PREAMBLE

> The entire purpose of the human brain is to produce movement. Movement is the only way we have of interacting with the world. All sensory and cognitive processes may be viewed as inputs that determine future motor outputs.
>
> (Wolpert, Ghahramani, & Flanagan, 2001, p. 478)

The issue raised by Wolpert et al. (2001), that the purpose of cognition is to provide input for human action, linking sensory and cognitive processes, is usually considered to be confined to a person's early childhood. Piaget (1952) asserted that for children, the sensorimotor stage of learning was the precursor to cognitive development. His constructivist view of learning suggested that an individual's perception of the world was created from the meaning attached to various events and experiences. Furthermore, both Dewey (1938) and Vygotsky (1997) recognized the importance of the sensorimotor aspects of development, especially for the young child, but did not pursue an investigation of its role in the development of older children or adults.

Models of learning, which included a sensorimotor stage, have been proposed by a number of researchers including, Fischer (1980), Case (1985), and Mounoud (1986). The models of each of these individuals present varying viewpoints. Both Case and Fischer implied that too much emphasis was placed on the maturational factors affecting the learning process. Mounoud's model advocated the importance of genetic inheritance, as well as the individual's interactions with the environment.

The many theories and conceptual frameworks of sensorimotor learning relate, mainly, to individuals at the beginning of their life. This situation presents an opportunity to add knowledge to both theory and practice, within the realm of sensorimotor learning that has wider applicability. The purpose of this study is to investigate a skill in the sensorimotor mode of learning, across the lifespan. In particular, the study considers performances of individuals undertaking a fundamental motor skill.

This thesis is organised into eight chapters. The first two chapters survey the literature to examine and provide critical commentary related to motor skills and their assessment. Chapter 1 explores three theoretical constructs particular to motor development and learning. The links between the concepts of motor skill learning, motor development, motor control, motor skill acquisition, and the psychomotor domain are examined. In addition, issues surrounding the instruments used to assess motor skills are explored. Chapter 2 reports on the meanings surrounding the term sensorimotor, as well as theoretical perspectives, both past and present, which have the sensorimotor mode as part of their initial structure.

The review of the literature raises a number of new questions. One fundamental question concerns the applicability of various theoretical perspectives' relevant to sensorimotor learning across the lifespan. A second important question relates to the ability of current assessment models to gauge the quality of movement for individuals.

Chapter 3 presents the Research Design, used to explore the research questions and themes. Included in this chapter are descriptions of the locations of each of the data collection sites, the characteristics of the sample of subjects, and the instruments used for data collection.

Chapters 4 to 6 consider those aspects of the study that involve the analyses of the data. Chapter 4 includes a description of the analysis, of the skill being investigated from a number of different perspectives. This analysis is achieved through the use of purposively sampled case studies. Chapter 5 presents an emerging framework that employs the case study results for assessing the quality of movement, across a number of cohorts, which represent different age groups. An analysis of the similarities and disparities occurring within and between the three cohorts is offered in Chapter 6.

The results of a statistical analysis of the framework, using the Rasch (1960) partial credit method is presented in Chapters 7. This chapter presents a unique visual method of presenting Rash (1960) output. Chapter 7 also includes a description of the data in terms of a cognitive developmental model of learning.

Finally, Chapter 8 provides a discussion of the possible limitations of the study, an overview of the findings, suggestions for future research, and this work's application to theory and practice.

CHAPTER ONE

Human Movement: From Theory Towards Practice

Introduction

The study of the human movement domain includes a diversity of theories, opinions and terms used to describe how the body moves. Even within a single field of this domain, for example, physical education, a number of different sub-disciplines exist such as, biomechanics, applied anatomy, physiology, motor skill learning and motor development. Each sub-discipline offers a variety of viewpoints about how, and why the body moves the way it does.

This chapter provides a description of a number of theoretical approaches that are relevant to the study of human movement. Through the provision of examples of several models that attempt to describe how humans are considered to develop and learn, specifically within the movement domain, the reasons for the diversity of opinion become evident.

There are four sections in this chapter. The first section reports on three theoretical perspectives that are applicable to the concept of human movement and its development. The second section addresses the issues associated with the term psychomotor, and a number of facets relevant to that particular learning domain. The third section describes the sensorimotor mode of learning. The fourth section examines several learning models that have the sensorimotor mode of learning as their starting point.

MOVEMENT: THEORETICAL PERSPECTIVES

This section describes three perspectives pertaining to an examination of human movement. First, an examination of the concept of motor development, from a maturational viewpoint, is undertaken. Next, concepts of motor learning and motor control are explored from a cognitive perspective. Finally, the Dynamical Systems theory is outlined.

Motor Development: A Maturational Perspective

The idea that motor development occurs as a result of an unfolding of a master plan existing within the genetic structure of the individual exemplifies the maturationalist point of view. Motor development has been defined according to Bilir, Güven, Bal, Metin, and Artan (1995, p. 2) as "the ability acquired by the organism to perform a range of voluntary activities depending on the level of [physiological] development of the central nervous system." Gabbard (2004, p. 8) stated "development is the term that can be applied to several human behaviours ... the process of change in the individual's level of functioning." According to Gallahue and Ozmun (2006, p. 5) it is a "continuous change in motor behaviour throughout the life cycle, brought about by interaction among the requirements of the movement task, the biology of the individual, and the conditions of the environment."

Initially, ideas about motor development that stimulated the thoughts of some researchers came from the work of Baldwin (1894). He theorised that babies were imitative from birth, and that the nature of their imitation changed during the course of their infancy. Imitation was deemed to be automatically elicited by the infant's experience of his or her own behaviour, or by the perception of stimuli in the environment, for example, through facial expressions. Baldwin referred to the former phenomenon as a *circular reaction*—the self-imitative repetition of a pleasurable response. The latter circumstance he termed, *instinctive mimicry*, which includes "those reactions which reproduce subconscious, vaguely present stimulations: for example, the acquisition of facial expression, the contagion of emotion" (Baldwin, 1894, p. 48). In both cases, actions were considered to be a response that reinstated the circumstances that triggered it. This situation also was deemed to create opportunities for learning.

Subsequent to Baldwin's work, in an attempt to add more depth to the maturational approach, Hall (1904) introduced the concept of *recapitulation* or *ontogeny recapitulates phylogeny*, which involved the repetition of evolutionary or other process during development or growth. Hall's theory included the notion that the physical aspects of growth needed to be complete prior to allowing deeper thoughts to be generated. His maturation theory did not greatly influence education. However, his writings provoked ideas that probably paved the way for future scholars.

Maturational theory took on a different emphasis when Gesell (1928) applied the concept of maturation to rates of growth and development of individuals. Gesell proposed that "genetics" controlled both growth rates and learning ability. Following on from Gesell's work, McGraw (1935) examined the effect of age and changes over time with the inclusion of environmental considerations, such as, how the setting affected motor performance.

In the mid nineteen thirties, Bayley (1936) attempted to delineate a series of expected motor achievements for individuals at particular chronological ages. However, her work, at that time, lacked data for both age range and movement quality variations. More recently her work has been revised and renormed. Such revision has led to "a psychometrically strong instrument that is grounded in modern theory" (Lichtenberger, 2005, p. 207). Ensuing from her initial work, Bayley (1993) has included descriptive scales for measures of the levels of gross and fine motor development.

Since the early work of Bailey (1936), the writings of Piaget (1952), Seefeldt (1979), and Gallahue and Ozmun (2006) have utilised the ideas of these *pioneers* and consequently the work of these authors has been selected to expand the discussion of the maturational approach. Their writings span a time period of more than five decades, and their contributions to both theory and practice have been compelling.

Piaget's Model

Piaget's theoretical position made an important contribution to the maturational perspective. Central to Piaget's (1952) stage theory was the relationship between the age of the performer and the changes in expected movement patterns. Flavell (1963) highlighted three main periods. These are:

- Period 1: Sensorimotor (from birth to two years of age) during which sensorimotor schemata, which is demonstrated through a range of acts up to, for example, demonstrations of practical intelligence by means of immediate comprehension as well as practical substructures of future notions, such as permanent object schema and sensorimotor causality.
- Period 2: Begins when language, game symbols, and picture making manifests itself, and goes through the preparatory phase of preoperative representation (non-conservation). This period ends no later than the eighth or ninth year of age with the setting up of operations that are called "concrete" because they still have a bearing on objects. For example, classifying things, putting them in series, noting connections and understanding numbers.
- Period 3: Commencing at about the age of eleven or twelve years, which is

> characterised by propositional operations (implications, etc.) with their uniting quality and their possible transformations made by relation to a fourth group; a combination of two elementary reversibility forms (inversion or negation and reciprocity).

With regard to the sensorimotor period, Piaget (1952) divided it into six substages termed, reflexive activity (birth-to-1 month), primary circular reactions (1-to-4 months), secondary circular reactions (4-to-8 months), coordination of secondary schemata (8-to-12 months), tertiary circular reactions (12-to-18 months), and invention of new means through mental combinations (18-to-24 months). The latter substage signified the peak of the sensorimotor period, as action and perception became integrated (Biggs & Moore, 1993, p. 38). This implies that older children and adults mediated learning with more abstract thinking than infants or babies, who did not resort to the abstract.

A stage approach of this kind describes a sequential process; it is not possible to arrive at a higher stage without undergoing lower-stage preparation. Thus, it is an internally driven system whose stages may be characterized by fairly precise structures.

Despite the link established by Piaget (1952) between age and the attainment of movement skills, Garcia (1992) pointed out that several authors, such as Seefeldt, Reuschlein, and Vogel (1972), Roberton (1978), and Gallahue (1989) indicated that movements were not necessarily considered to be age dependent, but age related. Under the maturational standpoint, the idea of the origin of genetically programmed movement patterns failed to explain how changes and adaptations to movement patterns could occur. Thus, while the maturational view of motor development focused on both growth and maturation as key elements, the significance of the contribution of environmental factors to motor behaviour was not a consideration.

Although some aspects of Piaget's developmental theory have been criticised on a number of grounds (Berger, 1988), according to Campbell (1997) what he has provided, from a maturationalist viewpoint, is a valuable intellectual legacy. This legacy has, in more recent times, led to the instigation a number of theoretical perspectives under the guise of what is termed, neo-Piagetian theory.

Seefeldt's Model

Seefeldt (1979) demonstrated applicability and specificity to the concept of motor development through his model, which contained four hierarchically arranged levels. Each level demonstrated a progression towards the achievement of motor proficiency.

The first level of his model comprised reflexive movements, which are present at birth. Some of these reflexes were considered to serve as an underlying basis for other future movements. The second level contained fundamental motor skills, and deliberation was given to the notion that young children needed to master these fundamental skills if higher skill levels were to be achieved. The third level contained transitional motor skills. Transitional skills were a combination of fundamental skills with modifications. The fourth level included sport-specific skills. Both levels three and four encompass the period between middle childhood and adulthood.

Two important factors emerged from Seefeldt's (1979) work. First, there was recognition that young children should master fundamental skills during early childhood if optimum development of higher skills was to take place. Second, that a "proficiency barrier" existed between the fundamental skills and the transitional levels. The barrier implies that unless proficiency in the fundamental skills was achieved, individuals would not progress to more advanced levels of skilled movement.

Gallahue and Ozmun's Model

Gallahue (1982; 1989), and Gallahue and Ozmun (1995; 1998; 2002; 2006) adopted a model that presents as being viable and workable in its application to studies of human movement. Gallahue and Ozmun (2006) considered that motor development could "be studied as a process or product" (p. 16).

Gallahue and Ozmun's (2006, p. 48) model was based on "developmental phases, along with developmental stages that were perceived to occur within each phase." The link between age and changes in observable movement was a basic tenet of the model, with the implied notion that movement efficiency changed over time. The various phases of movement and their accompanying stages, are shown in Figure 1.1.

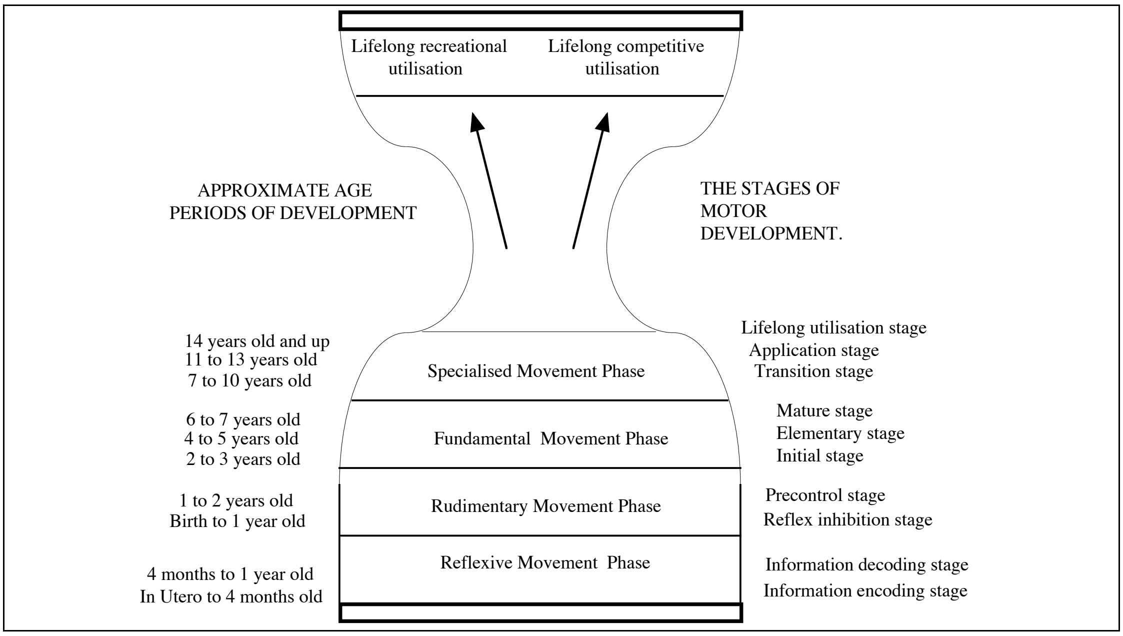


Figure 1.1: Phases of Motor Development: Gallahue and Ozmun (2006)

The model shown in Figure 1.1 has widespread appeal because it demonstrates a process that has practical applications within the realm of pedagogy. The model's four phases, with their accompanying stages, provide a synopsis of motor development that appears to be applicable to all individuals. In should be noted, however, that McClenaghan and Gallahue (1978) indicated that not all movement patterns fit precisely into the arbitrary stage progressions. In addition, there has been a "lack of agreement among motor development researchers regarding the description of at least one phase, the fundamental movement phase" (Garcia, 1992, p. 36).

In summary, with a focus on movement changes over time, the maturational theorists explain that an individual's genetic legacy simply unfolds. Accordingly, progress in motor skill development is considered to be largely predetermined, that is, an individual acquires movements in a specific stage and/or phase like order. These sequences can be used to ascertain expected movements for children of a specific age, despite the notion that the exact timing in terms of chronological age may vary.

Motor Learning and Control: Cognitive Perspective

A major factor that influences human movement is learning. Motor learning has been defined as "a change in behavior resulting from practice or past experience" (Gallahue & Ozmun, 2006, p. 15). A second factor that influences movement is the notion of *control*. Studies of control aim to provide an understanding of the processes that lead to skilled movement as well as to factors that cause the breakdown of such skills.

Within this subsection the views of four writers are presented – Connolly (1970), Adams (1971), Schmidt (1975), and Willingham (1998). These authors support the viewpoint that the quality of motor learning and/or control emanates from events that arise as a result of an hierarchy of subroutines that are the consequences of events and programs of increasing complexity occurring within the brain.

Cognitive theories have been classified as being within the concept of motor learning and control (Rose, 1997), yet they can also be considered to exist within the broader framework of motor development theory. The issue of motor control, according to Rose (1997), involved "the study of postures and movements and the mechanisms that underlie them" (p. 4). However, for Gallahue and Ozmun (2006) motor control is a narrow field of study, which is essentially part of learning and development.

The following summary of the work of each author is presented in chronological order. This order highlights the evolutionary progression of the research in this field.

Connolly's Information Processing Theory

Connolly (1970) used the term "information processing" to describe the situation whereby the manner and speed with which feedback was processed by the brain was considered to be an integral part of the individuals' decision making process. Connolly's assertion was that the extent to which an individual could deal with or process information, when a motor response was required, was associated with changes in the brain, and was age related. Furthermore, he indicated that the processing of information would improve over time even in the absence of specific environmental input.

Connolly provided the following example of the processing required when an individual is attempting to grasp an object.

> an individual when picking up an object requires a series of operations, which includes estimating the distance and the radial direction of the object, taking account of posture, obstacles and other cues; then initiating and monitoring a series of movements, which will bring the person's hand to a particular spatial location. This action requires information from different sensory channels, which must be integrated by the central nervous system and certain translation functions must develop.
>
> (Connolly, 1970, p. 11)

Specifically, Connolly claimed that as an individual moves along the continuum from childhood to adulthood, changes in the brain's structures enhance the ability to filter out extraneous stimuli. The result being that motor performances improve in quality and speed.

Both Anshel (1989) and Pangrazi (1995) provided support for Connolly's (1970) Information Processing Theory, specifically in relation to pedagogy. These two researchers embraced this theory because it could explain the process whereby the execution of motor skills, of varying quality and speed, occurred.

Adams' Closed Loop Theory

Adams (1971) considered that motor skills, performed by an individual, could be improved by the action of the brain having some measure of the "correctness" of the movement. The idea that feedback was matched with some "ideal" was termed the Closed Loop Theory. Adams implied that the performer relied on the ability to access information in a closed loop control mechanism within the brain. Thus feedback about the extent to which the movement matched some preconceived ideal movement was essential for the performer to change the nature of the movement.

In addition, Adams suggested that through constant repetition of a movement skill, two important processes occurred. Firstly, constant repetition created a memory trace in the brain via a stimulus response reaction, experiencing the results of movement as well as through a feedback mechanism. Secondly, repeated skill movements resulted in the emergence of a perceptual trace, aided by exposure to muscular, auditory and visual feedback.

As an individual continued rehearsing a movement, Adams claimed that references to past movements were developed. The two memory traces created in the brain were compared against each other, and any comparison discrepancy resulted in the elimination of errors. As the performer improved, the two traces became more matched and it was at this point learning progression took place. A balanced interaction of stimulus response (behaviourist) and cognitive (perceptual) theories and the use of feedback are seen as important aspects of this model of skill acquisition. A continual process of discrepancy elimination between the memory trace and the perceptual trace was considered to take place.

Adams' (1970) theory appears to be accurate in experimental situations where slow linear positioning responses, are made by the body. However, the theory's practical application breaks down under conditions in which rapid movements are required. An additional shortcoming appears to be the inability to explain how "novel" movements are produced. A further criticism of the theory is the fact that for every movement, a memory trace needs to be created. Given the number of movements made by an individual, an "overload" on the memory capacity would appear to be inevitable (Kelso, 1982).

Schmidt's Schema Theory

Schmidt (1975) termed his model the Discrete Motor Learning Skills or Generalized Motor Program (GMP), which supported the idea that both previous movement experiences and internal and external proprioceptive feedback (emanating from the senses) were compared to a stored memory of optimal movement patterns. A comparison between the desired movement outcome and the actual movement performance was considered to follow.

This idea implied that information was stored in the brain, where differences in movements were duly noted, thereby assisting the performance of future movements. As such, future movements would apparently more closely resemble the desired movement outcome.

Schmidt attempted to overcome some of the weaknesses in Adams' (1971) theory, such as the novelty and storage of information, by explaining how variations in movement responses could be accounted for in situations in which the performer was not in control of environmental variables. In such cases, the performer could be required to move at varying speeds whilst eliciting novel motor responses.

The schema theory has wide acceptance, however, a possible weakness in this theory is that it does not account for the origin of the initial stored memory. The GMP may also be challenged with regard to its notion that movements are represented within the central nervous system.

Willingham's Control Based Theory

The idea that components associated with motor control were located in different anatomical locations within the brain, and that those different cognitive areas manifested themselves in different ways was proposed by Willingham (1998). This process Willingham termed the Control-based theory (COBALT). He attempted to deal with some of the practical shortcomings of former theoretical models through the application of a motor control and skill-based learning theory.

Apart from suggesting that a link existed between certain locations within the brain and motor responses, Willingham surmised that motor behaviour could manifest itself either as a conscious (explicit) act or subliminally (implicit). The conscious mode was considered to contribute to learning "at any point" during skill acquisition, particularly during the early learning periods, however, he implied that the possibility existed for the conscious mode to be invoked at a later more advanced stage of learning, if the learner perceives a particular motor control process to be unusually or uniquely demanding. The unconscious mode was considered to be sufficient to support the administration of a number of the motor control processes, in particular, the perceptual-motor integration and sequencing processes.

The first of these two modes of learning/processing, the conscious mode, was regarded as important for the selection of the movement skill's targets or strategies, and requires attention to meet the demands of the process. The second mode of learning, the unconscious mode, was considered not to require attention and involved mainly in fine-tuning the processes selected, or identified, during the conscious process. Willingham's assertion was that the interface, or interaction, between the learning systems appears to be uni-directional. That is, the conscious mode of learning/processing is invoked initially, and is followed by activation of unconscious processes.

There has been some conjecture surrounding whether both these modes are in fact independent forms of learning. It has been noted that some individuals subjected to experimental conditions, demonstrated parallel development of knowledge within both the explicit and implicit learning systems (Zihlman, 2006). This finding is incompatible with the Willingham's COBALT model.

In summary, the concept that the brain contains some form of neurological "trace" that body movements can be compared against is central to the cognitivist's argument. The shortcoming of this assumption is that movements arise from plans and instructions commanded by an "executive function" in the brain. The whereabouts of this executive and the origins of these motor plans are unresolved.

In addition, the issue of complexity of both the human biological system and the environment, in which it operates, is intricate. As a result, the information processing theory appears to fall short of an explanation for complicated movement behaviours. Models of this persuasion imply that movement results from a "top-down" sequence of events, rather than emanating naturally out of the complex interaction among many connected elements, in the same way that other complex systems in the natural world self-organise themselves, without any apparent central self-control emanating from an initial stored memory.

Movement Changes: Dynamic Systems

This subsection presents, firstly, an outline of Dynamic Systems Theory (DST), which provides an alternative perspective pertaining to how human movements may be considered to occur. A description of the ideas of Bernstein (1967) is followed by an account of the ideas of six authors, specifically those of Buchanan and Ulrich (2001), Thelen and Smith (2002), and Garcia and Garcia (2006) who endorse the advantages of a dynamic systems approach to the study of changes in movement.

Historically, DST is considered to have emanated from the work of Bernstein (1967) whose ideas were based, according to Bongaardt and Meijer (2000), on the concepts of Andronov and Chaikin (1949). Bernstein considered what was termed the "degrees of freedom" (Turvey, 1990) associated with the complexity of bodily movements and also addressed problems associated with the complexity of motor responses. Degrees of freedom include the internal bodily factors that promote or restrict efficient movement as well as the impinging environmental influences. For example, the degrees of freedom include the muscles, joints and limb segments, which are able to vary in position and action. He defined movement coordination as "the process of mastering redundant degrees of freedom of the moving organ, in other words its conversion to a controllable system" (p. 127). Bernstein regarded the formation of specific functional muscle-joint linkages, as being a way of constraining the large number of degrees of freedom to be controlled when individuals moved.

There are four basic tenets of DST that apply to changes in movement patterns, these are: constraints, self-organization, patterns and stability. The first concept includes the idea that motor behaviour arises from a system surrounded by constraints. Newell (1986) listed three constraints, specifically, the organism, the environment, and the task at hand. The organism constraints refer to those features unique to the person, including physical characteristics such as height, weight, and somatotype (body-shape), as well as their cognitive, psychological and emotional attributes. The environmental constraints stem from both the physical and socio-cultural environments. However, taking into account the individual's unique features and environmental constraints, Clark (1995) stated: "it is the task requirements, which form the observable movement" (p. 174). Thus, task constraints modify the system into the observed behaviour, and from a dynamical systems perspective, movements that do occur are considered to be a result of the interaction between those constraints.

A second requirement of DST is the inclusion of the processes that create organised action, termed self-organization. Complex systems comprising numerous simpler elements, governed by dynamical principles, are considered to be responsible for the development of spontaneous organisation.

The third fundamental of the dynamical systems approach is that of pattern formations, that is, from complex systems of neurons and motor units a pattern arises. These patterns result from the dynamical systems' collective dynamics, which could be represented through the creation of a model for all possible states of the system. These possible states are referred to as the state space (Abraham, Abraham & Shaw, 1992; Abraham & Shaw, 1982). In addition, within the state space, what are termed, *attractors* or *attractor states* emerge when "a behaviour assembles into preferred patterns or coordination modes" (Buchanan & Ulrich, 2001, p. 315).

Stability is the fourth concept in the collective states of a dynamical system. Small perturbations, disturbances to movement patterns, tend not to disrupt the system from its stable position in the state space. However, when variability increases the system becomes unstable. The loss of stability is characteristic of a system in transition. "Less stable behaviours are more easily nudged from their shallow attractor spaces into alternative behaviour states than are more stable ones" (Buchanan & Ulrich, 2001, p. 316).

As a logical extrapolation resulting from the interconnectedness of these systems and sub-system, a self-organising modifiable response occurs. As a consequence the demands of the motor task and prevailing environmental conditions can modify the response (Thelen & Smith, 2002). This means that proponents of DST consider that the body consists of a complex network of spontaneous self-organising, selfassembling systems and sub-systems (Thelen, 1989; Thelen & Ulrich, 1991). In addition, DST theorists regard the human body as being in a continual state of change that results in the development of new movement patterns.

Buchanan and Ulrich (2001) noted that several researchers (Newell, Morris, & Scully, 1995; Ulrich, 1997; Vereijken, van Emmerik, Whiting, & Newell, 1992) have confirmed Bernstein's (1967) ideas, showing that when adults attempted to acquire a novel skill they were seen to demonstrate a number of movement qualities explained by DST. For example, initially freezing out degrees of freedom, that is, stiffening up and coupling joints to act as a unit rather than independently. Subsequently, performers increase exploratory behaviour, loosen up skeletal joints and search for more efficient patterns of movement before achieving the third phase in which patterns become stable and efficient.

Following the work of Bernstein, and also taking into account the advent of chaos theory (Haken, 1977), an investigation of the applicability of DST to human movement was initiated by Kugler, Kelso, and Turvey (1982). Clark (1995) added to this argument stating that "the dynamical systems approach provides the theoretical framework from which an adequate theory explaining motor skill acquisition can be derived" (p. 173).

DST has been examined from a number of practical perspectives within the movement domain. Examples are provided in the writings of Buchanan and Ulrich (2001), Thelen and Smith (2002), and Garcia and Garcia (2006). Each is considered briefly in the following paragraphs.

The application of DST principles designed to improve physical functioning has been described by Buchanan and Ulrich (2001). They alluded to the therapeutic movement program, known as the Feldenkrais method, which has five major points of similarity with DST. These are, self-organization, attractor states, perturbations, multiple sub-systems affecting behaviour and the mutual emphasis on the interaction between perception, and action sub-systems (Buchanan & Ulrich, 2001). These authors also pointed to some differences, which were concerns about the goal in relation to the process, the problem of nonlinearity, and the interactions amongst sub-systems.

Taking into consideration the notion that "the organism, the task and the context self-organise behaviour to a preferred form" (Kamm, Thelen, & Jensen, 1990, p. 26), a number of questions about existing assumptions associated with motor, perceptual and cognitive development were posed by Thelen and Smith (2002).

They suggested that a new theory of the development of cognition and action was required, which amalgamated recent advances in DST with current research in neuroscience and neural development. In particular, they demonstrated that by the processes of exploration and selection, multimodal experiences form the basis for self-organising perception-action categories. This alternative to current cognitive theory, presented by Thelen and Smith (2002) emphasised the dynamics of the processes of change. They implied that several classic issues in early cognitive development needed to be reinterpreted.

An example of the practical application of the DST perspective, in physical education, was provided by Garcia and Garcia (2006) who applied this theory to a classroom situation. The approach used by these two authors reflects the notion that DST incorporates the Ecological task analysis approach (Davis & Burton, 1991), which had as its central tenet "the idea that motor skills, the movement form and the performance outcomes results from the dynamic interaction between the task goal and conditions, the environmental situation, and the capacities and intent of the performer" (Balan & Davis, 1993).

Garcia and Garcia (2006) analysed three components of a physical education lesson, using what they considered to be a DST approach. The three components analysed were: the organism, the environment and the task. A video analysis of a "typical" physical education lesson revealed several organism characteristics of the class, such as the somatotypes and the manner in which they organised themselves into groups.

Next, environmental factors, such as the learning context were analysed. Environmental lesson characteristics included the ideas that students showed different skill levels, had different participatory expectations, found the learning environment hostile, and received feedback that was not specific. An analysis of task characteristics of the lesson indicated: three skills used in combination, the concept of spatial awareness was applied, some students demonstrated immature patterns, only some students demonstrated readiness, and less skilled students' interest declined with increased difficulty.

The conclusion drawn by Garcia and Garcia (2006) was that "the environment and the task were most capable of being manipulated in teaching to enhance motor development" and that there is a "gap between the maturing organism, the environment, and the task" (p. 33). This practical example was aimed at demonstrating how a DST perspective could be incorporated to improve teaching through awareness, on the educator's part, of the value of analysing the dynamical interaction between the three components.

In summary, DST is radically different from both the maturationalist and cognitivist's views about how changes in movement occur. DST theorists imply that movement patterns emanate from the interactions of a number of components, networking within and amongst each other, as well as taking into account environmental conditions. This notion of interconnectedness is what distinguishes DST from both the maturational and cognitive perspectives. However, because the brain is not central to the initiation of movement in DST and because dynamic systems approaches "lack a theory of learning that could justify the idea of the accumulation of knowledge" (Goulay, 2005, p. 12), there has been some resistance to the total acceptance of DST to explain all movement situations.

Conclusion

A number of standpoints of different theoretical perspectives related to the study of movement have been provided in the foregoing section. These theories have their own strengths and weaknesses. Each theory, however, contributes to an understanding of what accounts for changes in movement types and the quality of such movements.

The maturational models demonstrated that all individuals experience a series of sequential movement patterns, which are age related. These changes in movement over time appear to follow a pattern. However, recognition is also given to the notion that there are individual variations in the actual timing of the progression.

Cognitive theorists profess that motor learning resulted from cognitive events and that the brain plays a major role in this process. In addition, the movement choices adopted by an individual are considered to arise from various anatomical locations within the brain.

Contrasting with both these theories is DST, supported by a number of researchers, who claim that DST is a "better" way of explaining movement outcomes. This theory appears to have gained significance amongst many researchers as an acceptable explanation for the way movement responses come about. "The strength of the DST framework is that it is able to explain changes in movement associated with motor control, motor learning and motor development – across a lifespan" (Miller, 2001, p. 65). Motor development studies conducted by Buchanan and Ulrich (2001), Clark (1995), and Miller (2001) exemplify this notion.

However, whilst supporters of the maturational model acknowledge the important role of the brain, and cognitive theorists consider it to be foremost in motor learning, there is still a lack of an explanation regarding the role of the brain in DST regarding decision-making related to an individual's choice of movement sequences. Many neuroscientists give primacy to the role of the brain in organising behaviour, yet DTS implies it is but one component among the many cooperatively directing patterns of action (Buchanan & Ulrich, 2001).

LEARNING DOMAINS

Bloom, Englehardt, Furst, Hill, and Krathwohl (1956) placed the attainment of motor skills within the psychomotor domain of their learning taxonomy. They suggested that learning took place within three learning domains – the cognitive, affective and psychomotor. Each of these domains can be described in terms of hierarchical parameters, each indicating an increase in complexity. This section presents information relevant to this taxonomy.

Bloom's Taxonomy

The seminal work of Bloom et al. (1956) was primarily designed to aid in the determination of educational objectives, based on the notion of identifying what the student was able to do as a result of education. The three learning domains they identified form a continuum, which may be used by educators as a tool for analysing educational activities.

The cognitive domain involves knowledge and the development of intellectual skills (Krathwohl, Bloom, & Masia, 1964). This domain includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills. The literature presents six major categories, which like the two other domains are presented as an hierarchy, from the simplest behavior to the most complex. Categories within the hierarchy can be thought of in terms of steps of difficulty. The first step must be mastered before the next one can take place. The categories within the cognitive domain are, knowledge, comprehension, analysis, synthesis and evaluation. Furthermore, within each category there are numbers of sub categories.

The affective domain involves describing how the individual deals with emotions. There are five major categories within this domain, which like the cognitive domain are arranged from uncomplicated behavior to the most sophisticated. These categories are, receiving, responding, valuing, organizing and characterization.

Although elaborate descriptions of the cognitive and affective domains were published, nothing was completed by Bloom et al. (1956) at the time of publication for the psychomotor domain. Their reasoning behind this omission was that they considered there was little need to teach manual skills to college students (Anderson & Krathwohl, 2001). This omission meant that physical education, creative and performing arts such as drama, music and even surgical procedures in the various branches of medicine were completely overlooked in their taxonomy.

Notwithstanding, Krathwohl (1973 as cited in Ferris & Aziz, 2005) who was one of the original contributors to the taxonomy, presented a description of the psychomotor domain well after the original date of publication. The description included an hierarchy of steps through which an individual may progress, namely, basic movements, readiness, movement skill development, movement pattern development, and adapting and originating movement patterns. A brief outline of the psychomotor domain is provided in the following paragraphs.

Psychomotor Domain

The term psychomotor has been applied to physical skills and the performance of actions involved in learning in the manipulative or motor-skill area of study (Bloom et al., 1956). Specifically, the term applies to movement or muscular activity, which is associated with mental processes (McCarron, 1997).

The psychomotor domain provides a connection between disciplines, such as rehabilitation, medicine, nursing, physical education and psychology. The use of the term psychomotor, which encompasses all activities related to movement, provides a common element within its descriptive structure that encompasses all these disciplines (Shemick, 1985).

Models of the Psychomotor Domain

Because Bloom et al. (1956) did not provide any initial detailed information pertaining to the psychomotor domain, a précis of the work is provided by three authors, Harrow (1972), Simpson (1972), and Dave (1975). These writers have addressed the characteristics, expected to be present, when an individual is operating in the psychomotor domain. In addition to the views of these three authors, Pangrazi's (2007) examination of the psychomotor domain, from a physical education perspective, is also presented.

Harrow's Inventory

Harrow (1972) produced an inventory comprising a number of different elements for the psychomotor domain that were related to child growth and development. This model focuses on the translation of physical and bodily activity into meaningful expression. Table 1.1 provides a summary of the model.

TABLE 1.1 HARROW'S ELEMENTS OF THE PSYCHOMOTOR DOMAIN (1972)

Name of Movement	Type of Movement
Involuntary movement	– reaction
Fundamental movements	– basic movements
Perception	– response to stimuli
Physical abilities	– stamina that must be developed for further development
Skilled movements	– advanced learned movements
Non-discursive communication	– effective body language

Each element shown under the first column in Table 1.1 is arranged in increasing order of complexity. *Involuntary movements*, also referred to as reflexive movements, are present at birth, for example the grasping reflex of a baby. *Fundamental movements* address behaviours related to "every day" movements, such as, locomotor, non-locomotor and the manipulative. *Perception* refers to the individual's response to visual, auditory and other sensory stimuli. *Physical abilities* include fitness-related concepts such as strength, coordination, endurance and flexibility. *Skilled movements* involve both simple and complex actions that have been learned, such as playing a musical instrument. At the highest level, *non-discursive* communication refers to expressive movements demonstrated through gestures, facial expressions and other creative movements, that is, the creation and application of movements used to express complex ideas.

The second column in Table 1.1 lists the type of movement expected to occur as the individual progresses. This development was considered to occur in much the same way that an individual developed cognitive skills. The individual moves through each movement element, presumably until the maximum ability level of that person is reached.

Harrow's inventory is particularly applicable to the development of young children's bodily movement, skills and expressive movement. Notwithstanding, Harrow's interpretation of the psychomotor domain favours the development of physical fitness, dexterity and agility, and control of the individual's body, to a considerable level of expertise. However, this inventory appears in a diverse range of literature ranging from dentistry to outcomes-based learning theory.

Simpson's Taxonomy

Simpson (1972) described seven major categories for the psychomotor domain, couched in terms of objectives designed to be applicable in the educational setting. The hierarchically arranged category names appear in the first column in Table 1.2. In the second column, a brief description of the typical behaviour expected for each category is provided.

TABLE 1.2: SIMPSON'S TAXONOMY FOR THE PSYCHOMOTOR DOMAIN (1972)

Category (Level)	Description (Typical behaviour)
Perception:	The ability to use sensory cues to guide motor activity. This ranges from sensory stimulation, through cue selection, to translation.
Set (Readiness to act):	Includes mental, physical, and emotional sets that determine a person's response to different situations.
Guided response:	The early stages in learning a complex skill that includes imitation and trial and error. Adequacy of performance is achieved by practising.
Mechanism:	This is the intermediate stage in learning a complex skill. Learned responses have become habitual and the movements can be performed with some confidence and proficiency.
Complex Overt Response:	The skilful performance of motor acts that involve complex movement patterns. Proficiency is indicated by a quick, accurate, and highly coordinated performance, requiring a minimum of energy. Often the performer can tell by the feel of the movement act what the result will produce.
Adaptation:	Skills are well developed and the individual can modify movement patterns to fit special requirements.
Origination:	Creating new movement patterns to fit a particular situation specific problem. Learning outcomes emphasise creativity based upon highly developed skills.

Commencing with column one at the top of Table 1.2, the levels through which an individual passes appear in order from the simplest to the most complex. According to Shemick (1985, p. 21) "the levels in the classification schema demonstrate the pathway that a learner follows in order to acquire a skill."

The information provided under the heading *Description* includes details of *what* is expected-to-be-observed for each particular level. As an accompaniment to each description, Simpson (1972) included a list of key words (verbs) that describe what needed to be "trained" or measured at each level. For example, at the *Perception* level the individual should be able to – recognise, distinguish, notice, touch, hear and feel. At the other end of the hierarchy, the *Origination* level, the individual should be able to – design, formulate, modify, re-design and trouble-shoot.

Simpson's model provides a more elaborate and detailed description of movement expectations than Harrow's (1972) model. In this regard, Shemick (1985) indicated that educators would find the educational objectives classification systems of Simpson most suitable for practical application.

Dave's Categories

The model of the psychomotor domain provided by Dave (1975) is also presented as an hierarchy. The model outlined in Table 1.3 includes descriptions of five levels/categories with an accompanying definition and a list of descriptive verbs.

TABLE 1.3: DAVE'S CATEGORIES OF THE PSYCHOMOTOR DOMAIN (1975)

Level	Category	Definition	Some possible verbs
1	Imitation	Observe a skill and attempt to repeat it, or see a finished product and attempt to replicate. Patterning behaviour after someone else.	attempt, copy, duplicate, imitate, mimic
2	Manipulation	Perform the skill or produce the product in a recognizable fashion by following general instructions rather than observation.	complete, follow, play, perform, produce
3	Precision	Independently perform the skill or produce the product with accuracy, proportion, and exactness; at an expert level.	achieve, automatically, excel expertly, perform, masterfully
4	Articulation	Modify the skill or produce the product to fit new situations; combine more than one skill in sequence with harmony and consistency.	adapt, alter, customize, originate
5	Naturalization	Completion of one or more skills with ease and making the skill automatic with limited physical or mental exertion.	naturally, perfectly

The first three columns in Table 1.3 provide basic information. Column one lists the levels, through which a learner moves, in hierarchical order. The second column indicates the categories or names of the levels. The third column defines the categories from *Imitation*, an example of which is the ability to watch the teacher or trainer, and repeat the action, process or activity. Examples of each of the other categories are: *Manipulation* that includes the ability to perform a task based on written or verbal instructions; *Precision* is the ability to perform with both expertise and high quality, without assistance or instruction and/or be able to demonstrate an activity to other learners. *Articulation* is the ability to relate and combine associated activities to develop methods to meet varying, novel requirements. The *Naturalization* category is attained when the individual can define the aim, determine the approach required, and plan a useful strategy to meet a specific need.

The fourth column is notable in that it also includes a list of possible accompanying "verbs", which provide keys for identification of each level. For example, descriptive verbs for the Imitation level can assist a teacher or researcher to assess the level at which an individual may be performing. Each of the other levels has a relevant word list, serving a similar purpose.

A possible limitation of Dave's (1975) version of the psychomotor domain appears to be that it is more relevant and helpful for post school, workplace and community related development. It is noteworthy, for example, that the initial Imitation level commences when the individual has reached a stage of physical and intellectual development to be able to watch a teacher or trainer, and repeat an action, process or activity.

Pangrazi's Steps

Corbin (1976 cited in Pangrazi, 2007, p. 70) stated "the psychomotor domain is the primary focus of instruction for physical education." Pangrazi (2007) indicated that there were seven levels within the psychomotor domain, which were in line with the developmental level of learners, these were simply: movement vocabulary, movement of body parts, locomotor movements, moving implements and objects, patterns of movement, moving with others, and movement problem solving.

Pangrazi also delineated the characteristics, interests and physical education programming guidelines for children at three developmental levels within the psychomotor domain. The following Table 1.4 shows Pangrazi's (2007, pp. 73-75) characteristics of children, shown here in abridged format, within the psychomotor domain at three developmental levels.

TABLE 1.4: CHARACTERISTICS AND INTERESTS OF CHILDREN: PSYCHOMOTOR DOMAIN

Developmental Level I (Approximate age range 5-7 years)	
	Noisy, active, egocentric, exhibitionistic, imitative and imaginative, and want attention
	Large muscles more developed: game skills not developed
	Naturally Rhythmic
	Fatigue easily but recover quickly
	Hand-eye coordination developing
	Perceptual abilities maturing
	Pelvic tilt can be pronounced
Developmental Level II (Approximate age range 8-9 years)	
	Capable of Rhythmic movement
	Improved hand-eye and perceptual coordination
	More interest in sports
	Sport-related skill patterns mature in some cases
	Developing interest in fitness
	Reaction time is slow
Developmental Level III (Approximate age range 10-11 years)	
	Steady growth (girls grow more rapidly than boys)
	Muscular coordination and skills improving, interested in learning detailed techniques
	Differences in physical capacity and skill development
	Posture problems may appear
	Upper primary girls may show signs of maturity; may not wish to participate in all activities
	Upper primary boys rougher and stronger

In addition to the characteristics of children shown in Table 1.4, Pangrazi was forthcoming with a number of programming guidelines, aimed specifically at teachers, for use in the psychomotor domain. These guidelines reflect the characteristics for each developmental level. For example, to cater for children in Developmental Level I, Pangrazi suggested vigorous games of short duration, with varied movement qualities such as balancing and/or manipulation of objects. A similar set of guidelines is suggested for the other two levels (see Pangrazi, 2007, pp. 73-75).

In summary, descriptions of the psychomotor domain provided by Harrow (1972), Simpson (1972), and Dave (1975) all follow an hierarchical set of categories similar to that used by Bloom et al. (1956). Harrow produced an inventory comprising a number of different elements related to children. Simpson described a list of typical behaviours for each category within her model. Dave's model included categories with an accompanying list of descriptive verbs. Pangrazi's description of the psychomotor domain comprised a graduated list of seven steps that are developmentally based, however, his main focus was to provide a set of guidelines for the physical educator.

Conclusion

The descriptions of the psychomotor domain provided information, which was expressed from a broader perspective than is the current view of most motor learning theorists within the discipline of physical education. However, there are some pertinent structural differences between these models. For example, Harrow's (1972) model appears to commence at a level that physical educationalists, such as what Gallahue and Ozmun (2006) refer to as the reflexive stage, with the next three levels referring to the capabilities of very young children. The model then demonstrates a large "jump" to the "skilled movements" level. In contrast, Simpson's (1972) model commences at approximately the third level of Harrow's (1972) model, which is similar to Dave's (1975) model. In short, an individual can copy or duplicate a movement. Pangrazi's (2007) model differs from these three models as it makes a practical connection to the discipline of physical education.

In describing the psychomotor domain each model has its uses and advantages. For example, the models suggested by Harrow (1972) and Simpson (1972) are relevant for certain types of adult training and development, as well as for teaching and development of young people and children. Dave's (1975) version appears to be relevant and helpful for work and life-related development. Pangrazi's (2007) model is aimed at school-aged children.

A combination of all models might be a more valuable instrument for gaining insight into the movement "typologies" through which an individual passes. However, despite the differing philosophical basis of their studies, the major stages of learning provided by these authors show a recurring theme, that of an hierarchical progression in the acquisition of movement skills.

TERMINOLOGY: A PERPLEXING SITUATION

This section provides a discussion of the issues related to the meaning of three terms employed within the psychomotor learning domain. These terms are *sensorimotor*, *sensory-motor* and *perceptual motor*.

From an historical perspective the term sensorimotor was used by Piaget (1952) to describe the first period of development in the life of a human. This period occurred between birth and approximately two years of age. The initial learning process was considered to commence with the body's sensory mechanisms such as touch, sound and sight.

According to Piaget (1952), the changes in learning were assumed to take place in the brain as a result of sensorimotor experiences. In addition, he considered that these experiences led to a permanent change in behaviour, which by definition implied that learning had occurred. Thus Piaget's use of the term sensorimotor was only used to describe the strong connection, observed in infants and young children, between their sensory experiences and how they responded in a physical manner.

To further confound the issue of nomenclature, within the discipline of neurophysiology and motor control, a similar term, sensory-motor, is used to describe neural pathways between the primary motor cortex, pre–motor cortex, sensory cortex, posterior parietal cortex, thalamus, basal ganglia and cerebellum. These pathways are all involved in human movement (Brodal, 1992; Rose & Christina, 2006).

In an attempt to unite and emphasise the connection between motor activity and cognition, the term perceptual motor has been employed by a number of authors (Cratty, 1979; Fitts, 1964; Kephart, 1971). Implicit in the concept of perceptual motor is the notion that the brain has input into the quality of the movement. The movement is controlled in that parameters such as force, speed and the specific context in which the movement takes place is accounted for in the action. For example, when an individual attempts to move an object of known weight and size the amount of force needed is "pre-determined" so that the movement is efficient. Even when the weight of the object is unknown, initial feedback in terms of weight is rapidly "calculated" and the correct force is then applied to move the object. However, movement errors can occur when the brain is "tricked" into applying more or less force than required to move the object, for example, if its weight is altered without the knowledge of the individual.

In summary, the term sensorimotor appears to apply to children, and implies that conceptual knowledge is initially gained through the senses, whilst the term sensory-motor applies to changes in neurological processes at any age. However, both these terms appear to be used at different levels of analysis in different disciplines for different purposes. The term perceptual motor involves an element of cognition, which directly affects the quality of the movement, exemplified by the element of control.

Conclusion

Even though the term sensorimotor is sometimes used variously to describe motor actions occurring across the individual's life span, its use appears to be most applicable to the period between birth and the time when the child is not "simply reacting" reflexively to stimuli. According to Gallahue and Ozmun (2006, p. 50) at about four months of age "sensorimotor activity is replaced with perceptual-motor ability."

It is noteworthy, that Collis (2003) considered that the original French term, sensorimotor, might not have a directly translatable equivalent in English. In addition, the use of the word, "sensori" according to Collis (2003) "most likely included aspects of cognition, except perhaps for the first month of life, and its intended meaning also involved more than just a reaction to sensory input; the term being described as a "syndrome of a thing" or a "process" (personal communication Collis, 2003). Thus, sensorimotor "knowledge" involves changes in cognitive activity, however, it appears to be carried out unconsciously.

The idea that gaining sensorimotor knowledge does not require conscious thought implies that knowledge can be attained physically, through the body's sensory mechanisms (i.e., kinaesthetically). This situation, wherein knowledge can be attained through sensorimotor experiences, may be apparent in children between birth and 18 months of age.

The term perceptual motor may be a better expression to use when the individual can purposefully connect movement actions to a preconceived result. The use of this term appears to have greater application to movements that occur across the lifespan.

STAGE MODELS OF LEARNING

This section examines four neo-Piagetian theories of learning that include a sensorimotor stage as part of their structure. The first three models, specifically, those of Fischer (1980), Case (1985), and Mounoud (1986), present the sensorimotor mode as a constituent of learning, placed at the commencement of the process. The fourth model, that of Biggs and Collis (1992) shows that the sensorimotor mode of learning is applicable across the lifespan.

Stage Theorists

At the outset, this subsection provides a brief overview of the evolution of neo-Piagetian theory. Following this overview, there is an examination of four stage-based models that have included sensorimotor processes within their theories.

The Piagetian model included recognition of the central role of mental processes. It also provided a detailed description of children's thinking, and revealed information about children's cognitive development in the real world. The model had a number of strengths. Firstly, it was systematic, had a broad scope and was able to be generalised. Secondly, it provided order and structure related to types of knowledge, stages of knowledge development, and processes of knowledge development. Thirdly, it provided guidance to educators, particularly about children, in determining student stages of knowledge and how to assist students move to higher stages.

New stage theories have built on the ideas of Piaget. Flavell and Wohlwill (1969) and Kholberg (1987) have reported that the constructivist Piagetian model has been re-investigated. The theoretical perspectives arising from this re-examination are collectively referred to as neo-Piagetian. Notwithstanding, most of these investigations resulted in similar findings, but some have fundamental differences from Piaget's (1952) original assertions.

Neo-Piagetians have attempted to try to explain and predict the course of cognitive development. These approaches include trying to determine how development progressed from an initial condition starting at birth to a final one at death. A second approach described the process as one of growth. A third gave consideration to the existence of an hierarchy of stages. Thomas (1992) noted that some theorists adopted only one of these perspectives; others combined two or all three.

A number of models have been proposed by neo-Piagetian theorists, which have a sensorimotor mode placed at the commencement of the process of learning. These individuals include Fischer (1980), Case (1985) and Mounoud (1986). A brief description of their models is provided.

Fischer's Theory

According to Thomas (1992, p. 354), it was Fischer (1980) who proposed a theory of cognitive development that "treats development as the construction of hierarchically ordered collections of specific skills." Fischer acknowledged the work of Piaget, as well as the ideas of information–processing psychologists and skill learning theorists, such as Skinner (1987). However, Fischer considered that Piaget (1970) placed too much emphasis on children's internal maturation and neglected environmental contexts. He also claimed that Skinner (1987) did the opposite.

Fischer suggested that development proceeded from the simplest sensorimotor acts of infancy to the manipulation of abstract systems in early childhood. These skills were concomitant with Piaget's schemes. Fischer constructed ten levels of development, classified under three tiers, termed *sensorimotor*, *representational* and *abstract*. Within each of the three tiers, cognitive development advanced through four types of levels — single sets, mappings, systems, and systems of systems. Fischer (1980, p. 486) considered a set to be a "source of variations that the person could control by physically or mentally acting on things." Table 1.5 shows the two sensorimotor developmental tiers of Fischer's (1980) model. Descriptions of the remaining developmental levels have been omitted, as they are not relevant to the sensorimotor mode of learning.

TABLE 1.5: ABRIDGED VERSION OF FISCHER'S LEVELS OF COGNITIVE SKILLS DEVELOPMENT

Cognitive Tiers & Levels		**Age of First Development**
Tier 1: Reflex		
Level 1:	single reflexes (action components)	3 to 4 weeks
Level 2:	reflex mappings (simple relations of few action components)	7 to 8 weeks
Level 3:	reflex systems (complex reactions of subsets of action components)	10 to 11 weeks
Level 4:	systems of reflex systems that form single sensorimotor actions	15 to 17 weeks
Tier 2: Sensorimotor		
Level 4:	single sensorimotor actions	15 to 17 weeks
Level 5:	sensorimotor mappings	7 to 8 months
Level 6:	sensorimotor systems	11 to 13 months
Level 7:	systems of sensorimotor systems forming single representations	18 to 24 months

(Fischer, 1980, pp. 479-522)

Table 1.5 shows that the first level on a Tier involved what Fischer (1980) termed single sets which meant "a source of variations that a person could control by physically or mentally acting on things" (p. 486). At the first level on a Tier a child could act on a set by itself but not one set in relation to another. An example of a single set, when operating in the sensorimotor Tier, is demonstrated when a child who may see an object and reach out to grasp it, but does not connect seeing the object with reaching out to hold it. Thus, on the sensorimotor Tier, a set is described in terms of a very simple response. In contrast, sets on higher tiers are considered to be more complex. For example, the physical actions of a child acting out a game can be considered to be quite elaborate.

When the child connects seeing an object with the act of grasping it, the mapping level is then deemed to have been achieved. The "bracket" connecting the Tiers in Table 1.5 delineates how the final level of each Tier is a starting point for the next.

As a further example, a child, within the sensorimotor Tier at level 4, can be considered to be capable of perceiving relationships between two systems of sensorimotor "action sights," such as sounds, touch sensations, movements. The ability to make connections between systems is considered to be the first step in being able to represent such attributes as weight, length and width mentally. As the child progressed chronologically, two attributes can be related and so on, until they reached young adulthood, during which time the individual can map one abstract set onto another and be able to think of abstract sets as systems, and in addition, interrelate systems.

> Fischer (1980) built into this theory several explanations that could account for unevenness of children's development across skills. This is referred to as the horizontal *décalage* problem, whereby inexplicable inconsistencies were noted for the varied paths of cognitive skill development that were sometimes found in empirical investigations
>
> Thomas (1992, p. 357).

One structure Fischer used included the notion of a set of "five conditions" that specified how one skill could be converted into a new more advanced skill. These conditions were termed *inordinate, compounding, focusing, substitution,* and *differentiation*. The first two conditions designated how existing skills were combined to produce new ones. The next two conditions identified smaller steps than those found in the second step (that is *compounding)*. The last condition, *differentiation,* identified how sets of skills became divided into sub sets, whilst the previous transformations took place. According to Thomas (1992) this theory is internally consistent, not able to be disproved and the idea of environmental support appeared to provide reasonable interpretations of empirical findings not explained in the classical Piagetian theory.

Case's Model

During the mid 1980s another version of a cognitive developmental model was proposed by Case (1985). Thomas (1992, p. 349) wrote "this model relied upon extensive empirical research incorporating the concepts and investigative methods of several previous researchers, including Baldwin (1894), Piaget (1952), Bruner (1964), Pascual-Leone (1976), and Klahr and Wallace (1976)."

Case's (1985) initial model acknowledged that there were unresolved problems associated with the Piagetian model. He considered several issues as being problematic, such as those surrounding short-term memory space, the number of cognitive transitions that took place during preschool years, the relationships between children's emotional and cognitive development as well as between their procedural and declarative knowledge. Figure 1.2 shows the sensori-motor stage of Case's model.

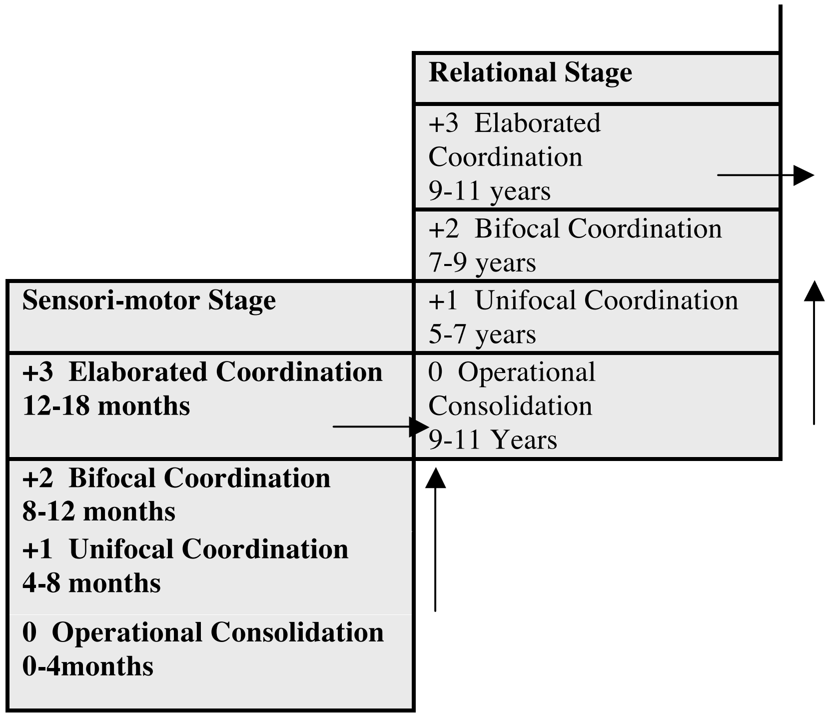


Figure 1.2: Case's (1985) Sensori-motor Stage of Mental Development

This abridged version of Case's (1985) model, shown in Figure 1.2, highlights the first two stages. These segments of the model demonstrate that a child advanced through a sequence of substages within each stage. The "higher" stages of this model indicate that the child's thought processes developed from less sophisticated towards more sophisticated modes of operation. The inclusion of substages allowed for rationalisation of Piaget's (1970) *décalages,* thereby adding to theory, for although Piaget (1970) recognised that inconsistencies did exist, explanations as to their nature were not provided.

Commencing with the operational consolidation substage, the starting point of Case's (1985, 1992) model, a child is able to perform responses that involve the representation and control of various relationships. According to Reid (1992) the idea that as the child gained sufficient experience and maturity, an advance to the next substage could be made. Progression in sensorimotor ability continues through the other substages as precision increases. For example, at the bifocal coordination substage the child needs to attend to two different factors in order to solve problems. By the time the elaborated coordination substage is reached, children should be able to solve problems that require two relational features to be mastered and coordinated with each other.

Following the sensori-motor stage, the child moves into the relational stage commencing once again at an operational consolidation substage. Not shown in Figure 1.2 but this stage-like process continues throughout the final two cognitive stages. The idea of substages is a key feature of Case's (1985, 1992) model.

Case's model showed a structure similar to that outlined by Piaget and Inhelder (1969), in that it consisted of a number of steps/stages. Included in the model is a phase of mental growth that was considered to occur from birth to approximately 18 months of age, and also incorporated the term sensorimotor as a descriptor of the intellectual functioning, occurring during an infant's development. Thus, the six substages of Piaget's and Inhelder's (1969) sensorimotor mode, ranging from reflexive activity at birth through to the invention of new ways of doing things, at about 18 months of age, were reconfirmed as a fitting description of this mode.

Mounoud's Model

Mounoud (1986) took a similar approach to that of Piaget (1952) by adopting a structural model, which replicated several aspects of the Piagetian model. For example, he included the stage concept, their names, the duration of each stage, the sub phases occurring within each stage, and an explanation of what a child *constructed* whilst advancing through a stage.

A major tenet of Mounoud's (1986) theory was that the general sensorimotor and mental filters (through which a child interpreted their world) evolved through a "genetically set" timing system. Mounoud (1986) postulated that a child developed coding abilities according to what was directly perceived. As a result, during the early years a child did not construct basic sensorimotor structures, but developed psychomotor records of interactions with the environment. Internalisation of perceptual-motor organizations of the environment began to develop as the child aged and new coding capacities, which were based not only on how things looked, but also on logical concepts. From this point the child moved to a mental view of the world based on concepts and then finally the content of the world was viewed from a standpoint of abstract symbols and signs (Thomas, 1992, p. 360). Table 1.6 provides an overview of Mounoud's (1986) model showing the first two stages evident during a child's first 24 months.

TABLE 1.6: MOUNOUD'S STAGES OF COGNITIVE AND MOTOR DEVELOPMENT

Stages	Child's Internal representations	Type of Organization
Birth	Sensorial representations (preformed) Linked with performed structures + new coding capacities (the perceptual code)	Sensori-motor organization (preformed)
18-24 Months	Perceptual representations (constructed) + new coding capacities (the conceptual code)	Perceptuomotor organization (constructed)

(Adapted from Mounoud, 1986)

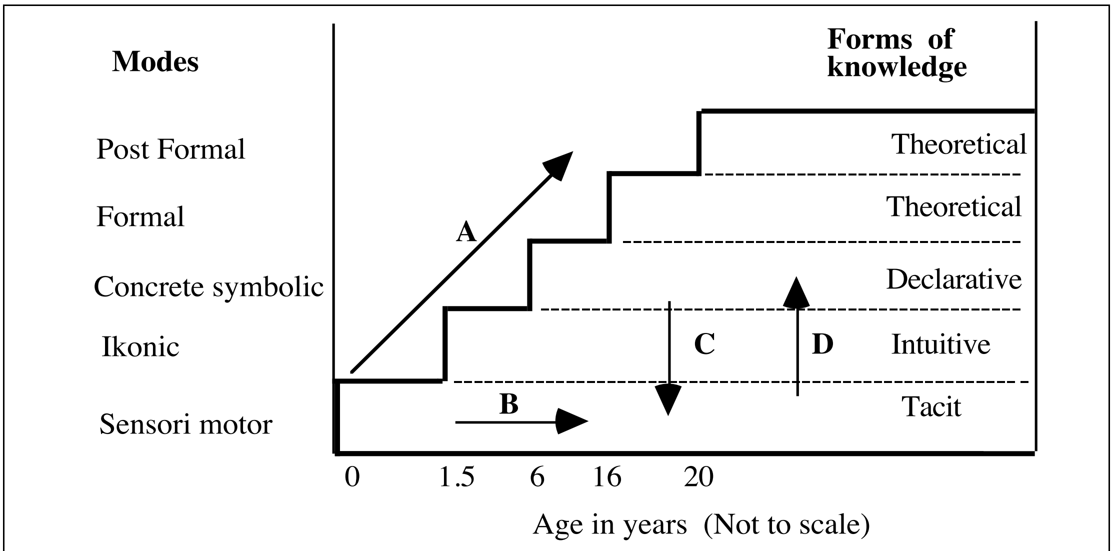
A "cycle" consisted of a "Stage" (column 1) followed by the child's internal representations or a "process" (column 2). Mounoud (1986) considered these developmental stages were common to all areas of knowledge. Note the changes (column 3) to the type of organization from sensori-motor to *perceptuomotor*. Not shown in Table 1.6 are the stages that follow, termed, *conceptumotor* to *semioticomotor*, which present increasing levels of intellectual capacities.

The main process involved the transposing the action schemata of the previous structure onto another plane. The second consisted of reshaping new material presented through thought processes. Mounoud (1986, p. 52) considered that these "two phases consist of the translation, by means of a new code, of the different contents with which the child interacts with objects, people, or his own body."

The SOLO Model of Biggs and Collis

Amongst the many observations made by neo-Piagetian researchers, were some that drew attention to the notion that there was a consistent learning cycle elicited by individuals. Biggs and Collis (1980) moved this way as they attempted to address some of the perceived shortcomings in Piaget's (1970) theory of learning. Consequently a framework was formulated that stipulated that it was the students' response to a particular situation that warranted attention.

Despite the fact that a number of learning theories contain certain fundamental cycles of learning that arise in similar form in a wide range of contexts (Pegg & Tall, 2001) the Biggs and Collis (1980) model, shown in Figure 1.3, has the potential to be used as a tool for determining the quality of learning, whether the skill is classed as relating to the cognitive, affective or psychomotor domain, across the lifespan. With reference to Figure 1.3, the following discussion centres on the sensorimotor aspect of the model the Biggs and Collis model which they termed the Structure of Observed Learning Outcomes (SOLO).



Key: A. Path of optimal development (Piaget). **B**. Single mode learning. **C**. Top down facilitation of learning. **D**. Bottom-up facilitation of higher order learning.

Figure 1.3: SOLO: Modes and Forms of Knowledge (adapted from Biggs & Collis 1992)

Biggs and Collis (1992) determined that students could operate in a number of different modes (see arrows B, C and D in Figure 1.3), including the sensorimotor mode, regardless of their age. This notion contrasts with other models, in which only a linear movement (see arrow A) through the various modes was considered.

Biggs and Collis (1992) considered that the age at which a child attains a certain stage was not necessarily a true indicator for that stage. To reiterate, the idea that attainment of a range of motor skills was age related but not age dependent was initially proposed by Seefeldt, Reuschlein, and Vogel (1972), and was later reinforced by Roberton (1978), and Gallahue (1989). In contrast, Piaget (1952) considered that all cognitive events were under the control of a master program within the brain (for each particular stage) and that this explained the way children at a particular age solved or “attacked” problems. However, Biggs and Moore (1993) did not support the master program hypothesis.

In summary, each of four models commences with a sensorimotor component, element, stage or phase of learning. Within the realm of sensorimotor learning Fischer (1980) included age related Tiers, Case (1985) used the term sensorimotor, as a descriptor of the intellectual functioning that occurred during an individual's development. The main principle of Mounoud's (1986) theory was that the general sensorimotor and mental filters evolved through a genetically set timing system. Biggs and Collis (1989) determined that students could operate in a number of different modes including the sensorimotor mode, regardless of their age.

Conclusion

Although Piaget (1970), Case (1985), Fischer (1980), and Mounoud (1986) incorporated aspects of sensorimotor processes, they failed to explain or describe in detail how sensorimotor processes can be applied across the lifespan, specifically, in the area of skill acquisition. However, the explanation of how the human infant developed from a "passive" individual to one capable of deliberate actions and thought did incorporate a sensorimotor perspective.

Only the SOLO model of Biggs and Collis (1992) accommodated the notion that the sensorimotor mode could be present throughout an individual's lifespan. This model offers the opportunity to explore the sensorimotor mode of learning in greater depth.

CHAPTER CONCLUSION

A number of theoretical perspectives within the realm of motor development, motor skill acquisition and motor control were examined in this chapter. It was noted that the main difference between each of these perspectives appears to be the role and extent of involvement of the brain. However, current thinking regarding human movement organization appears to rely more on a dynamical systems perspective, rather than either the maturational or cognitive perspectives.

Descriptions of the psychomotor learning domain were scrutinised. Commencing with Bloom et al. (1956), the work of three additional authors who added detail to the taxonomy, specifically for the psychomotor domain, was outlined.

The issues relating to the complexity of concepts embodied within the study of human movement were raised. With regards to these issues, commencing with a re-examination of terms used within the realm of human movement, a relationship between these terms becomes evident. In their 2002 work, Gallahue and Ozmun considered motor development to be a "process that begins at conception and continues throughout life" (p. xv). In addition, this development, according to these authors could be thought of as a "continuous change in motor behaviour throughout the life cycle, brought about by interaction among the requirements of the task, the biology of the individual, and the conditions of the environment" (Gallahue & Ozmun, 2006, p. 508). Furthermore, Clark and Whitall (1989) considered that motor development involved the study of the changes in motor behaviour over the lifespan and the processes underpinning these changes. Hence, motor development has, in the light of the dynamic systems perspective, been redefined as a process whereby "the organism, the task and the context self-organise behaviour to a preferred form" (Kamm et al., 1990, p. 26).

The attainment of a movement skill, involving changes that can be expected to occur during learning, has been described in a number of ways. One definition of motor skill learning, suggested by Rose (1997), is that it includes "a set of internal processes that lead to a relatively permanent change in the learner's capacity for skilled performance" (p. 144). Another observation made by Magill (1993) was that "one characteristic of motor skill learning is that, it is possible to identify distinct stages or phases all learners seem to experience as they learn skills through practice" (p. 59).

The issue of motor control, involves the study of the processes that underpin movement (Rose, 1997). Similarly Gallahue and Ozmun (2006) stated "motor control involves examining underlying mechanisms responsible for movement, with particular emphasis on what and how these processes are organised (p. 508). In contrast, however, Laszlo (1992) omitted references to motor development, motor skill and other movement behaviours when referring to motor control. The omission of these concepts lends itself to the idea that a gap in understanding exists between the various sub-disciplines that have at their core human movement. Gallahue and Ozmun (2006, p. 16) stated that motor control "is an aspect of motor learning and development that deals with the study of isolated tasks under specific conditions."

Noting that the psychomotor domain is the term used to encompass physical movement, coordination, and other areas involving motor skill learning, Figure 1.4 represents a new model that summarises the hypothetical relationship between the concepts of motor development, motor learning and motor control within the psychomotor domain.

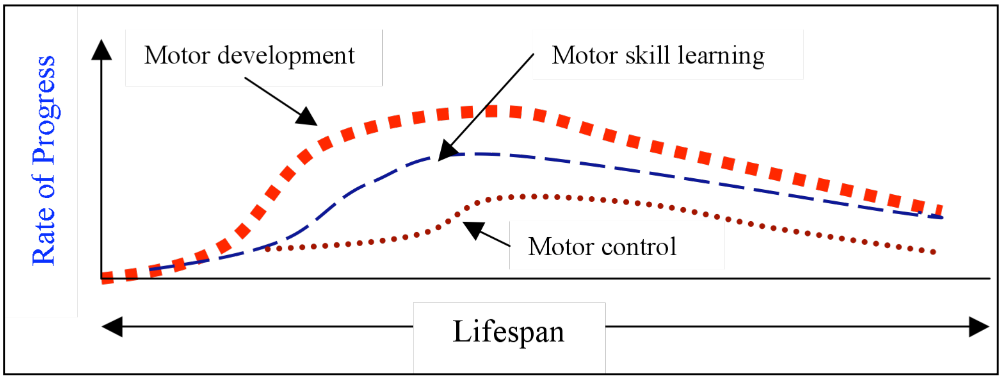


Figure 1.4 An Hypothetical Connection between Motor Development, Motor Skill learning and Motor control

Figure 1.4 illustrates that motor development begins prior to birth and progresses at a rapid rate for typically developing individuals. Throughout the lifespan this process may either be limited, due to a number of factors, for example ageing, or may continue to progress for some individuals performing certain types of skills.

The placement of the line representing motor development, above the other two graphs, implies that both motor learning and motor control follow, and are dependent on, an individual's motor development. In conjunction with an increase in motor development, acquisition and learning of more complex skills can take place. This process of learning motor skills commences early in a child's life and may also continue throughout the life of the individual. The progression of both motor development and learning affects and influences motor control. Embracing all these terms is the encompassing notion of motor behaviour.

The following chapter examines issues that have arisen from the examination of the literature in this chapter. The two main issues under review in the next chapter are: How do humans acquire movement skills, and how are these movements assessed?

CHAPTER TWO

Acquisition and Assessment of Motor Skills

Introduction

In the previous chapter an examination of the literature related to three theoretical perspectives pertaining to human movement was presented. In addition, both the psychomotor domain, and the sensorimotor mode of learning were described and explained, using a number of examples. From the exploration of the literature, it was evident that the processes involved in both motor skill acquisition and its measurement required further investigation. The purpose of this chapter is to explore these two concepts. To facilitate this process, the focus will be on the fundamental skill – the forward roll. This skill is selected primarily because it is the only fundamental motor skill that has been partially validated (Williams, 1980). The implication is that the developmental sequences have been the subject of research, and there is an extensive literature available for this skill. Nevertheless, there is still potential to expand upon this body of work.

There are four sections in this chapter. The first section examines the literature applicable to motor skill acquisition. The second explores motor skill assessment. The third section examines one specific model of learning, the Structure of Observed Learning Outcomes (SOLO), which has the sensorimotor mode of learning (tacit form knowledge) as its foundational mode. The final section presents the themes and questions that emerged from the literature, reviewed in this and the previous chapter.

MOTOR SKILL ACQUISITION

This section presents, an outline of the concept of motor skill and motor skill acquisition with an emphasis on the description of the model proposed by Fitts and Posner (1967). This is followed by a description of the views of six other authors, representing three different perspectives.

The word “skill” can be used in different ways. For example one can say, “that tennis player is a very skilled performer,” which has a different meaning compared with the term when used in the sentence “serving is an essential skill to playing tennis.” The term skill, as used in the latter example, denotes that a task has a specific goal. In addition, when referring to the term, motor skill, the definition also includes the idea that voluntary movements are involved in order to achieve the goal.

Probably the most difficult interpretation of the term skill occurs when it is used to refer to a skilled performer, which in most cases infers a qualitative expression of the performance. In this case the word skill, when designating the quality of performance, is usually based upon how well the individual accomplished the goal of the task (Magill, 1993).

The acquisition of motor skills as described by Clark (1995) points to the difference between skill acquisition and learning:

> Just because you did not 'teach' the infant to walk does not mean the infant did not 'learn' to walk … Motor skill acquisition is the process of learning motor skills in the context of the performer's previous experience and biological status. (p. 178)

Clark (1995) made the observation that the subtle difference between acquiring a motor skill and learning that skill, is that skill acquisition is a process. A description of this process of how people acquire skills in the realm of human movement is not unique. A number of researchers, through the practical application of various theoretical perspectives, have accomplished this task. Foremost amongst them is the Fitts and Posner (1967) model. Others who have put forward differing viewpoints include Adams (1971), Gentile (1972), Graham, Holt/Hale, & Parker (1998), and Vereijken (1991).

The following two subsections provide information focused around the general theme of motor skill acquisition. All these models of skill acquisition demonstrate the phases, steps or levels through which an individual may pass when attempting to attain new motor skills.

A "Benchmark" Model

This subsection provides an outline of a motor skill acquisition model, which describes changes expected to occur during the process of learning a movement skill. Initially, Fitts (1964) identified three major phases through which adult learners progress in their advancement towards the successful attainment of a motor skill. Fitts and Posner (1967) termed these phases *cognitive, associative* and *autonomous*.

During the cognitive or *early* phase, an individual has started to learn, or attempted to learn a new skill or technique. Characteristics of this phase include verbal and cognitive problems, which have to be dealt with by learners.

Fitts and Posner (1967) indicated that the cognitive phase was characterised by frequent extensive errors in performance. The learner was concerned with *what* movements were necessary to perform the skill. They also noted that performers engaged in self-talk, and in addition, the performer could exhibit a range of variations in the execution of a performance. Furthermore, the beginner appeared to be aware that something was wrong, but appeared to be unable to take the necessary course of action to address the errors in order to improve performance.

The learner was regarded as having moved into the second phase, termed the associative or *intermediate* phase, once most cognitive problems had been overcome. The "term associative was borrowed" (Fitts & Posner, 1967, p. 12) from the analysis of verbal learning of Underwood, Runquist, and Schultz (1959).

When the learner was perceived to have reached this second phase, most of the fundamentals or basic elements of the skill would have been learned. A shift in focus would be evident with the organisation of more efficient movements, aimed at achieving the appropriate movement pattern demanded by the situation. The number of movement errors decline or are less gross. Nevertheless, there might still be inconsistencies between performances.

These variations in performance, in the second phase, occur as the learner attempts new solutions to movement problems, however, greater movement efficiency would be evident (Fitts & Posner, 1967). The learner could probably identify some errors and monitor kinaesthetic feedback (bodily awareness), and at the same time self-talk would become less important for performance.

Learners now focused on refining their movements, concentrating on *how* to perform the skill. The idea that the learner concentrated on *how* to perform a task was reinforced by Schmidt (1991) who indicated that "this stage generally lasts somewhat longer than the verbal-cognitive stage ... perhaps months with many sports skills taking even longer if the learner is having difficulty" (p. 173).

The term autonomous or *final* was applied to the last phase of the Fitts and Posner model. The learner may achieve this final phase after sufficient practice. A characteristic is a slow rate of improvement in skills, as the performer must have already achieved a high degree of proficiency before this phase was reached. Self-detection of errors now becomes possible, which can lead to self-correction and adjustments in technique. If the performer achieves this phase, movements become habituated or automated.

The apparent automation of movements allows the performer the freedom to move away from concentrating on the actual skill execution, to focus on other aspects of the performance. For example, if a performer operating in the autonomous phase was engaged in a sequence of movements, requiring the combination of a number of skills containing several elements, then the number of movement sequences that come together to make up the total performance is reduced.

Such "chunking" of information permits the performer to focus less on *what* or *how* to perform the actual skill and more on achieving good form, style, or some more critical phases of the performance that may be perceived as difficult, or focus on a major change in some aspect of the imminent performance. Fitts and Posner (1967) stated "there is a good deal of similarity between highly practiced skills and reflexes. Both seem to run off without much verbalization or conscious content" (p. 15).

It should be noted that the phases outlined by Fitts and Posner were not clearly delineated by a definite overall change in movement behaviour, but regarded as part of a continuum. The apparent gradual change in performance makes identification of the phase at which a learner is operating at any one time, difficult, and this is particularly so when learners do not exhibit all the motor actions typical of a single phase.

In summary, the descriptions provided by Fitts and Posner (1967) illustrate how, as a result of practice and/or instruction, motor behaviours change for individuals, engaged in acquiring a new skill. This model stands alone in the literature, as being the most widely cited, specifically, within the disciplines of psychology, physical education and kinesiology. "Fitts and Posner's three-stage theory of motor skill acquisition is widely accepted in both the motor skills literature and the surgical literature" (Reznick

& McRae, 2006). Because this model is referred to in so many texts and publications, it can be regarded as a "benchmark" model.

Alternative Models of Skill Acquisition

This subsection provides a brief outline of four models of skill acquisition, which provide alternatives to the Fitts and Posner (1967) model. However, the foundational elements of these works involve similar ideas to those of Fitts and Posner. The two-stage perspectives of Adams (1971) and Gentile (1972), the three stage model of Vereijken (1991) and the three levels of skill proposed by Graham, Holt/Hale, and Parker (2006) are provided as examples.

The two stage models of Adams (1971) and Gentile (1972) are different to each other in their intended purposes. The two-stage model of Adams presented a simplified version of Fitts and Posner's model whereby he combined both the cognitive and associative phases into one, which he termed the *verbal-motor* stage. The second stage of Adams' model was named the motor *stage,* which was also similar to Fitts and Posner's (1967) autonomous phase.

In contrast, the two-stage model of Gentile (1972) was originally intended to provide teachers with a "cohesive account of motor skill acquisition" (Rose & Christina, 2006, p. 181). The first stage related to the learner's goals, which involved "getting the idea of the movement". This idea was similar in concept to Fitts' and Posner's (1967) cognitive phase, however, it was implied that the learner decided what needed doing and the learner was required to differentiate between what was relevant to the task and what was not. According to Magill (1993, p. 61) "the learner attempted to establish a movement sequence that effectively achieved the goal of the skill" a statement he reaffirmed in later publications (see Magill, 2007).

Gentile (1972) called the second stage the *fixation/diversification stage*. The learner needed to accomplish two elements of skilled performance in order to be regarded as having reached this stage. Firstly, the learner had to be capable of doing what was necessary to achieve the goal of the skill within the environment in which it was to be performed. Secondly, consistency must have been displayed in achieving the skill's goal. With a stable environment, the emphasis would be on making the movement pattern consistent on each performance. The work of Gentile is also highly regarded amongst authors within the area of physical rehabilitation. Some of her more recent work relates to skill acquisition, action, movement, and the neuromotor processes, aimed at addressing physical therapy within the area of rehabilitation (Gentile, 2000).

Unlike the previous two examples, Vereijken (1991) proposed a three-stage model of motor skill acquisition that described how the learner attempted to manage the dynamics of the movement to “solve” a movement problem. This model emerged from the mastering the degrees of freedom approach described by Bernstein (1967) as well as by ecological theorists such as van Emmerik, Whitting, and Newell (1992).

During what she termed the *novice-stage*, Vereijken (1991) considered that the learner attempted to reduce possible joint movements or to constrain the movements of a number of joints so that they, more or less, acted as a single unit thereby “freezing out” the degrees of freedom. Her observation of performers showed that movements appeared to be rigid and unresponsive to changing environmental factors. When the performer became more experienced, a release of these constraints occurred, and the learner was deemed to have moved into the *advanced stage*. A characteristic of this stage included smooth movements that resulted from joints functioning as part of larger units, with their associated muscle synergies changing, thus “allowing some joints to move synchronously, and yet permitting others to move independently” (Rose & Christina, 2006, p. 181). Some modification of movements to meet environmental demands could be observed.

The final stage of Vereijken’s (1991) model was the *expert stage*, which “differed from the previous stage in which the learner was able to exploit reactive forces, thereby reducing the need for active, muscular forces” (p. 120). When this stage was achieved, according to Rose and Christina (2006) the relationship between the learner’s perception of what is required to solve the movement problem, and the emerging dynamics of the resulting action, was permanently redefined.

There has been some dissention regarding Bernstein’s (1967) initial ideas concerning how the degrees of freedom would be manoeuvred in each of the three stages of Vereijken’s model. For example, Ko, Challis, and Newell (2003) predicted that subjects released degrees of freedom in the early stages while suppressing previously released degrees of freedom as learning progressed. Future investigations may refute or verify these claims.

The provision of a further example, the model of Graham, Holt/Hale and Parker (1998; 2006), demonstrates another approach to how skill acquisition may be regarded. These authors built upon the "movement orientation" work of Stanley (1977) to resolve questions concerning what constituted a beginning, an intermediate or an advanced movement skill level. Their classification system was given the title of, the Generic Levels of Skill Proficiency (GLSP). The aim of this approach was directed at educators in order to assist them to determine the level of proficiency at which a learner may be operating, in a practical sense. The idea was that once a level of performance was determined, the educator (teacher) could apply the appropriate cues to assist the learner to move forward in their skill development.

In summary, a number of models have been presented that have been proposed to describe how motor skills are acquired. The model that stands alone is the three phases of learning proposed by Fitts and Posner (1967). Adams (1971) considered that there were two stages of skill acquisition, which essentially compressed Fitts' and Posner's first two stages into one. In contrast, Vereijken's (1991) portrayal is more aligned with Dynamic Systems Theory (DST) and the release of the degrees of freedom of skeletal joints. Gentile's (1972) model and the model of Graham, Holt/Hale and Parker (2006) are similar in that their intention was to design practically oriented instruments to aid teaching.

Conclusion

The notion that the model proposed by Fitts and Posner (1967) is currently recognised amongst physical educationalists as being a benchmark, is evidenced in the number of publications employing this model. Reference to their model may be found, for example, in books by Gentile (2000) and Magill (2007), to journal articles, such as Masser's (1993) publication in the Journal of Teaching in Physical Education, in an article addressing sensorimotor skills, in the *Journal of Experimental Psychology* by Beilock, Carr, MacMahon, and Starkes (2002), to syllabuses including the NSW Board of Studies (1999) senior physical education syllabus, and so on. However, the alignment of one model, that of Vereijken (1991), with Dynamic Systems Theory poses new questions and challenges to the direction in which learning models within the psychomotor domain may be destined.

MOTOR SKIL ASSESSMENT IN PRACTICE

Assessment of physical skills "probably emanated from the Sigma Delta Psi tests developed in 1912" (Burton & Miller, 1998, p. 217) and between then and 1975 more than one hundred assessment tools were published. However, very few of these tests continue to exist in their original format. “The plethora of new test instruments developed after 1975 had their roots in tests developed before that year” (Burton & Miller, 1998, p. 39).

Instruments employed to assess movement skills have traditionally been divided into quantitative and qualitative categories. This division is largely artificial because most measurement instruments are, in reality, a combination of both paradigms. The majority of the tests prior to 1975 were concerned with the outcome or product of the movement, thus assessments were based on quantitative measures. Outcome or product data quantify performance, with measures such as how far, how much and how quickly output was produced. Burton & Miller (1998) imply that quantitative analyses of movement have undergone a revival with the advent of better computer technology, which has subsequently led to this mode of research being “a necessity” for credibility. It can be argued, however, that even these objective measures may not be absolutely free of bias.

This section contains two subsections. Descriptions are provided of two methods of assessment that are applied to a single fundamental movement skill, namely, the forward roll in gymnastics. These are described from both a competitive gymnastics perspective, and secondly, from a biomechanical perspective. The second subsection provides a description of three alternative perspectives also used to assess this fundamental gymnastic skill.

Assessment System for the Forward Roll

This subsection provides details of two systems used in the assessment of the forward roll. The first examines the “conventional” scoring system employed in the realm of competitive gymnastics by the Australian Gymnastics Federation (AGF) (2002) and is based upon error deductions from an hypothetical maximum score. The second provides details from a biomechanical assessment perspective.

Competitive Gymnastics Scoring Systems

Within the sport of competitive gymnastics, performers are generally required to conform with externally imposed movement patterns, and gymnasts strive to achieve “model” or “ideal” forms of movement. The governing body for gymnastics is the Federation Internationale De Gymnastique (FIG) (2002), which constructs a code of points for each gymnastics event under its jurisdiction. The code includes a set of criteria that gymnastic judges refer to when the score for a particular performance needs to be determined. The criteria or scale employs performance faults or errors that receive deductive penalties.

The code contains a set of elements used to delineate whether any additional values need to be considered, based on the apparent difficulty of each component of a performance. These carry a ranking of difficulty ranging from "A" to "E", (which includes a subcategory termed *super E* introduced in 2003). In this scoring system "A" is the least difficult and super E has the highest degree of difficulty. In 2006 the FIG introduced a new system of scoring. This revised system of allocating scores permits the gymnast to score more than, what was once considered to be the "perfect" ten points. This point score system is achieved through allocating additional or bonus points for the difficulty of specific gymnastic elements. Thus a gymnast may be allocated, for example, a score of 13.3 out of a possible 15 points, rather than a score out of a maximum of 10 points.

To assist gymnastic judges to determine a score for a particular performance, the FIG regularly issues tables, used by judges to determine deductions for "general faults". For example, in the case of a gymnast losing balance and falling, defined as one or both knees contacting the surface, a penalty of .50 points is incurred. In addition, for example, a gymnast performing "D" or "E" elements does not gain bonus point if the total errors made exceed .3 points. This system is intended to produce quality performances rather than numerous different "tricks".

In general, in order to reduce judging discrepancies, each gymnast's score is calculated through a formula that includes the elimination of the highest and lowest scores awarded by the judges with the remaining scores averaged. This average score is used to rank performers. In addition, there are generally two judging panels, consisting of an "A" panel that determines the starting score and, in addition, judge the execution of the performance. The "B" panel is charged with judging solely the execution.

A gymnast is entitled to feedback and therefore the judging panel is usually equipped with a visual "short-hand" version of the performance on which deductions are noted. The FIG Scientific Technical Coordinators produce a list of shorthand descriptive characters, for use by judges at all levels of qualification (see Appendix A).

The following Table 2.1 provides a facsimile of the FIG deductions for faults that occur during a gymnastic performance. This table shows only those deductions relevant to a floor routine, that is, those activities that do not involve any apparatus, such as uneven parallel bars or vaulting. The inclusion of this example, serves to demonstrate how skills can be assessed in competitive gymnastics. Note, however, that within the field of gymnastics the scoring system is constantly being modified in an attempt to permit a more accurate assessment of performance.

TABLE 2.1: GENERAL FAULTS SHEET: FLOOR ROUTINES (WOMEN)

FAULTS	***Small***	***Medium***	***Large***
DEDUCTIONS	.05/.10	.20	.30
Body Form, Aesthetic and Technical Faults *			
– Bent arms in support or bent knees	X	X	X
– Leg or Knee separations	<Shoulders	>Shoulders	
– Insufficient height of elements with flight	X	X	
– Insufficient exactness of tuck, pike or stretch position	X	X	
–Throughout the entire exercise:			
~ Insufficient completion of movements head gesture and/or arm-hand gesture at end of movements	X	X	
~ Relaxed or incorrect foot/leg/body/trunk posture	X	X	
~ Insufficient flexibility	X	X	
~ Insufficient dynamics	X	X	
~ Insufficient artistry	X	X	X
Execution Faults*			
– Hesitation during jump, press or swing	X		
Adjust grip position, additional hand placement or hand support	X		
Landing Faults (all elements including dismounts)*			
– Insufficient extension in preparation for landing	X		
– Deviation from straight direction	X		
– Legs apart on landing	X		
Movements to maintain balance*			
~ slight hop or small adjustment of feet	X		
~ extra arm swings	X		
~ additional trunk movements to keep balance	X	X	X
~ extra steps	.10		
~ very large step (1 met)		.20	
~ body posture fault	X	X	

* denotes deduction for each time. "X" indicates penalty deduction.

(Federation Internationale de Gymnastique, 2002, p. 72)

The four sub headings, highlighted under *Deductions* shown in Table 2.1 provide data that show the types of errors that receive a penalty deduction for female gymnasts.

Similar inventories of errors exist for other gymnastic events, and within each of these events the opportunity exists for the performer to demonstrate dominant movement patterns.

Biomechanical Perspective

Descriptions of the forward roll outlined by George (1980) are based on the principles of biomechanics and "correct" form. A biomechanical perspective is achieved through a comparison of the performer with descriptions of what are deemed to be sound movement principles for a gymnastic skill.

George (1980, pp. 72-74) provided descriptions of what could probably be construed as "ideal" forms of a number of skills from a biomechanical perspective, and can be regarded as a ceiling-type instrument. George's analyses have been embraced by coaches of gymnastics, whose aim is to improving skill performances (personal communication, Maunder, 2000).

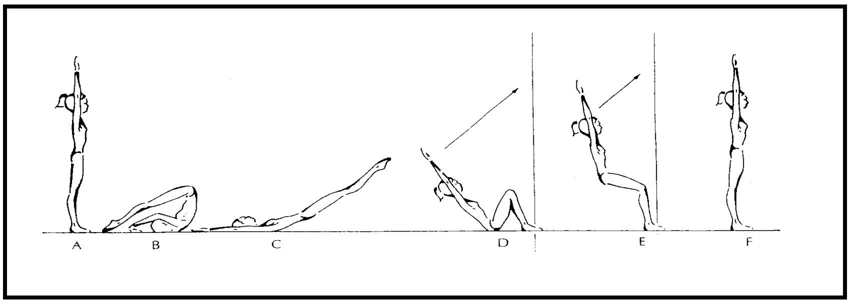
Amongst the descriptions of various gymnastic skills, George provided information of several varieties of the forward roll. However, the simplest form of the roll, known as the tucked forward roll, is described in a "stage-like" manner, subdivided into seven elements. A summary of the main points of George's description for the tucked (basic) roll follows in Table 2.2.

TABLE 2.2: DESCRIPTIVE ASPECTS OF THE FORWARD ROLL

Element	Description
A	The skill is started from a standing position with the arms held directly overhead. Body shape is fully extended.
A-B	The performer bends at the hips until the hands contact the mat. The head is ducked forward, and the body is lowered onto the upper back by bending slightly at the shoulder and elbow joints. As the hips move in front of the shoulders the entire upper body begins to form a curved or hollowed shape.
B-C	The hips extend to a point such that the entire body unit now forms a slightly curved one-segment shape. This increases momentum.
C-D	The slightly curved shape facilitates the upswing phase of the skill and should be maintained for as long as possible. At the very last moment, however, the hip joints flex, which causes the entire body to rise off the mat. The knee joints simultaneously flex, causing the feet to be positioned underneath the oncoming body weight.
D-E	Using foot contact as the final vertical reference point for support the accrued momentum allows the performer to begin standing immediately.
E-F	The skill is completed such that all body segments line up with one another and with the upper vertical at the same time.
F	The final position is identical to the start.

(George, 1980, p. 72)

Each element of the forward roll, “A” to “F” shown in Table 2.2, overlaps the previous one. The descriptions, which accompany each of the elements, provide an account from a biomechanical perspective how, when executed correctly, they contribute to the roll in its entirety. Figure 2.1 provides a pictorial sequence of the basic forward roll, using the same elements as described in Table 2.2.



(George, 1980, p. 72)

Figure 2.1: Elements of the Forward Roll

Following the starting position “A” in Figure 2.1, the elements “B” to “C” show how the individual can control rotational momentum. Momentum is needed to achieve a standing position at the conclusion of the roll and is achieved by maintaining slightly a curved (dished) body shape until well past the point at which the legs become vertical. What is absent from the illustrations is the descent from the standing start element “A” to the inverted position “B” on the surface, however, these descriptions do allude to the desired action.

In summary, the two methods of examining the forward roll are similar. The biomechanical requirements of George (1980) can serve as the basis of the gymnastics scoring system. However, the scoring system used in the sport of gymnastics incorporates not only biomechanics but also, for example, flair, artistry, amplitude and other dynamics as part of the assessment process.

Alternative Assessments of the Forward Roll

This subsection provides details of three alternative perspectives used to describe the performance of the forward roll. Each perspective demonstrates a different approach to analysis and is presented in the order in which they were established. These perspectives are; the Developmental Sequences of Roberton and Halverson (1977) the Developmental Stages of Gallahue and Ozmun (1995; 1998; 2002; 2006), and the Levels of Proficiency of Graham, Holt/Hale and Parker (1998; 2006).

Developmental Sequences Perspective

Roberton and Halverson (1977, p. 87) "hypothesized developmental sequences in the forward roll" which were later partially validated by Williams (1980). Prior to Williams' (1980) validation, Roberton and Halverson (1977) suggested that developmental sequences were evident within what was termed the initial phase and the completion phase of the forward roll. The initial phase was deemed to be the point in time from when the first movement took place in the roll to the point when the hips begin moving forward and downward. The completion phase included the time from that point to the termination of the roll. In the light of Williams' work, Roberton and Halverson (1984) modified the developmental sequences, and the newly adopted versions of the sequences are shown in Tables 2.3 and 2.4, for both the initial and the completion phases of the forward roll.

TABLE 2.3: INITIAL PHASE OF THE DEVELOPMENTAL SEQUENCES FOR THE FORWARD ROLL

	<u>Head and arm action component</u>
Step 1. Head support.	Little weight is taken on the arms and hands. The hands are often placed on the surface even with the line of the head. The angle at the elbow is approximately 45°. The child may be unable to hold the weight evenly, so the body collapses to one side.
Step 2. Head and arm support.	The arms and hands partially accept the body weight. The base of support of the hands tends to be wide from side to side and behind the head towards the feet. The angle at the elbow is greater than 90°.
Step 3. Arm support.	The arms and hands now accept the weight as the roll begins, permitting the head, with the chin tucked to slide through the arms.
	<u>Leg action component</u>
Step 1. One-leg push.	One leg leads in leaving the surface, and then the knee and hip of the lead leg flex while the other leg extends on the push-off.
Step 2. Two-leg push.	Both legs push off equally. The knees flex to about 90° as the balance is lost.

(Roberton & Halverson, 1984, p. 88)

The original article published by Roberton and Halverson (1984) included images of individuals' performance of the forward roll. One series of images was of a four year old, the second image was a child of nine years-of-age and the final image was of a young adult, whose age was unspecified. In addition to the inclusion of images, these authors included key additional "observation-tips" and comments about the execution of the roll, as well as teaching hints to accompany their observation tables.

TABLE 2.4: COMPLETION PHASE OF THE DEVELOPMENTAL SEQUENCES FOR THE FORWARD ROLL

	Arm action component
Step 1. Little arm assistance.	The arms may remain back by the head until pulled off by the forward motion of the body.
Step 2. Incomplete assist.	The arms swing forward to assist in the completion of the roll when the shoulders and/or middle of the back have touched the surface. The elbows are extended during the assist. The hands may be used to push the body to the feet at the end of the roll.
Step 3. Continual arm assist.	The arms swing forward to assist in continuation of the momentum of the roll, as soon as the weight has transferred to the shoulders. The arms continue to assist in a forward-upward direction until the weight is over the feet.
	Head and trunk component
Step 1. Head and trunk lag.	As the hips begin the forward-downward movement, the child abandons the body to gravity. The upper trunk and hips land on the surface almost simultaneously. As the middle of the back and the hips land, the head and upper back lag behind often remaining close to or just off the surface, even when the lower back has made contact.
Step 2. Partial head and trunk lag.	The shoulders touch the surface before the middle of the back has touched. The body usually continues the roll in a semi-piked position over the pelvis.
Step 3. No head and trunk lag.	The head leaves the support surface just after the shoulders touch. Both the head and trunk continue moving forward and upward throughout the roll. By the time the lower back contacts the surface, the head and shoulders are well off the mat.
	Leg action component
Step 1. Knees extend; hips extend.	The legs tend to hold their push-off position until the lower back or pelvis touches the support surface. At this point, extension in the hip increases, contributing to the loss of curl in the roll. The knees either increase in extension or continue in an extended position. The angle at the hip may reach 120 degrees and is then held if the body continues rotating over the pelvis.
Step 2. Knees flex; hips extend.	Leg action begins as in Step 1. When the middle of the back touches the support surface, extension at the hips increases also as in Step 1, but the knees flex rather than continuing in an extended position. The roll may continue with the body in this position or the hips may flex.
Step 3. Knees flex; hips flex.	The knees begin flexion just after the hips begin the forward-downward movement in the roll and maintain that flexion throughout the roll. The hips continue flexion throughout the roll.

(Roberton & Halverson, 1984, pp. 92-93)

Williams (1980, p. 703) aimed to develop a category checklist of developmental characteristics for the forward roll, based upon the component approach of Roberton and Halverson (1977). This process involved an attempt to determine the "usefulness" of a component approach for describing actions occurring during the forward roll. In addition, age-relatedness of category sequences was explored.

The potential usefulness of the components as a developmental checklist was examined using three criteria. The first was the comprehensiveness of the category system for describing observed movement behaviours. The second included the observed ordering of each component sequence in relation to the hypothesized ordering. The third involved the sign of the slopes of age-related functions generated from the data. Three components were delineated: Hand/Arm, Head/Neck, and Hip/Leg. These are outlined in Table 2.5, noting that the format of the table has been slightly modified from the version presented by Williams (1980), however, the data are the same.

TABLE 2.5: ORGANISATION OF THE COMPONENT SYSTEM: THE FORWARD ROLL

Component Name	Phase[1]	Number of steps[2]
Hand/Arm	Initial	3
	Middle	4
	Late	3
Neck/Head	Initial	3
	Late	3
Hip/Leg	Initial	2
	Late	4

1. Each phase is a temporally distinguishable division within the forward roll.
2. Numbers indicate the steps within each component phase.

(Williams, 1980, p. 706)

Each component, shown in column one of Table 2.5, is divided into phases describing the temporal course of actions occurring throughout the forward roll from initial hand placement to heel strike. The next column shows the Phases, hierarchically arranged in steps, ordered from primitive to advanced. The hypothesized ordering was designed to test whether the least mature behaviour pattern would precede the intermediate, which would precede the occurrence of higher levels. In addition, the most primitive behavioural step was hypothesized to be observable most often in younger children.

Williams (1980) demonstrated that:

> every hypothesized step within each component phase was observed in the sample of children tested. Not unexpectedly, however, some steps were observed more that others. It was also noted that only one action, occurring in the middle phase, not hypothesized previously was observed (p. 707).

She also stated, "the hypothesized category system for the forward roll was an objectively obtained and comprehensive descriptor of the observed movement configurations in the children tested" (Williams, 1980, p. 703). See Tables 2.6 and 2.7 for a description of the steps within the component phases for the forward roll.

TABLE 2.6: DESCRIPTIONS OF STEPS WITHIN COMPONENT PHASES FOR THE FORWARD ROLL[1]: INITIAL PHASE[2]

Component: Steps	Hand /Arm	Head/Neck	Hip/Leg
A	*Hands used unequally* – collapse to side may occur – frontal alignment of hands is uneven – angle at elbow approximately 45°	*Vertex of head is initial point of contact* – dorsiflexion of head on neck with loss of balance	
B	*Broad base of support by hands* – ventrally or laterally – angle at elbow is greater than 90° of rotary action	*Vertex is initial point of contact* – ventroflexion on chest with initiation	
C	*Narrow base of support by hands* – hands in line, slightly ventral to head – elbow angle approximately 90°	*Crown of head is initial point of contact* – head remains ventro-flexed throughout rotary action	

1. Only the five component phases, which showed some evidence of proper sequencing, are listed.
2. Designates a step within a component phase: "A" is most primitive; others are progressively more advanced.

(Williams, 1980, p. 710)

The three components of the initial phase of the roll are described in terms of hierarchical developmental steps. The components, which are grouped, reflect a whole or total body approach to analysis. Note that the hip/leg component is absent from this phase.

TABLE 2.7: DESCRIPTIONS OF STEPS WITHIN COMPONENT PHASES FOR THE FORWARD ROLL: LATE PHASE

Component: Steps	Hand /Arm	Head/Neck	Hip/Leg
A	*Humeral abduction with balance loss* – elbow angle approximately 90° – elbow held laterally – wide base of support	*Shoulders remain on surface* – until lower back contacts surface	*Hip/knee extension exceeds120°* – with lower back contact
B	*Hands contact surface next to hips with contact of hips* – active elbow extend – hands used to push to feet	*Shoulders remain on surface* – until midback contacts surface – neck extension with thoracic contact	*Hip extension greater than 90°; knee flexion* – with lower back contact
C	*Arm position remains ventral (do not contact surface*) – active extension of elbows – humeri flexed horizontally	*Sequential loss of contact with surface* – neck remains ventro-flexed throughout	*Hip extension less than/equals 90°; extension to 120°* – with lower back contact
D			*Hip extension less than 90°; knee flexion 20° or less.* – hip/knees remain flexed throughout

(Williams, 1980, p. 710)

The late phase of the forward roll is analysed using the same components as the initial phase. Furthermore, for both phases the analysis conducted by Williams (1980) showed that five of the seven component phases met the criteria suggested for the screening of potential developmental sequences. Further testing, using longitudinal data, was deemed necessary, in order to determine whether they were valid developmental sequences. Notwithstanding, some steps within the other two component phases, according to Williams, were apparently out of sequence or ill defined. A recommendation emerging from this study was that a cross-sectional examination of the phases would be needed before longitudinal validation could be achieved.

Developmental Stages Perspective

Gallahue and Ozmun (1995) provided a simplified description for the elements (developmental sequences) of the roll, which was based on the comprehensive studies of Roberton and Halverson (1977), Wickstrom (1983) and Williams (1980). The model of Gallahue and Ozmun has been retained unaltered in the reprint of their work in 2006.

Three stages occurring within the fundamental phase were described, termed the initial, elementary and mature. Within each stage there a series of developmental sequences for the forward roll is present. Table 2.8 provides an outline of the expected movement behaviours for each stage of the roll. The model has been modified in that the developmental difficulties have been omitted from the Table.

TABLE 2.8: GALLAHUE AND OZMUN'S DEVELOPMENTAL SEQUENCE OF BODY ROLLING

Body Rolling		
Initial		
	1.	Head contacts surface
	2.	Body curled in loose "C" position
	3.	Inability to coordinate use of arms
	4.	Uncurls to "L" position
Elementary		
	1.	After rolling forward, actions appear segmented
	2.	Head leads action instead of inhibiting it
	3.	Top of head still touches surface
	4.	Body curled in tight "C" position at onset of roll
	5.	Uncurls at completion of roll to "L" position
	6.	Hands and arms aid rolling action, but supply little push-off
	7.	Can perform only one roll at a time
Mature		
	1.	Head leads action
	2.	Back of head touches surface very lightly
	3.	Body remains in tight "C" throughout
	4.	Arms aid in force production
	5.	Momentum returns child to starting position
	6.	Can perform consecutive rolls in control

(Gallahue & Ozmun, 2006, p. 198)

The performer in each stage of motor development of body rolling would display a number of characteristics. At the initial stage the least mature forms of a movement are expected to be present. As individuals mature, they would display more precise movements until the mature form became evident.

Gallahue and Ozmun (2006) indicated "a number of developmental difficulties associated with the action of rolling" (p.198). For example, they noted the head forcefully touching the surface, an inability to push off with the arms, failure to remain tucked, and lack of sufficient momentum to complete one revolution.

Levels of Skill Proficiency Perspective

Graham, Holt/Hale, and Parker (2006) based their perspective on the classification methods of Stanley (1977). Their classification system comprised four levels of ability which were termed "generic levels of skills proficiency *(GLSP)*: precontrol, control, utilization, and proficiency" (Graham et al., 2006, p. 88)

At the precontrol level, a child attempting a forward roll "may complete a revolution on a mat or may get stuck, not rolling at all or rolling half forward and half to the side and finishing flat on their back" (Graham et al., 1998, p. 88). The child may exhibit an exploration of ways in which the body can be "round" was also characteristic. When first attempting a forward roll, the child would exhibit characteristics which demonstrated little use of the arms and hands, with the whole body usually uncurling in the middle of the roll, and the child finishing in a sitting position (Graham et al., 1998, p. 413).

At the control level, children become capable of controlling their body whilst rolling. They can use their arms and hands to push, and the body stays curled. According to Graham, Holt/Hale and Parker they can change direction, vary speed, start from different positions, and combine rolling with other activities including performing a series of rolls (travel rolling).

At the utilization level:

> children can be seen as no longer having to 'think about' staying round and are able to use the roll in combination with other skills and on equipment and large apparatus. Additionally, they can use rolling as an expressive form and in combination with manipulative skills such as rolling after catching a ball.
>
> (Graham et al., 1998, p. 415)

The notion of "not having to think about it" resembles the description of autonomous stage of Stages of Skill Acquisition of the Fitts and Posner (1967) model. The autonomous stage is the ultimate stage in their three-stage model, which describes a progression of the typical movement behaviour of a beginner through to an expert practitioner. However, in this instance the execution of the movement is only concerned with a single element of the skill.

Children at the *proficient* level in rolling could be observed, for example, rolling over high equipment and performing aerial rolls, including the ability to adopt a movement or sequence of movements to a variety of situations. According to Graham et al. (1998) this ability is what differentiates the utilization level performance of a skill from an individual at the proficiency level.

Table 2.9 provides a modified outline of elements in which the illustrations have been omitted and which, according to Graham et al. (1998), a child may exhibit when performing a forward roll.

TABLE 2.9: KEY OBSERVATION POINTS: PROFICIENCY OF ROLLING

Point	Description	
1.	a.	Hands and arms take body weight evenly at beginning
	b.	Body should not collapse to one side
	c.	Rolls on vertex of head *
	d.	Legs apart *
2.	a.	Head slides through as weight goes from hands to upper back
	b.	Head leaves surface as soon as shoulders touch
	c.	Arms spread apart and leave surface when back contacts *
	d.	Legs apart *
3.	a.	Arms leave surface as soon as shoulders touch surface
	b.	Arms out to side *
	c.	Arms move through above body *
	d.	Legs apart *
4.	a.	Body stays curled and roll ends on the feet
	b.	Legs apart *

* Incorrect observation points

(modified from Graham et al., 1998, p. 416)

A description outlining both the correct procedure in the execution of the roll, as well as what should not occur, which is indicated with an asterisk at the end of a line, is shown in Table 2.9. The list is aimed at assisting the instructor, teacher or coach to guide a performer towards the attainment of an adept performance of the forward roll.

In summary, the perspectives Halverson and Roberton (1977), Gallahue and Ozmun (1995, 1998, 2002, 2006) and Graham et al. (1998, 2006) provided three different accounts about how the forward roll may be described. Halverson and Roberton

(1977) provided a developmental perspective, which is aimed at assessing the components of a skill, into developmental phases. The aim of Gallahue and Ozmun (2006) was to provide a descriptive instrument based upon developmental sequences as an observational assessment aide. The approach of Graham Holt/Hale and Parker (1998) was designed to allow assessment for pedagogical purposes. These perspectives contrast with those of the FIG and George's (1980) biomechanical and aesthetic requirements for the sport of gymnastics.

Conclusion

The phases model of Roberton and Halverson (1984) demonstrated a detailed component (segmental) approach to the analysis of the forward roll. The use of a "check list" (see Appendix B) is an additional instrument that permits economical data collection (personal communication, Roberton & Langendorfer, 2003). The model allows for the notion that an individual may display different phases of development for different body components; hand/arm, head/neck and hip/leg for two identified phases of the forward roll.

The developmental stages model of Gallahue and Ozmun (2006) included sequences. The model was based on the foundational work of Roberton and Halverson (1984), as well as Williams (1980). The model offered by Gallahue and Ozmun (2006) presents a practical system for classifying individuals at each of the stages of the fundamental movement phase. "This method encourages both the total body configuration and segmental analysis approaches to assessing fundamental movement pattern development" (Gallahue & Ozmun, 2006, p. 188). Utilising this perspective requires analysis of movement through observation using a total body configuration approach, which provides a general overview of the stage at which an individual is performing. If the movement is observed to be at the *mature* stage, further assessment is deemed unnecessary under this classification system. If the movement is judged to be initial or elementary, then a segmental (component) approach is utilised. From a developmental perspective, the aim is to determine which body segments may be lagging behind the other body segments involved in the performance.

The maturationalist approach of Graham, Holt/Hale, and Parker's (1998) offers a perspective that differs from the others in that it consists of four hierarchical levels. The precontrol level involves activities of "an exploratory nature, such as arching the back, rocking and weight transfer" (Graham et al., 1998, p. 417). The "control level includes being able to roll in different directions and from different positions as well as being able to roll safely" (Graham et al., 1998, p. 418).

> The performer at the utilisation level no longer has to focus on rolling as an isolated skill. Much of the rolling at this level is used as a form of weight transfer between balances as well as demonstrating proficiency. Additionally, rolling is used to transfer weight onto, from, and over large apparatus
>
> (Graham et al., 1998, p. 429)

The proficiency level is characterised by the ability "to perform aerial rolls (saltos) and intricate combinations of rolls with other movements" (Graham et al., 1998, p. 434). The inclusion of more challenging factors provides a further measure that separates individuals at the proficiency from those at the utilisation level.

Each perspective demonstrates an approach to the assessment of the forward roll, aimed at solving an assessment problem. Therefore, each perspective demonstrates a slightly different approach. Because each perspective has been designed for a specific purpose, and is aimed at a particular section of the population, usually children, there appears to be a need for a broader instrument. This instrument needs to be able to be effectively utilised across the wider population.

THE LIFESPAN CHALLENGE: THE SOLO MODEL

This section contains four subsections. The first subsection provides an overview of the Structure of Observed Learning Outcomes (SOLO) model. The second presents a description of the model's response levels. The third examines the model's foundational mode, that is, the tacit mode of learning. Finally, the model's potential as a research instrument is explored.

Overview of SOLO

This subsection explores the development of the SOLO model of learning and provides a description of its basic elements. In addition, the differences between the SOLO model and other stage models, discussed previously, are addressed. More specifically, an outline is provided of the different SOLO pathways of development available to the learner.

Piagetian ideas were taken up by Biggs and Collis (1980) with the development of the SOLO learning model; originally referred to as the SOLO Taxonomy. Theorists, like

Biggs and Collis, who have incorporated aspects of Piaget's theories, as well as accommodating findings of more recent studies and research in cognitive developmental psychology are given the title of neo-Piagetian (Cuthbert, 1996, p. 39).

Biggs and Collis (1980) sought alternative solutions to the question of how people learn, and to determine the extent to which Piaget's *décalages* were apparent amongst the general populace. Even though Piaget recognised there were certain décalages (inconsistencies) amongst individuals, he was apparently not aware of their widespread nature.

SOLO Modes and Forms of knowledge

The model proposed by Biggs and Collis (1982; 1992) comprises an hierarchy, which is aimed at demonstrating the level of abstraction at which individuals of a particular age may function. The model has five modes of learning: the sensorimotor, ikonic, concrete symbolic, formal and post formal. The sensorimotor mode of learning is evident soon after birth and is of most interest in this thesis. Two key aspects of this mode involve the coordination of movement and the acquisition of motor skills within the physical environment. This type of skill acquisition involves "knowing how" to complete a physical task, and is termed tacit knowledge. For example, a young individual performs skills such as grasping, crawling, walking, running and leaping. An older individual may be able to strike a golf ball, sail a small boat or drive an automobile. Skilled individuals can carry out the complex movements but may not be able to advise others how they do them; they appear to "know" that they have performed a complex act well because it "feels right".

The description of the SOLO model presented by Biggs and Collis (1991) showed the sensorimotor mode described in three age related terms. These are: (i) the time of infancy between 4-to-8 months of age, described as a time of "perceptual-motor skills"; (ii) early childhood, between 6 months and approximately 7 years of age described as a time of "motor skills"; and (iii) early adulthood between approximately 16 years of age and 21 years of age, described as a time of "sports skills". It is noteworthy that later versions of the SOLO model omitted these descriptive elements. It should be noted, however, that this underpinning mode or tacit form of knowledge extends beyond the childhood age range. This is an important difference, identified by Pegg (1991), between this model and those described in the previous chapter.

Biggs and Collis (1991) also described the various other modes of learning associated with the SOLO model. They indicated that individuals operating within SOLO model's ikonic mode demonstrate actions that are made more abstract by internal representation in some form, with thought drawing heavily on imagery and being frequently affect laden. The ikonic mode is associated with the intuitive form of knowledge, that which is perceived or felt directly and which involves the imaging of objects and events.

In the concrete symbolic mode, Biggs and Collis indicate that an individual demonstrates a significant shift in abstraction from direct *symbolisation* of the world through oral language to symbol systems that is applicable to the experienced world. Because functioning in the concrete symbolic mode involves the use of symbol systems, which have referents in the material world, the communication of declarative knowledge is facilitated.

The SOLO formal mode can be described as working in terms of "principles" and are operating in the theoretical realm of knowledge. Individuals are no longer restricted to a concrete referent. In its more advanced form there is the development of disciplines.

Lastly, in the post formal mode an individual is able to question or challenge the fundamental structure of theories or disciplines. Within this mode individuals are able to consider not only what is perceived to be real but also what may be possible.

Learning Levels

Within each mode of learning Biggs and Collis (1982, pp. 24-25) identified a number of SOLO levels. A description of their work is summarised in the following paragraphs. The levels are presented in hierarchical order (i.e., increasing complexity).

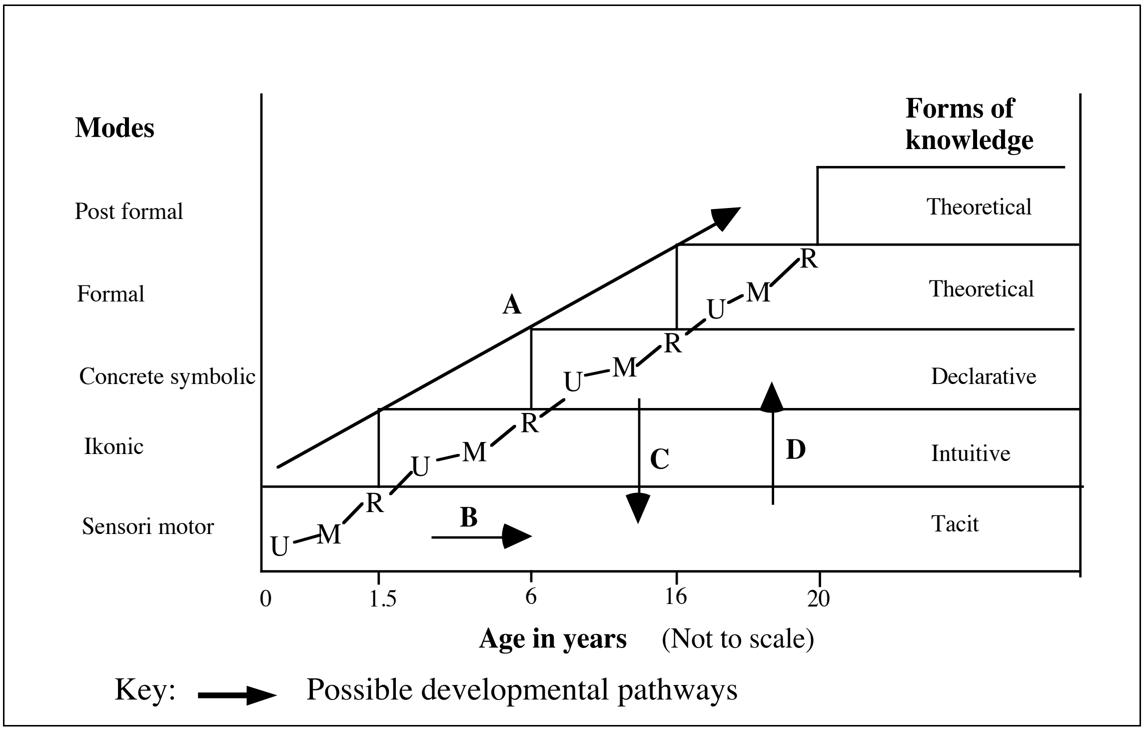
*Unistructural (*U*)* responses indicate that the individual has understood the task but relates only one piece of relevant information. Whilst the content of the response may have been consistent with the data, considerable variability may often emerge within the response itself.

Multistructural (M) responses contain several dimensions of data, consistent with the stimulus item, but fail to become amalgamated. Generalisations are based on a few limited and independent aspects of the task.

*Relational (*R*)* responses demonstrate that the learner is able to identify a number of elements consistent with the stimulus item and relate them to one another around a particular concept. However, this level of response did not take general principles into account so that generalisations are not consistent within different contexts.

When the target mode for a particular action is explicit, these levels are valuable descriptors. Biggs and Collis (1991) offered an alternative view when the target mode was not clearly defined, noting that unistructural, multistructural, and relational levels occurred within each mode.

Biggs and Collis (1991) considered that in some instances individuals could operate in a number of learning modes, using for example prior modes or even a number of modes within a specific learning context. This phenomenon is referred to as multimodal learning. Figure 2.2 highlights what Biggs and Collis describe as the four possible pathways of development - "A," "B," "C," and "D" within the model.



(Panizzon, 1999)

Figure 2.2: SOLO Pathways

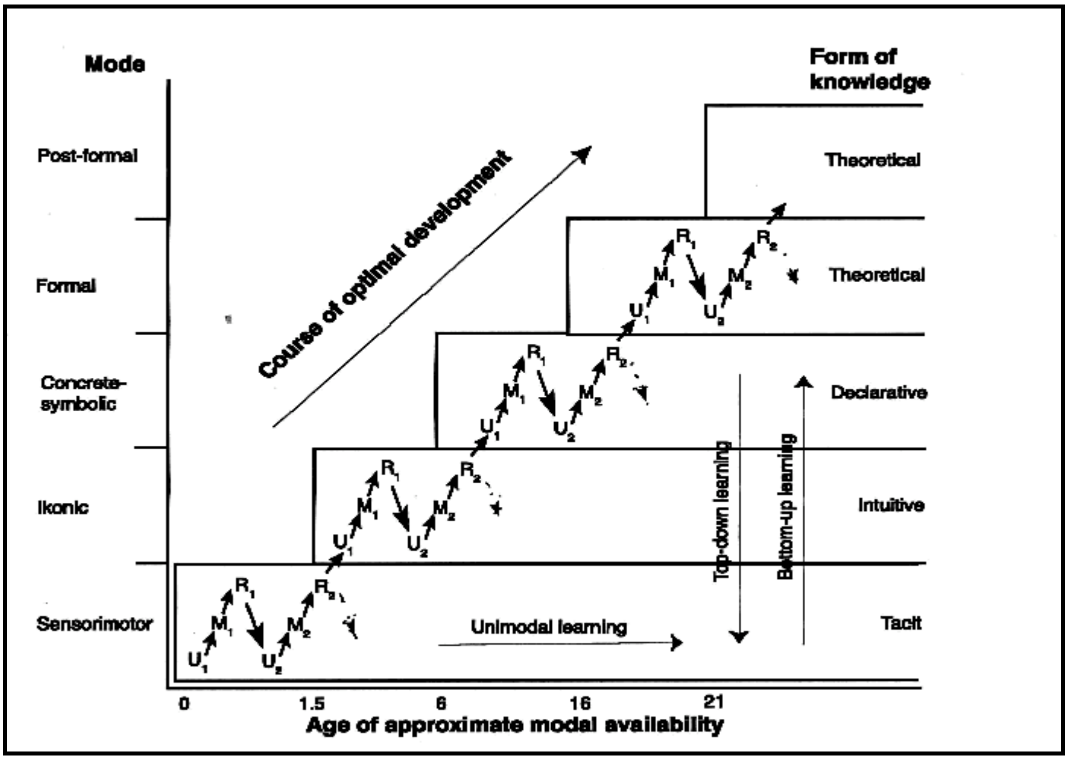
The typical pathway or course of optimal development assumed by stage theorists, (such as Piaget, 1952) in which a stage emerged and replaced its predecessor is represented by arrow "A". This singular pathway is also a possibility within the SOLO model, however, in the majority of instances, growth within higher modes is supported by earlier modes. Alternatively, learning may involve the application of only one mode (arrow "B") termed unimodal functioning. In contrast, arrows "C" and "D" represent multimodal learning. Arrow "C" demonstrates "top-down facilitation of lower-order learning" (Biggs & Collis 1991, p. 70) as it identified those instances in which an individual uses higher-order modes to improve their performance in a mode acquired earlier. For example, athletes/performers working in the sensorimotor mode may take time to watch videos (ikonic mode), or read relevant books (concrete symbolic mode) in an attempt to gain new information about how performances could be improved (Pegg, 2008).

Arrow "D" is a "bottom up facilitation of higher-order learning" (Biggs & Collis, 1991, p. 71). In this case, modes acquired earlier were utilised to achieve learning in a developing mode. Such a pathway could be demonstrated in science classes if students undertook experiments and viewed demonstrations (ikonic and concrete symbolic mode) that facilitated their understanding of a concept within the formal learning mode. It was this type of learning, according to Biggs and Moore (1993) that was advocated by constructivist theory in science. Therefore, with the exclusion of children of very young age, the SOLO model implied that a number of modes of learning were available to an individual for any particular learning situation.

Learning Cycles

A SOLO cycle consists of three levels, namely, unistructural (U), multistructural (M) and relational (R), and in the original version of the model proposed by Biggs and Collis only one learning cycle was identified within each mode. However, further investigations have routinely found more than one UMR cycle within a mode. For example, Levins and Pegg (1994) demonstrated at least two cycles of learning within the concrete symbolic mode, (U_1-M_1-R_1-U_2-M_2-R_2) in a number of topic areas including those associated with algebra, evaporation, geometry, plant growth, and statistics. In addition, Panizzon (1999, p. 67), in her study of students' understanding of diffusion and osmosis, alluded to two cycles within the formal mode of SOLO.

A representation of this relationship between modes and levels in line with the version of SOLO presented by Inglis and Pegg (2003) is shown in Figure 2.3.



Inglis and Pegg (2003) adapted from Biggs and Collis (1991) and Pegg (1992).

Figure 2.3: Cycles of Learning within the SOLO Model

For example, within the tacit mode of knowledge a characteristic of a unistructural performance (U), according to Collis (2003), includes individuals losing track of "where they are up to" in the sequence of events. A multistructural (M) performance is identified by the fact that the individual is able to develop a theme or an overall pattern relating to what is required. Recognition of errors in performance is possible, but takes a period of time to "see" the error or know how to correct it. A relational (R) performance is abstract, and the individual has both the "theme" of the task in mind and a "picture" of what to do. They are able to aim for a finished objective and there is intuitiveness about what is required.

The SOLO model demonstrates that cognitive growth is sequential, moving from one level to the next. For example, the question relating to the flow from a relational response in one mode to a unistructural level in the following mode depends, according to Biggs and Collis (1991), on a number of factors that influenced the transition. One of these factors could include some elements of physiological maturation, e.g., when the facilitation of neural transmissions is expedited due to the completion of myelinization of neural sheaths. A mandatory condition, however, was that the individual had to have been at the relational level in the previous mode. The reasoning behind this is inherent within the hierarchical nature of the SOLO model. This model supports the concept that each level is a prerequisite for the succeeding one.

Another factor for consideration involves the amount of working memory available to the individual. Seemingly, older children have a greater capacity for processing information than younger children, and that factor affects the type of response produced. For example, as a reply to a question is being structured, the individual needs to keep the question in mind and then attempt to relate their answer to the question. Perhaps an older individual is better able to "chunk" information into more efficient manageable units, showing similarity, to the concept of the autonomous mode of learning proposed by Fitts and Posner (1967).

Biggs and Collis (1991) identified that the social context, in which an individual functioned, was a contributing factor to cognitive change. For example, "parents could initiate cognitive change if they provided scaffolding, modelling, and content for their children" (Biggs & Moore, 1993). Thus it appears that social interaction could accelerate an individual's cognition. This hypothesis added support to the notion of social constructivism through the recognition of the important role played by others in a person's learning.

Furthermore, being challenged with a problem was another factor likely to initiate change from one mode to another. Biggs and Collis (1991) argued that modal shifts occurred when individuals were forced to reorganise their prior knowledge when they attempted to solve a new problem. This notion linked in with the ideas of Pines and West (1986) who espoused the importance of a conflict situation for cognitive growth. It appears that modal shifts can result from a combination of factors. Whilst the number of factors is beyond the control of the individual it should be acknowledged that some factors, for example, interpersonal interactions and conceptual challenges, could give rise to a change in mode of functioning. However, Pegg (2003, p. 242) indicated "that the absorption of one mode by another is never complete as the learner always has the option of operating at a lower level than the one attained."

In summary, SOLO is an hierarchical model that is suitable for measuring learning outcomes of different individuals (Biggs & Collis, 1982). The model includes five modes of learning. Within each mode there are different levels of response, which form one or more of cycles of learning. The response levels are ranked based upon the complexity of the individual's reaction. A person exhibiting "limited" response based on a single relevant aspect is classified as unistructural, whereas higher ranked responses may be either multistructural or relational. The individual may "operate" at different levels when responding to different intellectual challenges. It is these challenges that create a situation whereby a person may move from one SOLO level to the next or into another learning cycle. A number of researchers who have employed SOLO have recognized how useful and applicable the model is for measuring students' cognitive attainment (Chick, 1998; Lake, 1999; Van Rossum & Schenk, 1984).

It is noteworthy, that there is a similarity between the SOLO concept that a "disturbance" must occur to solicit a change, and one of the underlying principles associated with Dynamic Systems Theory. Within DST there is the notion that a *perturbance* must be of sufficient strength to create a change in movement.

Biggs and Collis (1991) hypothesized that in order for an individual to move from one cycle to the next there must be dissatisfaction with the performance. Being challenged with a problem appears to be a factor likely to promote change from one mode to the next. Furthermore, Biggs and Collis (1991) also reinforced the idea that modal shifts occurred when individuals were forced to reorganise their prior knowledge when they attempted to solve a new problem. However, prior to the observation of a number of cycles by these researchers, Case (1985) stated that both Baldwin (1895) and Piaget (1952) noted a circular cycle within the six-sub-stages of the sensorimotor mode. In addition, Case (1985) claimed that "in order to construct some concepts, for example, the concept of invisible movement, that there was a necessity for the individual to coordinate two primary circular reactions" (p. 15).

The Foundational Mode of SOLO: Is it tacit?

The foregoing description of the SOLO model provided details pertaining to the modes and cycles within the cognitive domain. However, this study is concerned largely with the sensorimotor mode of learning and from an information-processing perspective its implied form of knowledge is tacit. The following subsection provides a number of discussion points related to this issue.

> The infant can only interact with the world in the most concrete way; by giving a motor response to a sensory stimulus. Sensorimotor

> learning becomes quite complex during the first year or so of life, but its nature remains that of coordinating actions with each other and with the environment. Sensorimotor learning leads to tacit knowledge, exemplified by skilled gymnasts or sportspeople, who know by the 'feel' during the execution of an act when and how to adjust their performance.
>
> Biggs and Collis (1991, p. 62)

In reference to this quotation, the point for discussion pertaining to the SOLO model's sensorimotor mode is that the implied form of knowledge is described as tacit (Biggs & Collis, 1991). According to these two authors the term tacit relates to an individual "knowing-how" to carry out an act, not to describing or explaining it. For example, for the expert performer knowing-how means acting and making judgments, without being able to articulate the principles of the action or the rules involved. In contrast, explicit knowledge involves consciously accessing learned knowledge, gained through conscious attention to cues and details, such as being aware of one's own movements.

Following a review of the literature, the notion emerged that tacit knowledge involves cognitive processes and/or behaviours, that are underpinned by mechanisms inaccessible to consciousness (Polanyi, 1983). He implied that even though explicit knowledge might be required for skill acquisition, once these skills were mastered an individual gained an understanding of these skills, and like the assertion of Biggs and Collis (1991) it defied verbal expression.

Wagner and Sternberg (1986) and Sternberg, Forsythe, Hedlund, Horvath, Wagner, Williams, Snook, and Grigorenko (2000) suggested knowledge gained tacitly required three conditions to be met. Firstly, it had to be acquired with little or no environmental support; secondly, it was procedural; and thirdly, it had to be practically useful. Accordingly, tacit knowledge was "generally acquired on one's own" (Sternberg et al., 2000, p. 107). This meant that knowledge was gained without the support of sources outside the body, specifically, structures within the environment. The term procedural implied that tacit knowledge was acquired through "first-hand" experience, which added strength to the tacit knowledge already acquired. Being "practically" useful implied having "instrumental value in attaining personal goals" (Sternberg et al., 2000, p. 109), that is, if there was no reason to learn something, it was unlikely that it was learned tacitly.

Research Potential: The SOLO Model and Movement Studies

An examination of the SOLO model's potential as a research tool is undertaken in this subsection. The model presents a theoretical framework upon which to test and interpret new ideas. Pegg (1991) stated:

> The purposeful nature of the SOLO model could be used successfully in a broad variety of both educational and research settings. Within the educational setting, the SOLO model can be a useful adjunct in the development of curricula in schools as detailed by Collis and Biggs (1991). A practical application of its use was provided by Stanbridge (1990) in the development of a new science curriculum within a secondary school. In this scenario, the curriculum was devised from the eye of the student rather than the perspective of the expert, while at the same time maintaining the logical integrity of the subject (p. 368).

Biggs and Collis (1991) indicated that the target mode for the discipline of physical education was the sensorimotor mode, along with ikonic and concrete symbolic support. For example, in the early years of schooling children are encouraged to "bend, curl, twist, rock, wriggle, stretch, balance" (Board of Studies NSW, 1999, p. 38) amongst many other activities in the development of motor skills. However, the concrete symbolic and ikonic modes are necessary when a child enters Primary School (Pegg, 1991),when for example, the teacher includes non-practical topics that are related to movement experiences, such as aspects of nutrition and the effects of drugs on the body (Board of Studies NSW, 1999, p. 44) or when the child reaches the Secondary School, in topics such as applied anatomy and biomechanics.

There is no literature at present that describes any empirical investigations into the sensorimotor mode, as represented in the SOLO model. However, Biggs and Collis (1991, pp. 188-190) included a U-M-R cycle for the sensorimotor mode in their diagrammatic representation of the model. Collis and Biggs (1991) also provided an example of the apparent applicability of the sensorimotor mode in a description of the advanced motor skill of sailing a small boat.

> One has to feel the wind shifts, for example, directly through the senses and translate these into immediate motor adjustments. Any attempt to interpose a logical process between the sense perception and the motor activity turns out to be counter productive. The appropriate mode is the sensorimotor mode and attempts to use 'higher' concrete symbolic mode lead to inefficient or ineffective learning. In the case of learning how to sail a small boat, for example, it is clear that one can be instructed in the concrete- symbolic and the ikonic modes about how to

> keep a sail boat moving in the required direction at the optimum speed under various wind direction and speed conditions. This instruction would incorporate reading, interpretation of diagrams and verbal question-and-answer sessions between the learner and instructor. When the learners are put on the water they find that the wind is constantly changing in both speed and direction with subsequent alterations in the course and attitude of the boat. The processing of the information via the concrete-symbolic and ikonic modes is too slow for optimum performance and, in certain circumstances, the delay can cause serious disturbance to both the attitude and course of the boat. To be safe and effective the learner sailors have to learn quickly to operate directly in the sensorimotor mode.
>
> Collis and Biggs (1991, p. 190)

With reference to this quotation, it appears that the sensorimotor mode of learning equates with "speed of action". Whether an expert sailor, who is apparently operating in the tacit mode, can react with maximum efficiency when confronted with a new or novel situation is yet to be determined.

In a further example, Biggs and Collis (1982) provided an analogy with the game of tennis to demonstrate the SOLO levels. They described how the game of tennis is sub-divided into a number skills such as, "hitting the ball over the net with a racquet, or a forehand return, or a backhand return, or a serve, and so on" (Biggs & Collis, 1982, p. 215). They described how, once one of these skills has been mastered (to some degree) through continual practice, another skill can be mastered, and so on until some level of success has been achieved in each skill. Once all the necessary skills have been mastered and a whole repertoire of tennis strokes can be undertaken, and the individual can then, presumably, concentrate on strategies and tactics.

The tennis analogy brings to the fore the notion of skills and teaching within the psychomotor domain. Biggs and Collis (1982, p. 214) indicated "that a serve in tennis is a skill," however, the actual skill itself comprises a number of general components, such as ... the hand placement on the racquet (and variations thereof), ball toss, back-swing, strike (plus racquet head angle variations), transfer of weight, and the follow through of the racquet arm. When a beginning tennis player individual is being coaching, the employment the part-whole-part method for example; the ball toss itself is a skill that needs to be practiced repeatedly, using either distributed or massed practice, until mastered. Then the ball toss is combined with the back swing, strike and the follow through. Thus even within the tennis serve there are individual skill components. In addition, the tennis serve is classified as a closed skill, which means that it is self paced and virtually unaffected by environmental constraints (Magill, 2006). The fact that it is a closed skill has implications for the way it is taught. Initially, closed skills are taught in a manner whereby tactical considerations are given scant attention.

A different approach is required, for example, when teaching the backhand or forehand return, which are termed “open skills” (Magill, 2007, p. 8). The execution of open skills is governed by factors that are beyond the control of the individual. For example, with regard to the return of a tennis ball; its velocity, spin (backspin, over spin, side spin or no spin) and the height of the bounce. Teaching an individual to perform the forehand return within a game situation may require a teaching strategy, such as the “teaching games for understanding approach” (Bunker & Thorpe, 1982; Thorpe & Bunker, 1992; Werner, Thorpe, & Bunker, 1996) in which game tactics are given priority over teaching skills directly, in the traditional manner.

In summary, Collis and Biggs (1991) have stated that the target mode for physical education is the sensorimotor mode. However, there is only anecdotal literature available that attempts to describe this foundational mode of the SOLO model. As such, the applicability of SOLO to the components of just one skill, such as the serve in tennis or the forward roll in gymnastics, warrants consideration. An empirical investigation has the potential to provide evidence to support or refute the anecdotal references to the sensorimotor mode of learning in SOLO.

Conclusion

The SOLO model demonstrates a structural usability, in that it is as broad in its applicability and amenable to practical application, particularly in the development of learning structures within the school classroom. The SOLO Taxonomy formulated by Collis and Biggs (1980) was designed to assist educators with evaluation of student learning outcomes. Of particular relevance to this thesis, is the notion that the sensorimotor mode is available to the individual across the whole age span, thus providing the foundational basis to the model. This concept presents a contrast to other models of learning.

There is a similarity between the description that Fitts and Posner (1967) provided for the autonomous phase of their motor skill acquisition model and the SOLO model of Collis and Biggs (1991). The difference between the two models, is that Fitts and Posner (1967) did not include an explanation of the existence of different levels of learning within the autonomous phase. The situation regarding the two other phases of Fitts and Posner (1967) model, namely, the cognitive and the associative, and how they relate to the SOLO model, may provide an opportunity for future consideration.

Panizzon (1999) included a UMR cycle in the sensorimotor mode in her description of the SOLO model. However, her research did not address the issues or modes of learning surrounding the tacit form of knowledge. Thus, it appears that there is some implied support for the notion that such a cycle exists within the sensorimotor mode, but no empirical evidence. In order to add to SOLO theory and to the model's veracity, there is a need to find more supporting evidence of the existence of a UMR cycle within this foundational mode. Research may reveal information that can be used to support the notion that SOLO can be more broadly applied in a wide range of "learning situations" within the realm of physical education.

CHAPTER CONCLUSION

This chapter included a discussion of models that included reference to the sensorimotor mode of learning. Emerging from this discussion is the implied notion that within the sensorimotor mode, learning can be described in terms of sub-stages, tiers, phases or cycles of learning.

An overview of the potential of SOLO to examine the sensorimotor mode was also included. The SOLO model may have the potential to become a tool for the practicing educator for use in determining, not only an individual's cognitive level, but also the level of a person's movement performance across a diverse age group.

The lack of a strong conceptual framework as a point of reference has been a major criticism of qualitative research (Knudson & Morrison, 1997; Lees, 2002). A SOLO perspective offers some potential to provide such a framework. Concurrently, the application of SOLO to movement analysis may assist physical education teachers to provide a means whereby motor skills generally, can be examined, as well as being able to provide an aid to understanding the place where students are positioned along the skill acquisition continuum. In addition, planning programs in physical education may take on a "new light" with the advent of a discovery of SOLO levels of learning within the sensorimotor mode of the psychomotor domain.

The discussion presented in this chapter regarding the characteristics of tacit knowledge raises several questions. The first question relates to whether the inclusion of *any* environmental influences or backing meant knowledge could not be considered tacit. This proposal seems untenable; the exclusion of all elements of environment would lead to an unrealistic situation whereby a change in the environment would have no impact on the learner's behaviour. Furthermore, the procedural aspects of tacit knowledge poses problems concerning the selection of exactly which significant aspects of an interaction need to be included in the determination of whether the knowledge is tacit. In addition, what is considered "practical" and "useful" depends on how abstract an interpretation is applied to these terms.

Dreske (1991) indicated that the isolated concept of knowing-how (tacit knowledge) involved more than just a certain technical or physical "intelligence," it also included knowing how to obtain desired goals, knowing what to do in order to attain them, and knowing when to do them. It appears then that "knowing how" aligns with, if not depends upon, some form of explicit knowledge involving cognition. This statement implies that tacit knowledge may not exist as a sole entity to the exclusion of other forms of knowledge. Dreske considered that skilful performances relying on unconscious attention was not an idea that should be rejected. However, the notion that a given performance could be used as the measure of the possession of the tacit knowledge could be questioned. Dreske also asserted that tacit knowledge might include a certain amount of "knowing-that" or explicit knowledge even in expert performances.

The notion of tacit knowledge is not a position that is generally supported by Dynamic Systems Theorists (Goulay, 2005). In dynamic systems models, knowledge is emergent in the moment, "the product of the intrinsic dynamics, the state of the system at that moment, and the immediate input … there is no analogue of latent knowledge … rather knowledge is emergent in the moment, in the task, out of the particulars at hand" (Smith & Samuelson, 2003, p. 436).

According to Goulay (2005, p. 15):

> dynamicists envisage knowledge as being distributed across organism-environment processes … they see knowledge as being in some sense 'dormant' until activated or evoked by the action of which it is constitutive. In other words there is no knowledge independent of the action to which the knowledge pertains and thus no tacit knowledge apart from activity.

The debate about whether the two paradigms, outlined in the previous paragraphs, are mutually exclusive is yet to be satisfactorily resolved. Perhaps the solution to this difference lies in the suggestion of Abernethy and Sparrow (1992) that some evidence existed to support "the hybrid view of a multi levelled motor system" (pp. 31-32). However, returning to the notion of Biggs and Collis (1991), relating to how an individual, for example a gymnast performing a skill, feels and reacts, the dynamic systems perspective appears to offer a feasible explanation.

The term tacit is used to describe the form of knowledge within the sensorimotor mode of the SOLO model. If tacit knowledge is regarded as having a cognitive component then weight is added to the argument that an alternative term, such as, perceptual motor, which by definition includes an element of cognition, might be more appropriate than the word "sensorimotor" to describe the underpinning mode of the SOLO model.

RESEARCH THEMES AND QUESTIONS

Although previous studies have alluded to the existence of a foundational mode of learning, specifically, the sensorimotor mode, empirical evidence is lacking. No current research has examined the sensorimotor mode of the SOLO model, although some other models have examined this mode during the period of childhood. The literature review presented in this, and the previous chapter, has provided information pertaining to the psychomotor domain, theoretical and practical frameworks of learning theories, which incorporate sensorimotor processes.

Two themes emerged from the literature review. Firstly, whether instruments developed to assess the motor learning mode are applicable across an individual's life span. The second theme is related to whether the SOLO model is an appropriate tool for motor skill analysis.

The research questions are framed around the problem of how individuals, who may be operating in the sensorimotor mode within the psychomotor domain, perform a fundamental motor skill. This study uses, as a template to conduct the investigation, the skill known as the forward roll in gymnastics. This skill is chosen as the medium through which the investigation is conducted because it is one of the few motor skills that has been validated in terms of its developmental sequences (Williams, 1980). Therefore, the forward roll provides a skill that has higher validity/reliability than has been available for other fundamental skills.

Of particular interest, based on the efficacy of the "conventional instruments" available to assess motor skill performance across the lifespan, SOLO appears to be an appropriate model to further investigate the psychomotor domain. Four research questions are to be addressed, which are:

Research Question 1 Are the criteria currently used in instruments that assess the forward roll applicable to performances representing individuals across the lifespan?

Research Question 2 What are the characteristics of an instrument designed to assess the forward roll when performed across the lifespan?

Research Question 3 Are the observable components for the forward roll the same for children, young adults and older adults?

Research Question 4 Is the SOLO model an appropriate tool for assessing participants' performance, representing a diverse developmental range, as they demonstrate the forward roll?

The following chapter takes up the challenge to address these four questions. This task commences with an outline of the proposed study addressing specific methods/techniques in the research design.

CHAPTER THREE

Research Design

Introduction

In the previous chapter the themes and issues emanating from the literature were presented, and the research questions formulated. This thesis is aimed at exploring those themes and issues, with particular reference to the sensorimotor mode of learning in the SOLO model.

This chapter describes the various facets of the research design, which comprises five main sections. These are the: Pilot Study, Main Study Design, Data Analysis and Design Evaluation.

PILOT STUDY

The Pilot Study, served to:

- Explore the efficacy of the data collection procedures, such as camera angles and placement.
- Trial interview questions to determine whether they are understood by participants, or need to be modified before exposing the research target group to the actual questions (Borg & Gall, 1989, p. 445).
- Determine whether there were discernable differences between movement characteristics of each individual.
- Converse with the coaching staff with the view of soliciting basic data about how their gymnasts' progress was measured.

Pilot Study Design

Details appropriate to the processes undertaken and various aspects of data collection for the Pilot Study design are described under the following headings; Pilot Study Research Questions, Location, Participants and Ethics, Equipment Placement, Data Collection, Interviews, Findings of the Pilot Study and Implications for the Main Study.

Pilot Study Research Questions

Prior to starting the Pilot Study six questions were formulated. The purpose of these questions was to help guide the design decisions associated with the Main Study. The research questions were:

- What camera location/position/height best suits the data gathering process?
- How do children respond to the presence of individuals/equipment outside their normal experience within the gymnastics arena?
- Did the prepared interview questions achieve their aim?
- When and where is the best time to conduct interviews?
- Is their sufficient variety in movement responses to warrant further examination of the sensorimotor mode of learning?

Location

The Pilot Study site was located in a coastal city on the mid-north coast of New South Wales, which has a population of approximately twenty-two-thousand people. Within the city there is a number of Gymnastic Clubs, however, Location A was selected for several reasons. Apart from its geographic proximity to the researcher's base, the club executive officers were willing to allow the study to be conducted at their venue, club members demonstrated a wide range of skill levels, the gymnastics practice area was large enough to accommodate visiting researchers close to the performers, and the facilities were built specifically to accommodate the various sub-disciplines within the sport of gymnastics.

The purpose-built Gymnasium at Location A was situated approximately six kilometres from the central business district. This site represents an "ecologically valid" environment, that is, one where children would "normally" perform such skills. The building contained a main performance area that was covered with gymnastic matting, upon which there was fixed apparatus such as parallel and high/low bars, pommels, teaching aids and a foam pit with a 20 metre runway designed for gymnastics. The whole area was encircled by a three metre high barrier of nylon mesh, which was aimed at preventing participants from falling onto the surrounding hard surface area and which also provided an exclusion barrier for non-participants. There was one entrance onto the practice area that was placed so that individuals who entered the area were monitored. Parents and other spectators remained outside this arena.

Participants and Ethics

The participants were children (*N*=13) of both sexes (3 males and 10 females) aged between 4 and 10 years (average age 6.7 years). Two of the children were attending the Club for the first time, whilst the remainder had participated in practice sessions for several weeks. A range of skill levels and experience was evident amongst the participants.

The management of the Club had gained the approval of children's parents/carers two weeks before filming and interviewing took place. Prior to the first session, the children and their parents/carers were provided with a written outline of procedures, as well as necessary a verbal clarification of the filming process and the reasons why their children were being filmed (see Appendix C). The information sheet also contained a copy of The University of New England Ethics Committee approval, number HE02/058 that applied to this study (see Appendix D). In addition, the parents/carers were required to complete a written consent form.

Equipment Placement

The equipment in the gymnasium was arranged by the Club coach, prior to the start of the study, as an activity circuit in a configuration that aided his teaching. Part of the coach's circuit, where filming took place, comprised an elevated box shaped platform approximately 400mm high and 2000mm long. At one end of this platform a 400mm high and 1800mm long wedge shaped gymnastic mat, was secured to one end of the platform with "Velcro" joining tape. The wedge shaped mat tapered to height of 25 mm. This configuration permitted the participants to stand on the platform and then roll "down hill" on the wedge mat, with little force required from the legs. See Figure 3.1.

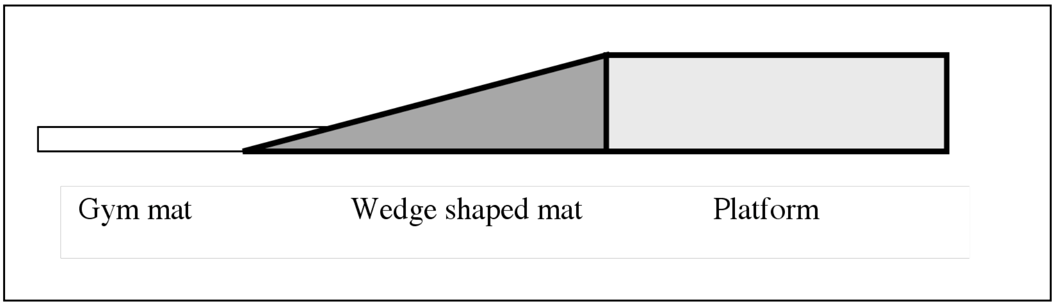


Figure 3.1: Equipment placement for the Pilot Study

Participants were videotaped as they rolled down the wedge shaped mat. Videotaping also took place nearby, on a run up mat, which was placed on top of a "sprung floor".

The placement of the equipment meant that trails of all camera angles were not possible. It was intended to videotape the children from both the left and right sides (laterally) as well as from the front (anterior) and rear (posterior). However, to achieve this aim the equipment would have required relocation. The researcher did not request a reorganisation of the equipment so as not to disrupt the “workings” of the club (i.e., cause disruption to the coaches and coaching organisation).

Data Collection

The date and time for data collection was prearranged with the Club manageress, via a telephone conversation. The club was given sufficient time to arrange for children of different ages to be present.

The trials were video-recorded on a single occasion, using a mains/battery operated Panasonic Digital Video Camera (Model Number NV-MX7A). The camera was “hand held” at a height approximately horizontal to the waist of each performer.

Data were recorded whilst the children were completing their regular gymnastics session. This meant the children were completing a circuit of gymnastic related activities such as walking along a low beam, jumping, balancing as well as rolling down an incline as well as on a flat surface. Each child was filmed rolling “in situ” whilst they were completing the rolling aspects of the circuit. The children were filmed, initially, from a lateral (side) position, at right angles to the direction of the movement. Filming from the left side was the only possible option because the gymnastic equipment was set-up (i.e., too close to a wall for filming from the right side). Whilst filming was in progress the coach moved from one activity to the next, and provided feedback and instruction.

In order not to intrude on the coaching session, the children were not issued with any instructions by the researcher. Filming began just prior to when they commenced the roll, and ceased when the individual completed the roll.

At the conclusion of the circuit session, some individual children, that is, those who were permitted to remain by their parents, were asked to perform additional forward rolls. The filming of these children took place on the gymnastic “run-up” mat and data were recorded from in front (anterior position) only. As this aspect of data collection did not disrupt the coaching session, the instructions “ready” and then “go” were issued just prior to switching the camera to record mode.

Following collection of the data on 8mm digital videotapes, the material was transferred to ½ inch (12.5mm) VHS videotape, which permitted viewing via a VCR in conjunction with a television that permitted “slow motion” viewing. Over the course of the study the use of a VCR was superseded, with the advent of compact disc (CD-ROM), and data were copied onto this format. Through the use of computer technology in conjunction with the CD-ROM, a “frame-by-frame” perspective, as well as stop and slow motion, was possible.

Interviews

The creation of a list of questions was undertaken some weeks prior to the Pilot Study, and was developed in collaboration with a knowledgeable researcher, who acted as a mentor. The intended purpose of interviewing participants was to gather information about what the participants understood about the performance of a forward roll using a prompting question, which was “How do you do a forward roll?” followed by probing questions, such as “Why?” or “How?” or “Tell me more about...”

The researcher considered that useful information could be gained by asking questions which would “allow follow up leads and thus obtain more data and greater clarity” (Borg & Gall, 1989 p. 446). In addition, structured questions were designed to ensure that the data were reasonably comparable from all respondents.

Questioning of individual children was conducted whilst the other children were engaged in the gymnastics circuit (see relevant section of Appendix E pertaining to children’s interviews at Location A). Interviews were conducted with the cooperation of the experienced researcher, who was also involved in investigating fundamental motor skill performances of children. The given name and age of each respondent was established and recorded in written format. The questions were completed and the interview data recorded as hand-written notes.

Findings of the Pilot Study

The first Pilot Study research question was concerned with camera configurations. It was deduced that camera locations, lateral (from the side) to the individual as well as anterior (front) and posterior (rear) views would be sufficient to meet the purposes of the Main Study. Filming from both lateral aspects, rather than from one as in the Pilot Study, and from a posterior aspect (also not possible in the Pilot Study) would be of value if it were feasible in different data gathering venues. Locating a camera superior to (above) or inferior (below) to the subjects was impractical at all the proposed data gathering locations.

The second Pilot Study question related to interviewing. Seven-of-the-thirteen Pilot Study participants were interviewed immediately after they concluded their performance of the roll, a further three were interviewed whilst they were waiting in line to participate at another part of the circuit and the remaining three were interviewed at the end of the circuit session. The timing of questioning did not appear to affect the children's responses.

The third Pilot Study research question pertaining to the wording of the interview questions did create the opportunity to reconsider the questions when asked to this cohort. Five-of-the-thirteen participants could not answer the initial question, "How do you do a forward roll?" Responding with a "shrug of the shoulders" or "don't know".

Feedback gained from the Pilot Study indicated that young children do not respond adequately to the questioning. However, when interview questions were trialled on five individuals who matched the young adult profile valuable comments were forthcoming. The main purpose of collecting interview data was to reinforce the observational data, to determine whether physical and psychological factors may lead to particular movement preferences, for example "fear" of injury may lead to a particular movement preference. As a result the decision was made to interview only the young adult and older adult cohorts

The fourth Pilot Study research question concerned the movement responses of the children. These participants demonstrated a wide range of skill levels, thus this research question was addressed. Some individuals were observed to have minimal capabilities when rolling, whereas other individuals could demonstrate a "modified version" of an aerial roll (somersault or salto) into a foam-filled gym pit.

The fifth Pilot Study research question, concerning the presence of "outside individuals" was how the children responded to the presence of the two researchers or the camera equipment. The lack of an adverse response indicated that they were familiar with observers and others taking photographs, such as parents and coaches. As noted, however, some children did appear reticent to provide answers when questioned about the performance of the forward roll, even when probing or clarifying questions were asked.

In addressing the sixth Pilot Study question, the gymnastics coach, and the gymnastics centre manager both indicated that they were not inconvenienced during the data gathering process. The coach performed his normal routine throughout the session.

Implications for the Main Study

The Pilot Study identified two main issues that were relevant to, and subsequently incorporated into, the Main Study. These were:

- Camera angles and positioning needed to be revised to account for a posterior aspect, as well as laterally, from both left and right and from an anterior aspect.
- The interview questions did not elicit responses that could be deemed suitable for gaining an insight into the reasons why and how children choose to perform the forward roll. The questions were, however, useful in gaining relevant information when asked to a sample of the young adult and older adult cohorts.

MAIN STUDY DESIGN

This section provides detailed information about aspects of the Main Study Design. The details are described under the following subsections: Locations, Participants, Data Collection Plan, and Interviews.

Locations

Apart from the Pilot Study site described earlier, data were collected from two additional venues referred to as Location B and Location C. Most of the children's data were gathered from Location B. Data for both young adults and older adults were obtained from Location C.

Location B was a township located in a rural area within the northwest region of New South Wales. It has a population of nine thousand people and is situated eighty kilometres from the nearest rural city and several hundred kilometres from a cosmopolitan city. This township contains a gymnastic facility and equipment that is unusual when compared to most rural or even cosmopolitan cities, as this venue is totally dedicated to the sport of gymnastics, which contains modern permanently fixed "Olympic standard" equipment.

The installations, within this facility include one 25 x 25 metres sprung floor surface, two 5 x 5 x 2 metres deep foam-filled pits, two vaulting areas complete with appropriate run-up areas, a second sprung floor area 2 x 25 metres long, three sets of permanently erected high and low bars, a lecture theatre, change rooms with all facilities, an additional ground floor teaching area, offices and seating for five hundred people. There was sufficient space available to videotape participants from the desired perspectives, without unduly interrupting the normal gymnastic programmes conducted at this location.

A board of directors, comprising local individuals, operates the centre. Coaching, as well as the day-to-day management, is under the control of volunteers, including a director of coaching as well as qualified gymnastic coaches and judges. All coaching staff members possess Australian Gymnastics Federation qualifications, ranging from Level 1 through to Level 3 accreditation. In addition, several coaches have gymnastic judging qualifications ranging from Regional to International level. The Club has an exemplary reputation for high quality gymnastics within NSW.

Location C was situated within a rural city in the northern highlands of New South Wales. The city has a population of approximately twenty-two-thousand people and is situated several hundred kilometres from a cosmopolitan city. There is a Public University located within this city, which has numerous buildings including a multipurpose gymnasium where the data collection took place. The facility contained portable gymnastics equipment, such as gymnastic mats of various shapes and sizes, balance beams and vaulting equipment. The space available to videotape participants varied, and depended on the availability of particular rooms. However, the desired videotaping perspectives were possible for the majority of the participants.

Participants

The three cohorts of participants in this study are referred to as, Cohort 1 (children), Cohort 2 (young adults) and Cohort 3 (older adults). For the purpose of this study, children are defined as individuals who are aged between 4 and 17 years. Young adults are defined as being between over 17 and less than 22 years of age, and older adults are aged between 23 and 48 years.

Cohort 1 comprised children who were all members of the community surrounding both Location A and Location B. There were 48 children in Cohort 1 (n=48) with and age range of 4-to-15 years. The average age was 9.7 years. This range was chosen because by 4 years of age children can enrol in gymnastics clubs, and 17 years of age is when most individuals leave school, move from rural towns, gain employment, or tend to become disengaged in gymnastics for various reasons, e.g., socialisation factors.

All individuals in Cohort 1 were members of a New South Wales (NSW) Gymnastics Association registered Club. Club members participating in the gymnastics sessions at Location A comprised boys and girls and at Location B they were all girls. The ability level of these participants ranged from beginners to State Champions (quasi-elite performers). Each parent/carer/child was provided with a copy of the permission note (see Appendix C).

Data for Cohort 2 (young adults) were collected at Location C. This cohort consisted of two subgroups who came from a variety of locations throughout New South Wales and other Australian States. One subgroup comprised University students enrolled in their first year of study. The second subgroup comprised students enrolled in elective Physical Education units in their third year of study. All participants from these subgroups were enrolled in a Bachelor of Education/Bachelor of Teaching degree at the University.

Despite the differences in the demographics, these two subgroups are considered to be representative of a single young adult Cohort. The average age of this Cohort 2 (n=24) was 18.9 years. This age range spans the time period when the students are generally present on campus at university. Each young adult and older adult participant was provided with a copy of relevant information and a permission note (see Appendix F).

Cohort 3 (older adults) data were also collected at Location C. The age range of this cohort usually embraces individuals who may have completed full-time study and have chosen to return to university to compete additional and/or further education. Students from this cohort attended residential classes held at the University and usually reside outside the immediate area of Location C, and originate from locations both within Australia and occasionally overseas. Cohort 3 comprises older adults (n=45) who were between 23 and 48 years of age. The average age was 35.9 years. In this case, all adults were enrolled in a generalist Primary Pre-service Teacher Education award. Table 3.1 provides an overview of the profile of participants involved in this study.

TABLE 3.1: SUMMARY OF PARTICIPANTS' PROFILE

Cohort Number	Cohort (Years)	Age Range (Years)	Average Age	Total	Location
1.	Children	4 to 15	9.7	48	A & B
2.	Young Adults	18 to 22	18.9	24	C
3.	Older Adults	27 to 48	35.9	45	C

The composition and range of participants (*N*=117), shown in Table 3.1 was warranted, given that this study includes an examination of performances of individuals across an age range that is as wide as practicable for investigation of the proposed skill.

Data Collection Plan

Minimisation of data errors requires an awareness of the target population's predispositions, as well as the possible circumstances surrounding their motivation for participation (Borg & Gall, 1989, p. 449). To alleviate possible problems prior to data gathering, the performers (participants) were provided with relevant written material in an introductory letter.

Data Collection Procedures

The recording procedures involved observation and recording on videotape of each individual's performance of the forward roll. Both the researcher and the accompanying experienced researcher conducted the recording, using a digital video camera. All participants were videotaped from three aspects, laterally (side-on) position, the anterior (front, approaching) position, and from a posterior (moving away, behind) position.

The hand-held video camera was situated approximately one metre from the floor and four metres from the participant. Positioning of the camera for the lateral aspect of videotaping meant that the participants were located at right angles to the camera when they were approximately at the mid point of the performance of the roll. The same camera position was used for all videotaping, however, a second videotaping area was designated by a series of gymnastic mats with its nearest point located approximately 4-to-5 metres from the camera, positioned at right angles to the initial videotaping area. Figure 3.2 provides a pictorial representation of the videotaping layout.

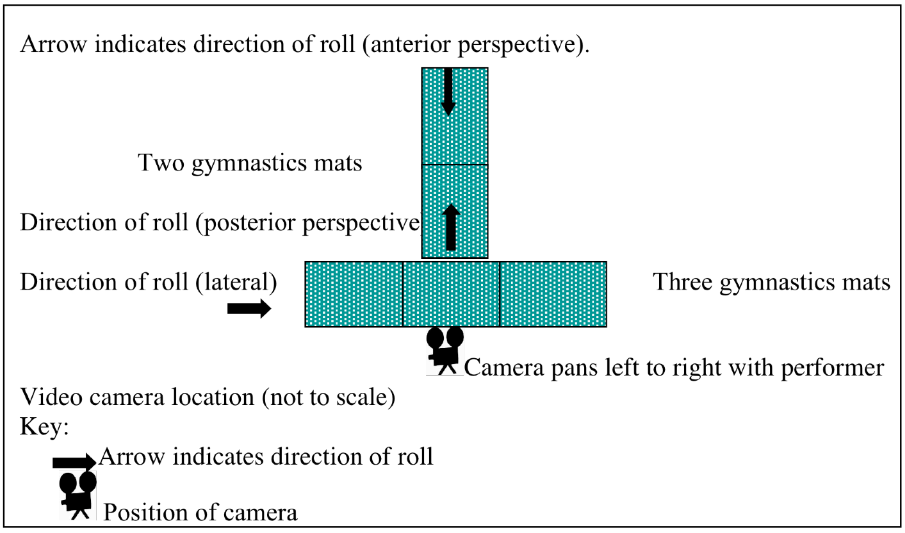


Figure 3.2: Camera Location, Mat Placement and Roll Direction

The arrangement for the video camera shown in Figure 3.2 allows observation from aspects that are advantageous for analysis of body movements as the lateral view observable in addition to the anterior and posterior aspects. In addition, this circuit configuration allows the use of a single camera to record the forward rolls without the necessity to relocate the camera. The use of three cameras, although highly desirable, was outside the resources of this study.

Collection of data at Location B (Cohort 1) required a slight variation from Locations A and C. The centre manager expressed the desire that videotaping must not interfere with practice, and in addition, he was concerned that if poorer performers were videotaped, the centre might “look bad” if the videotapes were shown outside the research arena. Thus some videotaping took place where angles/locations were not standardized. To some extent this perceived limitation was overcome when some individuals were videotaped separately, away from their regular training schedule, for example, at the conclusion of the regular practice program. Individuals videotaped separately were selected on the basis of their status as either beginners (or who were attending the centre for the first time) or on their grading across a range of gymnastic levels.

The instructions to each cohort differed slightly. At Location B most recordings took place whilst the gymnasts were performing their regular practices. However, when they were filmed separately the instruction “ready” followed by “go” was given.

For both Cohorts 2 and 3, instructions were issued prior to performing the roll. Each participant was asked to stand at the end of the designated mat area and on the instruction “go” was asked to perform a single forward roll, then return to the start position and perform a second roll. At the conclusion of these two rolls the participant was requested to move to the second designated area where they were asked to stand at one end of the second set of gymnastic mats and roll once. The participants could roll either towards or away from the camera in the first instance and then perform one roll moving in the opposite direction to the one they had just completed. Participants were also instructed to perform these rolls on the verbal instruction “go”. This instruction was issued immediately after the video camera was switched to record mode.

Data Collection Times

Data gathered from Cohort 1 (Location B) took place over a period of several months, specifically, on Saturday mornings between the hours of 9 am and 10 am, during the time period when the targeted participants were involved in their normal gymnastics routine. At this time, the Club’s coaches provide a range of coaching and learning programs that cater for gymnasts of all skill levels.

For Cohort 2 (Location C) videotaping and auditory data were gathered during the time allocated to practical physical education lectures. The voluntary participants were withdrawn from the class, videotaped and then interviewed. This process occurred over a four-week period.

Gathering data from Cohort 3 (Location C) took place over three consecutive days. All participants were recorded, whenever possible from the same three aspects as outlined previously in this section.

Data Treatment

All the videotaped materials were converted at a later date to Compact Disc (CD), MPEG format. Using the CD form of storage allowed the data, collected over a period of time, to be reordered so that each individual’s performance was placed in sequential order, regardless of the time difference between recording dates. This process also permitted the removal of extraneous visual material and allowed more rapid comparisons to be made for each individual. In addition, visual data recorded on CD permitted individual "frame by frame" observation of the participants, with the added benefit of having a time reference calibrated in terms of the forward arrow on the computer, with each "press of the forward arrow" corresponding to a tenth of a second in movement time. This referencing system became invaluable in the observational analysis of the data. The original data were stored in a locked cabinet and on the secure central electronic file server within the University.

Interviews

Voice recordings of interviews, for selected young adults and older adults, were collected using a miniature tape recorder. Interviews for these participants were conducted in a room adjacent to the videotaping area, where other participants were unable to overhear either the researcher's questions or the participants' responses. The interview data were transcribed and emerging themes noted (Cohen & Manion, 1992). In 2007, the data were subjected to the word analysis program "Leximancer" (Smith, 2000) This program is capable of "finding meaning from text based documents and can identify key themes, concepts and ideas from unstructured text" (Retrieved 5th November 2007 from http://www.leximancer.com/). See Appendix G for interviews and Appendix H for Leximancer.

The names, and ages and time-span since each participant had previously performed a forward roll were recorded. The initial question was global: "How do you do a forward roll?" The response to that question was used to determine how further questioning should proceed, i.e., used as a guide for follow-up questions. Each individual's response determined the direction of more probing questions. For example, following the response to the first question, the following question can be asked "If **you** were to do a forward roll now, can you tell me how you would go about doing it?"

Alternative probes, were also considered, such as "If you were to tell your classmates how to do a forward roll, what would you say?" and "If you were to perform a forward roll in the Olympic games how would it be different from the one you just performed?" From each response a pertinent or key word used by the respondent in his or her reply was used in the follow-up question to gain further information. To attempt to gain greater understanding of the subjects' thoughts they were asked a question such as, "When ***you*** do a forward roll, what are ***you*** thinking about?" The purpose of these questions was to elicit an indication of the key elements involved in the forward roll from the participant's perspective, and in addition, to determine whether "other factors" may have an influence on the way the skill was performed.

DATA ANALYSIS

This section details the two processes involved in the data analysis plan. They are the Rationale for Mixed Methodology and the Process of Analysis.

Rationale for Mixed Methodology

In general assessment instruments have traditionally been divided into two categories, quantitative and qualitative. This division is sometimes clouded by the fact that most measurement instruments are, in reality, a combination of both paradigms. The majority of the tests employed to measure skills have been concerned with the outcome or product of the movement, thus assessments were based on quantitative measures. Outcome or product data quantify performance, with measures such as how far, how much and how quickly output was produced.

With the advent of better computer technology quantitative analyses of movement has become quite popular amongst researchers involved in the area of mathematics and computers in sport (personal communication, de Mestre, 2008). This improved technology, coupled with more powerful and advanced statistical instruments have subsequently led to the quantitative mode of research being more readily accessible to those individuals who wish to take advantage of this method of analysis.

However, the case for undertaking qualitative analysis was asserted by McPherson (1996) who claimed that this type of analysis probably demands a higher level of understanding of the activity being examined than is required for a quantitative analysis. She stated that "involvement in qualitative research is not simply measuring variables with established methods but must also include visual and conceptual dissection of the movement" (McPherson, 1996, p. 87). Visually and conceptually "unpacking" a movement sequence provides an opportunity to appreciate the quantitative results within the context of the performance. Moreover, Hay (1987) stressed the importance of conceptually breaking down skills into their mechanical constructs as a precursor to both qualitative and quantitative analysis. In addition Knudson and Morrison (1997, p. 25) stated for research in physical education, that qualitative analyses "have commonalities and could be used by almost any profession in the qualitative analysis of human movement."

According to Bain (1989) scant qualitative research has been undertaken in the realm of physical education. Bain suggested that a reason for this was that many physical educators lacked a social science background, and through their training have been exposed to the positivistic traditions of psychology, which support notions of internal and external validity, reliability and objectivity. However, in defence of qualitative research, Hardy, Jones, and Gould (1996) associated the positivist notion of internal validity with the qualitative criteria of credibility, that of external validity with transferability, that of reliability with dependability and that of objectivity with conformability.

Lees (2002) considered that the development of qualitative analysis was based on both scientific principles and subjective observations. He also indicated that the advantage of a qualitative analysis was that it could be used by a wide range of people in a variety of instructional and clinical settings.

In summary, quantitative analysis provides advantages in that its use adds credibility to the findings. In contrast, although qualitative analysis is characterized by subjective interpretation, Knudson and Morrison (1997, p. 4) pointed out that qualitative analysis in physical education involves the "systematic observation and introspective judgment of the quality of human movement." The rationale for qualitative research methodology is well founded in their definition. As such the methodology used to aid this research investigation is termed mixed-method, that is, a combination of both qualitative and quantitative analyses.

The Process of Analysis

Four steps are described in this subsection. These are: Initial Descriptions, Case Study Analysis, Rasch Analysis, and SOLO Analysis. Initial analysis involved close scrutiny of data to determine the important movement structures. These structures were coded and then subjected to further examination through the employment of Rasch analysis. Next, data are analysed through the lens of the Structure of Learning Outcomes (SOLO).

Initial Descriptions

The videotaped performances were, in the first instance, analysed through the use of a television with "slow motion" facility, for all participants. The data were subject to further in depth scrutiny after being converted to CD format, permitting "freeze frame" viewing. The visual information of each participant's performance was "transcribed" into written format. Table 3.2 provides an example of the transcription of one participant's performance.

TABLE 3.2: EXAMPLE OF VIDEO DATA TRANSCRIPTION

Sub. No.	CD No.	Elapsed Time (Sec.)	Description
One	One	0.00	Head eyes focused horizontally forward. Arms by sides. Weight on right straight (extended) leg. Left knee flexed dorsally. ***Moves feet*** (walks towards mat).
		0.01	Head remains upright. Raises arms to almost vertical ***left hand is slightly higher.*** Steps forward with left leg. Brings feet together. ***Moves weight to one leg*** (right) then back to left (rocks to side). Looks to side left (at coach)*.
		0.02	Head/eyes looking forward. Arms held at shoulder height approx. shoulder width apart (maintained till full squat position).
		0.03	Eyes focus on surface, slight neck flexion. In squat position. Arms just below horizontal …right slightly higher. Subject "bounces slightly".
		0.03	Eyes focus vertically on floor; the neck is slightly flexed. Knees bend ***together*** and squat position maintained. Arms held in horizontal position until full squat, then arms move towards mat in conjunction with the flexion of neck.
		0.04	As neck maintains flexion, arms flex at elbows and hands/arms abduct. ***Right hand contacts surface first***. Body rocks forward.
		0.04	Body continues forward (rolls) and back of head contacts surface. Arms maintain flexed at elbows and hands/arms in a wide position on either side of shoulders. Hip flexion 110° Knee flexion 90°. Toes in contact with surface.
		0.04	Hip over-head rotation. Curved back. Legs remain flexed at the knee. ***Left leg/foot leads slightly in rotation***
		0.04	Arms straight and both hands leave mat ***simultaneously*** after shoulders contact surface … shoulders on surface. Angle of upper torso approx. 45°.
		0.04	Upper left arm and left elbow contact surface. Rotation continues (the back lands flat on surface).
		0.05	Neck flexes slightly as head leaves surface. Upper left arm and left elbow contact surface, laterally approx. 30 cm from body. Lower left arm vertical. Right arm similar position. Upper back leaves surface. Hips extend slightly. Lower back contacts surface. Legs apart at knees ***left knee higher than other.*** Right foot dorsi flexed. Left plantar flexed.
		0.05	Neck in straight alignment with spine. Eyes focused forward in horizontal plane. Arms wide, slightly below horizontal at each side of body. 5^{th} digit of left hand abducted. Right knee flexed approx. 140°. Left knee flexed approx. 90°***. Left knee much higher than right. Knees separated approx. shoulder width.*** Subject balanced on buttocks. ***Right foot contacts surface before left.***
		0.05	Eyes momentarily look at right hand on surface then look towards camera. As ***right hand contacts*** surface in front of right foot, elbow medial to knee (arm is straight). Left arm bent

	at approx. 140° with fingers touching surface. Knees wide apart with upper body in front of upper legs/knees. Hip flexion allows this position.
0.05	Head eyes focused at 45° to roll line (looking at camera). As right hand contacts surface both knees (which were fully flexed) begin to extend. Left and then right hand leaves surface, and arms continue in upward motion.
0.05	**Subject looks left towards camera*.** Knees continue to extend. ***Body is tilted to the right. Left shoulder higher than right.*** Left arm reaches horizontal with slight elbow flexion. Right arm is flexed approx. 45° at shoulder. This occurs when there is 90° knee flexion. Knees apart. Body slight forward lean.
0.05-0.06	Neck rotates left. Both forearms move to a position superior to elbows as knees extend. At point when upper arms become horizontal extension of elbow occurs and arms/hands are raised to maximum extension together above head.
0.06	Subject continues to rotate body (left) before full vertical position is reached.

* Examples discussed in next Section concerning External Validity.

Transcribing the data permitted similarities and differences between individuals to be determined. For example in Table 3.2, the favourable aspects of the performance are underlined. The unfavourable aspects are presented in bolded text. The performances of all participants (*N*=117) were recorded in the same manner. Analysis was based upon the observed movement deviations from an ideal performance (George, 1980).

Case Study Analysis

Following analysis of all movement transcripts, a sample of nine participants was selected for the purpose of comparing movement quality. Three individuals from each cohort were purposively selected to exemplify performances of differing quality, based on an ideal performance proposed. Each case study was then analysed from three additional perspectives, notably, the Developmental Phases of Roberton and Halverson (1977); Developmental Stages of Gallahue and Ozmun (1995; 1998; 2002); and the Levels of Proficiency of Graham, Holt/Hale, and Parker (1998). The purpose of these analyses was to determine the extent to which each of the different perspectives could assess the forward roll, specifically, for individuals who represented an age span of forty-four years (4 – 48 years of age).

Assistance was sought, in the first instance, to determine the quality of the performances, from a qualified international gymnastic judge (personal communication, Croft, 2006) who was based at Location B. The quality of a gymnastic performance, according to Croft is indicated by how much a performance deviates from the biomechanical and aesthetically ideal form. Ideal forms of movements closely resemble those proposed by George (1980).

Following the perspectives analysis of the nine case study participants, comparisons of the performance of participants across each cohort were conducted to establish whether the patterns of movement were similar or different. An outcome of this analysis was a framework, emerging from the data analysis that was useful for examining the movement quality of the forward roll.

Rasch Analysis

The Rasch model, which is based upon Item Response Theory (IRT) provided a useful method for attaining approximate measures that assist with the "understanding of the processes underlying the reason why people, and specifically chosen items behave in a particular way" (Bond & Fox, 2001, p. 19). Rasch is particularly suited to investigations in a wide range of human sciences and, which according to these authors is the only technique generally available for constructing such measures.

The framework that emerged from analysis of the case study data were coded and statistically analysed using Rasch (1960) analysis through the employment of the ACER statistical package, *Quest* (Adams & Khoo, 1993). Employing this step established how well each item fitted within the underlying construct, of movement quality.

"Analysis using the Rasch methodology provides fit statistics designed to aid the researcher in making a number of unified decisions about the data" (Bond & Fox, 2001, p. 26). Indications of how well each item fits within an underlying construct is included in the analysis. Fit (infit and outfit) indices assist in the investigation relating to whether the assumption of unidimensionality is supported empirically. Fit statistics also help to determine whether the item estimations may be held as meaningful quantitative summaries of the observations, that is, whether each item contributes to the measurement of a construct.

The model incorporates a theoretical idealisation (also called construct or latent trait) of the data's interrelations. This is expressed as an "unachievable" state that can be mathematically represented as an ideal straight line on a map.

Rasch (1960) provided a method whereby a logarithmic transformation can be achieved on the items as exemplified in this study, namely, the descriptors for the forward roll, as well as person data (i.e., the children, young adult and older adult cohorts). These transformations represent the estimation of persons' ability (the term "ability" is replaced by "movement quality" in this thesis) and item difficulty detected in the data set. The person movement quality and item difficulty estimates, after being subjected to a logarithmic transformation, are displayed in computer output as a "log odds unit" (Ong & Van Dulmen, 2007, p. 521). More commonly, however, the term logit is employed to describe the unit. The logit scale is one in which the unit intervals between the locations on the person-item map have a consistent value. For example, the series of numbers found on the extreme left of an Item Person Map are expressed in terms of logits. In addition, the use of Rasch's methodology generally sets at 50% the probability of success for any person on an item located at the same level on the item-person logit scale.

The Rasch model also provides indices that help the investigator to determine whether there are enough items spread along the continuum, as opposed to clumps of them, and enough spread, in this study of movement quality amongst persons. The *person reliability index* indicates replicability, which means that if a person was given a different test to measure the same construct, they would receive comparable results. The *item reliability index* indicates the replicability of item placements along the pathway if these same items were given to another sample with comparable abilities. "From high item reliability it can be inferred that we have developed a line of investigation in which some items are more difficult and some easier, and that we can place confidence in the consistency of these inferences" (Bond & Fox, 2001, p. 32).

The output delivered by *Quest* (Adams & Khoo, 1993) includes estimates of item difficulty and subject ability (movement quality) for both dichotomous and partial credit observations. The data for the forward roll were scored polytomously and thus the partial credit form of the *Quest* model was employed. The partial credit model specifically incorporates the possibility of having differing numbers of steps for different items on the same test (Masters, 1982).

Quest output includes an "item fit" map, based upon infit mean square estimates. The map indicates an item mean square 30% above and below the expected value. This range is used as a guideline for determining the adequacy or otherwise of the fit of the items to the model. Measures for the infit mean square and infit *t* values show the degree to which the set of items fit the model. When a set is perfectly scaled and compatible with the model, the expected value of the infit mean square is approximately 1.0 (one) and the expected *t*-values are approximately 0.0 (zero).

The reliability estimate relates to the proportion of the observed estimate variance considered to be true. This provides an estimate of the likelihood of similar result being obtained if the items were applied to a similar sample (Linacre, Heinemann, Wright, Granger, & Hamilton, 1994).

The indices of the degree to which the data fit the model, item fit maps, infit mean squares, infit *t* values and reliability estimates are important pointers for the validation of the descriptor items used in this study. If the descriptors for the forward roll do provide a "qualitative instrument" for estimating the movement quality levels of persons performing the forward roll, then an additional quantitative validation of the process would add considerable weight to its validity.

Rasch (1960) was chosen as the preferred method for analysing the data because it is unique in the way it can provide a means whereby the underlying the reasons why people, and items behave in a particular way. In brief, this model is useful for "transforming raw data into abstract equal interval scales and can provide the objectivity necessary for the construction of a scale that is separable from the attribute in the persons it measures" (Bond & Fox, 2001).

SOLO Analysis

To address the question regarding whether there are SOLO cycles and levels present within the sensorimotor mode of learning, it was necessary to reanalyse the original data. This involved assessing the quality of a motor skill, from a SOLO perspective. Extending this metaphor, the image one sees through a microscope depends on the magnification of the lenses, that is, one capable of a microanalysis of the underlying structures; SOLO does not require such a microscopic picture. Similarly, it is not essential to view data from a macro-lens perspective, to determine whether generalisations of the end (final) products are achieved. What was required is a lens that has a focus between these two extremes, specifically, so that those features that are "immediately observable" are apparent. An hypothesized characteristic of the SOLO lens includes observation of performances with learning SOLO cycles in focus; "it is a deductive model" (personal communication, Pegg, 2005).

The analysis, through a SOLO lens, was confined to those individuals who were able to complete the skill. Thus analysis involves three levels of the SOLO model, referred to as *unistructural, multistructural,* and *relational*. These levels are cumulative and are representative of changes in the precision of a movement, exemplified by the amount of control an individual has over the performance of the skill. The levels within each learning cycle are determined through observation of the learning outcomes; the individual's movements are the focus.

Because analysis is aimed at capturing what can be directly observed, it is the outcomes of a motor performance that are important. The SOLO lens, in this study, is focused on the performance of a single motor skill; the forward roll.

In summary, the establishment of an effective research design necessitated a planned approach, which commenced with a Pilot Study. The Pilot Study established the need for a number of modifications to data collection procedures. These modifications were incorporated into the Main Study. The Main Study comprised three main processes; firstly, qualitative analyses of the recorded images. Secondly, a quantitative analysis of the data was conducted to add an additional and valuable dimension to the research study. Thirdly, the criteria deemed to be pertinent to the SOLO model were established. The data were, therefore, explored from multiple points of view.

EVALUATION OF THE DESIGN

Threats that compromise the design and, hence, the interpretation of the data need to be recognised and systematically addressed. This section describes the steps taken and the extent to which attempts were made to reduce or eliminate such threats. There are three subsections: Validity, Reliability and an Overview of the Design Evaluation.

Validity

The term validity involves both internal and external dimensions. A tension between these two notions is created because of the fact that research results need to be interpreted, yet at the same time the results also need to be generalisable. The researcher must attempt to achieve a balance between these two constructs.

Internal Validity

Internal validity can be regarded as the basic requirement for an experiment to be interpretable (Campbell & Stanley, 1963). Moreover, Cohen, Manion, and Morrison (2001, p. 107) indicated that "internal validity seeks to demonstrate that the explanation of a particular event, issue or set of data which a piece of research provides, can actually be sustained by the data."

Campbell and Stanley (1963) pointed to a number of variables that can interfere with internal validity. Some of these variables do not impact greatly on this study, such as *History* or *Maturation* and *Experimental mortality,* due to the short time span over which data were collected. However, a discussion of relevant factors impacting on this study follows.

History includes the specific events occurring between the first and second measurements in addition to the experimental variables. This threat may be apparent in longitudinal studies and was a consideration when data for the children's cohort were collected over a period of months. However, in this study data were collected from individual participants within three weeks of their initial collection date. After that time, on successive data collection occasions, collection involved different individuals. "New enrolments" at Location B aided the collection of data from "first-time" participants. The data for the young and older adults were collected for each individual on a single occasion. Moreover, this research did not involve any intervention procedures, e.g., test and retest.

Maturation refers to processes of the participants as a function of the passage of time (not specific to particular events), e.g., growing older, hungrier, more tired, and so on. The amount of time spent interviewing and filming each individual was less than ten minutes in most instances. However, the time spent engaging in the gymnastics program, was one hour in duration at both Locations A and B. Thus fatigue/boredom may have been a factor, which is clearly outside the control of the researcher. At Location C participants were also engaged in physical activity, and were removed from the class in which they were actively engaged for filming and interview purposes. Nevertheless, the type and amount of activity at this location, was judged not to be physically taxing, and was considered to be within the "normal" routine for the participant. As such the presence of the researcher did not introduce and changes in conditions relevant to this factor of maturation.

Testing includes the effects of taking a test upon the scores of a second testing. Initially this threat was considered and was included as a reason for carrying out the Pilot Study. In this study, the data collection site for the children was carried out where they would normally perform gymnastics, and where they were performing activities, which they would normally perform. Thus the setting was natural, both for the Pilot Study and the Main Study, and as such observers would be accepted as part of the normal background of individuals present.

Scrutiny of the recording of performances within the children's cohort revealed that the presence of recording apparatus, the researcher and even the coach distracted some children (see Table 3.2, in which the description of Subject 1 at 0.01seconds, indicates the participant "looks at the coach"). As several performances of individuals were recorded in succession and on different occasions, there were ample data that did not show performers being distracted.

There were some distractions evident during data gathering from the two other cohorts, however, these instances occurred before participants attempted a performance, and were usually in the form of a question, such as "Do I only perform one roll?" Thus performances may have been affected in some way, but the nature of the interference was undetectable, and was merely to clarify the task requirements.

The sex of the data gatherer, as suggested by Rothstein (1985), may present as a threat to validity. The principal researcher was male and the knowledgeable research assistant was female. Both were present at Locations A and C, however, only the principal researcher was present at Location B, where the main data collection for children took place. The constituents at Location B were mainly female, i.e., coaches and gymnasts, however, the Head Coach (Centre Manager) was male, and the principal researcher, who had been the only other male coach for several years, were both a familiar part of the learning environment, and therefore their presence was not considered a confounding issue. This situation extended to children who were included as new enrolments. All the participants at Location B had either a sister, or a mother who was either a former coach or gymnast at the Centre or had attended "observation sessions" and were acquainted with the researcher.

Instrumentation refers to the association between the variables observed and the constructs they intend to measure. Threats to validity occur when unreliable tests or instruments create errors in the study. The notions of content and construct validity are at issue and are discussed in the following paragraphs.

Content validity refers to concerns about whether the items in an instrument measure what they are intended to measure. This issue is relevant to the qualitative (process) assessment of the forward roll. A new framework (instrument) was constructed and subsequently used to analyse the process of rolling. The framework was drawn from an analysis of a number of instruments that had previously demonstrated rigor when applied to the target group for which they were intended. In addition, the new framework was a component of peer refereed conference proceedings, and subsequently published (Haynes, Miller, Callingham, & Pegg, 2005), a measure, which assures some degree of validity.

Construct validity is concerned with the degree to which a test measures an hypothetical construct (Thomas & Nelson, 1996). To ascertain the construct validity of the new framework, Rasch (1960) was applied to the coded data. This form of analysis, based upon Item Response Theory was used to determine the degree to which the items in the new framework measure, and fit, an underlying construct, namely, the quality of movement. In addition, some of the individuals within the children's and the young adult cohort were classified as quasi-elite performers. For the purposes of this thesis this categorisation was applied to individuals who had qualified to perform at State championship level. Similarly, the term, elite gymnast was applied to an individual who was eligible to compete at National level.

External Validity

According to a number of authors (Borg & Gall, 1989; Campbell & Stanley, 1963; Cohen et al., 2001), external validity addresses the question of generalisability – to whom can we generalise the findings? However, for research involving qualitative methodology, the term generalisability can be "interpreted as comparability and transferability" (Eisenhart & Howe, 1992, p. 647). In addition, Lincoln and Guba (1985) purported that detailed descriptions of the data be provided so that individuals are able to decide for themselves whether findings are transferable. There are, however, factors that may jeopardize external validity in this study, which include the selection of subjects and associated reactive effects, i.e., the experimental environment is so different from the real world that generalisation is not possible.

Selection of subjects alludes to the possibility that the sample of subjects may not be representative of the population as a whole. The participants in the children's cohort were all members of a gymnastic club. Whilst this means that differences would exist between the participants and the wider population, it is most likely that this group is equivalent to those in other clubs. Despite the fact that some individuals in this cohort were classified as being within the "semi-elite" category for their particular performance level, other individuals were "beginners" whilst some had engaged in practice for a number of months, thus the case is made that the full spectrum of abilities were represented in this cohort.

The younger and older adults were included in this research on the basis of attendance at a university residential school, voluntary participation and as such may have attracted individuals who were more confident, better coordinated and more skilled than the general populace. Due to the nature of the activity, which involved the use of gymnastic equipment, taking the research into the broader community was, however, not a viable option.

Reliability

Reliability may also be referred to in terms of internal and external components. The internal reliability component is concerned with consistency, specifically, in relation to data collection, analysis and interpretation under specified conditions. The external component refers to the content of the data. As this study is a mixed mode, cross-sectional investigation these two components of reliability can pose problems, specifically in relation to the method used to analyse the data, which may produce variations if untrained individuals attempt to replicate the study. Notwithstanding, in qualitative research, reliability can also be considered as a juxtaposition between what is recorded as data and what happens in the natural setting (Brogdan & Biklen, 2007). Strategies employed to reduce the threats to internal reliability have been identified by LeCompte and Goetz (1982) and the following sub section describes the reliability issues relevant to the design and implementation of this investigation.

Internal reliability

Peer examination may reduce the reliability of collected data. Two means of attempting to ensure internal reliability were applied to this study. Firstly, intracoder reliability, which is an attempt of a single coder to produce a consistent result in the coding of qualitative data over time, was undertaken. Secondly, intercoder reliability, which refers to the aptitude of additional coders to reach consistent agreement in the coding process. The first of these threats to reliability have been attended to through systematic coding and recoding of the data by the principal researcher. Data were recoded on four separate occasions, with a six-month time increment between coding. Intercoder checks were conducted at the conclusion of the data analysis. The second was managed through a second person coding a sample of responses.

Recording of data is also a possible threat to internal reliability. This threat was over come, initially, through the use of videotape recordings. Their use, and subsequent transfer to compact disc permitted the "preservation of data, unobstructed" (LeCompte & Preissle, 1993, p. 340). The practical nature of recording data with a camera was balanced against the possible disadvantage of its presence during data gathering, which may have caused some distraction to the subjects.

External Reliability

Several factors need consideration within this construct. The *researcher status* refers to the role that the individual researcher plays. At Location B the researcher was well acquainted with the participants. The older children were observed to be "keen to do their best" which appeared to reflect the ethos at the Gymnastic Club. The young adults, at Location C, were familiar with the researcher and the knowledgeable research assistant as a lecturer in a movement studies component of their degree. In addition, information pamphlets were distributed to participants, describing the nature of the research, their ethical position, as well as indicating that there were safeguards related to data storage. Older adults (Location C) were provided with the information pamphlet, and in addition, the collection of data was undertaken towards the end of their residential school. This timing of data collection, at the end of the school, permitted the potential participants to have maximum exposure to and thus become more familiar with the researcher.

Measurement error relates to testing conditions, scoring, instrumentation and the participants. The subjects may produce different results depending on their health status, psychological state, and fatigue. The participants were in apparent "good health" because if they were not, they would not have attended the relevant sessions where data were collected. Similarly, the participant's psychological state was catered for as the participants were engaged in their normal routine or were volunteers. Fatigue may have been a factor for some older adults. Some had travelled from interstate to attend the "residential" school, where data were collected. However, a period of several days had lapsed before participants' data were gathered.

Scoring of data was unobtrusive and undertaken when viewing the video recordings. Participants at each location were present whilst data were recorded, however, no comments were made in terms of comparing performances. Children situated at Location B were accustomed to performing "in public" within their gymnasium. Data collection for younger adults and older adults were located out of direct sight, to the rear of the gymnasium at Location C, and participants were summoned to perform one at a time.

CHAPTER CONCLUSION

This chapter provided a description of the research design and how the implementation of the design was to be conducted. The design involved four processes, which were:

- The Pilot Study, which provided feedback regarding potential problems and issues that needed addressing prior to the Main Study. The chief problems were the camera location and the interview questions.
- The design for the Main Study, which took into account the findings of the Pilot Study. However, some issues remained, such as the camera positioning for the children's cohort, with particular reference to the agreement that filming would not interrupt the activities at Location B.
- The data analysis involving both qualitative and quantitative techniques. This study can best be described as a mixed method, cross-sectional deductive analysis. As such the research does not involve any intervention processes.
- An evaluation of the design that provided evidence regarding the validity and reliability of the proposal. Designing a research study that met the criteria for these two constructs was essential.

In the following chapters, Chapter 4 provides a description of the data analysis for a selected sample of participants, employed to determine the extent to which various perspectives of examining the forward roll fulfil their respective purposes. Chapter 5 provides a description of a new framework that draws together the data, which emerged from and examination of the perspectives presented in the previous chapter. In Chapter 6 an examination of the data that describe the performance criteria of all individuals across and extended age span, namely 4 – 48 years of age is presented. Finally, in Chapter 7 the findings of the case study analyses and the new framework are subjected to a multifaceted analysis using statistical Rasch procedures as well as being examined from a SOLO perspective.