 55) and explained that the “use of artificial means, the transition to mediated activity, fundamentally changes all psychological operations just as the use of tools limitlessly broadens the range of activities within which the new psychological functions may operate” (p. 55).

The “artifical means” and “tools” of which Vygotsky spoke in the 1930s could not have been the computer, yet the computer remains the one artificial tool which has changed the psychological operations which Vygotsky mentioned, in significant and fundamental ways. Technology has transformed the way in which humans interact with reality, and so we could even say that modern technology has been instrumental in changing the nature of reality itself, thereby demanding “new ways of thinking”, as in Cilliers’ (1998, p. 2) phrasing.

Technology has had a pervasive influence on theories of brain functioning and thinking, a fact readily acknowledged by brain researchers (Groves & Rebec, 1992) and cognitive psychologists (Groome, 1999). Computer technology has not only transformed human thinking by providing a (albeit imperfect) metaphor of humans as data processors, it has also served to perpetuate classical physicist themes and methodology in cognitive research to the extent that intelligence is now increasingly being equated to the ability to access and process information.

The South African Green Paper on E-commerce (RSAa, 2000) says: “Distance education, virtual campuses and technological training will dominate the education sector in the future”. The Green Paper markets its vision statement as “Generating a knowledge-based society to help create an information economy”. The Green Paper vision statement reminds strongly of Bowers’ (1999) warning against neo-Social Darwinism, where he warns that the enthusiastic but indiscriminate adoption of information and communication technologies (ICT) can lead to a situation where a particular society’s survival in the global economy is guaranteed by its capacity to participate in the technological race. Social Darwinism is regarded as a meta-narrative that is steering an evolutionary process in which computer technology has become the basis of human intelligence, and where societies who do not conform to the technological paradigm as the new cultural metaphor, become extinct (Briggs & Peat, 1999). More specifically, Bowers' (1999) main concern centres around the increasing dominance of computer technology in education, and the advancement of a view that equates human intelligence with access to information.

Because contemporary psychology does not recognise cognition as the complex, self-organising system that it is (Goertzel, 1993), most approaches to cognitive intervention based on psychological theories of cognition are inclined to focus on the instruction of discrete component skills associated with expert problem-solving, while ignoring the complexity and richness of the contexts in which real-life problems often occur. In real-life situations that require individuals to learn through complex problem-solving, one is confronted by others' perceptions, reactions and biases, as much as one is confronted with the facts of the situation. Theories of cognition that perpetuate the classical physicist principles of linearity, determinism and predictability are ill-equipped to deal with cognition as it is expressed in the real world.

Warning against the dominance of information-based approaches to intelligence, Bowers (1999) points out that

> anyone who claims that the public, including classroom teachers and teacher educators, is not being indoctrinated with a new orthodoxy that is both "scientifically" based and heavily promoted by the computer industry is in a state of deep denial about the scale and significance of the cultural change now being legitimated in the name of progress (p. 26).

Bowers' thoughts are echoed by Briggs and Peat (1999) who warn that scientific theories can become cultural metaphors that act like a two-edged sword, beneficial only when viewed within the context in which it was created. Bowers' (1999) concern specifically centres around the fact that computer technology is creating a reality which facilitates and promotes a cognitivist approach to cognitive development despite a large body of evidence that shows that human cognition is (at least) partially socially and culturally determined. Earlier, Goertzel (1993) observed how cognitive scientists and behaviourists tend to agree on the structure of the mind and the futility of arguing about the processes underlying behaviour, and the tendency of the cognitive scientists to regard the mind as a "hodge-podge of special-case algorithms, pieced together without any structure" (p. 1). Such a dialogue is possible because, in principle, cognitive scientists and behaviourists follow the same reductionist philosophy characteristic of classical physics.

Through computer technology, virtual realities have been created that require individuals to adapt to an artificial world mediated by the computer. The artificial world is bringing about a marked shift in emphasis in the mental processes required for problem solving. In a fast, technology-driven world, *accessing* and *processing* information (gathering facts) efficiently are viewed as the hallmarks of successful problem solving, while *contemplating* and *understanding* information (exploring ideas) are under-emphasised. It is probably at least partially because of this trend, that Goertzel (1993) maintains that contemporary psychology lacks the tools to confront comprehensive questions about the nature of the mind.

Potter (2000) finds himself in agreement when he exclaims that "it is exciting that, despite the quantity of psychological research that has already been produced, virtually all of the work is still to be done" (p. 36).

2.4 THE MODERN PERIOD

2.4.1 Quantum uncertainty and multiple realities

2.4.1.1 <u>Introduction</u>

"For most of us, life is seldom black and white. The wave-particle duality marked the end of the 'Either-Or' way of looking at the world" (Zukav, 1980, p. 65).

After a period of approximately three hundred years during which classical physics had gone unchallenged, discoveries were made which were to change the course of scientific inquiry not only in physics, but in psychology as well. The first discovery was that of Max Planck, considered to be the father of quantum mechanics, who demonstrated in 1900 that energy is not transmitted smoothly and continuously, but explosively in energy packets of a certain value. The second discovery was Albert Einstein's theory of the nature of light in 1905 which challenged for the first time the fact that light was made of waves (Zukav, 1980).

The relevance of Planck and Einstein's discoveries to psychology was that they would later compel psychologists to acknowledge the fact that not everything in nature behaves in a predictable manner as classical physics had dictated. It was Einstein's particle theory of light (discussed in section 2.4.1.3) which led some physicists to speculate that photons (light particles) are conscious organic matter, and that the study of physics really entails a study of consciousness (Zukav, 1980). But it was not only Planck's and Einstein's discoveries that impacted upon the study of cognition in a dramatic way. There were other discoveries that contributed to the theory of quantum mechanics that later influenced theories of cognition in a significant manner. The most important of these are the formulation of Erwin Schrödinger's wave theory in 1926 and Werner Heisenberg's Uncertainty Principle in 1927.

In the next section, the basic principles of the theories of Einstein, Planck, Schrödinger and Heisenberg will be discussed and their relevance to the study of cognition will be elucidated. It is important to note however, that the contribution of these theories does not lie in the single contribution of any particular theory per se. It is rather the way in which the theory of quantum mechanics changed scientists' way of seeing reality, that impacted upon psychological and cognitive theory.

As Perna and Masterpasqua (1997) claim, "quantum physics embraced uncertainty as both fundamental and worthy of scientific exploration" (p. 4).

2.4.1.2 1900 : The quantum hypothesis and the birth of non-linearity

After being advised by his mentors at the close of the nineteenth century to study biological science since all the important problems in physics had been solved (Barrow, 1998), Max Planck persisted with his studies in physics and later became one of the founding fathers of quantum theory. Planck's major discovery was that energy is absorbed and released by atoms only in specific amounts, called quanta (Zukav, 1980). His discovery revolutionised the study of physics because no longer was change in nature viewed as smooth and regular, but it became possible to view change as something that could occur in leaps and bounds.

The notion of developmental change and learning as dynamic, asynchronous processes (as opposed to classical, linear processes) already appeared in the writings of Vygotsky in the 1930s when he stated that "there are highly complex dynamic relations between developmental and learning processes that cannot be encompassed by an unchanging hypothetical formulation" (Vygotsky, 1935/1978, p. 91). More recently, cognitive therapists have been using the term "perceptual shift" to indicate how significant qualitative changes can occur instantaneously in the way people structure their cognitions (McMulllin, 2000).

But it would take more than Plank's quanta to revolutionise the study of physics and ultimately, the study of cognition in psychology.

2.4.1.3 1905 : The dual theory of light and the notion of conscious matter

Albert Einstein is well-known for his famous equation $E = mc^2$, that expresses the relationship between mass and energy. But he made another important contribution to physics that is more pertinent to the discussion in the present study: the photo-electric effect of light.

When Einstein discovered that light shining on the surface of a metal could knock electrons out of the metal, and that certain frequencies were better at knocking electrons out of their orbits than others, the stage was set for the formulation of a particle theory of light which used Planck's quanta to explain why certain light frequencies have more energy than others and are thus better able to knock electrons out of the metal (Cairns-Smith, 2000). However, apart from contradicting the widely held notion that light consisted of waves, the photoelectric effect of light also appeared able to demonstrate that electrons may be "conscious", in that it is possible to show how a single photon travelling through a small opening will hit a metal plate in different spots depending on whether a second small opening is open or not (Zukav, 1908; Cairns-Smith, 2000). This dual theory eventually led to the theory that electrons only look like particles because they are actually standing waves, which really means that an electron is represented by a collection of probabilities (almost like an energy pattern), rather than a particle.

Much later, Erwin Schrödinger's theory helped to explain just how electrons could be viewed as standing waves (Cairns-Smith, 2000).

2.4.1.4 1926 : Wave theory and multiple perspectives of reality

Erwin Schrödinger's wave theory is possibly the one theory that has been the most influential in the development of theories of cognition that emphasise multiple subjectively constructed realities instead of one, objective reality. Shrödinger's theory is also the theory that gave rise to the notion that man's study of nature, and his study of himself, alters nature and therefore it is not possible to know (like the classical physicists believe) what an objective reality would be.

Shrödinger's wave theory deals with possibilities and probabilities, instead of actualities. Shrödinger said that everything is uncertain until it is observed or measured. Once a phenomenon is observed, one possibility is actualised and all the other possibilities collapse. The famous Shrödinger cat paradox illustrates this phenomenon well because, as Zukav (1980) points out, it helps to illuminate the basic differences between classical physics and the new physics.

The Shrödinger cat paradox poses the following problem: A cat is placed inside a box with a device which can release a gas capable of instantly killing the cat. A random event will determine whether the gas is released or not. As the box is sealed and the experiment begins, there is no way to see inside the box to observe whether the cat is killed or not. The interpretation of the outcome of this experiment varies whether one views it according to classical physics or quantum physics (Zukav, 1980).

Classical physics tells us that the cat is either dead or not, we only need to open the box to see which it is. However, according to quantum physics, the cat is both dead and alive until we open the box and observe it. When we do so, one possibility collapses and the other possibility which we observe, is the one that has been actualised. Zukav (1980) explains that "this is known as the collapse of the wave function because the hump in the wave function representing the possibility that did not occur, collapses. It is necessary to look into the box before either possibility can occur. Until then, there is only a wave function" (p. 86).

However, this interpretation represents only one possibility of what may actually be happening. Zukav (1980) explains that there is another interpretation, known as the Many Worlds Interpretation, which states

> At the instant that the atom decays (or doesn't decay, depending upon which branch of reality we are talking about), the world splits into two branches, each with a different edition of the cat. The wave function representing the cat does not collapse. The cat is both dead *and* alive. At the instant that we look into the box, our wave function also splits into two branches, one associated with the branch of reality in which the cat is dead and one associated with the branch of reality in which the cat is alive. Neither consciousness is aware of the other. In short, classical physics says that there is one world, it is as it appears, and this is it. Quantum physics allows us to entertain the possibility that this is not so (p 86).

Quantum physics therefore shows us that instead of one reality, there may well be multiple realities. Multiple realities is a key aspect of constructivist approaches to cognition that assume that reality does not exist "out there" but is construed through our minds. Therefore, the world can only be experienced as we construe it and our representations of the world reflect our access to the world by an act of knowing, so there is no way of knowing to what extent we have modified the representation that is being constructed (Zietsman, 1995). The notion of multiple realities is probably what Perna and Masterpasqua (1997) had in mind when they contrasted the postmodernist self as "an open system suspended in a milieu of multiple perspectives" (p. 6) to "the modernist self, who assumed that there was only one reality to be observed" (p. 6). Here, we glimpse for the first time evidence that postmodernist thought in psychology (but also in the social sciences at large) was catalyzed by quantum physical theories of the nature of reality outside the discipline of psychology.

Zukav (1980) said about our experience of reality that "we cannot eliminate ourselves from the picture. We are a part of nature, and when we study nature there is no way around the fact that nature is studying itself" (p. 31). Regarding the role of the self in scientific endeavour, Zukav (1980) reflects on the classical notion that human beings are "outside" the natural world that they observe and goes on to say that

> Scientists, using the "in here – out there" distinction, have discovered that the "in here – out there" distinction may not exist! What is "out there" apparently depends, in a rigorous mathematical sense as well as a philosophical one, upon what we decide "in here." The new physics tells us that an observer cannot observe without altering what he sees. Observer and observed are interrelated in a real and fundamental sense (p. 92).

According to quantum physics the interrelationship between the observer and the observed is very important, because "what we experience is not external reality, but our interaction with it" (Zukav, 1980, p. 93). What we observe in nature, depends on how we interact with it. Whether we view light as particle-like or wave-like in nature depends on how the experiment is set up, both are possibilities. In other words, our picture of reality depends on our *perception* of it. As such, scientific knowledge does not reflect the structure of reality – reality has no definite structure – but rather the result of a dynamic interaction between various elements in nature, of which we are one.

Similarly, whether we assume that cognition is symbolic or connectionist depends on how we set out to prove it. In a symbolic model of cognition we can draw on language and concepts as symbols and prove how people think in terms of them. We may even say that such a model corresponds to a particle-theory of the mind. On the other hand, a connectionist model of cognition assumes no symbolic activity and will draw on the rich pattern of relationships between neural networks in the brain to prove that cognition consists of relationships. Such a model corresponds to a wave-theory of the mind. Quantum theory tells us that both models are possible, in other words, a theory of cognition need not be either one or the other, it can be both.

As we shall see later, the principle of interaction is at the core of Vygotsky's dialectical approach to conceptual development, and it is at the heart of all approaches to cognitive development that emphasise cognitive development as the result of an interaction with our social and cultural environment. In respect of our interaction with reality, quantum physics demonstrated through the Heisenberg Uncertainty Principle that there is no such thing as an exact science and that human knowledge can never be certain or complete (Zukav, 1980).

2.4.1.5 1927 : Heisenberg's Uncertainty Principle and multiple realities

Simply stated, Heisenberg's Uncertainty Principle states that we can never simultaneously know the position and the momentum of a particle in space. We can only know one of the two variables with certainty, the other will remain uncertain (Zukav, 1980). Barrow (1999) confirms that "quantum mechanics gives no exact predictions for the future location and speed of motion of an object given its starting state. It gives only probabilities that it will be observed to be at some location with some velocity" (p. 24).

Shrödinger's wave theory explains why this is so. The moment we interact with that which we observe, all possibilities but one which is represented by the observed object's wave function collapse and we are left with one reality, the one which we are observing (or the one of which we are conscious). Alternatively, the Many Worlds Interpretation states that the moment we observe something, reality splits and we see only the branch of reality which contains us and that which we are observing. Together, Schrödinger's wave theory and Heisenberg's Uncertainty Principle question the existence of an objective reality in the same way constructivism does.

Zukav (1980) explains that

> The tables have been turned. "The exact sciences" no longer study an objective reality that runs its course regardless of our interest in it or not, leaving us to fare as best we can while it goes its predetermined way. Science, at the level of subatomic events, is no longer "exact," the distinction between objective and subjective has vanished, and the portals through which the universe manifests itself are, as we once knew a long time ago, those impotent, passive witnesses to its unfolding, the "I"s, of which we, insignificant we, are examples. The Cogs in the Machine have become the Creators of the Universe. If the new physics led us anywhere, it is back to ourselves, which, of course, is the only place that we could go (p. 114).

2.4.2 Complex cognition: A classical and quantum perspective

One of the greatest differences in the way that classical physicists and quantum physicists view the world, is to be found in their views about the complexity of reality.

In terms of classical physics, complexity entails a discovery of the components of the universe as they are governed by exact laws. Classical physicists see a predictable one-to-one correspondence between elements of reality and the elements of the theory which explains reality. It is this one-to-one correspondence between reality and theory which led Einstein to believe that quantum theory is incomplete (Zukav, 1980).

The information-processing approach to cognition provides a good example of how the classical physicist approach of one-to-one correspondence permeates theories in cognitive psychology. An important assumption of an information processing approach to cognition is that cognition consists of a finite amount of elements, functions and processes and that it is possible to capture each component of cognition and map it in a theory of cognition.

Essentially, the information processing model reflects an *input system* (visual, auditory, tactile, and so on), a *central processing unit* (CPU, containing the sensory register, short term memory, working memory, and long term episodic and semantic memory), and an *output system* (thought and behaviour). The CPU is guided by the executive control in the form of metacognition, which helps a person to plan, monitor and adjust her processing of information (Lerner, 2000).

Figure 2.1 below captures the essential elements of the information processing model of learning.

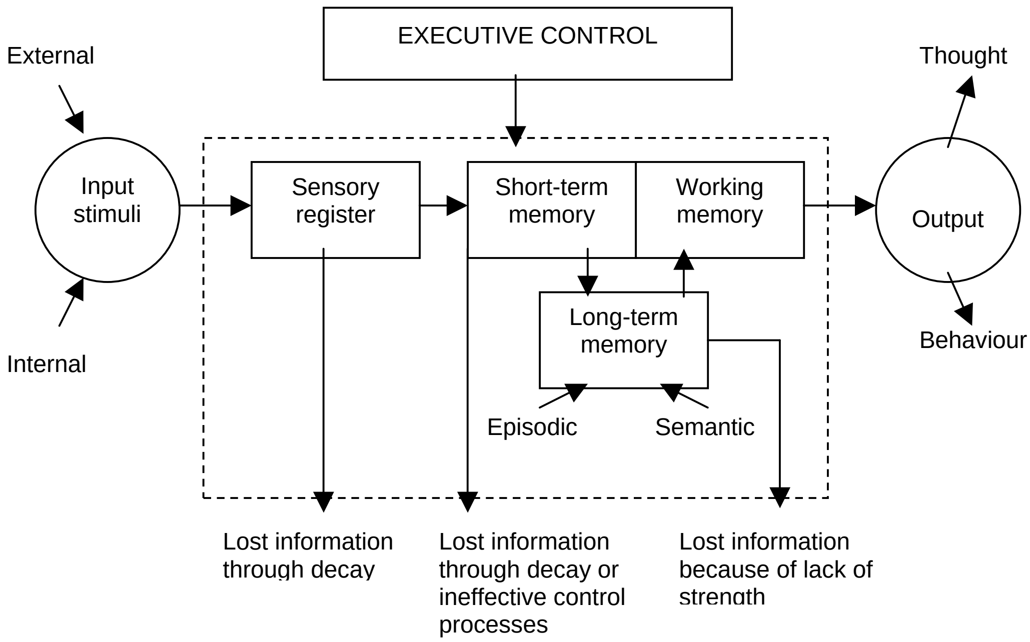


Figure 2.1: An information processing model of learning adapted from Lerner (2000)

Figure 2.1 shows that the information processing approach essentially conceives of cognition as a relatively stable and predictable process. Any unpredictability in the processing system is explained as lost information through decay, ineffective control processes or loss of memory strength. Instead of incorporating unpredictability in cognition into the explanatory model as an essential feature of cognition, it is depicted as a uni-directional flow (or loss) of information out of the system. The information processing approach provides a convenient way of thinking about cognition in a crude way, but it remains a classicist approach to cognition that does not succeed in capturing the complex nature of cognition.

Quantum physics has an entirely different picture of what a complex reality is. Probability and uncertainty are viewed as necessary and integral aspects of complexity. Quantum physics opened up the possibility for psychologists to consider the existence of multiple subjective realities. More importantly, the publication of Bell's theorem in 1964 showed that the realisation of one actuality from all the possibilities and probabilities contained in the wave function of a subatomic object when the wave function collapses, is not subject to chance as was previously thought, but may be dependent upon a distant action happening across space. In other words, Bell's theorem suggests – and can prove experimentally – that information can travel faster than the speed of light i.e. superluminally. Therefore, it is possible that an action in one locality can somehow affect the behaviour of a separate part across space. Zukav (1980) quotes David Bohm as saying

> Parts are seen to be in immediate connection, in which their dynamical relationships depend, in an irreducible way, on the state of the whole system (and, indeed,on that of broader systems in which they are contained, extending ultimately and in principle to the entire universe). Thus, one is led to a new notion of *unbroken wholeness* which denies the classical idea of analyzability of the world into separately and independently existent parts…(p. 297)

The implications of this position is that the world does not consist of separate components, but that everything in one place is connected to everything else in another place (Zukav, 1980). This brings us to the third period in physical science, marked by the emergence of chaos theory, which is concerned with the interconnectivity of complex systems.

2.5 THE POSTMODERN PERIOD

2.5.1 The new paradigm

At a meeting of the American Association for the Advancement of Science in 1972, a meteorologist called Edward Lorenz asked the following question: "Does the flap of a butterfly's wings in Brazil set off a tornado in Texas?" (Lorenz, 1993).

The subject of this paper dealt with the complexity and inherent chaos of weather systems and, more importantly, how miniscule changes in a complex system can produce appreciable changes in the end-states of the system. This effect, called The Butterfly Effect, has since become the leading symbol of chaos theory, which since its early beginnings in the 1970s, has been called "the new science" (Lorenz, 1993), "the new paradigm from the physical sciences" (Perna & Masterpasqua, 1997), and "the science of change" (Briggs & Peat, 2000).

2.5.2 Cognition and the science of change

The applicability of chaos theory to the study of cognition is mainly contained in the way chaos theory describes complex systems. Traditionally, theories of cognition have focused on reducing chaos and complexity in order to discover the structure of cognition. In the next chapter, I will suggest that the contrary is desirable, namely that theories of cognition must embrace the complexity and unpredictability of cognition, rather than reduce and control it. For the moment, I would like to point out two important implications which postmodern developments in the physical sciences hold for the study of cognition, which influenced the direction of the current study.

One of the most important questions that postmodern science raises about our scientific pursuits concerns the *scientific methods* which we use. In previous sections, I have shown how classical physics established the superiority of the experimental approach and dictated the implementation of controlled studies in which every variable must correspond to and be explained by a particular element of theory. In contrast, chaos theory dictates that complex systems must be studied naturally as they occur (Lorenz, 1993). This is because the behaviour of complex systems are extremely sensitive to initial conditions. If the conditions upon which the complex system is dependent, are changed or reduced (as would be done in a controlled experiment), then the behaviour of the system will change and lose its complexity. The entire experiment will be invalidated because the behaviour we observe will not be characteristic of the natural behaviour of the system.

The second implication that postmodern science holds for the study of cognition, concerns the *phenomenon* that is studied. In addition to studying a system as it occurs naturally, chaos theory also suggests that the phenomenon (in this case, cognition) we study is much broader in scope than cognitive psychologists were heretofore prepared to acknowledge. In essence, it requires the study of cognition not only as a physiological phenomenon, but also as a social, emotional, cultural, perhaps even political phenomenon. It calls for an approach to cognition that acknowledges the many and varied ways in which the context, as representative of the initial conditions of the system, is co-responsible for the phenomenon of cognition.

The physical sciences have shown us that it is possible to “prove” that light consists of particles **and** waves depending on how we choose to set up the experiment. Both states are possible if we accept that light is a wave function which contains both possibilities (particle and wave) and that one is realised the moment an observation is made. Similarly, if we devise our “experiments” in certain ways because of our belief that cognition is either predetermined or chaotic, we can “prove” both. Information-processing theorists have had considerable success with their model of cognition because the existence of the computer “proves” that the input-processing-output model of information processing is plausible (Lerner, 2000).

On a more sophisticated level, but still within the realm of cognitive psychology, cognitive neuroscientists use statistical techniques such as structural equation modelling to “prove” the relationship between variables such as age, intelligence, domain knowledge and metacognitive knowledge and their combined direct and indirect impact on children’s ability to recall information from a text (Schneider, 1998). In mathematical psychology, scientists have created stochastic computers (a computer which involves chance as well as precision) that “prove” that cognition involves a large element of chance, and quantum computers that “prove” that cognition is not deterministic (Goertzel, 1993). The point is that cognition can be conceived of as being both deterministic *and* chaotic depending on the way we choose. Both views are needed to understand what cognition truly is.

The larger part of the twentieth century has been taken up by a preoccupation with the deterministic nature of cognition. Postmodern developments in science advise us to spend the time to come investigating the complex and chaotic nature of cognition.

In the next chapter, I will look more closely at what it could mean to investigate cognition as a chaotic phenomenon.

META-NARRATIVE 2.3